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RESEARCH ARTICLE

The Effects of Physical Activity in Individuals with Autism Spectrum Disorder: A Qualitative Study

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Abstract
This qualitative study aimed to investigate the effects of physical activity habits on the developmental progress and family dynamics of children with Autism Spectrum Disorder (ASD), as reported by family members. Through semi-structured interviews, the study explored the influence of physical activity on social skills, overall behaviours, and family functioning. The participants comprised 20 parents (11 females and 9 males) of children diagnosed with ASD, aged between 8 and 12 years, residing in Istanbul. The study revealed seven themes: "The Role of Physical Activities in Everyday Existence," "Regular Participation in Physical Activities," "The Frequency and Intensity of Physical Activities," "The Reaction of Children with ASD to Physical Activities," "The Effect of Physical Activities on General Behavior and Social Skills," "The Impact of Physical Activities on Family's Daily Life," and "The Effect of Physical Activities on Family Quality of Life." The findings emphasize the significance of physical activities for children with ASD, illustrating their potential to enhance social skills, emotional well-being, and overall quality of life. Additionally, these activities reduce family stress levels and enhance overall family functionality.In conclusion, based on these findings, physical activities play a vital role in the lives of children with ASD, potentially improving their social skills, emotional well-being, and overall quality of life. Moreover, engaging in such activities can alleviate family stress and enhance family functioning. These results underscore the importance of incorporating physical activities into the lives of children with ASD and provide valuable insights for designing effective intervention strategies to support their development and well-being.

Keywords
Physical Activity Habits, Developmental Progress, Family Dynamics, Social Skills

INTRODUCTION

Autism Spectrum Disorder (ASD) is recognized as a complex neurodevelopmental disorder that is typically distinguished by difficulties in social interaction, communication, restricted interests, and recurring behaviours, as outlined by the American Psychiatric Association in 2013. Manifesting predominantly in childhood, ASD is a lifelong condition with significant implications for affected individuals. In recent times, there has been a discernable increase in ASD prevalence, thereby escalating its importance as a health issue affecting individuals and families alike (Baio et al., 2018).

Participation in physical activities can confer many health advantages for individuals with ASD, akin to benefits observed within the broader population (Sowa & Meulenbroek, 2012). Engagement in such activities can foster the growth of various physiological systems and enhance motor abilities while lowering obesity risks. Additionally, physical activity can alleviate anxiety and depressive symptoms often prevalent among individuals with ASD, strengthening their self-efficacy (Pan et al., 2010). Consequently, it is

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conjectured that physical activity can improve the quality of life for individuals diagnosed with ASD. Research, such as the study by **Jones et al. (2017)**, suggests that children with ASD typically demonstrate decreased physical activity levels. This lack of participation can deleteriously affect their physical and psychosocial well-being. For instance, reduced physical activity levels may exacerbate obesity risks, impede motor skill development, and compromise these children's overall quality of life **(Jones et al., 2017)**. Hence, understanding the physical activity habits of children with ASD and assessing the impacts of these habits on their development and familial life becomes of paramount significance.

The objective of the present study is to conduct a comprehensive investigation of the physical activity habits of children with ASD and assess the effects of these habits on their developmental progression and family life through the lens of the families. The experiences and observations of family members can aid in our understanding of the factors influencing the participation of children with ASD in physical activities and the impact of such participation on familial dynamics. The findings of this study could provide crucial insights for developing strategies to foster the participation of children with ASD in physical activity, which could potentially enhance their health and overall quality of life. Moreover, this study intends to identify resources and methodologies that can be harnessed to support and guide families.

MATERIALS AND METHODS

Research Model

The study was conducted within the framework of a qualitative methodology, utilizing a semi-structured interview approach. The selection of this approach was necessitated by the desire to structure the interview process so that families could articulate their meanings and experiences, thereby allowing for data collection and a deepening understanding of their personal experiences **(Braun & Clarke, 2013)**.

In the interviews, subjects such as the daily physical activity habits of the children (for example, sports they participate in, physical games and exercises), as well as the duration and intensity outside these groups and individuals was taken into account. "In this study, additional precautions of these activities, were discussed. Concurrently, the families' observations and thoughts concerning the impact of physical activity on their children's overall behaviours and social skills were also gathered. The intent here was to test the hypothesis that physical activity could aid in developing social skills in individuals with autism, as previously suggested in the literature **(Bremer et al., 2015)**.

Furthermore, the families' views on how physical activities influence their children and, in turn, how these activities affect their daily lives and familial dynamics were collected. This was an effort to comprehend the possible effects of physical activity on family functionality and the quality of family life **(Anderson et al., 2012)**.

Each interview took place in an environment where the participant felt comfortable and lasted approximately 60 minutes. With the consent of the participants, the interviews were recorded and subsequently transcribed.

Demographic Characteristics of the Study Group

The study group comprises parents of 20 children diagnosed with Autism Spectrum Disorder (ASD), ranging from 8 to 12 years of age. These participants resided in Istanbul and were selected via a convenience sampling method. All the children in the study group have received an ASD diagnosis, which is the primary focus of this investigation. The mean age of the participants is 10 years, with an overall age distribution between 8 and 12 years. This demographic information delineates the scope of the study and characterizes the participant group. Most children examined within the study group have confronted one or more additional developmental issues co-occurring with ASD symptoms. These challenges may encompass language and speech delays, learning difficulties, Attention Deficit Hyperactivity Disorder (ADHD), and anxiety disorders.

This article's necessary ethics committee permissions were obtained with Istanbul Aydın University Social Sciences Ethics Committee Commission Date: 31.05.2023 Issue/Decision No: 2023/05. Regarding vulnerable groups, the authors took into account the needs and priorities of the groups/individuals in which the study was conducted, in accordance by Articles 19 and 20 of the WMA Declaration of Helsinki, and the situation that the study could not be carried out were taken by the researcher(s) to protect the volunteers."

Table 1. Demographic characteristics of children with ASD diagnosis participating in physical activities

No.	Gender	Age	Participated Activity	Additional Developmental Challenges
1	Male	9	Football	Language and Speech Difficulties
2	Female	10	Swimming	Sensory Auditory Sensitivity
3	Male	8	Cycling	Motor Skills Difficulties
4	Female	11	Dance	Social Interaction Issues
5	Male	12	Football	Anger Management Difficulties
6	Male	10	Running	Attention Deficit Hyperactivity Disorder
7	Female	9	Swimming	Emotional Regulation Problems
8	Male	11	Basketball	Language and Speech Difficulties
9	Female	8	Cycling	Motor Skills Difficulties
10	Male	9	Running	Attention Deficit Hyperactivity Disorder
11	Male	12	Football	Social Interaction Issues
12	Female	10	Dance	Sensory Auditory Sensitivity
13	Male	8	Basketball	Language and Speech Difficulties
14	Female	11	Dance	Interaction Issues
15	Male	9	Running	Motor Skills Difficulties
16	Female	12	Swimming	Emotional Regulation Problems Social
17	Male	10	Football	Attention Deficit Hyperactivity Disorder
18	Male	9	Cycling	Behavioural Issues
19	Female	11	Swimming	Language and Speech Difficulties
20	Female	10	Dance	Motor Skills Difficulties

Table 1 displays the demographic information, the participated activities, and the additional developmental challenges (if any) of the 20 participants.

Table 2. Demographic characteristics of participating families

No.	Level of Education	Age	Gender
1	Bachelor's degree	42	Male
2	High school	35	Female
3	Bachelor's degree	38	Female
4	Associate degree	30	Male
5	Bachelor's degree	41	Male
6	High school	37	Female
7	Bachelor's degree	43	Female
8	Master's degree	48	Male
9	Associate degree	33	Male
10	Bachelor's degree	39	Female
11	High school	36	Male
12	Bachelor's degree	40	Female
13	Associate degree	31	Female
14	Master's degree	46	Male
15	Bachelor's degree	44	Female
16	Bachelor's degree	37	Male
17	High school	34	Female
18	Master's degree	49	Male
19	High school	35	Female
20	Elementary school	53	Female

Table 2 showcases the demographic characteristics of the families participating in this study. These include the level of education, age, and gender of the participants. From a total of 20 participants, it can be observed that the majority have obtained a bachelor's degree, followed by a high school education. The level of education extends from elementary school to master's degree level, indicating a broad range of educational backgrounds. Age distribution among the participants spans from the early 30s to the early 50s, with a somewhat equal representation of both male and female participants.

In order to conduct this research, necessary permissions and consents were obtained from the Social Sciences Ethics Committee of Istanbul.

This decision was dated 31.05.2023 and numbered 2023/05. Furthermore, detailed information about the research content was provided to all participating volunteers.

Semi-structured interviews allow for a comprehensive environment wherein participants can convey their experiences and viewpoints. The interview protocol utilized in this study, which is semi-structured, is delineated in Table 3 below.

Table 3: Semi-structured interview guide

	Interview Questions
1	Can you briefly introduce yourself and your family?
2	What is the role of physical activities in your child's daily life?
3	What physical activities does your child participate in regularly (e.g., sports, physical games, exercises)?
4	Could you provide information about the frequency and intensity of these activities?
5	How does your child respond to these activities? Do you think your child enjoys these activities?
6	Have you noticed any impact of physical activities on your child's general behaviours? If so, could you describe this impact?
7	Do you believe physical activities affect your child's social skills? What are your observations or thoughts on this matter?
8	How do you evaluate the impact of physical activities on your child's general behaviours and social skills?
9	How have physical activities impacted your family's daily life and dynamics? Is this impact positive or negative?
10	How do you assess the possible effects of physical activities on family functionality and quality of family life?
11	Finally, is there anything else you want to add regarding your child's physical activities?

This semi-structured interview protocol is designed to elicit in-depth insights from respondents concerning their children's physical activity practices and the implications of these behaviours on familial dynamics and the development of their children's social competencies. It facilitates an open environment where participants can candidly share their experiences and perspectives. While quoting the participants' views, a coding system (“P1, P2, P3”, etc.) which expressed that they were participants was preferred

RESULTS

In this section, we present the insights derived from interviews conducted with parents regarding their children's involvement in physical activities. These perspectives shed light on the perceived outcomes of such engagements, as observed by the participating families. The study identified seven overarching themes: "The Role of Physical Activities in Everyday Existence," "Regular Participation in Physical Activities," "The Frequency and Intensity of Physical Activities," "The Reaction of Children with ASD to Physical Activities," "The Effect of Physical Activities on General Behavior and Social Skills," "The Impact of Physical Activities on Family's Daily Life," and "The Effect of Physical Activities on Family Quality of Life."

The Role of Physical Activities in Everyday Existence

P3*: “Physical activities are indispensable to our child's daily life. He not only enjoys being active, but it is also crucial for his developmental progress.”*

P14*: “Physical activities play a pivotal role in our child's life. They serve as a conduit for channelling our child's energy positively and healthily, concurrently fostering his healthy development.”*

The remarks above underscore the significance of physical activities in children's daily lives as perceived by their families. Parents recognize and affirm their children's fondness for physical activities and emphasize the crucial role these activities play in their offspring's development.

The comments also highlight the need for children with ASD to participate in physical activities, suggesting that these activities help direct their energy and facilitate healthy growth. The assumption is that being physically active bolsters children's physical, mental, and emotional well-being, enhancing their quality of life. Furthermore, these statements accentuate the idea that the needs of children with ASD for physical activities are not disparate from those of other children, positing that they, too, can equally benefit from such undertakings. The condition of being

ASD is stated not to alter the importance or impact of physical activities.

Regular Participation in Physical Activities

P5: *"Our child demonstrates a strong preference for regularly playing football. Additionally, there is a weekly gymnastics class in which they participate with considerable enthusiasm."*

P16: *"Our daughter exhibits a marked affinity for swimming lessons. She greatly enjoys the tranquil cadence of the waves and the unrestricted movement of her body in water. Swimming offers her an avenue for self-expression, fosters body control, and physically strengthens her. Concurrently, she harbours a distinct passion for cycling. The joyful expression on her face while cycling underscores her growing independence in navigating the world from her perspective, enhancing her self-efficacy and self-confidence. Indeed, our daughter is diagnosed with ASD, but this in no way inhibits her enjoyment of life, her capacity for learning, and her development. Autism is merely a facet of her existence and one component contributing to her individuality and uniqueness. Like any child, she is discovering her paths, exploring her abilities, and viewing the world through her unique lens. Having a child with ASD serves as a reminder that everyone is unique and requires a different rhythm and timeline to find their distinctive path. As a family, we derive great satisfaction from standing by her side, growing alongside her, and learning new things from her every day."*

The statements above depict the assessments and impacts of regular physical activities for children with ASD, as interpreted by their families. These statements underscore that participation in physical activities by individuals on the spectrum facilitates their self-expression, body control, and empowerment. Family narratives illustrate that children derive joy from engaging in their favoured activities and that these activities bolster their self-confidence. For instance, participating in activities like football and gymnastics can enhance a child's motor skills and aid in self-expression, while swimming and cycling augment body control and induce a sense of freedom.

Furthermore, families underscore that the ASD diagnosis does not hinder their child's development. They assert that while autism is part of their child's life, it is one element that makes their child special and unique. Families convey that everyone finds their path, discovers their abilities, and perceives the world from their unique perspective.

The Frequency and intensity of physical activities

P17*: "My son attends football training three times a week. He adores football, and it is almost impossible to dissuade him from attending the training. He also goes to gymnastics lessons once a week. His activeness and mobility have improved significantly with football and gymnastics. Understanding his intensity is complex, however. He is a child on the OSB, which affects how he perceives the world and reacts to his surroundings. Routine and order are vital to him. That is why having a set schedule for his training and lessons is paramount."*

P19*: "Our daughter participates in swimming lessons twice a week, and she engages in cycling whenever she wishes to. The frequency of these activities depends on her interest and availability."*

The views presented above provide valuable insights into the frequency and intensity of children's participation in physical activities. Firstly, they indicate that being on the autism spectrum influences a child's perception of the world and their reaction to events around them. When considering the intense schedules of their children, families acknowledge that some may interpret this as imposing an excessive burden on the child. However, they underscore how these activities assist their children, observing benefits such as developing social skills, enhancing physical health, and improving emotional regulation and focus.

Additionally, families assert the importance of achieving an appropriate balance to meet the child's needs and provide the healthiest and most satisfying life. While noting the necessity for personal time for rest and focusing on their interests, they emphasize that activities are tailored to the children's needs and abilities. This may require flexibility to support the child's comfort and development.

The Reaction of Children with ASD to Physical Activities

P1*: "Our son truly loves football. Seeing the joy on his face when he plays is simply priceless. Watching him eagerly attend every training and his excitement each time he learns something new brings us immense happiness. Likewise, he finds a way to express himself during gymnastics lessons.*

We are delighted to see how much pleasure he derives from these classes.

Despite specific challenges, football and gymnastics help enhance his social skills and physical coordination. These activities give him significant confidence in discovering his abilities and interacting with others."

***P2**: "My daughter adores her swimming lessons, which bring her great happiness. Riding a bicycle is therapeutic for her; it calms and soothes her. The fact that she can enjoy different activities helps her cope with her situation. We are overjoyed with this outcome."*

The provided statements elucidate how children with ASD respond to specific physical activities, as relayed by their families. The experiences underscore the affection and enjoyment the children display towards these activities. Families have reported their children exhibiting happiness and motivation when engaging in football and gymnastics activities. They suggest that These pursuits assist in the children's social skill development, physical coordination enhancement, and self-discovery of their abilities. This indicates that despite the inherent challenges of ASD, children can express themselves through these activities. Moreover, these engagements bolster the children's self-confidence and ability to interact with others.

Families express great satisfaction in observing their children's joy and passion related to these activities. This situation demonstrates that families focus on supporting their children's interests and establishing effective communication. Concurrently, these activities provide enlightening experiences for the families and assist them in better understanding their children.

The statements illustrate the positive effects of physical activities on children with ASD and show that these activities can provide valuable experiences for children and their families. Furthermore, it emphasizes that focusing on the interests and passions of children by their families facilitates the children's self-expression, supports their development, and strengthens familial bonds.

The Effect of Physical Activities on General Behavior and Social Skills

***P15:** "When we discovered our son was on the autism spectrum, many things in our life changed. However, we decided to embark on this new journey with him and have tried to support him every step with immense love and patience. Mainly when we directed him towards physical activities, we noticed noticeable positive changes in our son. Previously prone to intense emotional and energetic outbursts, he became calmer and more focused after regular physical activities. Actions such as running, jumping, and playing games help him express the energy building up inside him. Also, we observe that these activities enhance his motor skills and increase his body awareness.*

The most exciting thing is how physical activities impact our son's social skills. Team sports and group activities have enabled him to communicate more comfortably with other children and expand his social circle. While living with a child with ASD has its challenges, seeing him achieve these small victories brings us great joy and hope.

Every child has a unique way of learning and developing. Our son needs to move, play games, and be physically active. This helps him better understand the world, express himself better, and, most importantly, enjoy life. Physical activities act like therapy for him. I would recommend this to every family, especially those with children with ASD."

***K20:** "My daughter's participation in physical activities has contributed immensely to her overall behaviour and social skills. As a regular part of activities, my daughter developed a self-confidence that we could not have imagined before, and her social skills improved noticeably. Physical activities positively influenced my daughter's overall behaviour by supporting her ability to focus, physical coordination, and cognitive abilities. It helped her overcome previous difficulties and provided an opportunity to improve her daily life skills.*

Regarding social skills, the impact of physical activities is undeniable. My daughter, who previously had difficulty interacting with people, now possesses improved communication skills. This has helped her interact more comfortably with others, enhance her emotional expression ability, and even make new friendships."

These case studies underscore the potential benefits of physical activities in positively influencing the overall behaviours and social skills of children with ASD. First, decreased emotional outbursts, enhanced tranquillity, and improved focus have been noted due to a child's consistent participation in regular physical activities.

Moreover, these activities reportedly contributed to the advancement of motor skills and augmentation in body awareness. In addition, participation in team sports and group activities was purported to assist in developing social skills, fostering more accessible communication with other children.

In the second case, a girl's involvement in physical activities reportedly boosted her self-confidence, refined her social abilities, and ameliorated her communication skills. These activities also supported enhancing focus, physical coordination, and cognitive abilities, improving her daily life skills. Furthermore, the activities augmented the girl's ability to interact with others and form new friendships.

These narratives demonstrate that physical activities could serve as an essential instrument for improving the general behaviour, self-confidence, and social skills of children with ASD. Physical activities can assist in channelling the children's energy, facilitating their self-expression, strengthening motor skills, and enhancing social interactions.

The effect of physical activities on general behaviour:

P11: *"Yes, our son engaging in soccer and gymnastics helps him channel his energy. These sports play a significant role in overcoming some of his challenges. On active days, he can remain calm and even focus, despite the noise and chaos around him. Even though his ASD sometimes distances him from social interactions, he learns to communicate with other children and enhance his social skills through sports. These activities not only assist him in understanding the world from his unique perspective but also offer us the opportunity to communicate better with him and understand him more deeply."*

K12*: "Living with my daughter's ASD diagnosis has turned every day into a new learning experience. We are trying to understand how she views the world from a different perspective. Although autism affects her social interactions and communication abilities differently, we have discovered some strategies that help us manage the situation. Physical activities, in particular, play a significant role.*

When my daughter is engaged in an activity where she can use her energy, she appears more balanced and peaceful. Most of the time we spend together, we prefer to try different physical activities with her - sometimes bike riding, sometimes a walk or dance. These activities balance her energetic nature and help her focus better."

These statements suggest that children with ASD can be positively supported in multiple aspects through physical activities, leading to favourable outcomes. Primarily, parents have indicated that engagement with physical activities helps channel their children's energy and aids in overcoming specific challenges associated with ASD. On days when the children are active, they are reported to remain calm and focused despite the surrounding noise and chaos. This suggests that physical activities play a significant role in regulating their behaviour and maintaining emotional balance. Moreover, it is noted that these children learn to communicate and develop social skills through sports.

Families shared their experiences of their daughter living with ASD, emphasizing the profound importance of physical activities. When she is engaged in an activity where she can expend her energy, they have noticed that she appears more balanced and peaceful. These activities, apart from balancing her energy, also assist in focusing. The families preferred experimenting with different physical activities, enhancing their child's focus. These narratives illustrate that physical activities could be crucial in managing behaviours, achieving emotional balance, and improving focus for children with ASD.

The impact of physical activities on social skills:

P5: *"My son is honing his teamwork and communication skills through playing football. The enhanced ability to communicate more effectively and interact better with his peers brings us great joy. This represents a significant advancement in his social interactions and self-expression capabilities. Observing this evolution in our child indicates that children on the autism spectrum, too, can develop their social and emotional skills, albeit at their own pace and through their methods. Football has transcended being merely a sport for our son and has served as a bridge between his world and ours."*

P11: *"The interaction my daughter has with other children during her swimming lessons is bolstering her social skills, understanding, and communication abilities. In the world of a child on the autism spectrum, such interactions hold immense value. This process plays a crucial role in*

making sense of her autism symptoms and enhancing social conformity.

Swimming lessons not only improve her physical skills but also boost her self-confidence. With each successful lesson, the pride and joy reflected on her face validate all our efforts and patience. Opportunities like these are essential to overcome the lack of self-confidence commonly observed in these children. Perhaps most importantly, such social activities do not make her feel 'different'. She discovers her abilities and skills in an environment where she is on equal footing with other children. She finds the chance to express herself and her abilities positively.

As a parent of a child with ASD, these are just a few of the advancements we hope to see in her growth and development. Every new accomplishment is a day won, every step is a significant gain, and every smile is a priceless gift."

These remarks underscore the enhancement of children's social skills by participating in specific sports activities. For instance, one family cites their football child's improved team collaboration and communication skills, enabling him to communicate more effectively with his peers. This signals significant progress in the child's social interactions and self-expression capabilities. This case serves as an example demonstrating that children with ASD can develop their social and emotional skills at their own pace and through their methods.

Similarly, the mother of a child enrolled in swimming classes indicates that her child's engagement with his peers has significantly cultivated his social proficiency, cognitive understanding, and communicative competencies. This process aids in the child's understanding of his ASD symptoms and boosts his social adaptation. Additionally, she notes that swimming lessons enhance her child's self-esteem and give him a sense of normalcy. It is underscored that such social activities allow the child to explore himself and his abilities and facilitate positive self-expression.

These statements indicate that physical activities significantly influence the social skills, communication abilities, and self-confidence of children with ASD. Parents express satisfaction in observing these positive progressions in their children's growth and development. This implies the potential of physical activities to enhance the overall quality of life and social integration of children with ASD.

The Impact of Physical Activities on Family's Daily Life

P17: *"Physical activities bring great vitality and energy to our child's daily life and family. Having us participate in sports together enhances our child's social skills, coordination, and focus. Simultaneously, these activities help our child release pent-up energy, resulting in a generally calmer and happier demeanour. I find these effects that physical activities bring to our family quite positive. I believe such experiences improve our child's life and our family's overall quality of life."*

P19: *"Physical activities serve as both an entertaining and unifying activity for our family. For our children on the autism spectrum, these sorts of activities contribute to their social and emotional development. This, in turn, increases the quality time they spend with our family and strengthens their relationships within the family. As they discover their rhythm and space, being with them and witnessing this process is a precious and positive experience for all of us."*

The statements above articulate the impact of physical activities on the daily lives of families, highlighting the positive effects facilitated by a child's participation on the autism spectrum. Academically, these declarations underscore the awareness and understanding of families, emphasizing the role of physical activities in enhancing the child's social skills, coordination, and focus. Simultaneously, the expending of energy to foster a calmer demeanour contributes to a more harmonious familial atmosphere.

These assertions also underscore the significance of quality family time. They purport that physical activities fortify familial relationships, augment the bond among family members, and offer opportunities for quality engagement. Consequently, they are perceived as enjoyable and unifying family activities.

This discourse presents a perspective emphasizing the importance of physical activities as an essential factor spotlighting the benefits and reinforcing familial bonds. Additionally, it emphasizes how, in the context of living with autism spectrum, physical activities can augment the child's quality of life, offering a positive experience for the family.

The Effect of Physical Activities on Family Quality of Life

P9: *"Physical activities enhance our togetherness as a family and increase our functionality. Such activities allow us to spend time together and tangibly convey support to one another. Particularly, engaging in these types of activities with our children on the autism spectrum aids in developing their social skills and enables us to establish a deeper connection with them. This positively impacts our overall family life quality."*

P20: *"Physical activities play a substantial role in our family adopting a healthy lifestyle. This not only contributes to the development of our child on the autism spectrum but also positively impacts the general life quality of our entire family. We each adopt a healthy lifestyle by spending time together, having fun, and learning to understand each other better strengthens our family's unity and commitment."*

The statements above reflect families' experiences emphasizing the positive effects of physical activities on family quality of life. These remarks indicate that the presence of a child on the autism spectrum enhances family cohesion and improves family functionality through physical activities. Physical activities foster togetherness among family members and create a supportive environment. The opportunity for interaction, communal time expenditure, and the provision of substantial assistance among family members positively influence the quality of familial life. Activities encompassing the involvement of children on the autism spectrum possess the potential to intensify familial bonds and concurrently facilitate the enhancement of the child's social competencies.

Moreover, the positive influences of physical activities on family health and lifestyle are underscored. Adopting a healthy lifestyle and spending time together contributes not only to the development of a child on the autism spectrum but also improves the general quality of life for all family members. Mutual enjoyment, understanding, and getting to know each other better augment the family's strength and unity.

These statements demonstrate families' recognition of the beneficial effects of physical activities on family unity, child development, overall quality of life, and their valuation of these activities.

DISCUSSION

It is essential to highlight the positive impact of physical activities on children diagnosed with ASD. Among the repertoire of strategies to improve social skills in children with ASD, sports and physical activities emerge prominently **(Pan et al., 2010)**. Numerous studies demonstrate that such activities help channel children's energies positively and assist in better self-expression **(Oriel et al. et al., 2011)**. Moreover, these activities have been found to enhance the emotional states of children with ASD and reduce overall stress levels, positively affecting family dynamics and functionality **(Sowa et al., 2012)**.

Parental reports generally corroborate these findings from the literature. For instance, most families of children with ASD perceive physical activities as predominantly positive experiences for their children and observe improvements in their social skills and overall behaviour **(Must, A. et al., 2015)**. Consequently, physical activities are crucial for enhancing social skills and emotional states in children with ASD. In addition, these activities can reduce parental stress levels and elevate overall family functionality. Children with ASD often face challenges in social interactions and may exhibit specific behaviour patterns. However, physical activities can help these children enhance their social skills and self-expression and positively channel their energy.

These findings suggest potential benefits that can improve multiple facets of life for children with ASD. Therefore, these children should be encouraged to participate in regular physical activities. Educating families on this subject and guiding them on how to facilitate appropriate physical activities for their children could improve the overall quality of life for the children and their families. Research conducted by **Pan (2010)** and **Sowa & Meulenbroek (2012)** has demonstrated that regular physical activity can enhance motor skills, social skills, and overall quality of life for children with Autism Spectrum Disorder (ASD). It is also noted that these activities may reduce stress levels and improve sleep quality in these children **(Lang et al., 2010)**. This emphasizes the importance of family involvement in physical activity programs tailored to the individual needs and abilities of the child.

In addition, a study by **Todd et al. (2010)** revealed that participation in physical activities by

children with ASD enhances the overall quality of family life, reducing stress levels and improving family dynamics. Therefore, not only does the involvement of children with ASD in regular physical activities foster social, motor, and emotional skills, but it also enhances the overall quality of family life.

Several studies show that regular physical activity can improve social skills, motor coordination, and overall emotional well-being in children with ASD. For instance, research by **Pan (2010)** found a significant improvement in the social skills and emotional well-being of children with ASD who participated in regular physical activities. Furthermore, a study by **Lang et al. (2010)** suggested that regular physical activity can enhance the motor skills of children with ASD. Research by **Bremer et al. (2015)** and **Pan et al. (2019)** further supported the notion that regular physical activity can positively affect individual behaviours and overall family dynamics, enhancing social skills, emotional health, and the overall quality of life for children with ASD. In addition, research by **Must et al. (2014)** found that physical activity increases the energy levels, attention spans, and social skills of children with ASD, leading to fewer problematic behaviours and improved sleep.

These findings underscore the importance of physical activity participation for children with ASD. Physical activity can aid in developing social skills, supporting emotional health, and improving overall quality of life while positively influencing family dynamics. The existing literature suggests that children with ASD and their families can substantially benefit from regular, structured physical activities. These activities can guide children in positively channelling their energy, expressing themselves better, and developing social skills while enhancing family dynamics.

A wealth of research underscores the potential benefits of physical activity for improving social skills, self-confidence, and overall quality of life in children with ASD. Studies have found that sports and physical activities can significantly enhance social skills and self-confidence in these children **(Bremer et al., 2019)**, contributing to their teamwork and communication abilities while encouraging self-expression, friendship formation, and improved interactions with their environment.

Beyond fostering social skills, physical activities contribute to emotional regulation in children with ASD. According to studies conducted by **Pan (2010)** and **Lang et al. (2010)**, engaging in regular physical activity can serve as a therapeutic tool in managing prevalent conditions, such as anxiety and hyperactivity, frequently encountered by children on the autism spectrum. **Pan (2008)** also highlighted that physical activity can bolster self-confidence and independence in children with ASD. Physical activities can reduce behavioural problems in children with ASD, diminishing hyperactivity, attention deficit, and aggression **(Pan et al., 2011)**. A meta-analysis by **Bremer et al. (2015)** further substantiates the role of physical activities in enhancing social skills. The study found that sports and exercise activities can improve social interaction skills, teamwork abilities, and empathy in children with ASD.

Research by **Lang et al. (2010)** indicates that regular physical activity can improve emotional state and reduce stress levels in children with ASD. **Sowa and Meulenbroek (2012)** also suggest that regular physical activity can enhance the emotional state, social skills, and cognitive functions of children with ASD while alleviating family stress levels.

In conclusion, both anecdotal and scientific evidence supports the positive impact of physical activity on children with ASD and their families. However, considering each child and family's distinct needs and experiences, it is crucial to acknowledge that the benefits of physical activity may only sometimes apply in some situations. Additional research and improved strategies are needed to fully harness the potential benefits of physical activity for these children and their families.

Findings suggest that physical activities can improve social skills, emotional well-being, and overall quality of life in children with ASD. These activities also reduce stress levels and enhance family functionality. Regular physical activity is shown to potentially improve motor and social skills and emotional health in children with ASD. Such activities can help channel their energy positively, aid self-expression, and enhance social interaction skills. Furthermore, physical activities have been found to decrease stress levels, improve sleep quality, and enhance overall life quality. The perspectives of families also reinforce the literature findings. Parents often perceive their children's

involvement in physical activities as a generally positive experience, noting improvements in their social skills and behaviours.

Based on these findings, we can conclude that physical activities are vital for children with ASD, potentially improving their social skills, emotional state, and overall quality of life. Moreover, these activities decrease families' stress levels and enhance family functionality. Therefore, participation in regular physical activities should be encouraged in children with ASD, and families should be made aware of and guided in this regard. However, given the unique needs of each child and family, physical activity programs should be tailored to individual needs and abilities.

Conflict of Interest:

There is no personal or financial conflict of interest within the scope of the study.

Information on Ethics Committee Permission

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Researchers' Contribution Statement:

Research Design- BEO; Statistical analysis- BEO, AK; Preparation of the article, BEO, AK, ASÖ; Data Collection- Performed by BEO, AK, ASÖ.

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RESEARCH ARTICLE

Tele-Rehabilitation for Boys with Duchenne Muscular Dystrophy in India Amidst the COVID-19 Pandemic: An Implementation Study

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Abstract
Purpose: Duchenne muscular dystrophy (DMD) is X-linked progressive neuromuscular disorder of childhood onset which leads to loss of ambulation, followed by respiratory and cardiac muscle weakness. Physiotherapy is integral to the multidisciplinary care plan for boys with DMD. During the COVID-19 pandemic, Tele-medicine was increasingly used to provide healthcare to patients. The study aimed to assess the efficacy and feasibility of Tele-rehabilitation among ambulatory boys with DMD. Materials and Methods: Ambulatory boys aged 5 to 12 years with DMD were recruited using purposive sampling. The Tele-rehabilitation program was designed by a neuromuscular team and provided by a physiotherapist through telephonic video calls twice a month for three months. A compliance diary was provided to fill out at home after each session. The outcome was measured with a change in Medical Research Council (MRC) sum score and gower's times at 12 weeks using paired t- test. Results: 92 boys with DMD were enrolled and 66 (71%) boys completed the program and had follow-up at 12 weeks. The baseline MRC sum score was 38.2±3.7, and the gower's time was 9.2±6.7 seconds. At 12 weeks MRC sum score was 38.8±4.2, and gower's time was 8.59±7.7 seconds (p-value- 0.03 and p-value- 0.001), respectively. The Vigno's and Brook's scores didn't show a significant change. Compliance of >50% to the Tele-rehabilitation exercise programs was present in 89% of subjects. Conclusion: A short-term Tele-rehabilitation program was feasible with a high compliance rate and efficacious in motor strengthening among boys with DMD.

Keywords
DMD, Tele-rehabilitation, Exercise Program, Compliance, COVID-19

INTRODUCTION

Duchenne muscular dystrophy (DMD) is the most common and X- linked neuromuscular disease, affecting approximately 1 in 3500 male births (Crisafulli et al.2020). This disorder is caused by a mutation in the dystrophin gene on chromosome xp21, leading to formation of dysfunction dystrophin protein, which leads to progressive muscle weakness (Birnkrant et al. 2018). Onset of symptoms typically occurs between 3-5 years of age with delayed walking. In the early stages of

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the disease, there is selective involvement of the pelvic girdles muscles followed by shoulder musculatures (**Giliberto et al. 2014**).

Boys with DMD in their second decade of life became wheel chair bound, and subsequently become dependent for Activities of daily living (**Birnkrant et al 2018**). Lack of mobility; loss of ability to use upper limbs; respiratory muscle weakness, bone weakness, scoliosis, cardiomyopathy and gastrointestinal disturbances are progressive complications of the disease (**Wasilewska et al. 2020**). The cardio-respiratory failure causes death in the second decade of their life.

Despite medical advances, DMD cannot be cured, however, appropriate therapies and multidisciplinary care can improve the quality of life and extend the life expectancy of affected boys to more than 30 years of age (**Passamano et al. 2012**). Multidisciplinary care components includes physiotherapy, orthotics, respiratory support, cardio protective, bone and spine health care and steroids etc. The use of corticosteroids have proven to be effective in reducing the progression of disease and helps in maintaining the mobility of the affected patient. It also delays onset of the respiratory and cardiac complications and reduces the possibility of kyphoscoliosis (**Balaban et al. 2005**)

Physiotherapy is a key component of rehabilitation as it includes stretching of tight muscles structures and postural alignment. The exercises also targets weak muscle structures by mild to moderate strengthening program to improve the muscle strength and endurance (**Hammer et al. 2022**). Thus exercise therapy is an important and integral part of rehabilitation as it maintains overall health, prevent disuse atrophy and improves quality of life.

Tele-rehabilitation is an extended way of rehabilitation that provides specialized treatment far off from hospital settings through remote consultation to patients using telecommunication technology at home or in the community (**Sobierajska-Rek et al. 2020**). Also, providing health care in the home setting could facilitate adherence, improve self-reliability, and adapts to real life domains (**Appleby E et al. 2019**). The biggest advantages of Tele-rehabilitation is that it is efficient and has a potential to deliver therapies in comparison to conventional ways of management especially to neuromuscular patients having ambulation issues, distance obstacles and pandemic barriers (**Akulwar-Tajane and Bhatt 2021**).

In India Tele-rehabilitation is increasingly used to provide care at home during the COVID 19 pandemic. It helped to reduce the risk of exposure to virus and provide quintessential care during the peak phase of pandemic. In addition, Tele-rehabilitation reduced the expenses that are related with receiving care for patients living in rural areas, travel related cost and can provide care to non-ambulatory patients. (**D'Souza and Rebello 2021**). However, there is lack of studies evaluating efficacy and feasibility of Tele-rehabilitation in patients with DMD. We planned this study with the objective to assess the effectiveness and feasibility of Tele-rehabilitation in improving the motor and functional scores of boys with DMD. Additionally, we aim to evaluate the compliance of the participants with the program.

MATERIALS AND METHODS

This pre and post experimental study, conducted between April 2022 to November 2022. Purposive sampling was used to identify the participants for the study, which included ambulatory boy with clinical and genetic diagnosis of DMD between the ages of 5 to 10 years enrolled in a tertiary care hospital's outpatient clinic. The Institute Ethics Committee approved the study protocol (INT/IEC/2022/Study-213). Prior to the inclusion of the children in the study, informed consent from parents and assent from the children was obtained.

Regarding vulnerable groups, the authors took into account the needs and priorities of the groups/individuals in which the study was conducted, in accordance with Articles 19 and 20 of the WMA Declaration of Helsinki, and the situation that the study could not be carried out outside these groups and individuals was taken into account. "In this study, additional precautions were taken by the researcher(s) to protect the volunteers."

Basic Clinical And Demographic Characteristics

Ambulatory boys, having typical signs and symptoms suggesting DMD confirmed with genetic testing or muscle biopsy, free from respiratory tract infections having basic knowledge of attending video call and sending email were included in the study. Baseline evaluation

including Medical Research Council(MRC) sum score, gower's time, Brook's and Vigno's upper and lower limb scores, was performed by physiotherapist and recorded on a case record form.MRC sum score is the most widely used tool for measuring muscle strength having grade 0 to 5 where 0 is "No contraction" to 5 is "Normal power"(**Florence et al.1992**) Gower's time is the time taken to get up from supine position to standing position is a timed function test and is widely used for evaluation of functional performance in clinical trials (**Angelini and Peterle 2012**).

The Vigno's functional scale explained by **Brooke in 1981** grades the severity of lower limbs from grade 1(walks and climbs without assistance) to10 (confined to bed). While the Brooke functional scale grades the severity of the involvement of upper scale from 1 (starting with the arms at the sides, the patient can abduct the arms in a full circle until they touch above the head) to7 (cannot raise hands to mouth and has no useful function of hands). Both functional scales have proven to have good inter and intra rater reliability and are widely used (**Brooke et al 1981**).

A physiotherapy training program was prepared in accordance with DMD care considerations 2018 with thorough discussion among co- authors (**Birnkrant, et al 2018**). Patients and their caregivers were asked to attend a video call demonstrating the exercise program for 30 minutes. Parents were advised to perform muscle stretching and strengthening exercises5times/week for 12 weeks. Exercises were demonstrated and reinforced through a video call after every 2 weeks interval by physiotherapist. Exercise program included six sets of exercises: mild to moderate self-strengthening exercises of target muscle groups: shoulder flexors and abductors, elbow extensors, hip flexors, extensors and abductors, knee flexors and extensors and abdominals (**Lott et al. 2021**). Self stretching of elbow flexors, forearm pronators, wrist and finger flexors; hip flexors, hamstring and plantar flexors. Respiratory exercises included: positive inspiratory pressure and positive expiratory pressure (**Sobierajska-Rek et al. 2021**). After 12 weeks of home physiotherapy program, a physical assessment by same physiotherapist was performed in the clinic. The outcome measures included upper and lower limb functional scores, MRC sum score, gower's time on patients who have completed 12 weeks training program sessions.

Statistical analysis

Data was recorded on a case record form, entered in Microsoft excel program and was analyzed. Statistical Package for the Social Sciences (SPSS version 26.0 Armonk, NY: IBM Corp) was used to analyze the data. Descriptive statistics were presented with mean, standard deviation, and percentages to record baseline demographics and clinical characteristics. To verify the normality of data we have followed two method by graph, the normal bell shaped curve and Kolmogorov-Smirnov test. The Brook's, Vigno's, MRC sum score and Gower's time had skewed distribution according to the Kolmogorov-Smirnov test and Shapiro wilk test. The MRC sum

score and Gower's time were compared using paired t-test. Brookes and Vignos can be presented as mean (SD) if the distribution is normal, but if distribution is skewed median and IQR is the better way to present. Hence for pre post analysis for two related groups, for skewed data Wilcoxson sign rank test is used. Hence Brookes and Vignos were compared using Wilcoxson sign rank test. p value of <0.05 was considered significant.

RESULTS

During the study periods a total of 92 boys with DMD, were recruited into the study and evaluated. The demographic characteristics are presented in the "Table 1". Mean (SD) age of the boys with DMD at enrolment was7.4±1.6 years. Median (IQR) Vigno's lower limb score was 2 (2,2), Brook's upper limb score was 1 (1,2). Mean (SD) MRC sum score was 38.2±3.7 and gower's time was 9.2±6.8 (mean, SD) sec. All 92 children were given telephonic instruction to perform home physiotherapy and fill the compliance diary. Fourteen children (15%) did not respond after few video calls and 12 children (13%) did not come for a follow up visit after 12 weeks.

Post12-week Tele-rehabilitation program (n=66) mean (SD) Brook's score was 1.33±0.51 with mean difference of 0.015 and p value 0.32, Vigno's score was 2.12±0.48(mean, SD) with mean difference of 0.030 and p value 0.15. Post 12-week rehabilitation mean(SD) MRC sum score was 38.77±4.22 with a mean difference of -0.18 and p value 0.03. Post rehabilitation mean (SD)

gower's time was 8.5±7.74second with mean (Table 2). The MRC sum score and Gower's time showed significant improvement ($p< 0.033$ and $p< 0.012$) respectively while there was no significant difference noted between Vigno's and Brook's scores ($p<0.32$ and $p< 0.15$) respectively as shown in "table 2".Patient compliance was measured by using an arbitrary scoring method used by (Malagoni et al. 2011), for evaluating patient's compliance of exercise based rehabilitation for difference of 0.56 second with a p value of 0.012 patients with intermittent claudication, 4 (highest compliance) to 1 (lowest compliance) based on percentage of physiotherapy attempted. A score of 4 was recorded for 13 patients (19.69%); a score of 3 was given to 20 patients (30.30%); a score of 2 was given to 26 patients (39.39%) and score of 1 was given to 7 patients (10.60%) shown in "table 3".

Table 1. Basic clinical and demographic charcteristic of participants (Duchenne muscular dystrophy)

No. of Subjects	N=92 X±SD	Z score
Age, years	7.38±1.62	
Height, cm	117.23±10.69	-1.34±1.68
Weight, Kg	19.38±5.23	-1.59±1.07
Vigno's lower limb score	2.13±0.39	
Brook's upper limb score	1.32±0.49	
MRC sum score	38.25±3.72	
Gower's time, sec	9.17±6.74	

Table 2. The pre and post Tele-rehabilitation outcome measures of boys with DMD at 12 weeks interval

Outcome measures n=66	Pre-intervention X± SD	Post-intervention X±SD	Mean difference	P value*
MRC sum score	38.55±4.2	38.77±4.2	-0.18±0.7	0.03
Gower's time(sec)	9.2±7.6	8.59±7.7	0.56±1.8	0.001
Brooks UL score	1.37±0.51	1.35±0.50	0.02±0.1	0.32
Vigno's LL score	2.15±0.43	2.12±0.48	0.03±0.2	0.16

Table 3.Patient compliance for the home-based Tele-rehabilitation

Compliance Score	No of patients	Percentage	Exercise session performed
4	13	19.7%	<90%
3	20	30.3%	80-90%
2	26	39.4%	50-70%
1	7	10.6%	<50%

DISCUSSION

This pre post experimental study on implementation of Tele-rehabilitation for 12 weeks under supervision of physiotherapist for boys with DMD was feasible with good compliance rate. The efficacy assessed with Vigno's and Brook's score, MRC sum score and Gower's time showed improvement in muscle strength with increase in MRC sum score and reduction in Gower's time over 12 weeks period. Though Vigno's and Brook's score didn't change over 12 weeks period. Tele-rehabilitation can be considered a reliable and promising approach for rehabilitation for children with neuromuscular disorder. Due to the mobility related barriers for boys with DMD, Tele-rehabilitation can deliver equally efficient results comparable to other treatment approaches.

We provided Tele-rehabilitation through video calls with instructions given by trained physiotherapist to parents and boys with DMD for 12 weeks period. In comparisons to other studies that require specialized software to implement rehab in patient's devices, our intervention requires only internet connection with a basic application in the patient's devices that they usually have, allowing its accessibility from remote locations. This is in contrast with several

other studies requiring complex technological platform, and software installation (**Moffet et al.2015**). Ease in administration of the physiotherapy programs allows high compliance and makes it easily applicable to other disease and settings.

One of the most important aspects of DMD is progressive deterioration of muscle strength and thus in functional performance of affected individual. The decline in muscle strength is not linear in boys with DMD, a precipitous decline is observed by the age of 8-10 years manifesting with difficulty in rising from floor of increase in gower's time, and difficulty in walking and subsequently loss of ambulation. Weakness in the pelvic girdle is followed by para-spinal muscles and upper limb weakness, manifesting as difficulty in sitting and postural maintenance, scoliosis, and difficulty in using upper limb for daily living activities. A twelve week rehabilitation program led to a milder improvement in muscle power measured with MRC sum score in response to the exercises and muscular training in antigravity positions such as straight leg raise and dynamic knee extension in supine and sitting positions respectively; similar findings have been reported by Abramson and Rogoff, and Vigno's and Watkins where strengthening exercises have shown improvements in MRC (**Jansen et al.2013; Huijgen e al.2008**). However, active and resisted exercises have been used for the authors in previous studies, whereas our study primarily focuses on active and active assisted exercises which is supported by our findings that MRC improvements are limited to patients with less diseases severity and least severity affected muscle groups (**Cramer et al. 2021; Pastora-Bernal et al. 2021**).

An improvement in Gower's time was observed by active, flexibility and stretching exercises. Similarly in a study by Lutfiye Akkurt et al reported that flexibility exercises of lower limb muscles are correlated with improvements in timed performance test (Gower's test) (**Akkurt et al.2019**). Similarly another study by Alemdaroglu et al found upper extremity exercises by arm ergo meter has improved the timed performance or Gower's test (**Alemdaroğlu et al.2015**).

In this study functional performances measured by the Brook's and Vigno's scales didn't show significant change over 12 weeks. These functional scores strongly correlate with muscle strength (**Lue et al.1992**) since we have found improvements in strength with subjects involving less disease severity and in fewer muscle groups. The baseline vigno's score was 2 and brooks score was 1, suggesting a mild disease severity. There is requirement of considerable muscle strength gain for improvement in vigno's score from 2 to one, which is unlikely in a progressive muscular dystrophy. During the rehabilitation period we have not seen any decline in their functional scales which may be supported by the fact that exercises delay the deterioration in the functional performance as consistent with the findings of Jensen et al in a randomized controlled trial (RCT) that maintaining in the functional performances of the boys with DMD while performing exercise training period in the form of active bicycle exercise program (**Jansen et al 2013**).

Tele-rehabilitation is employed in various other conditions during the COVID 19 pandemic and reported that it is acceptable to patients. In a RCT, Barbara et al studying the feasibility of Tele-rehabilitation reported that it is effective as well as feasible; as it provides satisfaction to the patient by delivering specialized services at their home with ease (**Huijgen et al.2008**). Steven et al studied Tele-rehabilitation in patients with stroke and found it feasible and is a holistic way to provide rehabilitation services (**Cramer et al.2021**). In a similar study Jose-Manual et al reported efficacy of Tele-rehabilitation on low risk cardiac patients and found it is a cost effective and reliable way of providing quality care (**Pastora-Bernal et al.2021**). In a pilot study Chen et al reported chronic stroke patients were highly compliant to the Tele-rehabilitation program and was equally efficacious in comparison to conventional way of providing rehabilitation (**Chen et al. 2021**). Several other studies on Tele-rehabilitation among children with chronic disorders have also documented its potency and feasibility for delivering equally productive care especially to medically fragile children or having any movement constraints (**Tanner et al. 2020; Schlichting et al. 2022**).

Selection of young ambulatory boys with DMD in current study was a potential limitation, since boys with DMD faces mobility constraints with progression of disease when they are wheelchair bound and become non-ambulatory. However, during the pandemic rehabilitation of all chronic neuromuscular disorder was compromised.

Further study targeting rehabilitation of non-ambulatory boys with DMD can be done to understand the acceptability and compliance in advance disease.

In conclusion, our study demonstrated that Tele-rehabilitation is acceptable for dealing motor impairments among boys with DMD from North India. Patients and boys with DMD have high compliance rate to the programs and the efficacy was demonstrated by improvements in MRC sum score and reduction in Gower's time over 12 weeks period. There is a need to conduct larger studies with longer follow up period to understand the efficacy of exercises through Tele-rehabilitation as a substitute of traditional rehabilitation therapies.

Conflict of Interest:

There is no personal or financial conflict of interest within the scope of the study.

Information on Ethics Committee Permission

The Institute Ethics Committee approved the study protocol (INT/IEC/2022/Study-213). Prior to the inclusion of the children in the study, informed consent from parents and assent from the children was obtained.

Author Contributions:

Study conception and design: PG, SB, APS, RS; Data Collection: PG, APS, SB, SSB; Analysis and Interpretation of results: RN, RS, SB, PG; Draft manuscript preparation: PG, APS, SB, SS; All authors reviewed the results and approved the final version of the manuscript.

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RESEARCH ARTICLE

The Influence of Imagery and Agility Training on Athletes Futsal Goalkeeper Reaction Time Metro City Senior High School

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Abstract
The purpose of this study is to determine: (1) Differences in the effects of image training methods using audiovisual and visual means on reaction time. (2) the difference between the effects of high agility and low response time; (3) Interaction between image and agility training model on reaction time of futsal goalkeepers. This study used experimental methods with a quantitative approach in a 2x2 factorial design and took a target sample, ie 24 students out of a total of 90 students. The data analysis method used was a two-way ANOVA test using the SPSS 23 program with a significance level of 5%. The results showed that: (1) There was a difference in the effect of image training methods using audiovisual media and visual media on reaction time, with a significance value of 0.001<0.05; (2) There is a difference between the effects of high mobility and short reaction time, with significant values of 0.018 < 0.05; (3) For reaction time of futsal goalkeepers, there is an interaction between imagination and agility training models with significant values of 0.373 > 0.05. The conclusions in this study are: (1) There is a difference in the effects of audiovisual imagery training and visual imagery training on the reaction time of goalkeepers in futsal players ; (2) Effects of high and low agility on goalkeeper reaction time in futsal athletes ; (3) Synergistic effects of imagination and agility training on goalkeeper reaction time in futsal players.

Keywords
Futsal, Goalkeeper, Imagery, Agility

INTRODUCTION

Each squad must have four field players and one goalie, with no limit on the number of substitutes. Futsal is distinguished by aggressive game intensity, rapid decision-making, high physiological loads, psychological stress, and heightened emotional states (Borges et al., 2021; Spyrou et al., 2020). Futsal in Indonesia has mushroomed so many investors have turned to futsal. This was also seen in the Futsal World Cup match held. Everyone is watching the game. The game of futsal is currently undergoing major changes, whether viewed from the technique of the game, regulations, organization, or from a publication point of view so that the development of futsal develops rapidly.

In the initial observations made by researchers on December 5, 2021 - January 23, 2022 at the Giga Futsal Arena in the framework of the Metro City Student Futsal League 2021, and from the results of initial observations using observation techniques, unstructured interviews and reaction tests using a whole body reaction, since and it is obtained that:

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Table 1. Whole body reaction

No	Name	Reaction Tests			Category	School
		1	2	3		
1	KMS	0,39	0,35	0,31	Medium	MAN 1 Metro
2	RYN	0,32	0,37	0,39	Medium	SMK Muh. 2 Metro
3	FHM	0,36	0,38	0,38	Medium	SMKN 2 Metro
4	HFZ	0,42	0,44	0,42	Low	SMK Muh. 3 Metro
5	RVD	0,35	0,35	0,33	Medium	SMAN 3 Metro

Source: Primary Data

Agras et al., (2016) argues about factors such as strength, stamina, power and balance are important in futsal, but evaluation of futsal players must also rely on futsal-specific skills. Futsal is a game of time variable for achieving their aims with success, as innumerable human motor skills. For example, one may argue that the fundamental objective of the goalkeeper's motor skills is temporal coincidence. This is due to the fact that he or she must intercept a moving ball by hitting or holding it in order to prevent it from reaching its destination. Someone arrives at the ball trajectory before or after the goal, and so their attempt is unsuccessful. However, in order to obtain it, Goalkeeper must deal with two other essential temporal factors underpinning motor skill performance: time for anticipation and reaction (Schmidt & Wrisberg, 2010; Tani, 2016). To put it another way, the goalkeeper's search for a time correlation in connection to the movement of the ball in order to prevent the target may be anticipated by the subsequent processing of implicit information and currently known target information, respectively.

In a competition situation, in this case a futsal competition, individuals will face a match that will determine the individual's career and the fate of the team being defended will win or lose. Various factors such as demands of managers or coaches, demands of supporters, demands of management to achieve victory will be a heavy burden for athletes. The quality of the opponent who is considered great, makes athletes feel anxious or afraid of making mistakes, fear of not performing optimally, fear of losing in skills and cooperation with team opponents, until the biggest fear is defeat that has an impact on individual careers in a team.

If these conditions are not handled, it will lead to what is known as competition anxietyAnxiety over competing is a state of stress, restlessness, and unease caused by viewing competition as dangerous, and it is accompanied by physiological changes (Maulana & Khairani, 2017). Fear comes in two forms, features and conditions. Trait anxiety is thought to be a relatively stable trait that leads to similia reactions to stressful situation over time (Singh et al., 2017).

Pre-race anxiety is one of the most common feelings in high-performance athletes, and it is claimed to hinder cognitive, physiological, and physical performance. Because such anxiety can have positive as well as negative effects, being able to handle it is one of the most critical aspects of an athlete's preparation (Muñoz et al., 2017). Many gamers struggle with anxiety that can have a significant negative impact on their performance (Slimani & Nikolaidis, 2018). Physical state anxiety reflects the player's physical/physiological state, whereas cognitive state anxiety reflects the player's mental state (Singh et al., 2017; Slimani & Nikolaidis, 2018) . Psychological symptoms of anxiety are feelings of fear, sadness, insecurity and feelings of inadequacy. Physical symptoms are heart palpitations, cold sweats, the body feels stiff, and cognitively finds it difficult to concentrate (Nurwidawati, 2015).

Harsono (2015) argues that "there are four aspects of training that athletes must carefully consider and practice: (a) physical training, (b) technical training, (c) tactical training, and (d) mental training". Physical exercise is one of the most important aspects without neglecting other aspects. Strength, endurance, explosive power, speed, flexibility, agility, balance, coordination, precision, and kinesthetic sense are all components of physical condition. The primary physical conditions in futsal include endurance, speed, strength, agility, and explosive power (Redita, 2021).

Currently, the program has a lot of training, especially for the younger generation of goalkeepers who are trained and nurtured in terms of technique and physicality. However, there are many obstacles that can be seen in the implementation of the exercise, there is no play approach that has been applied to the reaction exercise. Constraints that occur in the construction of goalkeepers, especially in the reaction training program. Positions in soccer and futsal are special positions that require even quicker and more accurate reactions. Reaction speed in futsal limits a goalkeeper's athletic ability. In addition to the reaction speed, it is also important to **(Montesano, 2016)** Emphasis on explosive power. Point out all the speed characteristics in futsal, not just reaction speed. In their opinion, these are all key factors that limit game performance **(Dragijský et al., 2016; Smpokos et al., 2018)**.

Otte et al., **(2019)** I agree with this claim. They emphasize quick attack building, constant reaction to newly created game situations, diving and saving shots, reflexive shots and diving shots from close range using hands and feet, characterized taking the cross as the goalkeeper's most important game activity. In many studies (**Birren & Schaie, 2021; Chang et al., 2011; Der & Deary, 2006; Hagovská & Nagyová, 2017; Jevas & Yan, 2001; Obetko et al., 2020**). Age has been proven to be the main factor that depends on a player's reaction time. Disjunctive reaction times shorten in adolescence, peak in adulthood, and begin to lengthen with age. This is a natural trend that futsal players can influence. However, as the demand for play continues to increase, researchers are looking for ways to influence these motor skills to some extent as well (**Obetko et al., 2020**).

A goalkeeper will have a hard time reacting to the ball he's aiming at if he doesn't have responsiveness and speed. The ability to react quickly is a valuable asset for a goalkeeper. Imagine the need for high reflexes as shots towards the goal are often shot from close range (**Scheunemann, 2012**). In addition, exercise is not enough to be done only motorly (with movement), but must be accompanied by non-motor training methods (without movement) such as seeing pictures or films about the movement to be performed, it can also be done by imagining or visualizing, or image the movement to be studied or specifically referred to as imagery. Imagery is translated into the sense of imagining". Imagery is one of the special techniques related to psychological skills by involving imagination.

Imagery training is a method of learning that involves remembering how to do the correct motions, repeating new actions, correcting less-than-perfect movements, assisting athletes in improving their skills, and assisting athletes in improving their performance in the face of various obstacles (**Sabilla et al., 2022**). Imagery is a valuable and vital strategy for mental management, which has an effect on self-confidence and has an impact on the athlete's performance **(Akbar et al., 2019)**. Imagery has been shown to improve athletes' performance and psychological skills in a variety of sports, including basketball **(Akbar et al., 2019)**, gymnastics **(Firmansyah, 2011)**, volleyball (**Sukar et al., 2019**), soccer **(Sartono et al., 2020; Sufriyanto & Putra, 2019)**, and others. The most effective use of image preparation for cognitive tasks and advanced athletes to provide more benefits to novices appears to be most effective when physical activity is prioritized.

The use of audiovisual imagery training in futsal games has been shown to improve the reaction time of futsal goalkeepers, players who do agility ladder training, and players who have low levels of anxiety in futsal players, particularly goalkeepers.

MATERIALS AND METHODS

Study design and population

The method used in this study is a factorial design method based on a quantitative approach. Quantitative approaches start with collecting data, interpreting data, presenting results, and many numbers are used. In this study, researchers used therapeutic image training using audiovisual and visual methods by comparing the mobility level of each sample to that of the experimental group. Sampling is done by selecting targets based on specific objectives based on factorial design as well as strata, random numbers, and areas (**Sugiyono, 2017**), in short: in this design, all groups were randomly selected and each group underwent a pretest. Groups in the study were declared good if they had the same pretest score.

It was deemed valid for study based on letter Number: 068/POR/A/III/2023 regarding assessing the validity of research data on physical fitness of Student Activity Unit participants in the field of

sports. Before participating in the study, research subjects supplied detailed, informed, and voluntary consent. Researchers must ensure that research subjects completely understand the objectives, procedures, risks, and benefits of research done in conformity with the Helsinki Declaration.

Measuring methods

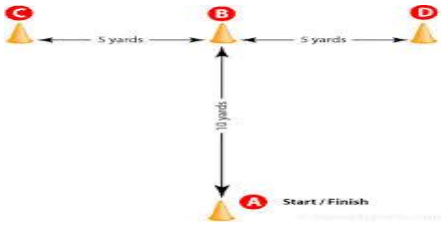
After scoring low and high on an agility test, the sample is divided into two training techniques and then divided into an exercise group. The outcomes are interpreted as high and low. Obtaining a high components group and a low component group, the samples used as research subjects were students who took part in Metro City Student Futsal League aged 16-18 years. In the training process visual exercises are performed on the futsal pitch using audiovisual aids. The procedure is for the student to watch a training video created by the coach as it is carried out on his pitch in futsal.

Inclusion requirements are standards that need subjects for research to act as study participants that meet the criteria **(Notoatmodjo, 2012)**. This study's inclusion criteria include: 1) Between the ages of 16 and 18. 2) A high school athlete who participates in Metro City student futsal leagues. 3) Serves as a guard, and 4) is male. Exclusion criteria are conditions where research participants cannot represent the sample because they do not match the requirements as a research sample, such as ethical barriers, refusal to be a respondent, or a scenario that makes research impossible (**Notoatmodjo, 2012**). In this study, the exclusion criteria were as follows: 1) age between 16 and 18 years; 2) high school athletes that do not play in student futsal leagues metro city throughout the year, metro city; 3) flanking, pivoting, and anchoring positions.

The data collection technique used in this research includes four activities: 1) data collection: population data collection from each high school futsal extracurricular in Metro City; 2) knowing the players' high and low agility by collecting data using instruments; 3) after understanding the high and low agility findings that will be handled, form groups based on each imagery criterion; 4) test the goalkeeper's reaction using the Whole Body Reaction Time Test.

The agility ability test uses the T Drill Test with a test form sourced from (**Widiastutik, 2015**). After testing the agility ability test instrument which was carried out on futsal extracurricular students at SMA Negeri Sport Metro, it had a validity value of (0.98) and a reliability of (0.89) as follows:

Figure 1. *'T' Drill Test*



Source : Mackenzie, 2008

Table 2. Norms *'T' Drill Test*

Ranking	Males (Scconds)
Excellent	<9.50
Good	9.51-10.50
Averaga	10.51-11.50
Poor	>11.50

source : Mackenzie, 2008

In collecting data, a measurement tool is needed, so that by using this tool data will be obtained which is the result of the measurement. (**Nurhasan. & Hasanudin., 2014**) explains that: "A test is a tool or procedure for measuring something in an atmosphere using predetermined methods and rules." In research, measurements are

carried out twice, namely at the beginning and end of the research or before and after the treatment is given. The type of instrument used to measure the goalkeeper's reaction speed ability in this study was the whole body reaction test with reliability and validity coefficients of 0.93 and 0.607.

Figure 2. Wholebody reaction time

Source : Miyatake, 2012

Table 3. Norms *wholebody reaction time test*

No	Category	Time (seconds)
1	Special	0.001 – 0.100
2	Very good	0.101 – 0.200
3	Good	0.201 – 0.300
4	Moderate	0.301 – 0.400
5	Less	0.401 – 0.500
6	Less than once	0.501– upwards

Source : Miyatake, 2012

Statistical analyses

Sampling The method was a directed sampling technique, with a sample of 24 students drawn from a total student population of 90. The data analysis technique uses the Analysis of Variance (ANAVA) test with a 2 x 2 factorial plan at α = 0.05 (**Siswandari, 2009**). To fulfill the assumptions in the ANOVA technique, a normality test and Homegeneity of Variance test were carried out with Leverne's test (**Budiyono, 2009**). To test the hypothesis using Analysis of Variance (ANAVA 2 x 2). If data analysis shows that there is an interaction effect between the methods, continue with the Tukey test. A summary of this study is as follows:

Table 4. Factorial Research Design

Agility \ ***Imagery***	Audiovisual A1	Visual A2
High	A1B1	A2B1
Low	A1B2	A2B2

RESULTS

To test the research hypothesis that was carried out using the analysis technique on the 2x2 factorial Anava, the summary can be seen in the following table:

Table 6. 2x2 Factorial analytical results (2 Way Variance Analysis)

Dependent Variable: post				
Source	df	F	Sig.	Info
Model	1	16.603	.001	There is a significant influence
Agility	1	6.968	.018	There is a significant influence
a. R Squared = .688 (Adjusted R Squared = .552)				
Info: There is a significant effect if the sig. < 0.05				

Source: Primary Data

From the results of the analysis above, it can be concluded that testing the main effect hypothesis as a comparison, there is a significant effect if the sig value is <0.05 and there is an interaction if the sig value is > 0.05.

Imagery Exercise

Based on the results of the 2x2 factorial analysis of variance (ANAVA) at a significant level of α 0.05, a significance value of 0.001 was obtained, thus sig0 < sigt, so that H0 was rejected because the calculated sig is smaller than the sig value at a significance level of α 0.05 (Sig0 < Sigt,) and F 16,603 where F calculated is greater than F table 3.10 at a significance level of α 0.05 (F0 > Ft,) can be accepted or said there is a significant effect. Based on the amount of influence that imagery training has on the reaction time of the futsal goalkeeper, it is 16,603 at level F. From this, it can be concluded that there is a large difference in the effect between visual and audiovisual imagery training on the reaction time of futsal goalkeepers.

Table 7. Imagery results

Variable	F	F Table	Sig.	Sig_t	Info
Imagery Exercise	16.603	3.10	0.001	0.05	There is a significant influence

Source: Primary Data

Figure 3. Imegary Diagram

Agility

Based on the results of the 2x2 factorial analysis of variance (ANAVA) at a significant level of α 0.05, a significance value of 0.018 was obtained, thus sig0 < sigt, so that H0 was rejected because the calculated sig is smaller than the sig value at a significance level of α 0.05 (Sig0 < Sigt,) and F 6.968 where F calculated is greater than F table 3.10 at a significance level of α 0.05 (F0 > Ft,) can be accepted or said there is a significant effect. Based on the impact of agility on a goalie's reaction time 6,968 at the level. So it can be concluded that there is a significant difference between high agility and low agility on the reaction ability of futsal goalkeepers.

Table 8. Agility results

Variable	F	F Table	Sig.	Sig_t	Info
Agility	6.968	3.10	0.018	0.05	There is a significant influence

Source: Primary Data

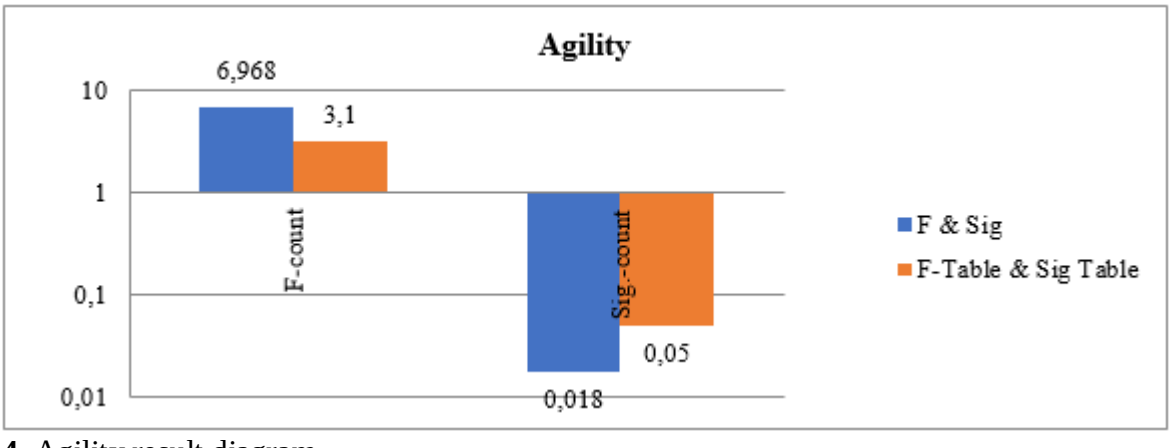


Figure 4. Agility result diagram

Imagery X Agility Exercise

Data analysis of image-trained reaction time agility of futsal goalkeepers. This is demonstrated by simple impact test results, which are shown in Table 9 and Figure 5 below:

Table 9. Imagery X agility results

Variabel	F	F Table	Sig.	Sig.	Info
Imagery X *Agility*	0.838	3.10	0.372	0.05	There is a significant interaction

Source: Primary Data

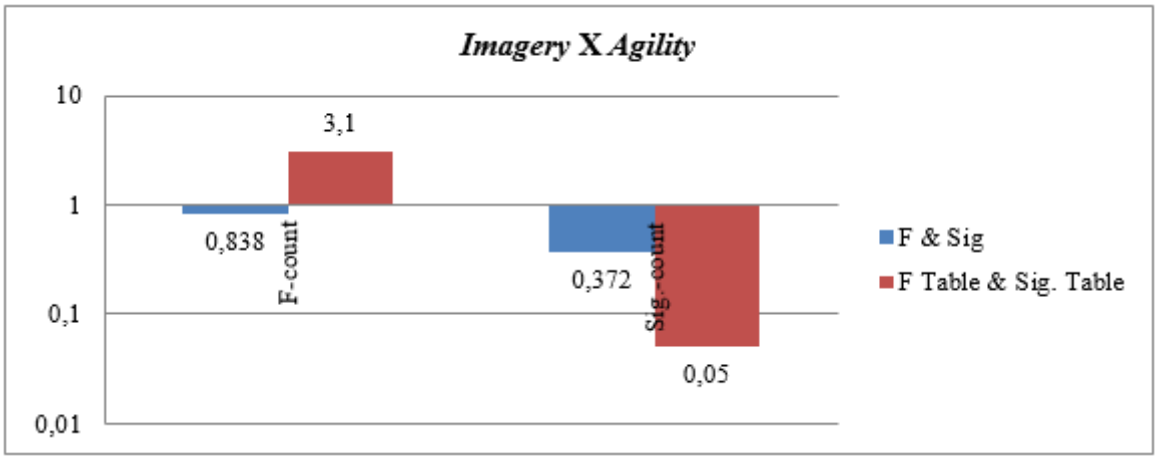


Figure 5. Imagery X agility result diagram

It can be seen that there is a 2x2 factorial anava table at a significant level of α 0.05, a significance value of 0.373 is obtained, thus sig0 > sigt, so that H0 is rejected because the calculated sig is greater than the sig value at a significance level of α 0.05 (Sig0 > Sigt,) and F 0.838 where F count is smaller than F table 3.10 at a significance level of α 0.05 (F0 < Ft,) can be accepted or said there is an interaction. Based on the degree of interaction imagery and agility training had on futsal goalie reactivity, it was 0.838 at level F. This suggests an interaction in futsal goalkeeper reactivity between imagery and agility training.

DISCUSSION

Imagery Exercise

In futsal, the reaction and anticipation of a goalkeeper is needed more because of the difference in the size of the field between football and futsal. In futsal, the goalkeeper will often receive attacks from other teams. Researchers who have repeatedly been the organizers of futsal matches, both regional and national levels, often see how a goalkeeper who doesn't have good reaction and anticipation will be the butt of the opposing players. Meanwhile, goalkeepers who have good reaction and anticipation will be able to secure all kicks that lead to their goal. Further, if goalkeepers are distracted penalty takers this also results in better goalkeeping performance (**Furley et al., 2017**). The skills acquired are a prerequisite for athletes to participate in activities outside of futsal training to improve basic futsal technical skills and improve basic techniques that are still lacking (**Sumantri & Anggara, 2022; Widiyono & Mudiono, 2021**). By creating the right sensory information that contributes to the successful execution of the correct behavior skill for a given situation, you will strengthen the blueprint so that it becomes more likely that you are serious about raising your standard of performance. and tactics. Research on the functional equivalence has shown that imagery and execution share similar although not the same neural networks (**Hardwick et al., 2018; Hetu et al., 2013; Zabicki et al., 2017**).

Furthermore, imagery training leads to more elaborate and more functional representation of structures in motor memory (**Frank et al., 2014, 2018**). Researchers have suggested that increased blood flow in brain regions indicates that the mental stimulus of movement activates some of the central nervous structures required for physical movement (**Kosslyn et al., 2001**). **Frank et al.**, (**2021**)Use image exercises during breaks between exercises helps and enhances higher motor skill abilities. While these covert adaptations as induced by mental types of practice do not necessarily transfer immediately to improvements in motor performance, they come into effect after task execution (**Frank et al., 2018**). In this study, two suitable training methods were applied, namely the imagery training method using audiovisuals and Imagery training methods use visual elements to find out which method gives the goalie a longer reaction time. Both of these training methods have the same goal, namely to improve the goalkeeper's reaction ability. However, each of these training methods has differences in terms of results with the amount of influence that Imagery training affects goalkeeper reaction time of 0.001 and an F value of 16.603, so it can be said that imagery training using audiovisual is better than imagery training using visuals. Based on the discussion of

the research results, it can be recommended that the imagery training method using audiovisual is more suitable to be applied in increasing the goalkeeper's reaction time because it has a better average than the imagery training method using visuals.

Agility

A physical fitness training program must be planned properly and systematically, aiming to improve physical fitness and the functioning of the body's systems so that athletes can perform better (**Mudayat, 2022; Sumantri et al., 2023**). Knowing when to apply the right training stimuli during an athlete's long-term development is critical to effectively programming and improving an athlete's performance (**Hammami et al., 2018; Lloyd et al., 2013; McNarry & Jones, 2014**). During the field training process, where players with different levels of agility receive solid instruction with imagery instruction using multimedia and visual, it produces satisfactory results, as evidenced by the improvements that result from the test results presented at the end of this research. However, players with great agility outperform individuals with low agility when the therapy is administered.

The statement made by the players after carrying out the treatment was that before doing this imagery exercise we could not imagine what to do on the field in the process of facing an opponent either one on one or when the opposing player attacked our team's goal, seen from the treatment given during the first meeting and secondly, at the third and subsequent meetings we understand that there will be imagery training that focuses on an imagination that will be carried out during the match and the calm that we see has a very good impact so that the physical condition factor increases in this case the agility of the futsal goalkeeper.

Combining imagery and physical exercise was more effective than physical exercise alone, indicating different effects of imagery and physical exercise. The same pattern of results was found for the performance results **(Simonsmeier et al., 2021**). First, all previous meta-analyses have provided evidence for the effectiveness of mental practice to improve performance. However, it has been hypothesized that imaging not only performs as described in various imaging models, but is effective in enhancing various outcomes such as psychological performance **(Cumming & Williams, 2013; Guillot & Collet, 2008; Martin et al., 1999**).

As expressed by **Irawadi** (**2011**) that "agility is one of the elements of special physical conditions, which is a combination of elements of strength, speed and flexibility". These three combinations will produce agility. The agility component in the structure of the trainer's training program places it in a special preparation phase, meaning that the agility component is influenced by the physical components of endurance, strength, flexibility, and coordination, all of which have been trained during the general preparation phase (**Mashud et al., 2019**). So it can be said that to train the agility component it is expected to pay attention to the supporting physical components, namely endurance, strength, flexibility and coordination because it can be said that these components are prerequisite components for the formation of agility in an athlete. Students with high agility skills did better than those with low agility. There is a significant interaction between training methods (series of games and series of sports) and agility (high and low) of futsal games, especially for goalkeepers, when documented by the prices of $p=0.000<0.05$. **Muhajir** (**2004**), "agility is the ability of a person to be able to change direction quickly and precisely when moving without losing balance". An athlete with good agility is not only able to perform a skill perfectly, but also can easily and quickly perform skills that are new to him.

Based on the results of the study, the magnitude of the influence that agility has on the results of the goalkeeping ability is 0.018 and for the F value is 6.968 at the sig level of 0.05. So it can be concluded that there is a significant difference in effect between high agility and low agility on the results Metro City Senior High School Goalkeeper Responsiveness. Therefore it can be recommended that high agility is more suitable for use in this study because it can improve the results of the goalkeeper's reaction ability futsal better and maximally.

Imagery X Agility Exercise

In this group where the results obtained after carrying out the final test carried out in the field were the interaction of the imagery training group with the player's agility getting better, then with imagery training the players practiced to be

implemented in matches through imagination in the minds of each player, making players more so that it impacts results better. Performance analysis through close video analysis showed that the successful pass rate increased significantly in the group (**Seif-Barghi et al., 2012**). Mobility performance depends on the complexity of cognitive demands. There is an interference effect between motor and cognitive performance, which can slow us down as environmental information becomes more complex (**Büchel et al., 2022**). Consider the cognitive challenges team athletes face during competition (**Huijgen et al., 2015**), A drawback of current agility testing is that it often relies on a simple think-time paradigm (**Pojskic et al., 2018; Sekulic et al., 2019; Spasic et al., 2015**) It merely represents lower cognitive functions such as processing speed **(Morral-Yepes et al., 2022). Darojat & Hariadi (2019)** Improved athlete mobility makes difficult movements easier, avoids injuries during training and competition, moves smoothly in different directions, and responds quickly to opponents' balls.

In long-term athlete development, knowing when to apply the right training stimulus is critical to effectively programming and improving athletic performance (**Hammami et al., 2018; Lloyd et al., 2013; McNarry & Jones, 2014**). Differences in the timing and pace of physical development in young people should therefore be considered when introducing specific training stimuli **(Sariati et al., 2021**). Several studies have shown that visual performance, like physical performance, is influenced by neurological activation and psychological demands (task difficulty, timing regularity, programming rules) **(Guillot et al., 2012; Jeannerod, 2006**). Additionally, images can be difficult to use when performing turnaround tasks, as they must be used to anticipate specific scenarios (**Jones-Wyatt et al., 2013**). Creating mental images of unpredictable actions is somewhat contradictory, as images lack environment-specific variability. In fact, an individual must create or manifest an image of their own volition **(Lindsay et al., 2019; McNeil et al., 2021**). The lack of overall improvement in reaction performance may indicate that imagery training is not effective for all components of perceptual motor performance. Discrepancies in performance change seem to indicate that participants may not be generating unpredictable stimuli during image acquisition **(McNeil et al., 2021**).

Research **Büchel et al., (2022**) have shown that agility performance depends on the complexity of cognitive requirements. Interference effects can occur between motor and cognitive performance, leading to a slower rate and increased complexity in receiving environmental information. The agility ability of a futsal player, especially a goalkeeper, is needed in every match to produce comfort and calm for other futsal players and the level of agility of a futsal player reflects the ability to move in various levels of difficulty quickly, precisely, and efficiently. Based on the above explanation, the results for shot accuracy on goal showed a significant interaction between imagery training method and agility, yielding significant values of 0.373 and 0.838 at the F level. From this, it can be concluded that there is a correlation between imaginative training and agility in futsal goalie reaction time outcomes.

Conclusion

Difference in effect of audiovisual imagery training & visual imagery training the reaction time of goalkeepers in metro city high school futsal players. There are differential effects of high and low agility on the reaction time of futsal goalkeepers in metro city high schools. At Metro City High School, there is an interaction between imagination and agility training for futsal players' goalie reaction times. To the researchers, the research objectives were limited to the influence of two levels of image training methods, two levels of dexterity training and as a follow-up to this study it was suggested to study various other variables and attributes that affect the reaction time of futsal goalkeepers.

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Conflict of Interest

We declare that this article we wrote has no involvement in any particular conflict of interest and the Declaration of Helsinki.

Ethics Statement

This study was performed by adhering to the Helsinki Declaration. Ethical approval of the study was obtained from Universitas ma'Nahdkatual Ulama Kebumen Ethics Committee at the board

meeting dated 20.03.2023 and numbered 17-06-2023 Ref. 0617079003, 2023

Authors Contribution

Study Design, EB; Data Collection, EB and RJS; Statistical Analysis, EB and RJS; Data Interpretation, EB and RJS; Manuscript Preparation, EB and RJS; Literature Search, EB and RJS. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Athletic Rehabilitation Specialist's Role in Raising the Level of the Players of Some Sports Clubs in the West Bank

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Abstract
This study aims to recognize the athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank from the viewpoint of athletes, the study depends on the analytical descriptive approach, and the sample of the study contained 74 male and female players. The study relied on the questionnaire as a tool for data collection, and the validity and stability of performance were confirmed. The results of the study indicated the importance of the role of sports rehabilitation specialists in raising the level of players of some sports clubs in the West Bank. It also found no significant differences in the view of different sports players about the importance of an athletic rehabilitation specialist due to the type and age variable of the athlete. While there are significant differences due to the type of sport variable in favor of team sports. The study recommended the need to have an athletic rehabilitation specialist among the training staff in sports clubs in the West Bank.

Keywords
Athletic, Rehabilitation, Club, West Bank, Sport

INTRODUCTION

The scientific progress of our time is present, including all aspects of the daily life of man, including the sports side, in particular sports in its current form, which has led to its interaction with Natural and Human Sciences with a view to preparing the individual a comprehensive, balanced preparation for reaching the highest levels of sports activity. Since the player is the effective component of the positive results we have always found, efforts to enhance the level of sports performance before and during the competition for the results he has honored, elected, and qualified to enter the stardom world. This is more opportunities for sports injuries that you have to stop performance for a certain period of time to take into proper treatment, after that period has passed, the player returns with all the physical capabilities that qualify him to perform the duties required of him. Sports injuries are a disaster in the field of sports practice in general. Each area or part of the body is subject to diverse and dangerous injuries, and the level of the player is affected by the gravity of the injury and the duration of the treatment and rehabilitation of infected members. (Fadli and Mohammad, 2017)

Athletic rehabilitation is a science that deals with sports injuries and aims to help the player restore the job of the injured part and return to sports that he has been practicing and preventing further injuries. This science includes assisting and treating the infected on the field and transforming this patient into specialized medical staff and cooperating as a unit to get the patient to safety. Athletic rehabilitation and sports medicine have evolved so that the qualified therapist can be predicted before it occurs. The sports therapist has

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sufficient science in Medical Sciences and Mechanical movement of the body.

Anatomy, Physiology, First Aid, and all these Sciences are based on scientific or international studies. The sports therapist has enough information about sports until he has a full foundation through which he can handle the injured athlete. Also, swelling, pain, and limited movement are the three complaints after any sporting injury, adding that the athlete aspires to return to what he was before the injury of his power and movement. Therefore, the sports therapist will be as much responsible to reach the patient at the best level.

Modern sports medicine and modern physical education are mainly directed to the prevention of injuries and strive to reduce Their incidence to the minimum, where sports injuries and pathological complications rates have risen. This is one of the most important tasks of an athletic rehabilitation specialist, as an athletic rehabilitation specialist plays a central role and therefore the absence of an athletic rehabilitation specialist affects (**Fadli and Mohammad, 2017**).

There are many studies that dealt with the importance of athletic rehabilitation, and we mention the study of (**Feng and Wang, 2022**) which came under the title of "Study on Sports Injuries and Rehabilitation in Badminton Players". The study aimed to discuss sports injuries and rehabilitate badminton players using the questionnaire and descriptive approach, which was applied to 60 badminton players. The study summarized that the degree of infection of badminton players was mostly light, with some medium and high injuries. A mixture of basic reinforcement associated with rehabilitation and expansion of manual therapy can accelerate the muscle rehabilitation of the lumbar spine in the rehabilitation process of badminton injuries. The study recommended combining physical training with traditional rehabilitation techniques and increasing athletic rehabilitation's effectiveness.

One of the studies that discussed sports injuries in group games Is a study (**Rajab et al., 2022**) which was titled "An Analytical Study of the Center for Wing Players Exposing Basketball Injuries" which aimed at identifying the most common injuries for basketball young women, according to the center of the wing players, using the questionnaire tool and descriptive approach, that was applied to an intentional sample consisting of 40 players from basketball for young women. The study summarized that most injuries to basketball young women in the lower limb are 98.31% of Foot joint and fingers injury, the most severe Injury to the upper limb is 44.99% of the face, and the most affected body in the basketball is the lower limb. The study recommended that basketball coaches be recommended to raise the physical capabilities of the basketball players, especially the wing players, request coaches focus on warm-up better before training courses for basketball players and use calm exercises after training to secure the safety of players and not exposure to injuries, work on holding workshops and lectures for players and coaches to make them aware of injuries, work to open sports medicine centers to diagnose sports injuries in a correct way and work to open sports centers to rehabilitate sports injuries.

A study by **Al-Barzai** (**2021**), which came under the title "The Reality of the Professional Preparation of the Field Injury Specialist In Kuwaiti Clubs", aimed the current study to recognize the level of educational qualification for the injury specialist in sports clubs, and determine the level of vocational rehabilitation of information and knowledge of athletic rehabilitation workers in sports clubs, using the descriptive approach in the survey method, and the questionnaire as a tool, which was distributed to 169 athletic rehabilitation specialists. The study summarized that athletic rehabilitation specialists in Kuwaiti clubs enjoy an Intermediate level with regard to professional competence in information and basic concepts related to athletic rehabilitation, mental skills, and professional skills. The study recommended the necessity of providing professional competency development programs for the injury specialist, and it is necessary not to allow non-specialists to work in the field of athletic rehabilitation.

The study by (**Zuhair et al., 2022**) which came under the title "Study the Reality of the Rehabilitation of Sports Injuries to the Iraqi Premier League Football Clubs " The study aimed to recognize the reality of the rehabilitation of sports injuries in the clubs participating in the Iraqi Premier League of football using the descriptive method and the questionnaire.The study summarized that the level of rehabilitation of sports injuries to the club's players was weak. The study recommended an increased interest in the

aspect of rehabilitation of sports Injuries and give it appropriate importance also to the therapeutic aspect, conducting courses for rehabilitation of topics related to therapeutic, rehabilitation, and special sports players, and building the scale of obstacles that accompany the rehabilitation of sports Injuries for the Iraqi Football Premier League players.

A study by (**Zurqeyatet al.,2018**) which was titled "The Impact of Mental Imagination on Improving Self-Confidence for Injured Athletes After Medical Rehabilitation" aimed at identifying the level of confidence of injured players and the impact of the mental perception of injured on their self-confidence using the semi-experimental approach, where an experiment was conducted on a sample of 4 athletics players at the University of Technology and Sciences Jordan was intentionally selected and a pre and post-test was conducted. The study summarized that self-confidence is negatively affected by sports injuries, as the level of self-confidence among the players in question in the pre-test came at an average level. The study also summarized that mental perception developed self-confidence at a high level, this confirms that mental perception is a positive way to raise the level of self-confidence among the injured players. Built on the findings of the study. It was recommended the need to use mental imagery in the athletic rehabilitation of Injured players and hold educational courses for sports coaches to educate them about the need to take care of the psychological aspects of players.

The study by (**Hanashi et al., 2012**), discussed this topic, which was titled "The Importance of Sports Medicine in the Treatment of Sports Injuries. "The study aimed to recognize some of the sports injuries exposed by football players and the contribution of sports medicine to their prevention and treatment them using the questionnaire and descriptive approach to collect data, which was applied to a sample of 80 soccer players. The study concluded that no importance is given to sports medicine in football-specific sports circles, which negatively affects athletes and their athletic level, the study also showed the absence of an athletic rehabilitation specialist in many of the sports teams under study. The study recommended the need for coaches to take care the health of players and the need for an athletic rehabilitation specialist in sports clubs.

This study came in order to draw attention and increase focus on the importance of athletic rehabilitation. The importance also stems from its focus on the role of athletic rehabilitation specialists in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players. This study represents a new addition to the field of research related to the study of Sports Sciences specifically in the Arab world.

The scientific importance of the current study depends on the fact that it addressed one of the most prominent problems suffered by sports clubs in Palestine and the West Bank, within the limits of the researcher's information, he did not find any studies that dealt with this subject, which would benefit scholars and researchers In the field of sports sciences through results and recommendations that could help coaches and managers of Palestinian sports clubs.

The researcher specialized in physical and athletic rehabilitation, and through the involvement of the researcher in the sports field in Palestinian clubs and follow-up of the Palestinian sports situation, he noticed that there is no specific sports qualification that rehabilitates the athlete returning from Injury, and the coach or his assistant works to follow up the returning player without having sufficient experience in the subject of rehabilitation and assessment of the situation. From here, the researcher found the need to highlight this problem, which has great importance in the future of players and their physical and athletic levels, So, it was necessary to conduct a study that clarifies the role of athletic rehabilitation specialists in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players, and accordingly, the problem of the study can be summarized in the question:

What is the athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players?

The objectives of this study are:

- The athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players.
- The role of athletic rehabilitation specialists in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players according to the variables (gender, type of sport, training age).

Study questions

What is the athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players?

What is the athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players according to the variables (gender, type of sport, training age)?

Study limitations

Time limits: The current study was applied from 1/03/2023 - 20/06/2023.Human limits: players of some team and individual sports in the West Bank. Spatial limits: the study was applied to the headquarters of individual and team sports clubs in the West Bank.

MATERIALS AND METHODS

Participants

The study community consists of excellent volleyball players, a number of which is according to the records of the Palestinian Volleyball Federation 2023 season (120) players and professional football players, a number of whom according to the records of the Palestinian Football Federation (240) players, the number of Muay Thai Martial Arts players is 30, and the number of swimming is 40, so the total number of the community is 430. Research procedures were carried out in accordance with the human research ethical standards of the 2008 Principles of the Declaration of Helsinki. Bırzeit University Etik Kurulu tarafından onayladı. Katılımcılardan çalışmaya dahil edilmesinden önce bilgilendirilmiş onam alınmıştır. In this study, additional precautions were taken by the researcher(s) to protect the volunteers."

Study sample

It consisted of male and female players of some individual and team sports clubs, whose number is (74), where they were selected in a simple random way, and a questionnaire consisting of 15 paragraphs distributed over three axes was distributed to answer them. Table (1) showed the demographic variables of the sample's study.

Study variables

Dependent variables Responses of the sample's study to the tool of the study.

Independent variables include the following:

Gender has two levels:

A. Male B. Female

The training age has three levels:

A-Less than 3 years old. B- From 3-5 years. C- More than 5 years.

The type of sport and it has two levels:

A - Team. B- individual.

Table 1. Demographic variables of the study sample

Variables		No.	Percentage %
Gender	Male	41	55.4
	Female	33	44.6
	Total	74	100
Training age	Less than 3 years	10	13.5
	Between3-5 years	15	20.3
	More than 3 years	49	66.2
	Total	74	100
Sport type	Team	54	73
	Individual	20	27
	Total	74	100

Study tool

The researcher reviewed several similar and related studies on sports rehabilitation (**Hemmat et al., 2017; Greising et al., 2020; Zaremski et al.,2019**) and the researcher prepared a questionnaire suitable for the study based on the researcher's own experience and taking advantage of previous researchers.

Tool validity

It was shown by presenting it to some experts in the field of sports and rehabilitation specialists, everyone agreed on the smooth formulation of the phrases and their content, the main axes, and the connection of each phrase to the axis that follows as well as the realism of the phrases.

Tool stability

Cronbach's alpha coefficient was used to calculate the stability of the tool, as the stability of the total score for all paragraphs was 85%.

Statistical analysis

The collected data was using the tool of the study, the questionnaire, and then uploaded to an Excel file, organized, and entered into the statistical (SPSS) program for analyzing the study data after encoding the answers, where descriptive statistics were used to calculate the arithmetic means (SMA), standard deviations (SD), t-test independent samples, and the One-way ANOVA test.

RESULTS

First question results

What is the extent of the role of athletic rehabilitation specialists in raising the level of players of some sports clubs in the West Bank from the viewpoint of sports players?

The arithmetic means, standard deviations, percentages, and total scores were used to answer this question for each paragraph in the scale, and Table (2) are shown that. To present the results of this study and interpret the results, the following percentages were adopted: (4 and above) 80% and above, the athletic rehabilitation specialist's role in raising the level of players is very high. (3.50-3.99)70-79.9%, the athletic rehabilitation specialist's role in raising the level of players is high. (3-3.49) 60-69.9%, the athletic rehabilitation specialist's role in raising the level of players is medium. (2.50-2.99) 50-59.9, the athletic rehabilitation specialist's role in raising the level of players is low. (Less than 2.50) less than 50%, the athletic rehabilitation specialist's role in raising the level of players is very low.

Table 2. SAM (Arithmetic means) and SD (standard deviations) of the role of athletic rehabilitation therapist in raising the level of players of some sports clubs in the West Bank (N=74)

No.	Paragraph	SMA	SD	Percentage	Paragraph Level
8	The correct diagnosis of the injury is one of the most important factors for the success of the hospitalization process	4.69	0.57	94	Very high
5	The psychological factor affects the hospitalization process	4.46	0.74	89	Very high
6	The specialist plays a pivotal role in the hospitalization process	4.34	0.58	87	Very high
2	The athletic rehabilitation specialist works to raise the level of confidence of the players in themselves.	4.34	0.60	87	Very high
3	The athletic rehabilitation specialist helps to improve the player's performance	4.32	0.68	86	highVery
10	It is the specialist who determines the size of the injury and the period of hospitalization	4.22	0.73	84	Very high
11	The athletic rehabilitation specialist works to raise the morale of the player	4.22	0.67	84	Very high
12	Athletic rehabilitation improves my performance	4.20	.66	84	Very high
11	athletic rehabilitation enhances my sense of self-confidence	4.16	.76	83	Very high
13	athletic rehabilitation sessions positively affect me	4.14	.58	83	Very high
4	I feel positive energy if I talk to a athletic rehabilitation specialist	4.07	.75	81	Very high
7	The absence of the role of a athletic rehabilitation specialist negatively affects the hospitalization process	3.96	.83	79	High
9	Self-treatment of players negatively affects the hospitalization process	3.84	.83	77	High
15	Absences from athletic rehabilitation sessions negatively affect my sports performance.	3.73	.76	75	High
14	My performance is negatively affected after treatment sessions	2.34	1.16	47	Very low
	The total degree of the role of the athletic rehabilitation specialist in raising the level of players of some sports clubs in the West Bank	4.07	0.34	81	Very high

It is clear from Table (2) that the athletic rehabilitation specialist's role in raising the level

Paragraph 8, which states that "the correct diagnosis of the injury is one of the most important reasons for the success of the hospitalization process," ranked first on the scale with a percentage of 94%, while paragraph No. 14, which states that "my performance is negatively affected after treatment sessions," ranked last in the scale with a percentage of 47%.

Second question

of players of some sports clubs in the West Ban was very high, with a percentage of (81%).

Are there any significant differences at ($\alpha \leq 0.05$) level in the role of the athletic rehabilitation specialist in raising the level of players of some sports clubs in the West Bank due to the variable of gender? To determine the differences and answer the question, a T-test was applied to independent samples, and Table results (3) show that.

Table 3. Results of the T-test for the significance of differences in the role of athletic rehabilitation specialists in raising the level of players of some sports clubs In the West Bank according to the gender variable (N= 74).

Gender / Depending Variable	Male (N=41)		Female (N= 33)		T value	Significance level*
	SMA	SD	SMA	SD		
The role of the athletic rehabilitation specialist in raising the level of players of some sports clubs in the West Bank	4.03	0.31	4.11	0,36	-1.04	0.30

*Significance level ($\alpha \leq 0.05$)

It is clear from Table (3) that there are no statistically significant differences at the ($\alpha \leq 0.05$) level in the role of athletic rehabilitation specialists in raising the level of players of some sports clubs In the West Bank due to the gender variable.

Third question

Are there significant differences at the significance (0.05) level in therole of the athletic rehabilitation specialist in raising the level of some sports clubs In the West Bank due to the variable of training age?

First: To answer the question, the researcher used the one-way ANOVA to know the role of the athletic rehabilitation specialist in raising the level of players of some sports clubs in the West Bank according to the variable of training age, and Table (4) explains that.

Table 4. Results of the one-way ANOVA for the role of the athletic rehabilitation specialists in raising the level of players of some sports clubs in the West Bank according to the variable of training age.

Variable	Contrast source	Total deviation squares	Freedom Degree	Average squares	p	Sign.
Training Age	Between-group	0.09	2	0.04	0.40	0.67
	in group	8.23	71	0.11		
	Total	8.32	73			

*Significance level ($\alpha \leq 0.05$)

The results of the study on the third question showed that, when using (ANOVA) to knowing the role of athletic rehabilitation in raising a level of players in the West Bank depending on the variable of the training age, there are no statistical differences at the significance ($\alpha \leq 0.05$) level.

Fourth question

Are there statistically significant differences at ($\alpha \leq 0.05$) level in the role of the athletic rehabilitation specialist in raising the level of players in some sports clubs In the West Bank due to the variable of the sport type? To determine the differences and answer the question, a T-test was applied to independent samples, and Table results (5) show that.

Table 5.T-test results on the significance of the difference in the role of the athletic rehabilitation specialist in raising the level of players of some sports clubs in the West Bank depending on the sport type variable (n=74).

Sport type / Depending variable	Team (N =54)		Individual (N=20)		T-value	Sign. level
	SMA	SD	SMA	SD		
The athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank	4.43	0.34	3.01	0.39	2.41	0.02

*Significance level ($\alpha \leq 0.05$)

It is clear from Table (5) that there are statistically significant differences at significance ($\alpha \leq 0.05$) level in the role of athletic rehabilitation specialists affected in raising the level of players of some sports clubs In the West Bank due to the type of sport variable in favor of players who play team sport.

DISCUSSION

Athletic rehabilitation is an important part of the field of sports medicine today, as it protects players from various injuries by increasing their physical level. Moreover, the presence of a specialist sports doctor contributes to increasing the quality of players' ability to deal with their injuries. The sports rehabilitation process has an important role in maintaining the level and physical readiness of players, and in addition to efforts to reduce injuries in general, it also contributes to accelerating the recovery process of players exposed to various injuries (**Dimen, 2012; Popchak et al., 2017**).

The related results of the 1st question: By examining the results of the first axis in the questionnaire of this study, which was distributed to a sample of (74) sports club players, the study concluded with regard to the first question, which states: "How important is the athletic rehabilitation specialist's role in raising the level of players of some sports clubs in the West Bank? " The results were related to the first axis, which came with a very high impact, with percentages ranging between (81%), where it was found that the highest paragraph was represented in the paragraph that states (the correct diagnosis of infection is one of the most important factors for the success of the hospitalization process) by 94%, as for the lowest paragraph. It was represented in the paragraph that states (my performance is negatively affected after treatment sessions), which amounted to 47%. The researcher attributes the results of the study to realize the sports clubs ' players the importance of the role played by the athletic rehabilitation specialist for the players.

The results of the study came different from the results of the study (**Hanachi et al., 2012**), which confirmed that sports medicine is not taken care of in sports circles, and the absence of a sports physiotherapist in many sports clubs.It was Incompatible with the study (**Zuhair et al., 2022**), which emphasized that awareness of the role of physiotherapists among club players in the Iraqi league is weak. The related results of the 2nd question by examining the results of the second axis of this study, which was distributed to 74 male and female players from sports clubs. The study concluded with regard to the second question, which states, "What is the importance of the role of the athletic rehabilitation specialist in raising the level of players of some sports clubs in the West Bank, according to the study variables (gender, sport type, training age)?" The study concluded that there are no statistically significant

differences regarding the importance of the role of athletic rehabilitation specialists in raising the level of players of some sports clubs in the West Bank due to the gender variable.

The researcher points to the importance of athletic rehabilitation for both sexes in order to raise the level of players' performance and to prevent common sports injuries, the researcher also attributes that there are no statistical differences due to the training age variable that sports players of various levels of experience are aware of the importance of physical therapy and the role of an athletic rehabilitation specialist, the researcher points the result of the study to the fact that team sports players are more susceptible to injury than individual sports players, affecting their perspective of the importance of athletic rehabilitation specialist in order to heal sports injuries.And as I agreed with the study of (**Zuraikat and Majali,2018**; **Close et al.,2019**; **Macdonald et al.,2019**)

Conclusions

Within the limits of the research nature and its objectives, the researcher reaches the following conclusions:

1. The effect of the hospital axis on the players by 94%, the psychological axis by 81%, and the performance axis by 47%.
2. The effect of psychological impact was very high on the players.
3. Lack of material support for Palestinian clubs due to the presence of an athletic rehabilitation specialist.
4. Sports training suffers from no periods to evaluate players and their level periodically.

Recommendations

Through the outcomes of the study, the study recommends:

1. Increased interest in educating athletes about ways to avoid sports injuries and prevent them.
2. Providing material and moral support to the athletic rehabilitation specialist in Palestinian sports clubs.
3. Increased awareness of sports players about the importance of follow-up and undergoing athletic rehabilitation sessions, especially after sports injuries.
4. The necessity of conducting more studies on the role of athletic rehabilitation and physiotherapists from the viewpoint of athletes and various sports players in the Arab world.

Conflict of Interest:

There is no personal or financial conflict of interest within the scope of the study.

Information on Ethics Committee Permission

Bırzeit University Etik Kurulu tarafından onayladı. Katılımcılardan çalışmaya dahil edilmesinden önce bilgilendirilmiş onam alınmıştır. In this study, additional precautions were taken by the researcher(s) to protect the volunteers."

Researchers' Contribution Statement

Planned by the author: Study Design, Data Collection, Statistical Analysis, Data Interpretation, Manuscript Preparation, Literature Search. Author have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

A Comparative Study of Some Coordination Abilities between Males and Females for the Age Group (10-12) Years

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Abstract

Coordination capabilities refer to a set of physical abilities that impact the organization and coordination of movements resulting in consistent performance. They are considered one of the necessary conditions for good performance. Therefore, the objective of the study is to identify the differences in coordination abilities between males and females in the age group of 10- 12 years. A hypothesis is that there are statistically significant differences in certain adaptive skills between males and females aged 10-12 years. The research community consists of primary school students from Mosul 135 male and 135 female students as samples. Tests were administered. T-tests for independent samples were given as numbers and percentages for categorical variables. a p-value of <0.05 was considered significant. The study concludes that the coordination skills of male and female students between the ages of 10 and 12 are equal. Males outperform females in the ability of motor coordination between the arms, eyes, and balls, which may be due to the nature of the test. Throwing a Tennis Ball (25 seconds)($t(270)=10,785$; $p<0.001$), Balance ($t(270)=2.023$; $p<0.044$), Throwing Balling ($t(270) = 3.072$; $p<0.002$), Significant differences were determined for Touch 30 Seconds ($t(270)=3.122$; $p<0.002$), Circuit Accuracy ($t(270) = 6.551$; $p<0.001$).In conclusion; Aging and participating in sports have a good impact on coordinative performance. Athletes with a genetic propensity for a certain sport may develop motor proficiency that is on par with or even surpasses that of older athletes with well-planned training.

Keywords
Coordination Capabilities, Educational Processes, Specialized Performance

INTRODUCTION

Changes in socio-economic life are associated with new challenges that also affect growing children. Decreased motor activity as a result of the global presence of new technologies, urbanization, and social changes, increased schooling activities and others lead to deterioration of physical health, changes in physical development, and condition of the younger generation. Due to the favorable correlation between the development of motor skills and outcomes in terms of health, fitness, and academic performance, childhood is a crucial time for acquiring and strengthening basic motor skills (**Boutios et al., 2021**).

Coordination; It is the ability to perform different movements by their purpose and in harmony with each other. In other words, it is a term meaning that the skeletal muscles and the central nervous system work in harmony and interact in a purposeful movement (**Aslan et al., 2016**). In addition to maturation, ongoing interaction with a stimulating and encouraging social and physical environment is also essential for the development of coordination and motor

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skills (Glass et al.2002; Bridge et al., 2007), a harmonious gait, adequate neuromuscular balance, and the ability to learn new abilities (Pons van Dijk, 2013). Studies conducted throughout Europe have revealed a decline in young children's capacity for coordinated movement (Roth et al., 2010). The lack of quality physical activity that kids engage in may be the cause of their poor coordination performance (Barnett et al., 2009).

The data obtained from the literature review on this problem show that there is a delay in the development of the physical abilities of adolescents. Physical capacity and motoric development are directly related to the development of motor coordination (MC). In addition to developing these abilities at primary school age, the "foundations" for gaining knowledge, skills, and habits for coordination exercises are laid (Boeva, 2012; Lyah, 2006). There are five basic motor coordination skills to be learned in physical education classes. Spatial orientation ability, kinesthetic differentiation ability, balance ability, reaction ability; and rhythm ability. Children with better coordination skills are more physically active and less likely to be sedentary than children with worse coordination skills. It is also a fact that activities such as running, tempo, agility, jumping, and balance are necessary to develop children's coordination skills (Tankoucheva, 2019).

When the literature is examined, it is based on many studies with children, and these studies often include studies comparing the physical, physiological, and coordination characteristics of children. In some of the studies, the characteristics of the groups formed without considering the age variable can also be compared, and thus, perhaps, an error is made in the comparison and interpretation of the measurement results because the age difference is not taken into account (Aslan et al., 2016).

Although the issue of coordination abilities has been adequately studied, it is also very important in all countries (Cillík et al., 2018; Timo et al., 2017). Ages between kindergarten and first grade are ideal for the development of coordination abilities. The majority of scholars think that, in contrast to other physical attributes at this age, significant emphasis should be directed to the development of coordination abilities (Issurin and Lyakh, 2017). Thus, there is a conflict between the requirement that young schoolchildren improve their coordination skills and the capacity of children to achieve the potential of their physical abilities in school physical education classes.

Growth during the Adolescent years may be slower than in other stages of development. During this stage, the physical development of the body has the potential to enhance neuromuscular compatibility. This study intends to investigate if there exist differences in coordination abilities between males and females aged 10-12 years. The researchers hold the belief that differences in both cognitive and physical performance exist (Halpern, 2000). The study of the student's stages of physical, reactive, and mental training is crucial for the development of the community, which is why developed countries create specific programs to teach physical education to students and develop their skills. Effective physical training requires coordination between an individual's neural and motor systems, which can lead to sporting achievements such as improved skills, tactics, and techniques (Starosta, 2006; Khasawneh, 2015).

This study aims to compare the cognitive and physical performance of males and females between the ages of 10 and 12. The aim is to obtain accurate information that can help in the development of school curricula and help students achieve optimal cognitive and physical performance through education and improved coordination skills. Objective evaluation methods to obtain a database for both sexes of students are inadequate. Therefore, it is important to compare the level of compatibility between males and females to identify their strengths and weaknesses in these abilities. This study is one of the limited studies that has dealt with this issue.

MATERIALS AND METHODS

Participants

Since this approach is one of the approaches that investigate the facts and draw the necessary conclusions to solve the problems in a particular society, the descriptive approach was used in the survey style due to the relevance and nature of the research problem. All the students were controlled by the ethics committee and reported under the ethical rules followed. The research population includes primary school students (boys and girls) aged (1080) years (10-12) from the six preparatory schools shown in Table (1). The sample of the

study was randomly selected and reached 270 students from both genders, 135 students in the age group (10-12) and female students in the same age group (135) (Table 1). The exploratory experiment the sample consisted of (30) individuals of both sexes, divided into men and women.

Ministry of Higher education Scientific Research University of Mosul Ethics Committee approved the study protocol (22-8-2023). Informed consent from the parents and assent from the children were obtained before children were included in the study. The authors took into account the needs and priorities of the groups/individuals in which the study was conducted, in accordance with Articles 19 and 20 of the WMA Declaration of Helsinki, and the situation that the study could not be carried out outside these groups and individuals was taken into account. "In this study, additional precautions were taken by the researcher(s) to protect the volunteers.

Table 1. Shows the research community and its samples for male and female pupils with ages (10-12)

Schools/Primary	Society	Sample	Male			Female		
			Sample	Exploratory	Constancy	Sample	Exploratory	Constancy
1. School (Boys)	210	45	36	4	7			
2. School (Boys)	180	45	35	3	8			
3. School (Boys)	195	45	34	3	5			
1. School (Girls)	180	45				34	5	4
2. School (Girls)	155	45				35	8	3
3. School (Girls)	160	45				36	7	3
Total	1080	270	105	10	20	105	20	10

To obtain the results that serve the research, the researchers used several means of collecting data using a survey of the opinions of experts.

Through the analysis of the opinions of the experts concerning the literature review, the coordination abilities were determined, and their tests and as follows: The test of passing the tennis ball on the wall for 25 seconds to measure the motor coordination between the arms, the eye, and the ball: The tester stands in front of the wall at a distance of approximately (1m), and upon hearing the start signal, the player passes the ball on the wall with one hand continuously until he hears the end signal or stops. The laboratory records the number of times the ball touches the wall for (25 seconds.

The jump test inside the numbered circles to measure the compatibility between the legs and the eyes: Draw (8) circles on the ground, provided that the diameter of each of them is (60 cm), and the circles are numbered from (1 to 8), where the tester stands inside circle No. (1), and when he hears the start signal, he jumps with both feet together to circle No. (2) and then to (3). Then to

(4) and so on until circle number (8). The tester records the time it takes to travel through the eight circuits.

Throwing two balls with the left and right arms up alternately to measure the kinetic rhythm: The tester is given two balls and we ask him to throw them up alternately without them falling to the ground (**Abu Bshara, 2010**) Scoring A point is awarded for each correct exchange of balls.

The front and back touch test for (x) within 30 seconds to measure the dynamic flexibility (flexion, extension, and rotation of the spine) with the eyes and arms alignment: Draw an (x) on two points. 1- On the floor between the feet of the laboratory. 2- On the wall behind the back of the laboratory (in the middle), Upon hearing the start signal, the tester bends the torso in front downward to touch the ground with the tips of the fingers at the (x) mark between the feet, then the tester extends the torso high while turning to the left to touch the (x) mark behind the back with the tips of the fingers, then rotates the torso and bends it down To touch the (x) mark between the feet a second time, then extend the torso while rotating to the right to touch the (x) mark behind the back. This action is repeated as many times as possible in 30 seconds, noting that the mark behind the back should be touched once from the left side and the other from the right side.

The shooting test on the overlapping circles to measure the accuracy of the throw with the eyes and arms compatible): Five tennis balls, a wall in front of which is a flat ground, three overlapping circles are drawn on the wall, the lower border of

the large circle rises from the ground by (24 inches), a line is drawn on the ground at a distance of (3 m) from the wall, where the tester stands behind the line and then corrects the five balls (successively) on the circles, trying to hit the smaller circle. The laboratory has the right to use either or both hands together in aiming.

Where if the ball hit the small circle or on the line specified for it / 3 points. If the ball hits the middle circle or is on the line specified for it / 2 points. If the ball hits the large circle or is on the line specified for it / 1 point. And zero if the ball came outside the three circles (Muhammad Sobhi Hassanein, 1987). In response to the ability of the research sample to implement the specified tests, a pilot experiment was conducted on 21/12/2021, the purpose of which was to identify the safety of the application in terms of performance and the method of registration and to show the possibility of the sample in applying the tests as well as the possibility of the assistant work team.

The test method was applied and re-applied to an exploratory sample of (30) male and female pupils from outside the research sample to identify the reliability of the tests (Başkonuş& Soyer, 2020). The correlation between the scores of the first and second applications was found that the tests had obtained high correlation coefficients that ranged between (0.87 and 0.93). Many scientific references, studies, and research related to measuring coordination abilities were reviewed. Tests that measure coordination abilities that were characterized by their reliability, and validity were selected (Başkonuş& Soyer, 2020). They were also presented to a group of experienced and specialized and obtained agreement rates between (75-100%) and thus face validity was achieved for these tests.

Statistical analysis

SPSS 25 (Statistical Package for the Social Sciences, version 25) statistical program was used to evaluate the findings obtained in our study. For categorical variables, descriptive statistics were presented as percentages and numbers for numerical variables, including mean, standard deviation, simple correlation coefficient, and T-test for independent samples. A 0.05 p-value was regarded as significant.

RESULTS

Table 2. is examined, age (t(270) = 1.203; p> 0.230) and height (t(270) =0.54;p> 0.957) among the female (n=135) and male (n=135) participants participating in the research no significant difference was found. However, a significant difference was found in favor of the girls in terms of weight (t(270) = 2,210; p<0.028) and BMI (t(270) = 2,847; p<0.005) of the male and female participants participating in the study. The girls had a lower BMI.

Table 2. Differences between demographic variables-independent groups T-Test

Değişken	Gender	N	X	SD	t	p
Age (years)	Male	135	11,14	0,78	1,203	0,230
	Female	135	11,02	0,73		
Height (cm)	Male	*135*	*137,24*	*8,99*	*0,54*	*0,957*
	Female	135	137,18	8,96		
Body Weight (kg)	Male	135	38,08	8,02	2,210	**0,028***
	Female	135	35,84	8,65		
BMI (kg/m2)	Male	135	20,07	2,81	2,847	**0,005***
	Female	135	18,93	3,72		

n= number of participants, x= mean, SD= standard deviation, T= T score,VKİ= Body Mass Index , p>0,05

The mean and standard deviations of male participants participating in the study were respectively; Throwing a Tennis Ball (25 seconds (t(135) 15.01±3.54), Jump for the Circle (t(135) 7.14±2.06), Balance (t(135)25.46±16.90), Throwing Balling (t(135) 2.82±1.14), Touch 30 Seconds (t(135) 16.22±3.26), Circuit Accuracy (t(135) 8.72±2, 38) was determined (Table 3).

Table 3. Mean and standard deviation values of male participants' coordination skills

Değişken	N	X	SD
Throwing a Tennis Ball (25 seconds)	135	15,01	3,54
Jump for the Circle	135	7,14	2,06
Balance	135	25,46	16,90
Throwing Balling	135	2,82	1,14
Touch 30 Seconds	135	16,22	3,26
Circuit Accuracy	135	8,72	2,38

The mean and standard deviations of the female participants participating in the research, respectively; Throwing a Tennis Ball (25 seconds (t(135) 9.77±4.38), Jump for the Circle (t(135) 7.25±2.09), Balance (t(135) 21.22±17 .54), Throwing Balling (t(135) 2.42±0.98), Touch 30 Seconds (t(135) 15.02±3.04), Circuit Accuracy (t(135) 6.67±2, 74) was determined as (Table 4).

Table 4. Mean and standard deviation values of female participants' coordination skills

Değişken	N	X	SD
Throwing a Tennis Ball (25 seconds)	135	9,77	4,38
Jump for the Circle	135	7,25	2,09
Balance	135	21,22	17,54
Throwing Balling	135	2,42	0,98
Touch 30 Seconds	135	15,02	3,04
Circuit Accuracy	135	6,67	2,74

Differences between the coordination skills of male and female participants-independent groups According to T-Test results; Jump for the Circle (t(270) = -0.438; p>0.662), no significant difference was detected. In other parameters, Throwing a Tennis Ball (25 seconds) (t(270) =10,785 ; p<0.001), Balance (t(270) = 2.023 ; p<0.044), Throwing Balling (t(270) = 3.072 ; p<0.002), Significant differences were determined for Touch 30 Seconds (t(270) = 3.122 ; p<0.002), Circuit Accuracy (t(270) = 6.551 ; p<0.001) (Table 5).

Table 5. Differences between the coordination skill tests of the participants by gender-independentgroups T-Test result

Ability Tests	Gender	N	X	SD	t	p
Throwing a Tennis Ball (25 seconds)	Male	135	15,01	3,54	10,785	**0,001***
	Female	135	9,77	4,38		
Jump for the Circle	Male	135	7,14	2,06	-0,438	0,662
	Female	135	7,25	2,09		
Balance	Male	135	25,46	16,90	2,023	**0,044***
	Female	135	21,22	17,54		
Throwing Balling	Male	135	2,82	1,14	3,072	**0,002***
	Female	135	2,42	0,98		
Touch 30 Seconds	Male	135	16,22	3,26	3,122	**0,002***
	Female	135	15,02	3,04		
Circuit Accuracy	Male	135	8,72	2,38	6,551	**0,001***
	Female	135	6,67	2,74		

DISCUSSION

Children's abilities must be developed from birth. Most significantly, this happens in school physical education lessons. It is also well recognized that exercise has advantages for the growth of mental and cognitive functions. The problem is still relevant today even though there has been enough research on the development of coordination skills. The importance of coordination skills, particularly for young athletes, is well understood, however, it should be highlighted that the majority of the strategies the authors describe are alternatives to extra or core

programs. In our study, the differences between the coordination skills of male and female participants in independent groups According to the T-Test results; No significant difference was detected in the Jump to the Circle skill. Significant differences were determined in other parameters.

It's likely that carefully thought out, long-term coordinated educational activities can increase children's activity levels, enhance the motor abilities of 9–10-year-olds, and advance their psychomotor development levels. Given the increasing complexity of movement during growth, developing coordination at young school age is crucial. The psycho-physical qualities of each age range should be considered in the education program for effective children to concentrate on and maximize their unique age-related motor learning skills (**Ricotti, 2011**).

A study submitted by **Ahmed** (**2016**) involved two groups of 10-year-old adolescent rhythmic gymnasts, a total of 20 participants. The experimental group (n=10) underwent an eight-week training program to improve their coordination skills. The traditional program was followed by the control group (n=10). The results of the study show that the experimental group scored higher than the control group in terms of coordination skills and performance levels. The results are evidence of effective training in coordination skills. Furthermore, it is expected that better performance requires better coordination skills. The researcher also used the descriptive approach using the Drer and Dale-Koch test battery to measure motor skills. The results of the study showed that there were statistically significant differences in all the motor tests for the (9) year old male category, while there were statistically significant differences in all the motor tests for the (9) year old female category, except for the one-legged standing test in favor of the 9-year-old (**Ahmed, 2016**)

The year 2019 conducted a study to determine the level of physical fitness of Chennai district Kabaddi and Kho-Kho players. 50 subjects from the YMCA College of Physical Education District Chennai were chosen at random to participate in the current study. Of these, 25 were participants in the Kho-Kho sport and 25 were Kabaddi players. Players of Kabaddi and Kho-Kho were evaluated on their level of physical fitness using the AAHPER youth fitness exam. For this study, 50 participants from the YMCA College of Physical Education District in Chennai were randomly chosen, of which 25 were kabaddi players and 25 were kho-kho players. A straightforward 't-test' was used to statistically assess the data. The threshold for significance was set at 0.05.

Further analysis revealed no appreciable differences between Kabaddi and Kho-Kho players in terms of attributes like power, coordination, and strength. According to the study's findings, there are no appreciable differences between Kabaddi players and Kho-Kho players in terms of traits like strength, coordination, and power (**Jesuudoss, 2019**)

Through previous studies, we can say that what distinguished this study is its connection to the process of sports training in terms of accurate digital data that it will provide, which the sports teacher or coach can stand on the level of these abilities through, an attempt by researchers to determine the level of coordination abilities between males and females. For the age group (10-12) years.

Conclusions

This is all equal for the research sample of male and female pupils, especially when schools ignore the physical education lesson, which contains plans, exercises, and games through which the physical education teacher can stand on the level of both physical and motor abilities and work on their development and improvement, as the physical education lesson is the only thing to develop these capabilities. From the results of the study and its objectives, the following can be concluded: Within the limits set by the research, male and female pupils aged 10-12 are equal in coordinating. The reason for this may be due to the nature of the test, but males outperform females in the ability of motor coordination between the arms, the eyes, and the ball. The study recommends that coordinative skills should be developed through the development of programs and plans for these age groups and that attention should be paid to physical education in schools for both genders, especially for girls. The best way for this age group is to focus on games that are compatible with their abilities.

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Conflict of interest

The authors declare no conflict of interest. No financial support was received.

Ethics Statement

Ministry of Higher education Scientific Research University of Mosul Ethics Committee approved the study protocol (22-8-2023). Informed consent from the parents and assent from the children were obtained before children were included in the study.

Author Contributions

Study Design, HAS and SY; Data Collection, HAS and AAAID; Statistical Analysis, HAS, AAAID; Data Interpretation, HAS and AAAID; Manuscript Preparation, HAS, SY and AAAID; Literature Search, AAAID, HAS and SY. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Construction of A Physical Fitness Test Battery for Middle-Aged Women

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Abstract

Proper measuring tools can provide the exact information about an individual's fitness level. The purpose of the study was to construct a suitable physical fitness test battery and to develop norms for middle-aged women in the Indian population. A total number of 405 middle-aged Indian women of 40-59 years were selected from three basic occupations of homemaking, office job, and manual labor. They were divided into two groups 40-49 years (n=230) and 50-59 years (n=175). The selected physical fitness variables for the construction of the physical fitness test battery were strength, strength endurance, agility, flexibility, balance, coordination, gait velocity, and cardiovascular endurance, which were measured by the standard and valid tests such as hand grip dynamometer, wall squat test, figure of eight-run test, sit and reach test, one leg stand test, plate tape test, and 6 min walk test respectively. Descriptive statistics, normality of the data, Pearson product-moment correlation, and Percentile score were calculated by SPSS version 21. Cajori's 5-grade evaluation norms were applied. The External validity of the newly constructed test battery was examined by using Eviews software version 9. Results revealed that the obtained data was normal and the selected variables were highly correlated. The Percentile scale revealed that the score from P_0 -P_{100} for each variable for both the groups and grading was expressed in five grades such as excellent, good, average, below average, and poor. External validity confirmed the validity of the physical fitness test battery for middle-aged women across the world.

Keywords
Physical Fitness, Middle-aged women, Percentile scale, Grading

INTRODUCTION

Women are the basic unit of the society and they are pioneers of the nation. They play significant roles in families as well as in society (**Mojumder, 2020**). Notwithstanding, the role of women in social, political, economic, religious, and cultural spheres is not recognized and their contribution is not counted as significant **(Bayeh, 2016**). In India, most of them are confined to family work and they seldom take care of their health and fitness with respect to their daily work. In many cases, they have no ample scope to pay attention adequately to their physical fitness. But it is worth noting that women live longer than men and are more likely than men to experience disabilities at a younger age (**Baum et al., 2021**). It has also been noticed from various studies that health status declines with aging and women experience a more rapid decline of health issues than men **(Crimmins et al., 2019**) consequently, they require assistance in their older age.

Middle age is the most important period in women's lives that is associated with different changes. During this period middle-aged women have to face many problems such as financial, family, job, and health issues **(Krantz & Ostergren, 2000**). Among these, health problems are the most vital in women's lives. In India generally, middle-aged women are involved in primary occupations like homemaking, office job, and physical work or manual work. Homemakers

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usually perform all kinds of household work such as cooking, sweeping, cleaning utensils, washing clothes, and caring for children, whereas Office going women perform office jobs, and Physical laborers perform cultivation, construction work, work in bricks field, and coal mines. Despite their occupations involving a certain amount of physical work still technological advancement discourages homemakers and office-going women to perform the optimum amount of physical activity. During this middle age period, women suffer from many non-communicable diseases such as heart disease, stroke, diabetes, obesity, osteoporosis, anxiety, hypertension, and Alzheimer's disease (**Bandyopadhyay & Das, 2022**). It was observed from different studies that physical fitness may help to prevent those noncommunicable diseases to a great extent (**Lin et al., 2020**). Therefore, the optimum level of physical fitness of a woman is an important prerequisite for enabling themselves to accomplish their daily living as well as satisfactorily contribute to the family and society.

Physical fitness plays an important role in all aspects of health which can also ensure the health status of an individual in every phase of life. The ability to perform daily living activities greatly depends on an individual's level of physical fitness. Physical fitness may be defined as the capacity to perform daily physical activities safely and independently without fatigue. Physical fitness may be expressed through various bio motor abilities such as strength, endurance, flexibility, agility, balance, and coordination. Strength is the ability to exert maximum force by a muscle or a group of muscles during a single control action to overcome resistance. Hand grip strength is an indicator of individual overall strength and can serve as a predictor of morbidity and mortality **(Labott & Donath, 2023**). Endurance is the physiological capacity of a person by which he or she can sustain a movement over a period of time. Many studies showed that endurance training improved cardiac output, and sleep quality, and result in lower heart rate, and reduced blood pressure **(Canpolat, 2023; Skrypnik et al., 2015**). Flexibility can be defined as the ability to execute movements with greater amplitude or range (**Geremia et al., 2015**). It is affected by muscle strength of the joint, tendons, ligaments, and other factors. From various studies, it has been proved that a person who has a good degree of flexibility can perform daily tasks efficiently and effectively (**Martins et al., 2023**). Agility is defined as a rapid whole-body movement with a change of velocity or direction in response to an external stimulus (**Labott & Donath, 2023**). It has been noticed from previous studies that the characteristics of agility such as tactile sensitivity, joint proprioception, leg strength, and power begin to decline gradually after 40 years of age **(Manderoos et al., 2017**). Balance is the ability to adjust the position in space. The ability of postural control is influenced by the sensory system (vestibular, visual, somatosensory), the cognitive system (central nervous system), and the Musculo skeletal system (**Dunsky, 2019; Ertürk et al., 2023**). Coordination is the ability to execute various movements smoothly with efficiency and accuracy.

Physical fitness is measured by valid tests and test batteries (**Han & Lee, 2022**). In developed countries, there are so many valid test batteries by which a particular age group of men and women can measure their total physical fitness level. The literature reveals that many test batteries have been constructed in many countries such as Groningen Fitness Test (**Lemmink et al., 2001**), Functional Fitness Test (**Rikli & Jones, 1999**), Euro Fit Test battery (**Tsigilis et al., 2002**), Alpha Fit Test Battery for Adults (**Suni et al., 2009**) on different population and also they have included strength, endurance, agility, flexibility, balance, coordination parameters in their test battery. But, in Indian society, there is no availability of a recognized test battery for middle-aged women by which women can evaluate their physical fitness level. Even researchers who are conducting research on middle-aged women related to their physical fitness, don't get any standard test battery from an Indian perspective rather they use the test battery and norms constructed on other population. Norms on a particular population is indispensible to identify an individual's status or position. Therefore, the purpose of the present study was to construct a suitable physical fitness test battery for middle-aged women in the Indian population and to develop pertinent norms.

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MATERIALS AND METHODS

Participants and Sample Size Determination

Before conducting the study, the sample size was determined with the help of Cochran's formula which indicates the minimum sample size n = 384 for the infinite population (Garret & Woodworth, 1981). As daily living highly involves physical

activities, so keeping in mind the participant's daily activities the three basic occupations of middle-aged Indian women such as Homemaking, Office job, and Manual labor were considered to select the true representative of the population. As per the National Sample Survey Organization (NSSO), in India 62% of women are engaged in home management, 18.5% are engaged in office work and 19.5% of women are engaged in manual labor. To get the targeted number of participants, they were chosen from middle-aged elderly women of three basic occupations as per the NSO ratio. Initially, a total number of 703 women were reached. Finally, on the basis of inclusion criteria, 405 middle-aged women [(n=405); Homemakers (HM)=251, Office goers (OG)=75, Physical worker (PW)=79] were selected for the present study. 298 subjects were excluded because they did not fit into inclusion criteria The adopted inclusion criteria were: i) middle-aged women between 40-59 years (**Adams et al., 2023**). ii) medically fit iii) physically healthy and iv) willing to participate in this study. The participants were divided into two groups 40-49 years age group (n=230,) and 50-59 years age group (n=175) of middle-aged women.

Selection of variables for construction of physical fitness test battery and their assessment protocol

Based on the literature and as per the feasibility, relevancy, and convenience the physical fitness variables such as strength, strength endurance, agility, flexibility, balance, coordination, gait velocity, and cardiovascular endurance have been incorporated for constructing a physical fitness test battery of middle-aged women.

Hand grip Strength Test-Hand grip strength (GS) was measured on the dominant hand by using a Grip dynamometer (Labdeal, Lab-226). The arm of the dominant hand was placed at a 90-degree angle and the elbow was placed by the side of the body. Each participant was given two trials with at least 15 seconds of recovery between each effort. The best result was recorded in kilograms (kg) (**Suni et al., 2009; Bandyopadhyay, 2020**)

Wall Squat Test-The strength endurance (SE) was measured by using the wall squat test. The back of the upper body was kept in touch with the wall with maintaining the position 90-degree angle between knees and hips. The total duration of time participants could hold the position was the score. Two trials were given and the best score was recorded in seconds (**Lea et al., 2021; McIntosh et al., 1998**)

Figure of Eight run Test-Agility (AG) was measured by using the Figure of Eight run test. Two cones were placed at a distance of 10 m. At the command 'go', each subject started from one cone and covered a 10 m distance to another cone and then went around the cone like a figure of eight and ran back to the starting cone. The time taken to complete the task was measured in seconds and tenths of seconds. The best of two trials was considered as a score (**Suni et al., 2009; Wood, 2018**).

Sit and Reach Test-Flexibility (Flex) was measured by using sit and reach test. The participants were asked to place the soles of their feet against the sit and reach box. Both knees were locked and pressed flat to the floor, then the participants placed their both palms side by side and moved the hand forward as far as possible on the measuring line, without any jerking. The best score was recorded among two trials to the nearest centimeter (**Abate Daga et al., 2021; Ponce-González et al., 2020**).

One Leg Stand Test-For measuring Balance (Bal) one leg stand test was used where participants placed their one foot at knee level along with the inner side of the supporting leg and rotate the thigh outwards. Participants were advised to stand as still as possible. Sixty seconds were the upper limit for the test. The Longest correct position maintenance time by the participants was recorded in seconds as a score. Two trials were performed and the best one was recorded **(Malmberg et al., 2002; Suni et al. 2009**).

Plate tape Test-The plate tape test was implemented to assess hand-eye coordination (Coord). The participants were asked to stand in front of the table where a blue rectangle of paper disc was placed at the center of the table and two yellow paper circles were placed at the side of the rectangle, one, on each side at a 30 cm distance. The participants were asked to place their non-active hand in on blue rectangle. They move their active hand over the non-active hand and touch the center of the two yellow discs. When the participants touch two yellow circles with their active hands complete one cycle. The time taken to complete 25 cycles was the score. The testing procedure was carried out twice, the better one result was recorded (**Jopkiewicz et al., 2015; Mack-Inocentio et al., 2020**).

10-meter walk Test-Gait velocity (GV) was assessed by a 10-meter walking test that measured the functional ability of an individual. Participants were instructed to walk 1.2 m before and after a 10-meter walking course, at their normal speed. The time taken for covering 10 meters was the score. Two trials were performed and to reduce the learning effects, the average of two trials was documented in m/s as gait speed **(Bohannon, 1997; Novaes et al., 2011**).

6-minute Walk Test-Cardiovascular Endurance (CVE) was assessed by a 6-minute Walk test. 30m long distance was marked by two cones in the open area. A warming-up period was provided and the participants were asked to walk the 30 m distance without assistance. The objective of the test was to cover as much distance in meters as possible in six minutes which was recorded as a score. (**Alameri et al., 2009; Jalili et al., 2018; Troosters et al., 1999**)

Design of the study

The study was conducted in West Bengal, the eastern state of India, from July 2021 to February 2022. The participants were chosen through local clubs and community centers from different places in West Bengal. Prior to the test, the participants underwent a medical examination by a registered medical practitioner to ensure that they were in good health. Healthy women were selected on the basis of basic information such as age, height, weight, occupation, etc. Written Consent forms were given to each participant and duly signed consent forms were collected from them. The participants reported in a group of an average of fifteen (5-15) at the test centers and for the collection of data, the selected physical fitness test was administered by the investigators along with the assistance of qualified expert members. Before appearing in the physical fitness test every participant underwent a warming session of 7 to 10 minutes consisting of walking, slow jogging, stretching, and bending exercises. On the first day the participants' age, height, weight, grip strength, strength endurance, gait velocity, and flexibility were measured. On the second day, the test for balance, agility, hand-eye coordination, and cardiovascular endurance was conducted to measure the said abilities. The study was approved and supervised by the departmental research committee, Physical Education, the University of Kalyani (Reg No 110050 of 2017-2018 Ref No. Ph.D./Phy.Edu./Ak/484 (30)/2022, dated 17 November 2022).The detail of study design is presented in Figure 1. Informed consent was obtained from the participants before their inclusion in the study. In accordance with Articles 19 and 20 of the WMA Declaration of Helsinki, the authors took into account the needs and priorities of the groups/individuals in which the study was conducted and the situation in which the study could not be carried out outside these groups, and individuals were taken into account. "Additional precautions were taken by the investigator(s) to protect the volunteers in this study."

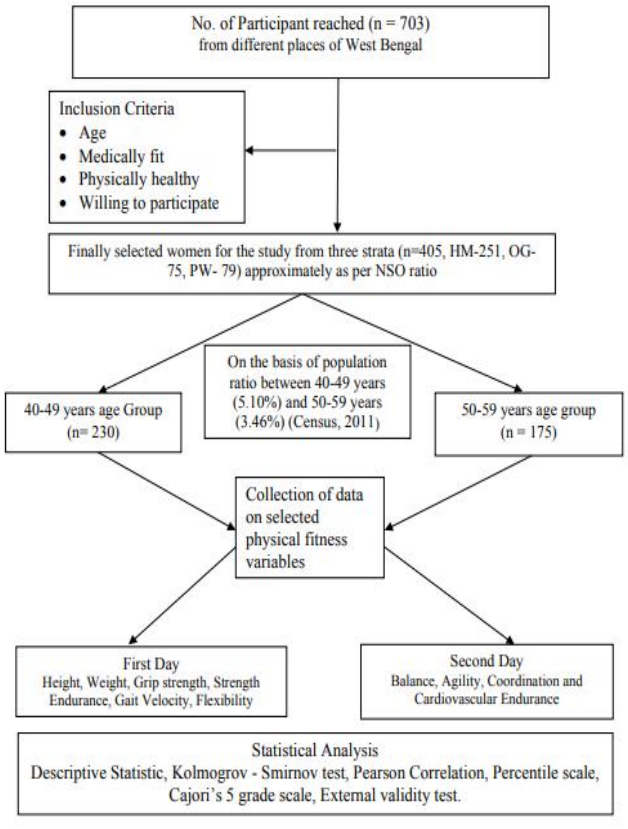

Figure 1. Flow chart of the study design

Statistical Procedure

The collected data were analyzed by using the SPSS-21 version. The mean and standard deviation were computed on each selected physical fitness variable. The normality of each variable was ascertained by the Kolmogorov-Smirnov test. Pearson Product moment correlation was applied to find out the relation among the physical fitness variables. Percentile scale was used to convert all raw data of each variable into percentile scores for both groups separately. Cajori's 5-grade evaluation norms i.e. poor, below average, average, good, and excellent were applied for grading each variable. The external validity of the test battery was

examined through the Unbiased Test, Efficiency Test, Sufficiency Test, and Consistency Test by using Eviews software version 9

General Characteristics of the Participants

The general characteristics of the participants were expressed through descriptive statistics on Age, Weight, Height, and BMI which are presented in Table 1. The mean and SD of age, weight, height and BMI of 40-49 years middle-aged women group were 44.03±3.03 years, 59.53±10.57 kg, 151.25±6.54 cm and 25.97±4.08 kg/m^2 respectively and the mean and SD of age, weight, height and BMI of 50-59 years middle-aged women group were 54.71±2.76 years, 55.05 ±9.62 kg, 148.53±5.51 cm and 24.93±4.09 kg/m^2 respectively.

RESULTS

Table 1. General characteristics of the participants

Group		Age (year)	Weight (kg)	Height (cm)	BMI (kg/m^2)
40-49 years	Mean±SD	44.03±3.03	59.53±10.57	151.25 ±6.54	25.97±4.08
50-59 years	Mean±SD	54.71±2.76	55.05±9.62	148.53±5.51	24.93±4.09

Note. SD= Standard Deviation, kg= Kilogram, cm= Centimetre, kg/m^2= Kilogram/Meter^2, BMI=Body Mass Index

Descriptive Statistics of Physical fitness variables

The mean, SD, range, and normality of the data of the selected physical fitness variables for both the middle-aged women groups of 40-49 years and 50-59 years are presented in Table 2

Table 2. Descriptive statistics of physical fitness variables for 40-49 years and 50-59 years age group of middle-aged women

Ag Gr.	40-49 years women age group					50-59 years women age group				
	Mean±SD	SEM	Range (Min-Max)	Normality: KS stat		Mean±SD	SEM	Range (Min-Max)	Normality: KS stat	
				Stat	sig				Stat	Sig
GS (kg)	17.61±5.56	0.36	25.00 (4-29)	.047	.200*	12.40±5.28	0.39	23.00 (1-24)	.050	.200*
SE (sec)	50.22±23.78	1.56	96.00 (4-100)	.038	.200*	45.33±21.62	1.63	88.00 (2-90)	.031	.200*
Bal (sec)	31.50±14.02	0.92	55.00 (5-60)	.056	.081*	26.47±10.72	0.81	58.00 (2-60)	.049	.200*
AG (sec)	12.26 ±2.93	0.19	12.80 (6.2-19.00)	.030	.200*	14.26±3.51	0.26	15.77 (6.60-22.37)	.037	.200*
Coord (sec)	17.50 ±3.51	0.23	18.24 (10.71-28.95)	.047	.200*	20.68 ±3.79	0.28	18.31 (12.14-30.45)	.037	.200*
Flex (cm)	17.87 ±5.32	0.35	25.00 (5-30)	.049	.200*	14.57±5.47	0.41	26.00 (1-27)	.041	.200*
GV (m/sec)	1.42 ±0.35	0.02	1.60 (0.6-2.20)	.037	.200*	1.25±0.35	0.02	1.68 (0.42-2.10)	.022	.200*
CVE (m)	503.60±69.36	4.57	350.00 (320-670)	.148	.200*	475.80±69.89	5.28	339.00 (310-649)	.030	.200*

Note. GS=Grip strength, SE=Strength Endurance, Bal=Balance, AG=Agility, Coord=Coordination, Flex=Flexibility, GV=Gait Velocity, CVE=Cardiovascular Endurance, Gr.=Group, kg= Kilogram, sec=Second, cm= Centimetre, m/sec= Meter/second, , m=Meter, SEM=Standard Error of Mean *p> 0.05

Table 2 reveals that the value of mean and SD of physical fitness variables such as GS was 17.61±5.56 kg, SE was 50.22±23.78 sec, Bal was 31.50±14.02 sec, AG was 12.26±2.93 sec, Coord was 17.50±3.51 sec, Flex was 17.87±5.32 cm, GV was 1.42±0.35 m/sec and CVE was 503.60±69.36 m for 40-49 years middle-aged women group. Similarly, the mean value of physical fitness variables for age group 50-59 years for GS was 12.40±5.28 kg, SE was 45.33±21.62 sec, Bal was 26.47±10.7 sec, AG was 14.26±3.51 sec, Coord was 20.68 ±3.79 sec, Flex was 14.57±5.47 cm, GV was 1.25±0.35 m/sec and CVE was 475.80±69.89 m. Further, Table 2 reveals that the obtained scores for each variable for both groups were normal.

Correlation among the physical fitness variables

Though tests for the physical fitness variables were chosen from standard test batteries or valid tests used in other experimental research for middle-aged women still Pearson Product moment correlation was computed on obtained data of the whole sample (n=405, age 40-59 years) to find out the relation among the selected physical fitness variables.

The Table 3 reveals that the variables were highly correlated with each other (r = 0.996 – 0.949). Hence the selection of a physical fitness variables for constructing a physical fitness test battery is justified and valid.

Percentile scores of the physical fitness variables

Percentile scores of all variables were computed on obtained field test data for the newly constructed physical fitness test battery of 40-49 years and 50-59 years of middle-aged women group by using the percentile score, which are presented in Table 4 (40-49 years) and table 5 (50-59 years).

From Table 4 it can be seen that in the 40-49 years of middle-aged women, the P_{100} score of GS, SE, Bal, AG, Coord, Flex, GV, and CVE variables were 29.00 kg, 100.00 sec, 60.00 sec, 6.20 sec, 10.71 sec, 30.00 cm, 2.20 m/s, and 670.00 m respectively. On the other hand, the P_0 score of selected variables were 4.00 kg, 4.00 sec, 5.00 sec, 19.00 sec, 28.95 sec, 6.00 cm, 0.60 m/s and 320.00 m respectively.

Table 3. Correlation among grip strength, strength endurance, balance, agility, coordination, flexibility, gait velocity, and cardiovascular endurance of 40-59 years of middle-aged women..

Variables	GS	SE	Bal	AG	Coord	Flex	GV	CVE
GS	1							
SE	.979** (.000)	1						
Bal	.993** (.000)	.983** (.000)	1					
AG	.994** (.000)	.982** (.000)	.996** (.000)	1				
Coord	.988** (.000)	.967** (.000)	.990** (.000)	.992** (.000)	1			
Flex	.965** (.000)	.965** (.000)	.966** (.000)	.964** (.000)	.949** (.000)	1		
GV	.993** (.000)	.976** (.000)	.994** (.000)	.994** (.000)	.990** (.000)	.964** .000	1	
CVE	.991** (.000)	.973** (.000)	.988** (.000)	.990** (.000)	.986** (.000)	.959** (.000)	.992** (.000)	1

Note. GS=Grip strength, SE=Strength Endurance, Bal=Balance, AG=Agility, Coord=Coordination, Flex=Flexibility, GV=Gait Velocity, CVE=Cardiovascular Endurance

**p< 0.01

Table 4 reveals that if a participant of 40-49 years of middle-aged women group scores 4 kg and below in GS then the participant would be given 0 points. If the participant scores 10 kg in GS, then the participant would be given 10 points. In the same way, if a participant scores 12.20 kg, 13.75 kg,

14.30 kg, 16.00 kg, 18.00 kg, 19.00 kg, 21.00 kg, 22.00 kg, 23.00 kg, 25.00 kg and 29.00 kg in GS then the participant would be given 20, 25, 30, 40, 50, 60, 70, 75, 80, 90, and 100 points respectively. In the same manner, participants of the 40-49 years of middle-aged women group score according to the percentile norms on other variables. The frequency of the percentile scores for 40-49 years of middle-aged women group scores GS, SE, Bal, and AG are presented in Figure 2, and Coord, Flex, GV, and CVE are presented in Figure 3.

Table 4. Percentile scores of all selected physical fitness variables for physical fitness test battery of 40-49 years of middle-aged women group.

Percentile	40-49 years age Group								Percentile
	GS (kg)	SE (sec)	Bal (sec)	AG (sec)	Coord (sec)	Flex (cm)	GV (m/sec)	CVE (m)	
P_0	4	4	5	19	28.95	6	0.6	320	P_0
P_{10}	10	17.1	11.1	16.39	22.34	11	0.94	410	P_{10}
P_{20}	12.2	28.2	20	15.04	20.70	13	1.12	443.20	P_{20}
P_{25}	13.75	32.75	22	14.33	19.98	14	1.17	465	P_{25}
P_{30}	14.3	37	24	13.78	19.31	15	1.23	480	P_{30}
P_{40}	16	44	27	12.94	18.43	16	1.33	490	P_{40}
P_{50}	18	49	30	12.17	17.43	18	1.41	510	P_{50}
P_{60}	19	56	34	11.34	16.41	19	1.52	525	P_{60}
P_{70}	21	63	39	10.61	15.34	21	1.63	544.10	P_{70}
P_{75}	22	67.25	42	10.15	14.89	22	1.69	550.50	P_{75}
P_{80}	23	73	45	9.57	14.33	23	1.76	560	P_{80}
P_{90}	25	84	52	8.35	13.05	25	1.90	593.60	P_{90}
P_{100}	29	100	60	6.20	10.71	30	2.20	670	P_{100}

Note. GS=Grip strength, SE=Strength Endurance, Bal=Balance, AG=Agility, Coord=Coordination, Flex=Flexibility, GV=Gait Velocity, CVE=Cardiovascular Endurance, Gr.=Group, kg= Kilogram, sec=Second, cm= Centimetre, m/sec= Meter/second, , m=Meter

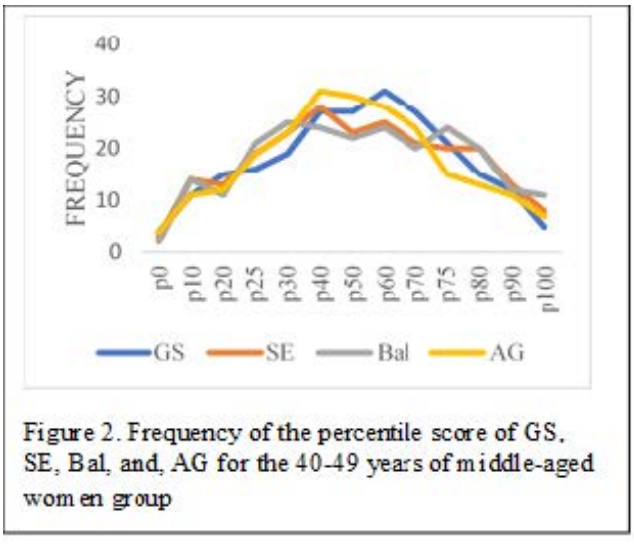

Figure 2. Frequency of the percentile score of GS, SE, Bal, and, AG for the 40-49 years of middle-aged women group

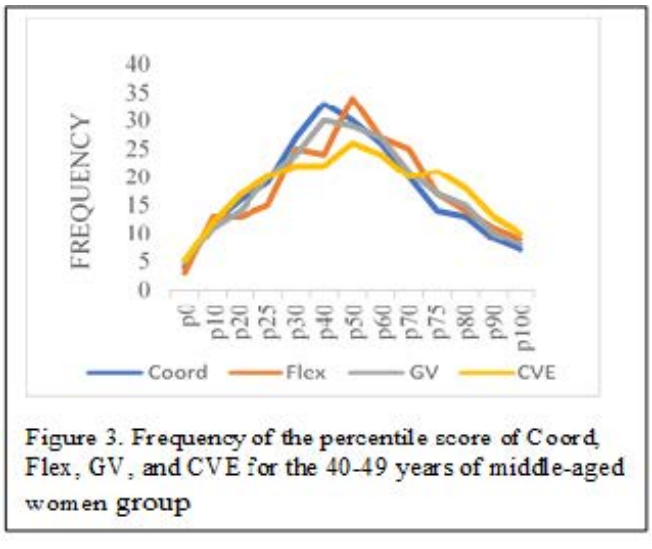

Figure 3. Frequency of the percentile score of Coord, Flex, GV, and CVE for the 40-49 years of middle-aged women group

From Table 5 it can be seen that in the 50-59 years of middle-aged women group, the P_{100} score of GS, SE, Bal, AG, Coord, Flex, GV, and CVE were 24.00 kg, 90.00 sec, 60.00 sec, 6.60 sec, 12.14 sec, 27.00 cm, 2.10 m/s, and 649.00 m respectively. On the other hand, the P_0 score of selected variables were 1.00 kg, 2.00 sec, 2.00 sec, 22.37 sec, 30.45 sec, 1.00 cm, 0.42 m/s and 310.00 m respectively. Table 5 reveals that if a participant scores 1 kg and below in GS then the participant would be given 0 points.

If the participant scores 5 kg in GS, then the participant would be given 10 points. In the same way, if a participant scores 8.00 kg, 9.00 kg, 9.80 kg, 11.00 kg, 12.00 kg, 14.00 kg, 15.00 kg, 16.00 kg, 17.00 kg, 20.00 kg, and 24 kg in GS then the participants would be given 20, 25, 30, 40, 50, 60, 70, 75, 80, 90, and 100 points respectively. In the same manner, the participants' raw scores of any

physical fitness variables based on the same test would be converted into percentile scores as mentioned in Table 5. The frequency of the percentile scores for 50-59 years middle-aged women of GS, SE, Bal, and AG are presented in Figure 4, and Coord, Flex, GV, and CVE are presented in Figure 5.

Table 5. Percentile scores of all selected physical fitness variables for physical fitness test battery of 50-59 years of middle-aged women group.

Percentile	50-59 years women age Group								Percentile
	GS (kg)	SE (sec)	Bal (sec)	AG (sec)	Coord (sec)	Flex (cm)	GV (m/sec)	CVE (m)	
P_0	1	2	2	22.37	30.45	1	0.42	310	P_0
P_{10}	5	15	13	18.84	25.95	7	0.77	380.8	P_{10}
P_{20}	8	25.2	17.2	17.33	23.84	10	0.95	417.2	P_{20}
P_{25}	9	30	19	16.57	23.19	11	1.01	429	P_{25}
P_{30}	9.8	33	20	16.21	22.45	12	1.05	441.8	P_{30}
P_{40}	11	39	24	15.17	21.46	13	1.17	458.4	P_{40}
P_{50}	12	45	26	14.33	20.68	15	1.25	472	P_{50}
P_{60}	14	50.6	28	13.52	19.58	16	1.33	490.6	P_{60}
P_{70}	15	57.2	32	12.5	18.49	17.2	1.43	510.2	P_{70}
P_{75}	16	61	34	11.94	18.06	18	1.5	523	P_{75}
P_{80}	17	65.8	35	11.24	17.34	19	1.56	535.8	P_{80}
P_{90}	20	76.4	40	9.37	15.79	22	1.75	571.4	P_{90}
P_{100}	24	90	60	6.6	12.14	27	2.1	649	P_{100}

Note. GS=Grip strength, SE=Strength Endurance, Bal=Balance, AG=Agility, Coord=Coordination, Flex=Flexibility, GV=Gait Velocity, CVE=Cardiovascular Endurance, Gr.=Group, kg= Kilogram, sec=Second, cm= Centimetre, m/sec= Meter/second, m=metre

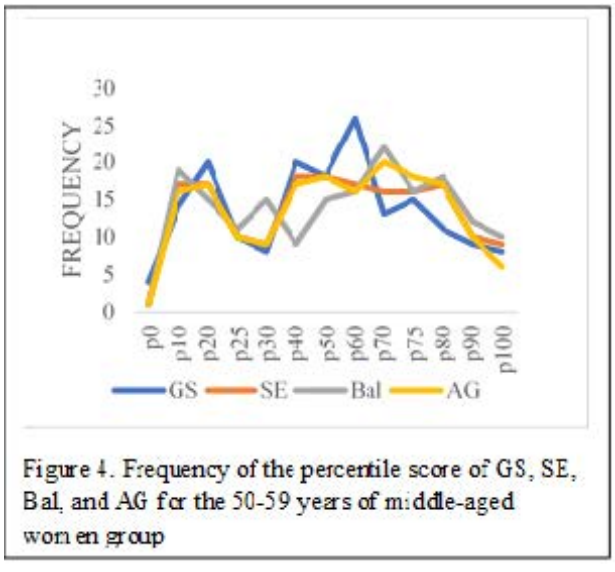

Figure 4. Frequency of the percentile score of GS, SE, Bal, and AG for the 50-59 years of middle-aged women group

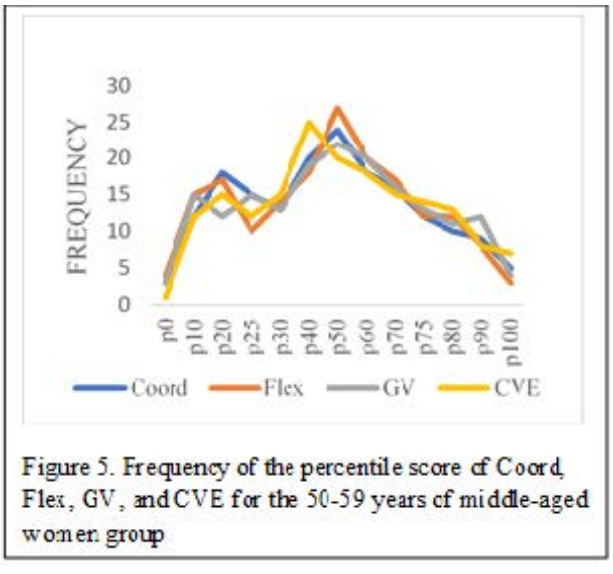

Figure 5. Frequency of the percentile score of Coord, Flex, GV, and CVE for the 50-59 years of middle-aged women group

Grading of all selected physical fitness variables for both groups.

Grading of all variables was computed by using Cajori's 5-grade evaluation norms, which are presented in Table 6 and Table-7. Cajori's 5-grade evaluation norms represent the five grades that are excellent, good, average, and poor. An excellent grade was given when a score of a variable lies between the means with +1.5 SD and above, good grade was given when a score of a variable lies between the means with +0.5 SD and above. It was average when a score lies between below the means with +0.5 SD and above the means with -0.5 SD. The below-average grade was given when a score of a variable lies between the means with -0.5 SD and below. Whereas the poor grade was given when a score of a variable lies between the means with -1.5 SD and below.

Table 6 reveals that the excellent score of GS, SE, Bal, AG, Coord, Flex, GV, and CVE in the 40-49 years middle-aged women group were ≤26.05 kg, ≤85.90 sec, ≤52.53 sec, ≤7.86 sec, ≤12.23 sec, ≤25.85 cm, ≤1.94 m/sec, and ≤609.72 m respectively. The poor score of the same group for

GS, SE, Bal, AG, Coord, Flex, GV, and CVE were ≥9.24 kg, ≥14.56 sec, ≥10.47sec, ≥16.66 sec, ≥22.77 sec, ≥9.89 cm, ≥0.95 m/sec and ≥397.48 m respectively.

Table 7 also reveals that in the 50-59 years middle-aged women group the excellent score of GS, SE, Bal, AG, Coord, Flex, GV, and CVE were ≤20.03 kg, ≤77.76 sec, ≤ 42.55 sec, ≤9.00 sec, ≤15.00 sec, ≤ 22.77 cm ≤ 1.77 m/sec, ≤580.66 m respectively, whereas a poor score of the same group for GS, SE, Bal, AG, Coord, Flex, GV, and CVE were ≥4.49 kg, ≥12.89 sec, ≥10.39 sec, ≥19.53 sec, ≥26.38 sec, ≥6.37 cm, ≥0.73 m/sec and ≥370.96 m respectively.

Table 6. Grading of all selected physical fitness variables of 40-49 years of middle-aged women group

Grade	40-49 years women group							
	Range of Scores							
	GS (kg)	SE (sec)	Bal (sec)	AG (sec)	Coord (sec)	Flex (cm)	GV (m/sec)	CVE (sec)
Excellent	≤26.05	≤ 85.90	≤52.53	≤7.86	≤12.23	≤25.85	≤1.94	≤609.72
Good	20.45-26.04	62.12-85.89	38.51-52.52	7.87-10.79	12.24-15.74	20.54-25.84	1.59-1.93	538.98-609.71
Average	14.85-20.44	38.34-62.11	24.49-38.50	10.80-13.72	15.75-19.24	15.22-20.53	1.25-1.58	468.23-538.97
Below Average	9.25-14.84	14.57-38.33	10.48-24.48	13.73-16.65	19.25-22.76	9.90-15.21	0.96-1.24	397.49-468.22
Poor	≥9.24	≥14.56	≥10.47	≥16.66	≥22.77	≥9.89	≥0.95	≥397.48

Note. GS=Grip strength, SE=Strength Endurance, Bal=Balance, AG=Agility, Coord=Coordination, Flex=Flexibility, GV=Gait Velocity, CVE=Cardiovascular Endurance, Gr.=Group, kg= Kilogram, sec=Second, cm= Centimetre, m/sec= Meter/second, m=Meter

Table 7. Grading of all selected physical fitness variables of 50-59 years of middle-aged women group

Grade	50-59 years women group							
	Range of Scores							
	GS (kg)	SE (sec)	Bal (sec)	AG (sec)	Coord (sec)	Flex (cm)	GV (m/sec)	CVE (sec)
Excellent	≤20.03	≤77.76	≤42.55	≤9.00	≤15.00	≤22.77	≤1.77	≤580.66
Good	15.06-20.02	56.14-77.75	31.83-42.54	8.99-12.51	15.01-18.80	17.31-22.76	1.42-1.76	510.76-580.65
Average	9.78-15.05	34.52-56.13	21.11-31.82	12.52-16.01	18.81-22.58	11.85-17.30	1.09-1.41	440.86-510.75
Below Average	4.50-9.77	12.90-34.51	10.40-21.10	16.02-19.52	22.59-26.37	6.38-11.84	0.74-1.08	370.9-440.85
Poor	≥4.49	≥12.89	≥0.39	≥19.53	≥26.38	≥6.37	≥0.73	≥370.96

Note. GS=Grip strength, SE=Strength Endurance, Bal=Balance, AG=Agility, Coord=Coordination, Flex=Flexibility, GV=Gait Velocity, CVE=Cardiovascular Endurance, Gr.=Group, kg= Kilogram, sec=Second, cm= Centimetre, m/sec= Meter/second, m=Meter

External Validity

External Validity of the newly constructed physical fitness test battery of 40-49 years and 50-59 years groups of middle-aged women were checked through Unbiased Test, Efficiency Test, Sufficiency Test, and Consistency Test and presented in Table 8. Table 8 reveals the positive unbiased test value which indicates that there was no estimation error in both the age group and sequence of estimators was robustly unbiased in both the age group. Similarly the positive value of efficiency test, sufficiency test, and consistency test indicate that the sequence of estimators were robustly efficient,sufficient, and strongly consistent. So the positive results indicate that the newly constructed physical fitness test battery is externally valid. Hence this test battery and its percentile norms are entitled to measure physical fitness of middle-aged women across the world.

Table 8. External Validity of newly constructed physical fitness test battery of 40-49 years and 50-59 years of middle-aged women groups.

External Validity	40-49 years	50-59 years
Unbiased Test	0.76	0.76
Efficiency Test	0.54	0.54
Sufficiency Test	0.499	0.499
Consistency Test	0.0001	0.0001

DISCUSSION

The aim of the study was to develop a physical fitness test battery for middle-aged women by which women can understand their health status. The present study showed that the mean of the GS, SE, Bal, AG, Coord, Flex, GV, and CVE was 17.64 kg, 50.22 sec, 31.50 sec, 12.26 sec, 17.50 sec, 17.87 cm, 1.42 m/sec and 503.60 m for women of 40-49 years age group and for women of 50-59 years age group the mean value of same variables were 12.40 kg, 45.33 sec, 26.47 sec, 14.26 sec, 20.68 sec, 14.57 sec, 1.25 m/sec, and 475.80 m respectively. The 25-percentile scale value of the 40-49 years middle-aged women group on selected physical fitness variables of GS, SE, Bal, AG, Coord, Flex, GV, and CVE were 13.75 kg, 32.75 sec, 22.00 sec, 14.33 sec, 19.98 sec, 14.00 cm, 1.17 m/sec, and 465 m respectively. For the 50-59 years age group of middle-aged women the 25-percentile scale of the same selected variables were 9.00 kg, 30.00 sec, 19.00 sec, 16.57 sec, 23.19 sec 11.00 cm, 1.01 m/sec, and 429 m respectively. Physical Fitness status is the indirect indicator of an individual's health. One can measure physical fitness status by physical fitness test battery which is made with various physical fitness components. Grip strength decreases with age for both dominant and non-dominant hands (**Adedoyin et al., 2009**). It has been recommended as an important predictor of overall muscle strength which is also recognized as a biomarker of general health status for the general population **(Bohannon, 2019**). It plays an important role in the clinical and surgical treatment, functional evaluation of people, talent identification in sports, and composition of the battery in different professional activities (**Amaral et al., 2019**). Generally, Grip strength is measured by handgrip dynamometer because it is valid, fast, inexpensive, and simple to test (**Zaccagni et al., 2020)**. Many researchers constructed reference values on GS by using the handgrip dynamometer with respect to their regional population. **Tsang** (**2005**) showed that the mean GS of 21-70 years women was 28.5±5.7 kg in Hong Kong Chinese adults. **Kamarul et al.** (**2006**) showed that the mean GS of 18-65 years women was 18.6±5.8 kg in the Malaysian Adults population. According to **Adedoyin et al.** (**2009**), the mean GS of 20-70 years women was 24.9±6.4 kg in Nigerian Adults. The obtained value of the Indian population was a little lower than the other populations mentioned above. The reasons behind this difference may have resulted from genetic factors, lifestyle, and biological changes in women (**Manoharan and Kowsalya, 2017**). Milanović et al., (2013) reported that strength endurance decreases due to the aging process. Muscle dysfunction is a functional impairment due to cumulative decline among multiple body systems. The deficiency of muscle strength endurance is more common in lower extremity muscles than in upper extremities. The weak muscles of the lower extremities negatively affect balance, walking performance, sit and standing ability **(Ramari et al., 2020**). Therefore, assessment of lower extremity muscles (especially quads, hamstring, and glute muscles) is an important part to understand of a person's health status. In the present study, the wall squat test was used to develop percentile norms of strength endurance for middle-aged women. **McIntosh et al.** (**1998**) mentioned that the mean SE of 40-49 years middle-aged women was 45.00 sec and 50-59 years middle-aged women was 39.00 sec on the Canadian population. The mean SE of both groups in the present study were very close to the mean SE of on the Canadian population. Balance depends on the vestibular system, cognitive system, musculoskeletal system, and the volume of physical activity. The efficiency of these systems decreases gradually when women enter at the age of 40 years (**Dunsky, 2019**). **Springer et al.**, (**2007**) stated that the mean Bal for the 40-49 years of women was 42.10 sec and for the 50-59 years of women was

40.90 sec in Washington, DC population. In the present study, the obtained mean of Bal on the Indian population is quite lower than the mean value of **Springer et al**. (**2007**) study on the Washington, DC population. The proper amount of agility of a person may help to change direction perfectly and accurately. Agility depends on strength, flexibility, and neuromuscular reaction time. **Milanovic et al**. (**2013**) also concluded that AG decreased due to the aging process. So, the inclusion of agility as a component of the physical fitness test battery is valid and justified. A certain amount of coordination is necessary to perform daily activities such as walking, cleaning, and climbing stairs. The level of coordination of middle age women decreases with aging however age is not the only thing that can cause a decline in coordination, Genetic factors, physical injury, and neurological disorders also can impair this function (**Seidler et al., 2010**). So, coordination is also a leading factor to live independently at an old age. So the inclusion of coordination as a component of test battery is worthy and justified The flexibility of hamstring and low back muscles may prevent musculoskeletal injuries, low back problems, postural deviations, gait limitations, and risk of falling (**Stathokostas et al., 2013**). Flexibility depends on muscle stiffness and stretch tolerance of an individual (**Milanovic et al., 2013**). According to Fit India Fitness Protocol and guidelines (2019) for ages 18 to 65 years, the mean Flex of 36-45 years of women was 18-19 cm and 46-55 years of women was 17-18 cm measured by the same test sit and reach. **Kordi et al**. (**2010**) expressed that the mean Flex of 40-49 years women was 25.72 cm and 50-60 years women was 25.13 cm in the Tehran population. The mean of the Flex of the present study is quite different from the result of (**Kordi et al., 2010**) study on the Tehran population but the mean of Flex of the present study is quite similar to the result of the Fit India Fitness Protocol and guidelines. The gait speed is an important element of functional ability of health which has been widely used in clinical settings as an indicator of frailty for older people. Gait speed is a reliable, inexpensive, feasible, and objective measure in a home care setting (**Mehmet et al., 2020**). Several physiological factors affect gait speed, such as the central nervous system, perceptual system, peripheral nervous system, muscle, bone, and joint (**Peel et al., 2013**). Different researchers mentioned that a gait speed below 1.0 m/s is a strong predictor for falls in elderly people **(Kyrdalen et al., 2019**). The assessment of gait speed serves several purposes, it provides an appropriate framework for the walking ability of an individual, and reference value can be provided according to sex and decade of age. **Novaes et al.** (**2011**) showed that the mean GV of the 40-49 years and 50-59 years of Brazilian women was 1.27 m/s and 1.27m/s respectively measured by the same test. **Bohannon** (**1997**) stated that the mean GS of 40-49 years of women was 1.39 m/s and 50–59 years women was 1.40 m/s in US Population. The mean GS of the 40-49 years age group of middle-aged women in the present study was quite similar to the results of **Bohannon's** (**1997**) study result in US Population. Novaes et al. (2011) recorded that the mean GV of 50-59 years of Brazilian women was 1.27 m/s which is very close to the present study of the 50-59 years of age group in the Indian population. Cardiovascular diseases are the upcoming leading cause of morbidity and mortality worldwide **(Pinckard et al., 2019**). A sedentary lifestyle is one of the major factors for cardiovascular diseases. Regular physical exercise has numerous positive effects on overall health it can also improve cardiovascular function by improving the heart and vascular system (**Nystoriak & Bhatnagar, 2018**). Therefore, the assessment of cardiovascular fitness is an important variable in research and health area. There is numerous field test by which aerobic fitness can assess, among them 6 min walk test is used because it is easy to administer. **Alameri et al.,** (**2009**) showed that the mean CVE of 16-50 years women was 386m in the Arabian population. In the present study, the mean value of the CVE variables is quite different from the above study. So, the inclusion of each and every component of physical fitness in the test battery is a necessary pre-requisite for measuring physical fitness level of middle-aged women.

Strength and Practical Implication

The test battery included the tests for measuring most of the variables of the physical fitness of middle-aged women. This study provided the grading for all selected variables separately. So only selected few items can also be effectively used for a particular purpose, Moreover, the external validity was established, hence **the physical fitness test battery may be used worldwide. The physical fitness battery will help to identify the** physical fitness status of middle-aged women and

accordingly, health professionals, fitness trainers, and exercise scientists can design a befitting exercise protocol for a particular middle-aged women group. Further this test battery and its norms can be used in conducting various research in physical education, health science, and in medical science.

Conclusion

Based on the findings, the study may conclude that the constructed physical fitness test battery is valid and appropriate to use for measuring the physical fitness status of middle-aged women throughout the world. The particular tests and their pertinent norms will definitely indicate the status of a particular ability of middle-aged women and on the basis of that the health experts and fitness trainers can design a suitable exercise protocol for them. Moreover, the budding researchers can effectively use the test battery and norms for various research.

Conflict of interest

Authors declared that there is no conflict of interest.

Ethics Committee

The study was approved and supervised by the departmental research committee, Physical Education, the University of Kalyani, India (Reg No 110050 of 2017-2018 Ref No. Ph.D./Phy.Edu./Ak/484 (30)/2022, dated 17 November 2022).

Author Contributions

Data Collection, Statistical Calculation, and, Manuscript preparation, were done by AK; Statistical Analysis, Data Interpretation, Manuscript Preparation, and, Final review were done by NB.

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RESEARCH ARTICLE

Application of Vagal-Mediated Heart Rate Variability and Subjective Markers to Optimise Training Prescription: An Olympic Athlete Case Report

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Abstract
Purpose: The aim of this case study was to investigate whether the variation in parasympathetic branch activity, in conjunction with subjective data, could optimize the training prescription for an elite athlete during an Olympic season. Methods: During the preparatory phase for the Tokyo Olympic Games, a world-class female 3000m steeplechase runner (Age: 20 years, Height: 168 cm, Weight: 52 kg, VO2max: 67.1 mL·min·kg^{-1}) recorded Heart Rate Variability (HRV), conducted orthostatic tests, and completed subjective evaluations four times a week throughout the different training periods that constitute a pre-Olympic season. The Pearson correlation coefficient and the Shapiro-Wilk test, along with paired T-tests, were used to assess correlations and compare mean differences between variables concerning baseline measurements and each of the other training periods. Results: The natural logarithm of the root mean square of the standard deviation during supine measurement (LnRMSSDsu) exhibited a significant negative correlation with the training load based on Rating of Perceived Exertion (RPE) and sleep quality ($P < 0.05$). Heart rate during supine measurement (HRsu) showed a significant positive correlation with subjective perceived exertion, sleep quality, stress, muscle soreness, and fatigue ($P < 0.01$). Compared to the baseline (rest), LnRMSSDsu, HRsu, RPE, and sleep quality were significantly different during the training, camp, and altitude training camp periods. Conversely, markers of standing Heart Rate Variability (HRV) did not differ during competition periods. Conclusion: Standing Heart Rate Variability, when combined with subjective markers, serves as a relevant monitoring tool for adapting training periods to regulate psychophysiological effects.

Keywords
Training Monitoring, Psychophysiological Stress, Olympic Athlete

INTRODUCTION

Careful planning of an athlete's training regimen is essential to optimize their performance during competitions. Coaches and sports scientists must strike a delicate balance between maintaining sufficient training load to induce adaptation and safeguarding their overall health, with a specific focus on preventing maladaptation and injury (Morton 1991). Periodisation is a training method that breaks the season into several phases. This enables the modification of training parameters to achieve performance goals by targeting necessary adaptations (Bompa 1983; Bompa 1987) Periodically during specific training phases, elite athletes face periods of intense training, often characterised by multiple sessions in a single day (Hartman et al. 2007) and compounded by

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heightened psychological pressures imposed by recovery and nutritional strategies, travel, and media obligations that disrupt an athlete's daily routine (**Faustin et al. 2022**). As a result, these athletes face a unique combination of psycho-physiological stressors that, if not managed appropriately, may impair vital cognitive functions such as learning, memory, and neuroendocrine function **(Kim and Diamond 2002**; **Kuipers and Keizer 1988**) and increase overuse injury risk (**Martin and Amos 2021**).

During increased physical activity and mental stress, observable changes occur in autonomic nervous system (ANS) activity. A commonly used indirect indicator of ANS is heart rate variability (HRV), which represents the variation in time intervals between successive heartbeats (**Malik 1996; Saboul 2013**). HRV analysis indicates the contribution of the parasympathetic nervous system, which is primarily regulated by the vagal nerve (**Brodal 2004**) referred to as vagal-mediated Heart Rate Variability (vmHRV). The analysis of HRV can be performed via multiple methods, with temporal analysis of vmHRV more reliable than spectral indices (**Al Haddad et al. 2011**)and is frequently used to reflect the activity of the parasympathetic branch (**Berntson et al. 1997**).

Using time domain parameters of vmHRV to measure training load (**Saboul, Pialoux, and Hautier 2013**), optimize training intensity (**Earnest et al. 2004**), monitor psychophysiological stress adaptation (**Flatt and Esco 2016**) and track recovery in athletes (**Abaji et al. 2016**), vmHRV is increasingly used as a tool to monitor psychophysiological adaptation to stress and recovery (**Brodal 2004**). It is now frequently incorporated into athletic training load management to enhance the efficacy of training programs in athletes undergoing strenuous training regimes (**Plews et al. 2012; Gordan, Gwathmey, and Xie 2015**).

Critically, several studies have reported the measurement if vmHRV in a single position is insufficient for fatigue detection in athletes (**Abaji et al. 2016; Fatisson, Oswald, and Lalonde 2016; Massin et al. 2000**). Thus, HRV data should be collected in several positions including supine or standing. Incorporating an orthostatic test, transitioning from lying to standing, during vmHRV testing prompts specific changes in vmHRV due to diminished vagal output and heightened sympathetic output. This test provides insight into the dynamic adaptations of the ANS during the transition from lying to standing (**Lutfullin and Almetova 2014**) and can provide additional information about changes in parasympathetic activity (**Tulppo et al. 2001**). Additionally, many studies treat vmHRV as a singular marker of the stress response, despite the physiological response despite the complex and systemic nature of the stress (**Baumann and Turpin 2010; Charmandari, Tsigos, and Chrousos 2005; Seaward 2006**). The intricate relationships between stress and vmHRV can often be hard to interpret based on the nature of the stressor. While vmHRV is a beneficial monitoring tool for understanding the effects of psychophysiological stress during different training phases of a season (competition, training phases), it can also be influenced by non-sport-related stressors (**Mosley and Laborde 2022**). As such, vmHRV analysis should ideally be coupled with a subjective assessment of self-reported variables. Using subjective measures of psychophysiological stress (RPE, sleep, muscle soreness, fatigue, and stress) can optimise the interpretation of vmHRV analysis by providing both physiological and psychological context to HRV changes (Saboul, Pialoux, and Hautier 2013). The inclusion of self-reported variables in subjective assessments is important, given the association of the parasympathetic nervous system with numerous factors relevant to psychophysiology, including cognitive, affective, social, and health phenomena (**Plews 2014; Dobbs et al. 2019; Manresa-Rocamora et al. 2021;Carrasco-Poyatos et al. 2022**). Despite the availability of many easy-to-use and non-invasive measurement tools, few studies have investigated changes in vagal system activity across different phases of an athletic season and multiple training periods in elite athletes. And to our knowledge, no study has investigated the changes in vagal system activity associated with the evolution of related self-reported variables in elite athletes during different training periods of a pre-Olympic season.

This case study examines the changes in vmHRV and associated subjective data collected during various training phases of a pre-Olympic season in an elite female athlete. More specifically,

the goal was to investigate whether the variation of parasympathetic branch activity with subjective data could optimize the training planning of an elite athlete. The athlete was monitored over 291 days of the investigation and was an international athlete preparing for the 2020 Tokyo Olympic Games. Analyzing the results of vmHRV in combination with subjective data provided feedback to the coach, allowing them to adapt the training program for each training period, fine-tune the planning as the competition neared, and adjust the training content.

MATERIALS AND METHODS

Subject

A Tier 5, World-class female 3000m steeplechase runner (Age: 20 years, Height: 168 cm, weight: 52kg, VO_{2max}: 67.1 mL·kg·min $^{-1}$) (McKay et al. 2022) collected vmHRV data and provided accompanying subject information for 291 days in preparation for Tokyo 2022 Olympic Games. All data presented were collected as part of routine professional practice in collaboration with exercise physiologists and athletic trainers from the French Institute of Sport (INSEP) and the French Athletics Federation, respectively. Year-round support was provided by INSEP, including accommodation (Paris, France), nutrition (advice and provision), physiological testing, and on-site medical treatment. Exercise training was prescribed and monitored by athletic trainers of the French Athletics Federation, with sessions completed on-site and in the immediate surrounding area (2500-acre Public Park). Specifically, the athlete completed regular endurance and track-based running sessions 10 to 12 times weekly, totalling 75-85km/week, with run sessions supplemented by two strength and conditioning and two yoga sessions. Data were collected through 5 distinct periods of the season (described below). The participating athlete was informed about the study protocol, their rights, and the associated risks of participation before providing written informed consent. All procedures were approved by the CERSTAPS ethics committee (Approval No. 2022-A00644-39) and conducted in accordance with the Helsinki Declaration (1964, revised in 2001). Regarding vulnerable and disadvantaged groups, the authors took into account the needs and priorities of the groups/individuals in which the study was conducted, in accordance with Articles 19 and 20 of the WMA Declaration of Helsinki, and the situation that the study could not be carried out outside these groups and individuals was taken into account.“Additional precautions were taken by the investigator(s) to protect the volunteers in this study.”

Periods of the season

The composition of the training programme and the distribution of the different training periods during a season are shown in figures 1 and 2, respectively (Fig. 1 and Tab. 1)

- Baseline (rest): a period of no training
- Competition: reduced training volume whilst intensity is maintained around periods of competition.
- Training: a period during which the athlete trained daily in their usual environment, typically within the French Institute of Sport and surrounding public park.
- Training Camp: a short period during which the athlete trains in a different training environment.
- Altitude Training Camp: All altitude training camps were completed at the National
- Altitude Training Centre, Font Romeu, France (~1800m elevation)

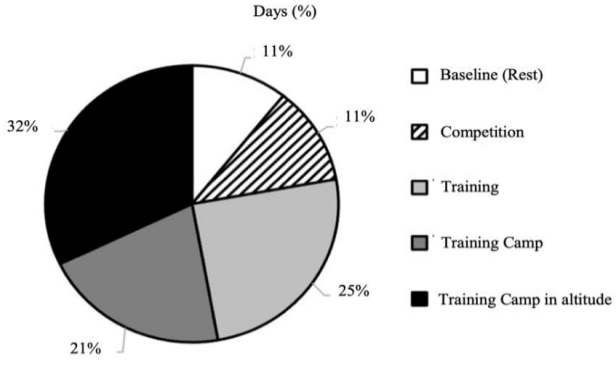

Figure 1. Distribution of the different periods of the season of a high-level athlet

Table 1. Example of a typical training week according to the different periods

		Rest	Competition	Training	Training Camp	Train Camp in altitude
Day 1	Morning	Rest	Rest	Footing + Bike	Footing + strethcing	Bike session + yoga
	Afternoon	Rest	Footing + stretching + yoga	Footing + technical + straight lines	Footing + technical + straight lines	Footing + Musculation
Day 2	Morning	Rest	Footing + Musculation	Track session	Track session	Footing + stretching
	Afternoon	Rest	Rest	Footing + Musculation	Footing	Bike session + stretching
Day 3	Morning	Rest	Track session	Footing	Footing	Rest
	Afternoon	Rest	Rest	Rest	Rest	Bike session + musculation
Day 4	Morning	Rest	Rest	Footing + stretching	Hill session	Track session
	Afternoon	Rest	Rest	Bike session + musculation	Footing + Yoga + stretching	Rest
Day 5	Morning	Rest	Footing + stretching	Track session	Track session	Footing + yoga
	Afternoon	Rest	Rest	Footing	Footing + musculation	Bike session
Day 6	Morning	Rest	Footing + straight lines	Active footing	Active footing	Track session
	Afternoon	Rest	Rest	Rest	Rest	Rest
Day 7	Morning	Rest	Competition	Bike session	Footing + yoga + stretching	Footing
	Afternoon	Rest	Rest	Track session	Rest	Rest

Lying to standing test: Orthostatic test

The orthostatic test, a variant of the tilt test, to collect R-R intervals for 10 minutes was completed 4 times weekly at approximately the same time (~8:50 am) in a darkened room (i.e. curtains drawn) (**Bourdillon et al. 2017**). Before starting the test, the athlete had to go to the toilet before recording their heart rate to avoid sympathetic activation during the recording. Upon waking, the subject attached a Garmin heart rate belt around their chest, maintained a supine position on their bed for 5 minutes, and asked to breathe normally and spontaneously before quickly standing and standing still for 5 minutes. Data were recorded throughout the test via a Garmin Forerunner 245 Music watch connected to the Garmin HRM-Pro heart rate monitor. All data were uploaded to Garmin Connect before exportation for further analysis.

Analysis of vagally mediatedHeart Rate Variability (vmHRV)

After exporting the data, each data file was viewed to correct for artefacts manually and then analysed using specialisedvmHRV analysis software "Kubios HRV Standard" (The Biomedical Signal and Medical Imaging Analysis Group, Department of Applied Physics, University of Kuopio, Finland) (**Tarvainen et al. 2014**). A systematic average correction was applied to all data to reduce the number of artefacts present. A test was considered unusable if the percentage of artefacts was less than 5%. The following vmHRV of the parasympathetic branch indices were calculated and processed:

Time-domain indices

Mean Heart Rate: HR (global activation indicator of the SNA)

Natural logarithm of the RMSSD LnRMSSD: (*Parasympathetic modulation (short-term components of vmHRV*

Subjective assessment of self-reported variables

In addition to collecting vagally mediated vmHRV indices, self-reported subjective markers were collected to provide psychophysiological and behavioural context to facilitate the interpretation of the analyses of vmHRV data. In this context, the athlete provided information on her previous day's activities, including subjective questionnaires, hich the coach routinely considered in the management of training load and recovery. Rating Perceived Exertion (RPE) - Each evening, the perceived difficulty of the day's training was self-reported by

the athlete using the Borg Category Report Scale (CR-10) (**Borg, Ljunggren, and Ceci 1985**). Subjective sleep assessment - Qualitative and quantitative sleep assessmentswere assessed via the Spiegel scale in conjunction with self-reported sleep duration. The Spiegel scale consists of six items that assessed sleep quality in the previous month, including sleep latency, duration, night waking occurrences, sleep depth, night-time dreams, and feeling upon waking up. Each item was scored from 0 to 5, with the final score ranging between 0 and 30 (**Ren et al. 2018**). Subjective assessment of fatigue, sleep, muscle soreness, and perceived stress (Total Subjective) - Perceived tiredness, sleep, muscle soreness, and stress was assessed using subjective questionnaires based on the Hooper scale (**Hooper et al. 1995**). Each of the 4 items was scored out of 7. These self-reported data were then summed to produce a single variable.

Statistical analyses

The Pearson correlation coefficient was calculated to estimate the correlation between each pair of variables. The results are presented in a correlation matrix in figure and table form.Levene's tests were performed to verify the homogeneity of variables. Before univariate analysis, the Shapiro-Wilk test was performed to check for normal data distributionbefore comparing each variable as a function of training load and period by one-way ANOVA. Paired T-tests were used to compare mean differences between variables from the baseline and each of the other training periods. All statistical analyses were performed with R (version 3.6.1; The R Foundation for Statistical Computing, Vienna, Austria) and the R-compatible Jamovi software (The jamovi project (2021); Version 1.6.23; Retrieved from https://www.jamovi.org). All data reported as mean ± standard deviationunless otherwise stated. The results were considered significant at $P < 0.05$.

RESULTS

A correlation matrix representing the relationships between the multiplevmHRV indices, and the self-reported subjective markers is summarised in a table (Tab. 2). This type of analysis makes it possible to visualise the intensity (significant or not) and direction (positive or negative) of the relationships between several variables. Among the main observations, LnRMSSDsu significantly correlated with the RPE and Sleep quality (P<0.05). HRsucorrelates significantly with RPE, Sleep quality, Stress and Muscle Soreness (P<0.05). Lastly, RPE significantly correlates with Muscle Soreness and Tiredness (P< 0.01).

Table 2. Correlation matrix (Pearson's r2) of the different HRV indices and self-reported

The different training periods were compared to the rest period representing the baseline. The vmHRV

	Ln RMSSDsu	Hrsu	LnRMSSDsu - LnRMSSDst	RPE	Spiegel questionnaire	Sleep duration	Sleep quality	Stress	Muscle Soreness	Tiredness	Total Subjective
Ln RMSSDsu	—										
Hrsu	**-0.260** ***	—									
LnRMSSDsu - LnRMSSDst	**0.766** ***	0.001	—								
RPE	-0.120	**0.134** *	**-0.149** *	—							
Spiegel questionnaire	0.011	0.052	-0.014	-0.107	—						
Sleep duration	-0.102	0.110	-0.087	-0.067	**0.343** ***	—					
Sleep quality	**0.122** *	**0.116** *	**0.124** *	0.122	**-0.564** ***	**-0.353** ***	—				
Stress	0.084	**0.164** **	0.064	-0.082	-0.009	-0.002	**0.208** ***	—			
Muscle Soreness	0.029	-0.001	-0.019	**0.202** **	-0.342 ***	**-0.455** ***	**0.436** ***	**0.216** ***	—		
Tiredness	-0.106	**0.122** *	**-0.177** **	**0.290** ***	**-0.145** ***	-0.079	**0.219** ***	0.136	**0.353** ***	—	
Total Subjective	0.033	**0.132** *	-0.022	**0.261** ***	**-0.458** ***	**-0.398** ***	**0.679** ***	**0.490** ***	**0.801** ***	**0.680** ***	—

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

indices and self-reported subjective markers classified according to the training period can be seen in Tab. 3. The evolution of LnRMSSDsu as a function of RPE and training periods during the different training periods is presented in Fig. 2. The comparison of HR, LnRMSSD according to the different training periods of the season is shown in Fig. 3. During competition, only RPE ($P > 0.05$) and Sleep Quality (Spiegel questionnaire) ($P > 0.01$) were significantly different during the competition period compared to the Baseline (Tab. 3).

Table 3. HRV indices and subjective markers classified according to training period

	Baseline (rest)	Competition	Training	Training Camp	Altitude Training Camp
LnRMSSSDsu	1.80 ± 0.14	1.80 ± 0.04	1.55***± 0.30	1.69* ± 0.18	1.82 ± 0.15
HRsu (bpm)	49.87 ± 2.62	50.19 ± 2.31	52.30 ± 2.56	53.5** ± 2.47	54.53*** ± 2.15
RPE (au)	0.00 ± 0.00	3.57* ± 2.65	5.18*** ± 2.04	4.64*** ± 1.44	4.62*** ± 2.09
Spiegel questionnaire (au)	28.00 ± 0.76	26.2** ± 1.6	26.56 ± 1.89	25.89*** ± 1.76	25.48** ± 1.85
Sleep duration (minutes)	530.00 ± 35.86	546.00 ± 57.13	529.85 ± 39.40	535.00 ± 53.39	504.03 ± 59.00
Total subjective (au)	13.00 ± 2.67	12.27 ± 1.06	12.85 ± 1.54	12.29 ± 1.19	13.84 ± 1.63

All data reported as mean ± SD. Significant differences represented by * P < 0.05, ** P < 0.01, *** P < 0,001,

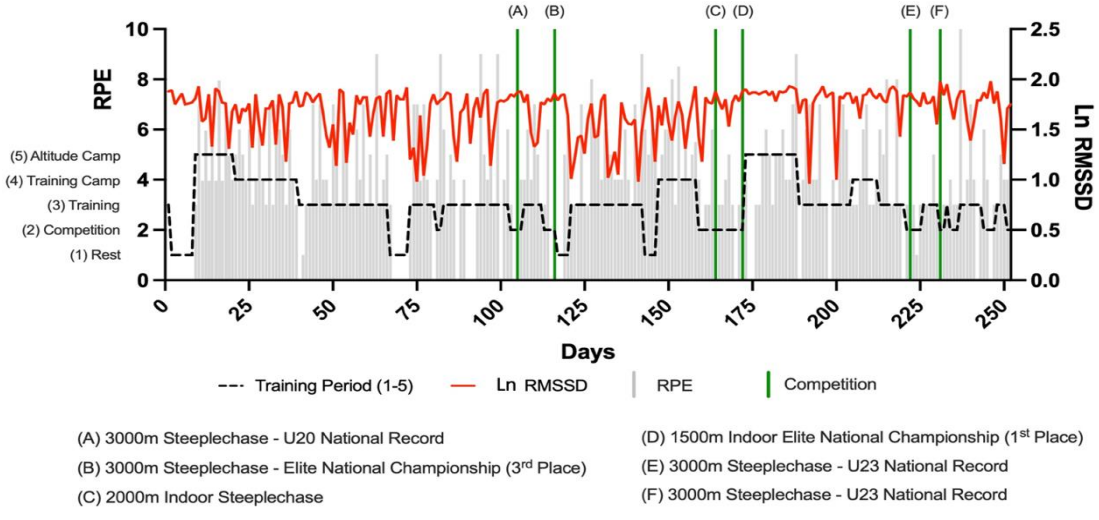

Figure 2. Evolution of the LnRMSSDsu depending of RPE and the training period during a pre-Olympic period

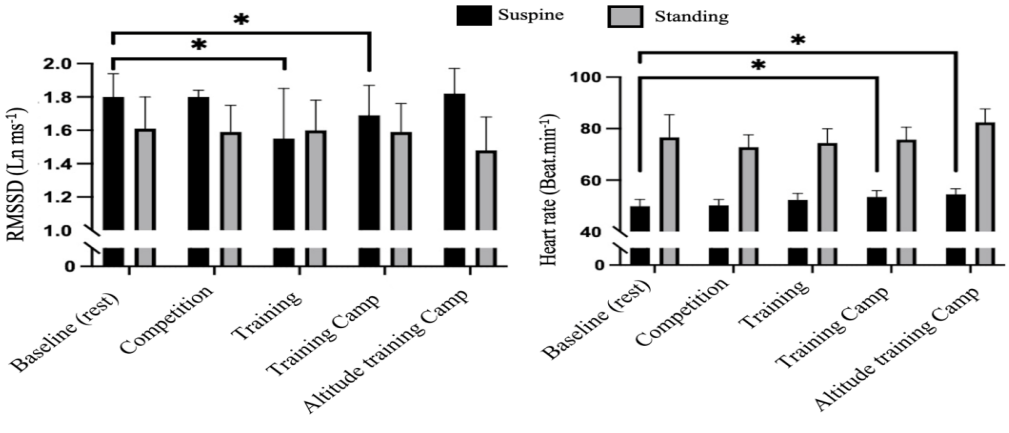

Figure 3. Heart Rate andLnRMSSD responses according to the period of the season

By comparison, during training, LnRMSSDsu were significantly lower (P> 0.001), and the RPE (P > 0.001) was significantly higher in comparison to the training and the Baseline (Tab 3. and Fig. 3). Furthermore, during training camps, LnRMSSDsu and Sleep Quality (Spiegel Questionnaire) were significantly lower (P> 0.05 and P> 0.001). At the same time, the HRsu and RPE were significantly higher (P> 0.5 and P> 0.001) between the Training Period and the Baseline (Tab. 3 and Fig. 3). HRsu and RPE were significantly higher (P > 0.001), and Sleep Quality (Spiegel Questionnaire) was significantly lower (P> 0.01) during altitude training camps in comparison to training camps and the baseline (Tab. 3 and Fig. 3).

DISCUSSION

The primary focus of this study was to assess the utility ofvmHRV combined with subjective markers for optimising training load prescription and management throughout an Olympic season in a high-performance athlete. During the monitoring period, the data generated from vmHRV and subjective reports were used by coaches to manipulate critical training variables, including intensity, duration, and recovery periods based on alterations in ANS activity and psychophysiological stress. This approach represented a data-informed approach and enabled the athlete to excel during critical competitions (Fig. 3).

Tapering is a common approach athletes employ to ensure optimal physiological condition in preparation for competition. Tapering involves a gradual decrease in the training volume with the maintenance of exercise intensity (**Mujika et al. 2000**). The resultant changes in vmHRV activity throughout taperingremain to be resolved. Nevertheless, the present case study observed that LnRMSSDSu and HRsuwere similar during the competition and rest (baseline) (Tab. 3). Additionally, in contrast to previous work by **Iellamo et al.** (**2002**),LnRMSSDsu was elevated following periods of intense training loads during specific preparation phases for competition (Fig. 2 and Fig. 3). This vagal activity change demonstrates that applying a tapering strategy enables a return of vmHRV to its baseline level, even while training continues. In this instance, the athletic support staff used daily vmHRV and subjective data to ensure sufficient tapering preceding competition.

We observed significant correlations between perceived training load, self-reported subjective data, and vmHRV indices, which contrasted the study by **Morales et al**. (**2017**) (Tab. 2). In conjunction with the observed decline in sleep quality, this data emphasises the value of coupling vmHRV with subjective markers for tracking the psychophysiological stress in elite athletes, particularly during competition periods. The performance results from national and international competitions and various national records associated with positive vmHRV adaptations in response to training modificationshighlight the necessity for a data-informedtapering strategy (**Plews et al., 2014**). Therefore, monitoring vmHRV with subjective markers enables training-specific alterations to training prescription for example, by adapting training content or postponing important training sessions and recovery periods increasing recovery time or switching from running to cyclingto ensure optimal performance at competition.

During the Training and Training Camp periods, it was observed that LnRMSSDsu and HRsu values significantly deviated from those during the rest period (Tab. 3). These substantial alterations in vmHRV indices align with periods of peak RPE (Fig. 3). **Baumert et al**., (**2006**)similarly reported changes in the parasympathetic branch activity during periods of high training load typically occurring during training camp periods. Consequently, monitoring the autonomic nervous system (ANS) using vmHRV is recommended to keep track of individual adaptations to increased training loads **(Manzi et al., 2009**). Effective training planning and programming for endurance sports necessitate an optimal physiological stress level to trigger positive adaptations in response to the training load (**Buchheit et al. 2010**) Critically, when exercise training is mismanaged (characterised by high training load, intensity and inadequate recovery) performance may be impaired or worsened and increased risk of overuse injuries.

In our case study, coupling vmHRV monitoring with subjective markers empowered the coach to tailor his training programs and content to optimise the positive adaptations brought on by the increased psychophysiological stress from the increased training load. This

approach to training periods and camps prepared the athlete adequately for competitions (Fig. 2.). Monitoring vmHRV and subjective markers enables personalised training (**Plewset al., 2014**) and training load adjustment (**Pichot et al. 2000**), enhancing different training periods for optimal performance and injury prevention.

During Altitude camps, RPE and HRsuwere significantly increased (Tab. 3 and Fig. 3), which may be partly explained by the increase in relative hypoxia (**Naeije 2010**). Despite the significant rise in HRsu, correlating with the increased training load, it's crucial to mention that LnRMSSDsu didn't decrease substantially. LikeField Schmitt, **Regnard, and Millet** (**2015**), LnRMSSD monitoring during altitude training failed to effectivelymonitor changes in ANS activity induced by training-related stress, which can't be separated from hypoxic stress. Moreover, it's widely acknowledged that altitude significantly impacts both the quality and quantity of sleep (**Bloch et al. 2015**), a hypothesis supported by this case study (Tab. 3). This deterioration in sleep quality can be attributed to the shift in the sleep environment, further exacerbating the effects of hypoxic stress on sleep. Therefore, using vmHRV in combination with subjective markers to monitor ANS activity is crucial to track the effects of psychophysiological stress induced by increased training load, intensified by hypoxic stress.

Practical application

Tracking shifts in ANS activity, particularly the parasympathetic branch, can provide a beneficial instrument for coaches to manage training across varying season periods. However, accounting for the cast range of inter-individual variabilities between athletes is crucial. Therefore, practitioners providing feedback to coaches must consider these personal differences and offer customised training load management to facilitate the stress/adaptation process. It's also vital to understand that elite athletes must impose a sufficiently high-stress level to trigger psycho-physiological adaptations that ultimately enhance performance. Unlike some suggestions, elite athletes might need to train even with reduced vagal tone (parasympathetic activity) to elicit necessary adaptations for performance improvement. As such, tracking changes in ANS activity, particularly via specific vmHRV markers, can furnish valuable insights for coaches about the autonomic adaptations resulting from the psycho-physiological stress applied to the athlete, effectively averting any overload phenomenon **(Bosquet et al. 2007**). In this regard, monitoring the training load and conducting a comprehensive analysis of the training program, including associated indirect factors, is imperative to facilitate long-term modifications to the training schedule (**Mujika 2012**).

However, there remains a necessity for more studies on elite athletes employing this methodology before we can assert that vmHRV, in conjunction with subjective markers, forms an effective tool for training planning.

Conclusion

In conclusion, this case study has reported alterations in ANS activity, specifically focusing on the parasympathetic branch, in conjunction with subjective data during varying phases of an Olympic season for an elite athlete. Combined with self-reported indicators, this approach supplied critical information that allowed practitioners to fine-tune the psycho-physiological stress imposed on their athletes during their decision-making process. Ultimately, this study underscores the sensitivity of vmHRV throughout different stages of an athletic season and pinpoints an imbalance in vagal tone during high training load periods (Training period and Training Camp period), manifested as a reduction in parasympathetic activity. Conversely, during lower training load phases (Competition Period), vmHRV improved, providing indirect feedback for perfecting pre-competition tapering and ensuring appropriate athlete recovery. From a monitoring perspective, vmHRV, along with subjective markers, could be an effective tool to adapt training periods, allowing the regulation of psychophysiological stress effects throughout an Olympic season.

Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Statement

This study was approved by the CERSTAPS ethics committee (Approval No. 2022-A00644-39) and conducted in accordance with the Helsinki Declaration (1964, revised in 2001).

Author Contributions

Planned by the author: Study Design, Data Collection, Statistical Analysis, Data Interpretation, Manuscript Preparation, Literature

Search. Author have read and agreed to the published version of the manuscript

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RESEARCH ARTICLE

Incentives and Their Role in the Job Performance of the Sports Federations in Kirkuk from the Point of View of Sports Federations Members

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Abstract
This study aims to determine the relationship between incentive, job performance levels and job performance among the members of sports federations in Kirkuk. The universe and the sample of the study were chosen with the intentional method consisting of (60) members of sports federations in Kirkuk. The researcher distributed (50) questionnaires to the study sample, then took a sample of (10) from the original community for the pilot study,the researcher used the survey method from the basic methods in the descriptive research because it is suitable for the nature of the study. According to our findings; The reward and financial incentive provided by the federation, moral appreciation was found to be an additional incentive to do more tasks (2.68±0.62 ; 2.60±0.60). On the other hand; It was determined that the participants preferred to receive financial incentives compared to moral incentives (3.98±0.55). Regarding the work performance of its members; It was determined that the positive performance evaluation results motivated me and pushed me to work efficiently (2.72±0.64), while the members obeyed the working rules and procedures (3.48±0.81). It also shows that there is a significant relationship ($p<0.00$) between incentives and job performance. Sonuç olarak; It is recommended to organize training courses for administrative leadership in the field of awards, the need to support and strengthen positive business relations between employees in non-sport sports institutions, incentives, human relations and employee evaluation methods, and to conduct a study on these incentives and improve work performance for other sports institutions.

Keywords
Sports Federations, Job Performance, Role, Incentives

INTRODUCTION

Today, it is possible to see changes and differentiations at certain rates in all areas of life. In the face of this change and differentiation, organizations have made an effort to keep up with the times and conditions. In our country, sports federations have been given the independent duty, powers and responsibilities to ensure the spread of sports to the masses, to train successful athletes, to represent the country on the international platform. The federations' ability to keep up with innovations within these responsibilities, to compete, to renew the institution, and to determine the most appropriate strategies for the institution depends on economic power (Çelik, 2016).

On the basis of branches of sports, the management and administration is carried out by sports federations. Whichever federation it is, it is possible to achieve its goals related to the area it serves, by organizing a solid organization within itself. The success of the organization depends on good and effective human resources. In order to fulfill the general purpose and target of sports, it can be realized by the managers who will implement the annual activity practices of the

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federation and the expanding and the personnel who know the dynamics that have the job (**Kılıç and Tabuk, 2022**).

Sports federations stand out as organizations that provide services in order to organize organizations related to sports branches in their own fields, to spread sports among the grassroots and to help young people get away from bad habits. When the service provided by the federations in this sense is evaluated in many respects, it imposes an important mission and responsibility on the federations. Sport is not only a visual phenomenon, but also the product of a successful organization. Employees with high motivation and performance have an impact on the emergence of this product (**Ek and Mukuru, 2013**).

Organizations, including sports federations, depend in the implementation of their activities and work on human resources, which implement their programs and achieve their goals, and the federations are always looking for how to make their human resources provide their best to achieve growth, development, increase productivity, and provide services efficiently, and all organizations are keen to carry out their work and various activities with a high level of efficiency and effectiveness, and the employee represents one of the most important basic variables affecting this efficiency, and the desire of employees to obtain rewards is a catalyst behind improving their performance (**Abbasand Suleiman, 2009**).Human resources have become a vital factor for sports institutions, which necessitates the presence of workers and administrative, technical and medical staff at the highest level, in addition to taking care of them through incentives to achieve their ambitions.

Corporate governance has become an important topic of discussion among all public and private sectors at local, regional, national and international levels. Therefore, the concept of corporate governance is one of the contemporary concepts that helps management authorities address important issues by expanding the active participation of employees in planning, goal setting and making the right decisions. Active participation of employees raises their performance levels to the optimum level, helps to ensure job stability and makes them highly committed to their jobs (**Rassouli, Sajjadi, Mosaffa, & Rasekh, 2020**).

Job performance refers to the degree of success and completion of the tasks that make up an individual's job. It is the opposite of how an individual achieves or satisfies the requirements of the job; Here, job performance is of fundamental importance to multiple organizations through optimal use of their strengths and human resources so that the organization can thrive and deal well with everyone (**Saber and Ibrahim, 2022**).

It increases their level of comfort and acceptance of their assigned duties, incentive system, working hours, social justice and work discipline. This leads to the personal and professional development of the employee and the organization as a whole. This organized structure of the system increases the performance of employees in institutions with all specialties in general and sports institutions in particular (**Fouad & Fayrouz, 2019; Yassin, 2012**).

The fact that the incentives process is one of the basic and necessary processes to raise the level of performance, and it is also the main task of successful management in helping, embracing and discovering capabilities, preserving them, and harnessing them for the interest of the individual first, and then the interest of work second. Hence, the research problem is represented as indicated by the recommendations of some previous studies, such as the study of **Zahia and Latifah** (**2021**) and **Al-Faris** (**2011**), which emphasized the need to reconsider the incentive system, strengthen it, and link it to employee performance, because it affects the achievement of the goals for which the incentives were set.

In addition to the paucity of studies addressing the impact of incentives in sports institutions, including sports federations, the importance of studying the issue of incentives has an impact in guiding the behavior of employees in various institutions, which is reflected in their job performance. Therefore, this study aims to examine the level of incentive and job performance among the members of sports federations in Kirkuk, as well as the relationship between the incentives of the members and their functional performance.

MATERIALS AND METHODS

The researcher used the survey method from the basic methods in the descriptive research because it is suitable for the nature of the study.

Participants

The study population represented by the members of sports federations in Kirkuk as a community to conduct the current research. Where the sample was chosen intentionally from the members of the sports federations in Kirkuk consisting of (60) members of the federation. The researcher distributed (50) questionnaires to the study sample, and then took a sample of (10) from the original community for the pilot study, in order to standardize the questionnaire, distributed as shown in Table (1).

The participating athlete was informed about the study protocol, their rights, and the associated risks of participation before providing written informed consent. Ethical approval was obtained from the Ethics Committee before starting the study Approval Date: 22.08.2023. After obtaining ethical approval, we obtained institutional permission. The entire study was carried out in a determined adherence to the principles contained in the Declaration of Helsinki. Additional precautions were taken by the investigator(s) to protect the volunteers in this study.

Table 1. Description of the basic research sample and the pilot study sample

Sample	Number Of Sports Federations	Number Of Members Of Each Federation	Total Number Of The Sample	Number Of The Pilot Study Sample	Total Number Of The Study Sample
Sports Federations	**20**	**3**	**60**	**10**	**50**
Total				**10**	**50**

Data Collection Tools

The researcher relied on obtaining data and information on the available theoretical side from Arab and foreign sources that dealt with the subject of the study (books, research, similar studies, and the information network (the Internet). A number of phrases were developed and formulated to suit the purpose and sample of the study, and it was taken into account when choosing them that they all have a positive trend. A five-point Likert scale was developed (completely agree, agree, neutral, disagree, completely disagree) for the responses of the sample's opinions on the phrases. The questionnaire of each(incentives, job performance)became in its initial form before conducting scientific transactions on it for rationing.

Pilot Study

The researcher conducted an exploratory study on a sample of (10) individuals from the main study sample and from within the study community, during the period from 2/1/2023 to 22/1/2023.

Scientific steps for questionnaires

A:Face validity

The questionnaire was presented in its initial form to (7) experts in the field of sports management in order to seek their opinions on the extent of the truthfulness of the phrases, and they agreed with a percentage ranging between (80-100%) to the phrases, and the approval of the experts on the questionnaire in its final form after the amendment was considered as the validity of the study tool.

B: Questionnaire validity: (internal consistency validity)

The validity of the internal consistency was calculated by means of the simple correlation coefficient (Pearson) between the score of each statement and the total score of the questionnaire (incentives, job performance), which is as shown in the following table (2).

Table 2. The internal consistency between the responses of each phrase and the total score of the Pearson simple correlation coefficient form to examine the validity of the questionnaires' phrase

Phrase No.	Incentives	P	Phrase No.	Job Performance	P
	Correlation Coefficient	Value		Correlation Coefficient	Value
1	0.843	0.04	**1**	0.774	0.01
2	0.924	0.00	**2**	0.843	0.04
3	0,738	0.02	**3**	0.924	0.00
4	0.774	0.01	**4**	0.774	0.01
5	0.684	0.02	**5**	0.907	0.00
6	0.907	0.00	**6**	0.757	0.01
7	1.000	0.00	**7**	0.657	0.03
8	0.688	0.02	**8**	0.774	0.01
9	0.757	0.01	**9**	0.843	0.04
10	1.000	0.00	**10**	0.924	0.00
11	0.924	0.00	**11**	0.843	0.04
12	1.000	0.00	**12**	0.924	0.00
13	0.774	0.01	**13**	0,738	0.02

$p<0.05$

C: The reliability of the questionnaire form (Crunbach alpha coefficient)

The reliabilitycoefficient of the questionnaire was calculated using the Crunbach alpha coefficient (incentives, job performance), and it is as shown in the following table (3).

Table 3. The value of the Crunbach alpha coefficient for the questionnaire phrases

	Axes	Phrases total	Crunbach alpha coefficient
1	incentives	**13**	**0.81**
2	job performance	**13**	**0.77**

Application of the questionnaire form

The researcher applied the questionnaire form (incentives, job performance) in its final form to the study community, numbering (50) individuals, during the period from 12/3/2023 to 3/4/2023 in the presence of the researcher and handing over the form hand in hand and after completing the application of the questionnaire Collected and unloaded private data to subject them to appropriate statistical processing.

Statistical Means

To identify the degree of estimation, the researcher relied on the arithmetic averages of the answers of the sample to be an indicator of the degree of estimation based on the following criterion in judging the estimation of the arithmetic averages, by dividing the grades into three levels (high, medium, low) based on the following equation, which is the correction criterion:

Upper limit of alternatives−minimum limit of alternatives =5-1= 1.33

levels 3

The first range: 1 + 1.33 = 2.33., the second range: 2.34 + 1.33 = 3.67., the third range: 3.68 + 1.33 = 5.01 then the estimates become as follows:

1. Less than or equal to (2.33) a low indicator.
2. Greater than (2.34) and less than or equal to (3.67) as an average indicator.
3. Greater than or equal to (3.68) a high indicator.

After obtaining the initial data set collected from the study population using the study tool, which was the questionnaire, statistical processing was used through the SPSS program in order to obtain clear scientific answers. Statistical analysis was done using the Statistical Package for Social Science (SPSS) version. Descriptive tests (mean and standard deviations) and validity and reliability tests were used in the present study. Correlation analysis was used to determine the relationship between incentives and job performance for members of sports federations in Kirkuk.

RESULTS

First objective:

Identify the level of incentives among the members of the sports federations in Kirkuk

Table 4 shows that; the lowest average of the answers given by the participants, respectively; You are satisfied with the reward and financial incentive policies provided by the Federation and Moral appreciation is an additional incentive to perform more duties than is automatically imposed (2.68±0.62 ; 2.60±0.60) was detected.

On the other hand, the highest average given by the participants; members prefer to receive financial incentives compared to moral incentives (3.98±0.55), working in the federation helps me stand out in society (3.92±0.69) and periodic awards related to reaching a certain goal at work, federation members to this goal It has been determined that there are answers given to the question that encourages people to make an effort to reach (3.88±0.32).

Table 5 shows that; the lowest average of the answers given by the participants, respectively; I find that positive performance evaluation results motivate and pushes me to work efficiently (2.72±0.64) and The policy followed by the federation makes you feel stable at work (2.74±0.63) was found to be at the lowest level.On the other hand, the highest average among the statements given by the participants about the job performance level; Members comply with the working rules and procedures (3.48±0.81) and I see that the federation presidents are interested in performance evaluation results on the basis of reward and punishment criteria (3.42±0.73).

Table 4. Arithmetic means, standard deviations and level expressions for participants' incentive statements

Incentives	X	SD.	Level
1Federation members feel job stability and security.	3.38	0.53	Average
2The federation provides opportunities to participate in decision-making.	3.76	0.47	High
3The federation is interested in providing certificates of appreciation to the deserving.	3.12	0.59	Average
4The federation provides opportunities to participate in training courses.	3.46	0.50	Average
5Bosses offer expressions of thanks, appreciation and praise when achieving the required goals.	3.72	0.49	High
6The federation provides appropriate working conditions.	3.26	0.69	Average
7Working in the federation helps me to stand out in society.	3.92	0.69	High
8Moral incentives of various kinds improve performance.	3,74	0.66	High
9You are satisfied with the policies of rewards and financial incentives granted by the Federation.	2.68	0.62	High
10Members prefer to receive financial incentives compared to moral incentives.	3.98	0.55	High
11Moral appreciation is an additional incentive to perform more tasks than automatically imposed.	2.60	0.60	Average
12Having financial incentives helps you to do more at work.	3.30	0.64	Average
13Periodic rewards associated with achieving a specific goal at work encourage federation members to strive towards achieving this goal.	3.88	0.32	High
Total	3.15	0.56	Average

Second objective:

Identify the level of job performance among the members of the sports federations in Kirkuk

Table 5. Arithmetic means, standard deviations and job performance level expressions of the participants

Job Performance	X	SD	level
1My job matches my skills and abilities	3.14	0.60	Average
2I feel satisfied with my work performance	3.00	0.83	Average
3Members develop their performance continuously	3.02	0.51	Average
4Members have a good communication skills with others	3.24	0.59	Average
5The administration relies on performance reports to discover the compatibility between the worker's performance and his work	3.04	0.69	Average
6Performance is evaluated based on scientific foundations and clear criteria	3.04	0.63	Average
7Members abide by work rules and procedures	3.48	0.81	Average
8Feel the fairness and justice of the outcome of my performance evaluation	3.08	0.77	Average
9I find that positive performance evaluation results motivate and pushes me to work efficiently	2.72	0.64	Average
10Mechanisms and methods of granting incentives affect performance	3.34	0.65	Average
11The policy followed by the federation makes you feel stable at work	2.74	0.63	Average
12I believe that a good incentive system works to improve the performance of members	2.90	0.58	Average
13I see that the heads of the federations are concerned with the results of performance evaluation on the basis that it is a criterion for reward and punishment	3.42	0.73	Average
Total	3.08	0.66	Average

Third objective:

Identify the relationship between incentives and job performance for members of sports federations in Kirkuk.

Table 6 shows that there is a significant relationship between incentives and job performance with the correlation value (0.56) and the probability value ($p<0.00$). There is a direct relationship between incentives and job performance and this shows that the more incentives are applied among the members of sports federations in Kirkuk, the higher the job performance and vice versa.

Table 6. Incentive correlation coefficient and job performance

Variables	X	SD	Correlation	P Value
Incentives	**44.80**	**1,95**	**0.56**	**0,00**
Job Performance	**39,60**	**2,70**		

DISCUSSION

Organizations, including sports federations, work on the implementation of their activities and human resources that implement their programs and achieve their goals. Therefore, the main task of successful management is that the incentive process is one of the basic and necessary processes to raise the level of performance, and at the same time helping, adopting and discovering, protecting and using talents for their interests (**Zahia and Latifah, 2021**). It increases their level of comfort and acceptance of the duties and duties assigned to them, the incentive system, working hours, social justice and work discipline.Sport needs to be increasingly sustainable, from local to global levels, as sports services are increasingly subject to scrutiny by stakeholders to ensure that activities are flawless. Therefore, it is particularly important for organizations such as federations in the nonprofit sports sector to demonstrate sustainability, safety and integrity (**Cuesta-Valiño et al., 2021**).

According to the results of our study, when the incentive statements of the participants were examined, it was determined that the lowest average was the reward and financial incentive policies provided by the Federation, and moral appreciation was an additional incentive to do more tasks. Therefore, the researcher believes that

there is no incentive system in sports federations. Since the budget of sports federations is insufficient, it is claimed that incentives are only applied if the sports federations are successful. On the other hand, it has been argued that the participating members prefer to receive financial incentives compared to moral incentives and that working in the federation is used as a tool to stand out in the society. Result of the this study agrees with the study of **Mohammed Ahamed Saber** (**2023**) on the necessity of paying attention to an incentive system among the heads of the departments of the faculties of physical education and sports sciences. According to a study by **Awad bin Omar** (**2020**), it is confirmed by her advice that incentives should be considered, as they have a positive effect and ultimately lead to higher performance levels. In another study, it has been suggested by **Al-Hallabia** (**2013**) that incentives are among the important factors that must be present for any organized effort aimed at achieving a high level of performance.

According to our study results; It was claimed that positive performance evaluation results motivate federation employees and push them to work efficiently. On the other hand, it was claimed that the members of the federation comply with the working rules and procedures, and the federation presidents are interested in the performance evaluation results on the basis of reward and punishment criteria. This result shows that there is a good job performance in sports federations, this is a result of the federation members' effective performance, motivation and desire to work in sports federations to achieve their work and to realize their own abilities, and the researcher explains why. The desire of the members of the federation to perform their duties in the federations without being paid and the work they do on a voluntary basis is the desire to serve sports in Kirkuk. **In Shami's** (**2010**) study, it was stated that work performance as the final output is of great importance in the organization, trying to achieve success and progress.

Therefore, the importance of performance is not only at the organizational level, but also goes up to the importance of performance in the success of economic and social development plans in the country. Another study conducted by **Alnsour** (**2012**) is consistent with the study by **Alnsour** (**2012**), in which the study reveals the willingness of beneficiaries to achieve satisfaction, despite the need for financial incentives of the employees included in the study.

The results of my study show that there is a significant relationship between incentives and job performance.There is a direct relationship between incentives and job performance and this shows that the more incentives are applied among the members of sports federations in Kirkuk, the higher the job performance and vice versa.This is what **Hussein** (**2008**) believes that the incentive system achieves many benefits for the individual, including (workers' feeling of justice and equality within the organization, increasing workers' production, reducing work losses, and others).The result of the current study agrees with the result of the study of **Nasser Rizk** (**2021**) that there is a significant relationship between financialand moral incentives and job performance among teachers in the Negev region.

The result of this study is also consistent with the study (**Al-Alish Muhammad Al-Hassan and Wissam Ali Hussein, 2016**) that organizations seek to improve the performance of employees in order for individual performance to be better in terms of quantity and quality. To achieve this, incentive systems must be linked to employee productivity, since incentives increase persistence. The worker has to perform the work by creating his desire by increasing the enthusiasm and motivation of the worker, which reflects positively on the overall performance and increase productivity.

Conclusion

The conclusions and recommendations reached by the study, as the results of the level related to incentivesand job performance were average among members of sports federations in Kirkuk, Also, the results showed that there was a statistically significant relationship between incentives and job performance among members of sports federations in Kirkuk. The researcher recommends the need to establish a culture of work in the spirit of one team as a moral incentive to reach the planned performance levels, the need to link the results of evaluating sports federations and granting incentives and rewards based on those results, the need to support and strengthen positive work relations between workers in sports and non-sports institutions, holding training courses for administrative leadership In the field of incentives, human relations and methods of evaluating employees, and conducting a study

related to the incentives and job performance of other sports institutions.

Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Statement

Ethical approval was obtained from the Ethics Committee before starting the study Approval Date: 22.08.2023. After obtaining ethical approval, we obtained institutional permission

Author Contributions

Study conception and design: MAS, ZMO, BOQ ; Data Collection: MAS, ZMO; Analysis and Interpretation of results: MAS, ZMO, BOQ; Draft manuscript preparation: MAS, ZMO, BOQ; All authors reviewed the results and approved the final version of the manuscript.

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RESEARCH ARTICLE

Blood Flow Restriction Exercises (BFR) an Effect on Strength Rehabilitation and Muscle Atrophy for Patients with Multiple Femur Fractures Aged 40-50 Years

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Abstract
The present study examined the effect of rehabilitation exercises with BFR in improving muscle strength, thigh muscle hypertrophy, and knee joint flexibility for those with double fractures in the lower body. Methods: 6 volunteer subjects (average age 44 (40–50) years) were randomized into one group that trained in restriction of blood flow period eight weeks. Participants were familiar with all testing and exercise protocols before starting the study. Rehabilitation exercises with BFR were done before and after—form for each player to record the sequence measurements. Quadriceps circumference measurement (cm), the range of motion of the knee joint, and Quadriceps muscle strength measurement were performed on the participants. Independent samples t-test was used to compare the scores obtained from the measurements according to categorical variables. The significance level was determined as P 0.05. Results: Thigh circumference (cm) There was a significant increase in thigh circumference from before the experiment (41.17 cm) to after the investigation (45.33 cm) (p<0,001). There's a remarkable development in post-test measurements (13.97 kg), (p<0,000) compared to pre-test measurements (8.83 kg), indicating an improvement in quadriceps strength. Hamstring strength (kg) in the post-test measurement (10.17 kg) demonstrated a remarkable development compared to the pre-test measurement (7.5 kg) (p<0,003). The post-test measurement (24.5 degrees) showed significant development compared to the pre-test measurement (60.83 degrees) (p<0,000), suggesting an improvement in the range of motion of the flexed knee joint. In conclusion, it shows that blood flow restriction is a safe and effective treatment for people with multiple fractures.

Keywords
BFR Training, Rehabilitation, Strength, Muscular atrophy

INTRODUCTION

Training using blood flow restriction exercise (BFRE) is gaining popularity among researchers and practitioners such as medical personnel, physical therapists, strength and conditioning trainers, and rehabilitation professionals (**Brandner et al., 2019**). Reported benefits include increased muscle strength, alleviation of post-traumatic atrophy, increased neuromuscular activity, decreased pain signaling, and increased bone mineral density (**Lepley et al., 2020; Hughes and Patterson, 2019**).

Exercise deprivation is generally associated with loss of strength, muscle atrophy, and reduced functional capacities in both older adults and the clinical population (**Mujika and Padilla, 2000**). Exercise provides a unique role in creating a strong yet stable synergy for high performance in individuals aged 40-50 years. In addition, the hip serves as an important component of the lower extremity kinetic chain, as deficits in hip strength, power, or endurance are factors that predispose to knee, ankle, or foot injuries (**Sundberg, 2004**).

Many people are exposed to a variety of fractures due to exercise or exposure to accidents

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in public life, and as we age, exposure to dangerous complications becomes more frequent, and these complications include atrophy of the large thigh muscles, weakness and low protein turnover, loss of strength, and an increased risk of developing fragility. Bones and possibly a recurrence of the injury again (**Ardern, 2011**) . Double fractures of the femur can be devastating injuries that severely impact an individual's quality of life. In addition to the physical pain and trauma associated with the injury. Many people are exposed to a variety of fractures due to exercise or exposure to accidents in public life, and as we age, exposure to dangerous complications becomes more frequent, and these complications include atrophy of the large thigh muscles, weakness, and low protein turnover, loss of strength, and an increased risk of developing fragility. Bones and possibly a recurrence of the injury again (**P de Mille, 2017**). The main research problem in the rehabilitation of the elderly is the factor of inability to carry heavy weights appears due to age and the inability of the muscles to bear these weights, which are necessary to restore muscle strength and size. In addition, muscle physiology appears to be altered by exposure to multiple fractures. Thus, the specialists are faced with finding alternative rehabilitation tools that will help this category to fully recover and not return to the injury (**Ohta et al., 2003**)

Blood flow restriction (BFR) therapy was introduced as a means to rapidly induce muscle hypertrophy, thereby increasing muscle strength and endurance at lower loads than standard strengthening regimens. BFR treatment is performed by partially closing the venous outflow from the extremity for a short time using an inflatable tourniquet while performing resistance exercises (**Sgromolo et al., 2020**). This has been found to induce localized cellular and hormonal changes that lead to muscle hypertrophy. Using BFR in combination with resistance exercise, muscle hypertrophy can occur with exercise in only 20% of 1 RMas compared to 60 to 100% of 1 RM recommended by the ACSM, effectively putting the load needed to achieve the desired effect somehow reduces. Since its use in athletes, indications for BFR therapy have been expanded for use in rehabilitation programs after injury or surgery, including knee arthroscopy, total knee arthroplasty, and Achilles tendon ruptures (**ACSM, 2009**). Resistance training with heavy loads cannot achieve the desired goal at the beginning of the injury due to pain, muscle weakness, and functional limitations that prevent achieving these recommended heavy loads. Patients with injuries often require the therapist to reduce the training load, which may limit the achievement of a neuromuscular response to treatment and delay rehabilitation goals (**Jacobson et al., 2020**).

Hence, the importance of this study is that it resorted, for the first time in Iraq, according to the researcher’s knowledge, to the use a new method that helps speed up the recovery of the injured and avoid problems of improper rehabilitation in the acute stage, especially for individuals who do not practice sports, as BFR provides a safe and effective low-load treatment method for those with double fractures in the lower body, as it gains more acceptance in clinical settings and more robust clinical trials are published. There has been a shift in the speed of its use and adoption in rehabilitation, especially in the early stages. Scientific trials have not only explored the ability of BFR to maintain and restore lost muscle mass and strength, but data is now available indicating its ability to maintain bone density after a fracture, reduce pain, swelling, and loss of function and recent studies have advocated its use in rehabilitation before a fracture. Therefore, The research aims to identify the effect of rehabilitation exercises with BFR in improving muscle strength, thigh muscle hypertrophy, and knee joint flexibility for those with double fractures in the lower body.

MATERIALS AND METHODS

Participants

The participants were comprised of 6 volunteers with a femoral double fracture, aged between 40-50 years and 21-45 days after their injury. All six patients attend regular physical therapy sessions for lower extremity rehabilitation for various reasons. However, all had chronic quadriceps and/or hamstring muscle weakness and were at least 1.5 months after the last surgical procedure, and their strength development was limited by their inability to successfully use traditional resistance training.

The lower extremities of all individuals were measured for comparison purposes, but some patients also had bilateral rehabilitation needs.

All patients had measurements of the affected lower extremity at least twice during their treatment period, pretest and posttest, and were using BFR therapy as part of their rehabilitation routine for at least 8 weeks. A participant with femoral fracture (4 males and 2 females; see Table 1 for participant characteristics) volunteered to participate in the study and gave written and informed consent for the experimental procedures. Participants had no known history of peripheral or neurological disorders, cardiovascular, pulmonary, or metabolic disease. In addition, none of the participants had participated in any resistance training in the last 2 months.

The participating athlete was informed about the study protocol, their rights, and the associated risks of participation before providing written informed consent. This research has been approved by the University Ethics Commission No. 242number and date 30/07/2023 was accepted with the research code number and was carried out according to the recommendations of the Declaration of Helsinki. Additional precautions were taken by the investigator(s) to protect the volunteers in this study.

Data Collection Tools

Form for each player to record the sequence measurements

Quadriceps muscles measurement (cm): Measuring tape is wrapped around quadriceps by specifying two parallel points in the middle of the thigh (Otman vd. 1995).

Goniometer to measure the range of motion of the knee joint

Measurements of joint range of motion (ROM) are part of a physical therapist's daily work. Activities of daily living and exercises can be complicated to perform when ROM is limited, and depending on the demands in daily living, the knee joint requires different ROM. In sports, a few degrees in ROM may make the difference between getting injured or not. The goals for physical therapists are to help the patients to regain full ROM, mobility, strength, and function after sustaining an injury. To measure joints with the manual universal goniometer is considered time-consuming and difficult with respect to repeated measurements.

Initial position

The patient takes a prone position on the abdomen and installs the device on the outer side of the knee joint along the thigh bone. The knee joint is flexed to the maximum extent it can reach. The difference in reading the device is between zero degrees and the angle of maximum flexion of the knee joint (Pereira et al., 2017).

Table 1. Group characteristics

Variables	Descriptive Statistics		
	Average	Standard deviation	Skewness
Age (year)	46	6.401	-0.06
Height (cm)	168.83	5.34	0.10
Body mass (kg)	77.83	7.19	0.58
Days from injury	19.33	5.92	0.02
Gender (Male/female)	Male: 4	Female: 2	
Affected limb	Right: 4	Left: 2	

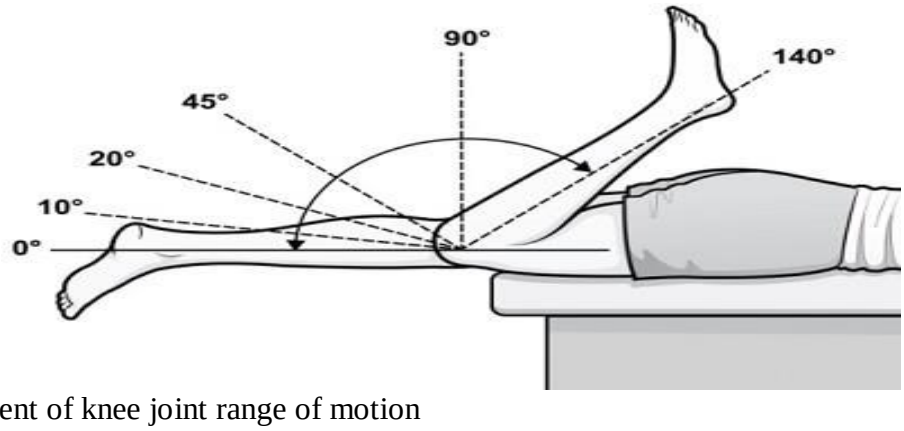

Figure 1. Measurement of knee joint range of motion

Quadriceps muscle strength measurement with dynamometer

The quadriceps muscle strength of the individuals participating in the study was assessed using a hand dynamometer (Medical Commander Power Track 2, USA). The measurements were repeated three times for the right and left sides. The highest value was recorded as Newton (N) (Bandinelli et al., 1999).

Performance specifications

Person stands erect on base of the device in appropriate place on middle of the base, hands in front of the thighs, and the fingers of the hands are pointing down. The tester grips the tension column tightly so that the palm of one hand is directed forward and the other is directed to the body. When the tester is ready to pull, he bends his knees forward, forming an angle of 90 °. It must be noted that the back is not bent, as well as the straightening of the arms without any bending in the elbows. At the end of the test, the legs must be fully extended.

Experimental Design

Participants were familiar with all testing and exercise protocols before starting the study. Rehabilitation exercises with BFR were done before and after. Therefore, the total duration of the experimental study was 8 weeks. During the rehabilitation exercises with BFR withdrawal period, the participants were asked to maintain their normal diet and physical activity levels.

Pre- measurements

Measurements and pre tests were performed on a group of members of the experimental research sample consisting of (6) injured, at Specialized Center for Physiotherapy and Physical Rehabilitation in Al-Kut Sports Club on Wednesday 2/2/2022.

Rehabilitation exercises with BFR

The rehabilitation program was applied individually to the injured, taking into account the rehabilitative exercises for pain limits. The rehabilitation program using rehabilitative exercises with the blood flow restriction (BFR) technique took eight weeks, with three rehabilitation units per week, each rehabilitation unit takes 60 minutes (Table 1).

Table 2. Rehabilitation exercise program used with blood flow restriction

Exercise name	*Name of the working muscle*	*Count times a week to exercise*	*Count of repetitions for each exercise*	*Count of sets*	*Rest between sets (*seconds)
Squats	Quadriceps and Hamstring muscles	3	5	5	30 - 60 s
Curly front	quadriceps muscle		15		30 - 60 s
Curly Back	Hamstring muscle		15		30 - 60 s
Push machine (like press)	Quadriceps and Hamstring muscles		10		30 - 60 s
Hack Back	Quadriceps and calves muscles		15		30 s
Raffles miscellaneous	Quadriceps, hamstrings, and calves		10		30 s

Post-measurements

Post-measurements and tests were carried out on a group of experimental research sample members on Thursday 4/4/2022 in the same order as the tribal measurements, under the same conditions, and for each patient separately.

Statistical Analysis

SPSS package program was used in the statistical analysis of our research. It was determined by the normality distribution and skewness coefficients of the data. Significance level was determined as P 0.05 and all data were presented as mean standard deviation (SD) unless stated otherwise. Independent samples t-test was used to compare the scores obtained from the measurements according to categorical variables.

RESULTS

Patients participating in rehabilitation exercises with BFR at 8 weeks no injury was recorded at any stage of the BFR exercises, and no adverse events (both acute and chronic) were reported for anyone doing the BFR exercise.

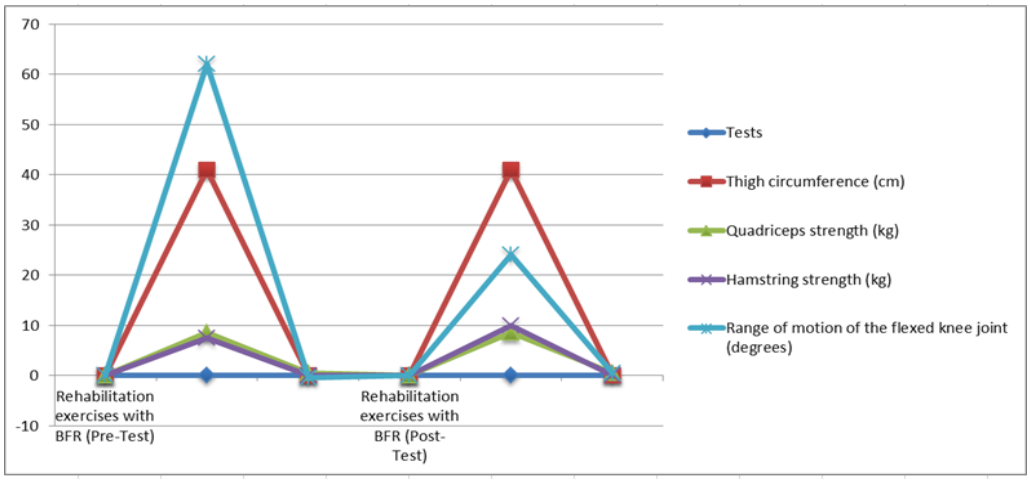

Figure 2. Statistical characterization of the variables examined before and after the Rehabilitation exercises with BFR program of the participant patients.

The findings from the study indicate significant differences between pre and post-tests, with improvements observed in all measured outcomes. Specifically, the results demonstrate the following improvements.

Table 3. Statistical characterization of the variables examined before and after the rehabilitation exercises with BFR program of the participant patients.

	Rehabilitation exercises with BFR (Pre-Test)			**Rehabilitation exercises with BFR (Post-Test)**		
Tests	X ± SD	Median	Skew ness	X ± SD	Median	Skew ness
Thigh circumference (cm)	41.17±1.60	41	0.041	45.33±1.21	41	0.04
Quadriceps strength (kg)	8.83±1.47	8.5	0.42	13.97±0.82	8.5	0.42
Hamstring strength (kg)	**7.5**±1.05	7.5	0.00	10.17±0.75	10	0.00
Range of motion of the flexed knee joint (degrees)	60.83±4.54	62	0.44-	24.5±2.59	24	0.42

It is evident from Table 3 on the differences between the pre- and post-measurement in (physical tests) for the experimental group (using the (BFR) blood flow restriction technique with qualifying exercises) that there are significant differences between the two measures at the level of 0.05 in all tests and in favor of the post-measurement, where the value of T Between (0.001 to 6.116), these values are greater than the tabular T value at the 0.05 level.

Table 4. Significant differences between the pre- and post-test in the variables under study for the study sample.

Tests	**Pre-test**		**Post-test**		**T value**	**level Sig**	**Type Sig**
	X	**SD**	**X**	**SD**			
Thigh circumference (cm)	41.17	1.60	45.33	1.21	0.001	0.030	Sig
Quadriceps strength (kg)	8.83	1.47	13.97	0.82	1.889	0.000	Sig
Hamstring strength (kg)	7.5	1.05	10.17	0.75	5.487	0.003	Sig
Range of motion of the flexed knee joint (degrees)	60.83	4.54	24.5	2.59	6.116	0.000	Sig

Thigh circumference (cm): There was a significant increase in thigh circumference from before the experiment (41.17 cm) to after the experiment (45.33 cm), (p<0,001), suggesting a favorable impact of the telemetry. Quadriceps strength (kg): The researchers observed a remarkable development in post-test measurements (13.97 kg), (p<0,000) compared to pre-test measurements (8.83 kg), indicating an improvement in quadriceps strength.

Hamstring strength (kg): The post-test measurement (10.17 kg) demonstrated a remarkable development compared to the pre-test measurement (7.5 kg), (p<0,003) indicating an improvement in hamstring strength. Range of motion of the flexed knee joint (degrees): The post-test measurement (24.5 degrees) showed significant development compared to the pre-test measurement (60.83 degrees), (p<0,000) suggesting an improvement in the range of motion of the flexed knee joint. Overall, the study suggests that the telemetry intervention was effective in improving thigh circumference, quadriceps and hamstring strength, and the range of motion of the flexed knee joint.

DISCUSSION

BFR resistance training can provide several advantages over traditional moderate-heavy resistance training; for example, these muscle adaptations are achieved despite relatively lower external loads, produce less muscle damage and therefore the frequency of training can be increased; muscle hypertrophy has also been demonstrated as follows: in as little as 1-2 weeks (**Scott et al., 2014**). BFR is combined with several different single-joint lower body (eg, knee extension, knee flexion, ankle plantar flexion) and upper body exercises (eg, elbow flexion, elbow extension) (**Patterson & Brandner, 2017**) as well as compound multiple exercises (-squat and common exercises such as bench press) (**Abe et al., 2012**). However, examination of a training program using a limited number of exercises (for example, one or two) does not reflect typical applied resistance training programs that include one or more exercises for more than one anatomical region (**ACSM, 2009**).

We showed that there are statistically significant differences between the pre-and post-test in favor of the post-test in the variables of muscle strength and range of motion (Table 2), and the researcher attributes this improvement to the use of the blood flow restriction (BFR) training with rehabilitation exercises in the early stage of injury, which greatly helped in performing exercises Rehabilitation with low intensity and many repetitions and without feeling pain, which led to an increase in muscle strength and range of motion, and this is consistent with what was found by (**Petrick et al., 2019 ; Anderson et al., 2019**), who was able to prove that blood flow restriction (BFR) produces beneficial adaptations for skeletal muscles. This provides a safe treatment method for patients to begin strength training in the early stages of rehabilitation to allow for a more effective return to activity and improve patient readiness.

Recent scientific research indicates that blood flow restriction training may lead to adequate strength gains with low-intensity exercise. This method is most appropriate when higher training weights are not appropriate, such as after surgery, compound fractures, or in cases of significant muscle mass loss.

The use of individual training is taken into account when using the blood flow restriction method, but in a safe manner, as the pressure must represent the minimum required for total arterial closure (**Loenneke et al., 2014**). Blood flow restriction training puts muscles under mechanical stress. (This mechanical stress also occurs during high-intensity muscle strengthening.). High pressure helps improve muscle hypertrophy, and growth, by activating specific muscle growth stem cells - releasing muscle growth hormones - hypoxia (lack of oxygen) - swelling of cells within the muscle (**Fujita et al., 2007**)

Development of muscular strength in this study agreed with the findings of that the inclusion of the rehabilitation curriculum on muscular strength exercises and their regular and gradual practice leads to various changes in the muscles such as increasing cross-section of the muscle and increasing size of fast fibers and increasing size and strength of tendons and ligaments and the density of capillaries. Clinical studies have shown that blood flow restriction can be a valid, acceptable, and effective tool for rehabilitation. As demonstrated by Hughes et al., in their systematic review and data analysis, it has been shown to be effective in mitigating strength loss and facilitating its rebuilding. Moreover, BFR training can

positively affect muscle size and other physiological variables, and thus adaptations act as an alternative to heavy load when Muscular strength training, especially in the early phase of rehabilitation (Brandner et al., 2019; Hughes et al., 2017)

All of these factors can only occur in normal training when training with high weights, and they can also be achieved during low weight training by restricting blood flow to the muscles because it creates an environment in which muscle growth can occur even if the training weight is reduced to a minimum, which is something It may be important after an injury or surgery. As your body recovers after surgery, you may not be able to put severe stress on your muscles or ligaments. . Low-weight exercises may be required, which has allowed blood flow restriction training to achieve maximum strength with low, yet safe weights (**Hasan and Hasan 2022; Scott, 2014**).

Conclusion

The available data strongly support the use of blood flow restriction as a safe and effective intervention for patients with multiple lower body fractures. The results of this study demonstrate significant improvements in muscle strength, size, and function, as well as a rapid return to normal function. Moreover, the application of blood flow restriction was well-tolerated by patients, as evidenced by the absence of severe pain during exercise. Taken together, these findings suggest that blood flow restriction is a promising therapeutic option for patients with lower body fractures seeking to regain muscle function and mobility. In addition to the significant improvements in muscle strength, size, and function, blood flow restriction has the potential to provide other benefits for patients with lower body fractures. By allowing for more targeted exercise and rehabilitation, blood flow restriction may also help to reduce the risk of further injury or complications during the recovery process.

Moreover, the relatively low intensity of the exercises performed with blood flow restriction may be especially beneficial for patients who are unable to tolerate more strenuous forms of rehabilitation due to pain or other factors. It is worth noting that the current data on blood flow restriction are limited to patients with lower body fractures, and more research is needed to determine its safety and efficacy in other populations. However, the promising results seen in this study suggest that blood flow restriction has the potential to be a valuable tool in the rehabilitation of patients with lower body fractures, and warrant further investigation.

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Disclosure Statement

The author have no conflicts of interest that are directly relevant to the content of this manuscript.

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Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Committee

No.6/242 and date 30/07/2023 was accepted with the research code number and was carried out according to the recommendations of the Declaration of Helsinki

Author Contributions

Study Design, BB, RJ; Data Collection, BB; Statistical Analysis, BB, RJ; Data Interpretation, BB; Manuscript Preparation, BB, RJ; Literature Search, BB, RJ. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Effect of Pre-Participation Aquatic Training Program on Running Performance in Marathon Runners

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Abstract
Objective: The most important objective was to determine the effect of an aquatic pre-participation training program for improving the running performance of middle-aged marathon runners. **Method:** The study was conducted among 100 recreational male and female runners (aged 25 to 35 years) fulfilling the inclusion and exclusion criteria. The subjects were randomly divided into two equal groups, the control group (n=50) and the experimental group (n=50) by using SPSS software. 6 weeks of aquatic training was conducted for the experimental group for 5 days per week while the control group underwent swimming. The scores were statistically examined by paired 't-test. **Results:** Results showed that there was a significant reduction in pain in both groups with a p-value <0.0001. Both groups showed significant improvement in cardiac endurance VO2 max. The mean post-VO2 max of the experimental group and control group showed significant improvement in VO2 max with p-value <0.0001. Experimental group showed more improvement in 1RM leg press test as compared to the control group. Mean pre and post-1RM leg press test was (pre:66.10±14.0) (post:73.40±15.20) with p value <0.0001. While of the control group was (pre:68.02±15.09) (post:69.40±13.94) with p value 0.0275. There was significant improvement in 50m sprint run test in the experimental group with pre mean 6.23±0.44 and post mean 6.00±0.46 with (p value <0.0001). Much improvement was not seen in 50m SRT of the control group, the pre mean was 6.11±0.44 and post mean was 6.06±0.48 with (p value 0.0832). **Conclusion:** It concluded that the pre-participation aquatic training program had shown a significant positive response in improving speed strength and reducing pain.

Keywords
Marathon Runners, Aquatic Training, VO2 Max, Pain, 50 M Sprint Test

INTRODUCTION

Long distance race is technically known as a Marathon but Marathon running has different distance parameters which consist of 3km, 5km, 10km, and more. Running a marathon requires intense training because the event calls for stamina, mental toughness, and tactical pacing. To prepare their bodies for the length and rigor of the race, runners must increase their strength through long runs and speed drills. Knowing the specific reactions of recreational runners to training interventions is crucial for designing training protocols because of the rising number of recreational runners who regularly compete in marathon and half marathon events worldwide (Ferrauti et al.,2010). Running is closely alike walking based on locomotor activity. But still, they have differences as a person who can walk will not have the ability to run.

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Running a marathon requires appreciable balance, significant muscle strength, and a considerable range of motion (**Landry M et al.,2014**) . Running performance completely depends on anthropometric measures like body mass index (BMI), skin fold measurement, and girth extremity (**Voight et al.,2011**) . The relationship between flexibility and running economy is one biomechanical factor that has produced contradictory results (**Beaudoin et al.,2005**). Anthropometric measurements help to increase the endurance of the runner. In addition to anthropometric prerequisites (such as body weight and body composition of the lower extremities, upper and lower body size relation), a number of movement criteria are intended to establish an economic running technique model (**Ferrauti et al.,2010**). Balance and coordination are improved through water-based exercise, which also stimulates the visual, vestibular, and perceptual systems (**Dundar et al.,2009**; **Asimenia et al.,2013**).

Marathon runners require rigorous fitness and healthy dietary needs. To get the right run during the marathon, a runner needs to increase their cardiovascular fitness and endurance, as well as the ability to conserve and manage energy during the race (**Ferrauti et al.,2010**). Due to poor fitness and because of exertion a runner is prone to develop injuries. Injuries caused by running are idiopathic but are frequently based on training errors. The few independent factors causing injuries are any previous injury, a competitive training motive, and an increase in the repetition of workouts too quickly. Running causes injuries because it is a weight-bearing exercise that works against gravity. Knee, ankle, or foot injury can result from running (**Kadav et al.,2023**; **Sandeep et al.,2022**). Common injuries occurring are Runner's knee, Hamstring pull, IT band syndrome, Shin splint, and Achilles tendinitis (**Cheuvront et al.,2005**).

The best and most important way to avoid injuries is to pay close attention to the overall training program and should increase the repetition moderately depending on the tolerance of the runner (**Cheuvront et al.,2005**) . The training of a marathon runner should include strength, power, and endurance exercises. Strength training helps to improve muscle work and proves effective to perform higher oxygen volume exercises. They even help to improve many parameters that are correlated with running the economy (**Landry et al.,2014**).

Rest and discontinued training program may help in the rehabilitation of sports injuries. For early rehabilitation of sports injuries, aquatic therapy is ideal, because of buoyancy which eventually decreases the gravity of the body and viscosity. These offer considerable assistance and resistance to a runner while performing training (**Prins et al.,1999**). Aquatic exercises help to improve joint mobilization, balance and gait training. It also facilitates stretching, strengthening, and endurance training (Sawant, R. S., & Shinde, S. B.,2019**)**. Aquatic therapy helps with functional recovery and also initiates resistance training for runners. It is used as a recovery technique and also to enhance the training program of a runner (**Kisner et al,2017**).

Water has unique properties which help to improve the therapeutic benefits. An aquatic environment with buoyancy, hydrostatic pressure, viscosity, and surface tension has a direct effect on the human body. Aquatic therapy also enhances patient relaxation and minimizes the risk of injury as well as delayed onset of muscle soreness. Buoyancy can be applied in three different ways during rehabilitation: as support, as resistance, and as assistance. To improve mobility, people frequently use these exercises. The cardiovascular changes brought on by immersion are also brought on by hydrostatic pressure, which also significantly affects the exercise training parameters (**Dumke et al.,2010**). Exercises performed in water may be beneficial for patients with acute painful musculoskeletal injuries. This happens because of the effect of relaxation, elevated pain threshold, and decreased muscle spasms (**Kisner et al, 2017**) .

Physiologic changes occur when a human is immersed both during rest as well as during exercises (**Dumke et al.,2010**) . A water-based training program provides support to the limbs and allows range of motion, with less muscle activation. This helps to improve advanced dynamic strengthening on land. Aquatic therapy helps athletes to return early to the game and also speeds up the overall rehabilitation process. Many athletes found water-based exercises more effective during their rest period and beneficial in regaining strength and mobility and also maintaining cardiovascular endurance (**Prins J et al.,1999**; **Thein et al,2000**).

The purpose of this study was to study the effectiveness of aquatic exercises to improve the running performance of the runner. Athletes have been suggested to be predisposed to hamstring strain injuries by intrinsic factors such as muscle weakness, muscle strength imbalance, poor passive flexibility, fatigue, insufficient warm-up, age, prior injury, poor neuromuscular control, and poor running techniques (**Watsford et al, 2010**). Marathon runners require a pre-training program to improve cardiovascular endurance as well as strength and energy to complete the long run (**Kolhatkar et al,2020**). We are here to discuss water-based training program proves to be more effective than a land-based program. Aquatic therapy improves the flexibility of muscles and also reduces the workload on the muscles (**Wicker et al, 2011**) . It helps to improve the speed of the patient run and also helps to strengthen the lower limbs.

MATERIALS AND METHODS

Selection of Subjects

For the corresponding study, the sample size was 100 [n=4×(SD)2/mean×(€)2]. 100 recreational marathon runners were selected from Karad who had a habit of exercising and were able to run a long distance. The age of the runners ranged from 25 to 35 years of age. The sample was similar to the characteristics of the subjects in related studies (Markovic et al.,2007) (Sporri et .,2018). (All the subjects volunteered to participate in this study with written informed consent. The runners were divided into an experimental group (n=50) and a control group (n=50) randomly by using SPSS software.

The participating athlete was informed about the study protocol, their rights, and the associated risks of participation before providing written informed consent. This intervention was conducted on humans. The interventional study was accepted by Institutional Human Ethics Committee of Krishna Institute of Medical Sciences, “Deemed to be University,” Karad (Protocol number-299/2022-2023). The study was explained along with the exercise protocol. Before performing the intervention on participants, an informed consent was obtained from them. The study was carried out in accordance with the recommendations of the Declaration of Helsinki. Additional precautions were taken by the investigator(s) to protect the volunteers in this study.

Selection of Test

VAS: To measure the amount of pain using Visual Analogue Scale (VAS) It is a scale that ranges from 0 to 10. Zero indicates “no pain” and ten indicates “worst pain imaginable”. Participants were asked to mark on a scale how much pain they have from 0 to 10 at rest and on activity(Intra class correlation co-score 0.97 [95% CI=0.96 to 0.98]).

1 RM leg press test: Lower body strength is measured by 1 RM leg press test. weight close to the subjects one repetition maximum is selected. The subject is asked to conduct as many leg presses before failure. If The number of successful bench presses exceeds 12, then 15 min rest is given to the subjects, weight is increased, and the test is repeated (**Lippincott Williams 2013**)

VO2 Max: The Queen's College Step Test was used to calculate the VO2 max. Prior to the test, participants were instructed to warm up for 5-7 minutes (e.g., by brisk walking and stretching). A stopwatch, metronome, and 16 ½ inch wooden stepping bench were also used. There were 24 beats per minute on the metronome. There was a brief demonstration. For three minutes, the participants were asked to step up and down repeatedly. Following the test, the pulse rate was recorded in a standing position for 15 seconds. Beats per minute are converted from this recovery pulse rate. The VO2 max in females is calculated as follows: VO2 max(ml/kg/min) = 65.81-(0.1847X step test PR/min) . In the Indian population the validity of the test was found (r=-0.83) (**Chatterjee et al., 2005**).

50-meter sprint run test: Using a stopwatch, the athletes' sprinting times in hundredths of a second (s) for a 50-meter dash were manually recorded in order to calculate their speed (**Fletcher & Anness, 2007**). Equipment includes a measuring tape, a grassy field marked at 50 meters, a start clapper, a skilled timer and a scorekeeper. Procedure: During the exam, only one sprint of 50 metres in length was permitted. The "time" in seconds it took to cover the distance was recorded by a stopwatch, which provided the data. There could be no more than two practise runs. The participants were urged to put forth their best effort. A standing start was used during the test. There were two allowed trials. The fastest time

measured in hundredths of a second was considered to be data speed was calculated using the following formula: speed = distance/time = 50/time. Meter/second (m.s-1) is the symbol for speed.

Criterion Measures

The study was pre/post experimental design. 100 recreational marathon runners were included in this study. Inclusion criteria included recreational marathon runners aged 25-35 years, who had pain while long-running, with no fear of water, and those who were willing to participate in the study. Subjects with open wounds, skin conditions, and high fever as well as those with a history of cardiac and respiratory conditions were excluded from the study. Aquaphobic participants were categorically barred from the study.

Table 1:Aquatic training protocol

WEEKS	EXERCISES	REPETITION	REST
WEEK 1	Treadmill (Slow run)	10 mins	30 sec
	Water Jog (on the spot)	10 mins	30 sec
	Flutter kicks	20kicks x 3 sets	45 sec/set
	Jumping Jacks	20kicks x 3 sets	45 sec/set
	Pool burpees	15 repetitions	45 sec
	Breaststroke	3 pool rounds	45 sec
	Sit kicks in deep water	20kicks x 3 sets	45 sec
WEEK 2-4	Treadmill (moderate speed run)	15 mins- 20 mins	30 sec
	Water jog with long step length: Forward Backward	4 pool rounds	30 sec
	Resistance flutter kicks	30 kicks x 3 sets	45 sec
	Pool burpees	20-30 repetitions	45 sec
	Sit kicks in deep water with ½ kg weight cuff	20 kicks x 2 sets	45 sec/set
	Pool tuck jumps	20 jumps x 3 sets	45 sec/set
WEEK 4-6	Treadmill	20 mins	30 sec
	Water jog with ½ kg weight cuff	4 pool rounds	45 sec
	Skiers with ½ kg weight cuff	20 repetition x 3 sets	45 sec/set
	Frogger exercise: Forward Backward	4 pool rounds	45 sec
	Pool hacky sack	20 repetitions x 3 sets	45 sec/set
	Swimming	10 mins	45 sec

Design of the Study

1.100 recreational marathon runners were screened and selected on the basis of inclusion criteria. Simple random sampling was selected for randomization of the sample by using SPSS Software.

2. Subjects were screened by assessing BMI, lower body strength by 1 RM leg press test, pain score by VAS, and cardiac endurance by VO2 max pre and post-intervention.

3. Informed consent was taken from the participants and was filled by them before the intervention. The procedure of the study was explained to each of them.

4. Participants were randomly divided into two equal groups; the Control group (n=50) and the Experimental group (n=50). The experimental group underwent an aquatic training program and the control group underwent swimming, where no special exercises were administered. The pre-participation Aquatic training program took place for a period of 6 weeks with 5 days of training (Monday to Friday) and the overall time for the exercises was 50 mins with 10 mins rest period.

Training Program (**Thein et al.,2000**; **Stemm et al.,2007; Robinson et al.,2004; Miller et al.,2002; Markovic et al., 2007; Sporri, et al., 2018**)

The subjects in the experimental group underwent pre-participation aquatic training. A 50-minute exercise protocol with a 10-minute rest period was established. The exercise protocol started with 10 mins of warm-up, followed by 30 mins of actual exercise training, and lastly 10 mins of cool down. The exercise protocol was 50 mins which were being performed 5 times a week. Every week the exercise protocol was changed with advancements in exercises to improve the strength, power, and endurance of the subject. The main focus during the initial phase [week 1] of the aquatic training is the unloading of the joints and stabilization. The goals are to increase the range of motion, increase circulation,and decrease pain.progression of the exercises in week 2-4 is done by gradually increasing the repetitions and resistance which improves the strength and flexibility.The progression in week 4-6 aim to increase cardiac endurance and strength.This was done by increasing the duration of exercises,along with the repetitions and resistance as shown in Table 1 . At every practice session of the participant, we focused on the security and safety of the subject more than the accuracy. So, we instructed the subject to perform the activity with a bit of changed movement to avoid injuries.

Statistical Analysis

Data collected was registered in an excel sheet and the statistical analysis was conducted using SPSS 26.0 for Windows (SPSS Inc., Chicago, IL, USA). Statistical analysis was conducted by using descriptive statistics, paired t-test was used to identify any significant difference between pre and post-training within the groups. The level of significance was set at $p \leq 0.05$.

RESULTS

Table 2. Demographic Data

	Total No	Experımental Group (N=50) [Mean±SD]	Control Group (N=50) [Mean±SD]
Age (Years)	100	26.78±1.54	27.16±1.65
BMI (kg/m2)	100	21.63±1.83	21.25±1.88

Table 3:Gender distribution

Gender	Total No	Experımental Group (n=50)	Control Group (n=50)
Male	100	38	42
Female	100	12	8

Table 4. Comparison of Pre and post-test mean scores of the selected outcome measures

	Experımental Group			Control Group		
Outcome Measures	Pre-Test [Mean±SD]	Post-Test [Mean±SD]	P Value	Pre-Test [Mean±SD]	Post-Test [Mean±S]	P value
VAS	6.02±1.47	1.69±1.09	<0.0001	5.94±1.61	4.57±1.71	<0.0001
VO2 MAX (ml/kg/min)	56.49±5.38	59.55±4.69	<0.0001	54.45±4.85	55.33±4.74	<0.0001
1 RM Leg Press Test (kg)	66.10±14.0	73.40±15.20	<0.0001	68.02±15.09	69.40±13.94	0.0275
50 SRT (m.s-1)	6.23±0.44	6.00±0.46	<0.0001	6.11±0.44	6.06±0.48	0.0832

DISCUSSION

The present study investigated the efficacy of 6 weeks of an aquatic training program on recreational athletes in the experimental group and the efficacy of a swimming program in the control group.

Eunkuk kim et al., (**2010**) demonstrated that 4 weeks of aquatic exercises in elite athletes showed significant reduction in VAS ($p<0.05$). **Hajouj et al**, (**2021**) demonstrated that 6 weeks of aquatic proprioceptive training in athletes with anterior cruciate ligament reconstruction showed a significant reduction in VAS ($p<0.05$). **Vaile, et**

al., (2008) in their study showed that aquatic therapy was found to be effective in reducing physiological and functional deficits.The pain perceived was improved (p<0.001) following aquatic therapy.

In the current study reduction in the mean VAS was 4.33 in the experimental group with p-<0.0001 which is considered significant while in the control group the reduction in the mean VAS was 1.37 with (p<0.0001) which was considered extremely significant. The hydrostatic effect may stimulate the sensory nerve endings in the skin, which would explain how pain is reduced in aquatic environments. Additionally, it was proposed that sensory overflow influences pain modulation and may raise the pain threshold, which rises in response to changes in temperature and water turbulence. Water's pain-relieving properties are attributed to a variety of buoyancy-related mechanisms. By reducing peripheral edema and reducing sympathetic nervous activity, hydrostatic pressure may reduce pain. The ease of movement could lead to a decrease in pain.

Biswas, & Ghosh, (2022) demonstrated that 14 weeks of aquatic plyometric training program is effective for improving aerobic capacity with significant increase in VO2 max with p value <0.001. Dawar Rezaimanesh et al.,(2011) demonstrated that six weeks of aerobic and anaerobic intermittent swimmimg exercise are effective on VO2 max with p<0.0001) Nagraj et al., (2020) demonstrated that six weeks of water aerobic exercise on college men students had significant improvement in VO2 max with p value (<0.05). Michishita et al., (2023) demonstrated that eleven weeks of aquatic training on soccer players had significant improvement in VO2 max with p value 0.05 (Dowzer et al, 1999) conducted a study to compare. The physiological reaction to walking or running on a land treadmill and a water treadmill at two various depths. Vo2 max was higher while using a water treadmill than while using a land treadmill, indicating an increase in aerobic fitness.

In the current study the experimental group showed iprovement in the mean VO2 max by 3.06 with p<0.0001 while in the control group the improvement in the mean VO2 max was 0.88 with p<0.0001 both the groups showed significant improvement in VO2 max. Movement resistance in the water is higher than in the water because the aquatic medium is denser than the air medium. As the depth of immersion increases, the hydrostatic pressure also rises. The aforementioned factor results in a greater energy expenditure during exercise in an aquatic environment than on land at the same time, increasing blood flow rates throughout the body. As a result, increases in stroke volume, heart rate, and cardiac output have an impact on the body's overall oxygen consumption (VO2 max). Arazi and Asadi ., (2011) demostrated that 8 weeks of aquatic and land plyometric training on basketball players has improved leg strength with increase in 1RM leg press (p<0.005) Hailu et al ., (2015) demonstrated that 12 weeks of water based exercises increases strength by 17% greater than land based exercises.

In the current study, the experimental group showed improvement in the mean 1 RM leg press test by 7.3 kg With a (p<0.0001) the control group showed improvement in the mean 1 RM leg press test by 1.38 kg with a p-value (0.0036) which is considered significant. Both the groups showed improvement in the lower body strength. Water provides a natural form of resistance, aquatic exercises often involve a wide range of leg movements, These movements engage multiple muscle groups in the legs the nervous system becomes more efficient at recruiting muscle fibers. The muscles adapt to the increased resistance by undergoing hypertrophy, which contributes to increased leg strength.

Biswas et al., (2022) demonstrated that 14 weeks of aqua-based plyometric training has shown improvement in running performance with a significant increase in the 50 m sprint test with a p<0.05. Arazi et al demonstrated that eight weeks of aquatic and land plyometric training on basketball players has improved running performance with a significant increase in 60 m sprint with a p<0.05. In the current study, the experimental group showed improvement in the mean 50 m sprint run test by 0.23 With a p<0.0001) the control group showed improvement in the mean 50 m sprint run test by 0.05with a p-value (0.0832) which is not quite significant. Active recovery, increased strength, and improved coordination could all contribute to athletes' increased speed after aquatic training. Aquatic exercises additionally improve joint range of motion and flexibility, which helps to enhance overall running performance. Based on the result, an aquatic exercise training program has shown significant improvement in runners' fitness as well

as strength, cardiac endurance,speed of the runners. In this study recreational male and female runners were selected, so further attempts can use a teenage group with an elite group of runners and future research should use larger samples to be better generalizability.

Conclusion

Aquatic therapy is proved to be effective for reducing pain, increasing range of motion and improving balance and coordination. Aquatic therapy has also given relaxation and soothing effect to the patient after the treatment as fatigue level of muscles is reduced and work load on muscles is also minimized. It concluded that pre-participation aquatic training program had shown significantly positive response in improving the speed and reducing pain. Whereas, the control group had limited changes in the post-test responses for strength and speed test. It proved that 6 weeks pre-participation aquatic exercise training program was effective for reducing pain and improving the speed test timings.

Clinical Implications

The preparation of marathon runners for the physical and mental demands of a marathon race includes pre-participation training. Running marathons is a strenuous activity that greatly impacts the body. Athletes can develop the necessary strength, flexibility, and endurance during pre-participation training to lower their risk of injury. It enables them to identify any flaws or imbalances in their musculoskeletal system and take appropriate action. The study can be conducted on large sample size with the use of aquatic equipments.

Suggestions

In-depth research can bedone to determine the most effective aquatic training regimens for different sports and athletic disciplines. Future research can look into how different combinations of aquatic exercises, durations, and intensities affect performance outcomes in particular. More studies may investigate into how aquatic training affects athletes' motivation, mood, and perceptions of exertion.

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Conflict of İnterest

Authors declare no conflict of interest.

Ethics Statement

The interventional study was accepted by Institutional Human Ethics Committee of Krishna Institute of Medical Sciences, "Deemed to be University," Karad (Protocol number-299/2022-2023).

Author Contributions

Study Design, SBS and SD; Data Collection, MM; Statistical Analysis, SD; Data Interpretation, MM and SD; Manuscript Preparation, SBS and SD; Literature Search, SBS, and MM. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Heart Rate Variability Biofeedback and Cognitive Restructuring for Self-Regulation: A Case Study

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Abstract
This study investigated the effects of a psychophysiological intervention programmed, comprising heart rate variability biofeedback (HRV BFB) and cognitive restructuring (CR), on the self-regulation skills of an 18-year-old female squash athlete who represents the Korean national team. The participant underwent ten programme sessions in a laboratory. HRV was measured during a 10-minute baseline period of natural breathing and during BFB-guided breathing exercises. Two questionnaires, the Competitive State Anxiety Inventory-2 (CSAI-2) and the Cognitive Emotion Regulation Questionnaire (CERQ), were used to assess the participant's psychological state. Descriptive statistics were employed to analyze changes in HRV and psychological state from the initial test to the post-test. Qualitative findings indicated improvements in the participant's self-regulation skills, particularly in her ability to transform negative thoughts. In conclusion, the intervention programme shows potential in enhancing self-regulation skills to the athlete. The combination of HRV biofeedback and cognitive restructuring appears to lead to positive changes in self-regulation, which could benefit athletes in managing their psychological state and improving competitive performance. Further research and practical applications are continued needed to fully explore the programme's efficacy.

Keywords
Athletes, Biofeedback Training, Breathing, Cognitive Restructuring, Heart Rate Variability, Self-Regulation

INTRODUCTION

Engaining in competitive sports frequently expose athletes into an amalgamation of physical and psychological challenges, sparking both somatic and cognitive anxiety. In the multidimensional model of anxiety (**Martens et al., 1990**), somatic anxiety is reflected in the physical responses driven by the autonomic nervous system (ANS), including sweating, changed breathing pattern, high blood pressure, and tremors. Simultaneously, cognitive anxiety involves psychological responses and can be rooted in negative cognition and distorted perceptions such as negative self-talk and imagery, worrying, and low self-evaluations. These findings imply that self-regulation within a psychophysiological state is critical for peak performance during competition (**Robazza et al., 2004; Davis et al.,2007; Lagos et al.,2008; Dupee et a.,2015; Hwang et al., 2016**). The intricate interplay between somatic and cognitive aspects of anxiety and their influence on athletic performance has been a longstanding concern in the field of sports psychology. The field strives to unravel the complexities of self-regulation within a psychophysiological context. Self-regulated ability is key factor as emerges as a critical determinant of peak performance in the competitive arena (**Lagos et al., 2008; Hwang et al., 2016; Thayer et al.,2009**).

Biofeedback (BFB) training has been suggested to improve self-regulation in sports

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(Ferguson & Hall, 2020). The BFB methodologies, which collect psychophysiological data and report on changes in psychological state, can help athletes not only understand their physiological responses but also improve their ability to regulate their psychological states. Previous BFB studies with athletes showed successful effects related to enhancing self-awareness, controlling anxiety, and improving performance (Lagos, 2008; Hong, 2011; Paul & Garg, 2012; Hwang et al., 2016). The representative physiological indices used in BFB training are electro myography, electro encephalography, heart rate, heart rate variability (HRV), respiration rate (RR), skin conductance, and temperature; among these, HRV is the most commonly used. HRV is a measure of changes in time intervals between heartbeats, which are controlled by the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) (Berntson et al., 1997), and it identifies imbalances in the ANS (Janelle & Naugle, 2012). Both branches of the ANS regulate heart rate, with SNS increasing the rate and PNS decreasing it, and HRV is the measure of the rate changes between heartbeats; these changes can be analysed by time or frequency. The time domain refers to the time intervals between heartbeats (i.e., RR interval parameters), and measures include mean HRV, standard deviation of all normal R-R intervals (SDNN), and root mean square of successive differences (RMSSD). On the other hand, the degree of ANS activation is measured in the frequency domain. This is done by analysing the spectrum, which produces three ranges: high frequency (HF: 0.15–0.4 Hz), low frequency (LF: 0.04–0.15 Hz), and very low frequency (VLF: 0.003–0.4 Hz); these frequency measures also include the LF/HF ratio (Park & Jeong, 2014).

HRV BFB via breathing training is a well-known approach to regulating both the SNS and PNS and enhancing external–internal synchronisation. HRV BFB is expected to produce positive effects (Dziembowska et al., 2016), such as reducing anxiety (Lagos et al., 2008; Prinsloo et al., 2011; Hwang, 2018); lowering stress levels (Kim & Min, 2015); enhancing self-control (Hwang, 2016); and improving sports performance (Strack, 2003; Paul & Garg, 2012). In an experiment, Choudhary et al. (2016) examined the effect of HRV BFB training on psychophysiological performance in 24 long-distance runners (5 km). The experimental group was instructed to practice resonance frequency breathing by performing four tasks during ten sessions of 30–40 minutes each, while the control group was instructed to do regular exercise. The HRV changes, along with blood volume, pulse, skin conductance and respiration, maximum oxygen consumption (VO2 max), and sports performance, were recorded and monitored during the breathing training and regular exercise; all of them showed significant differences between groups. In addition, in sports performance, the experimental group showed a more improved mean race record (15.89 seconds) than that of the control group (18.11 seconds).

In another study, Lagos et al. (2008) applied a 10-week programme of HRV BFB training to a high school golfer. The participant practiced breathing exercises each day for 20 minutes with a portable device. During the breathing exercise, HRV and breathing rate were measured, along with mood state, competitive anxiety level, and sports performance. After the training, the student's total HRV and LF had increased, and his heart rate and breathing patterns were more synchronised. Furthermore, his anxiety and negative emotions decreased, but his golf performance increased. Beauchamp et al. (2012) applied HRV BFB to an Olympic short-track speed skating team in six to ten sessions of 45 minutes combined with general psychological skill training and concluded that the HRV programme had contributed to arousal control and relaxation for warm-up, which resulted in improved performance in the Games. As Beauchamp et al. (2012) suggested, we focused on an integrated approach in this study to enhance self-regulation skills.

Even though BFB training alone can be beneficial for performance enhancement, integration with cognitive restructuring (CR) is more effective for treating anxiety among athletes. Cognitive Restructuring (CR) is a cognitive-behavioral therapy technique that aids individuals in identifying and altering negative thought patterns or cognitive distortions (Beck, 1988; Choi & Lee, 1998) CR extends Beck's cognitive therapy (1988) to correct extreme interpretations of physical sensations and cognitive errors of thought. Cognitive therapy focuses on correcting cognitive distortions that interpret body reactions as threats based on anxiety responses (Choi & Lee, 1998), and changing the cognitive interpretations of these

body reactions can significantly reduce bodily sensations such as hyperventilation (**Rapee, 1986; Beck, 1988; Clark, 1993; Choi & Lee, 1998**). **Salkovskis et al.** (**1991**) found that implementing a CR programme to reconstruct misinterpretations of body reactions decreased anxiety symptoms, which implies that cognition can be a significant aid to athletes with chronic anxiety. **Clark et al**. (**1994**) compared the effects of three different treatments—cognitive therapy, applied relaxation, and imipramine—on 64 panic disorder patients and found that all three were effective, but cognitive therapy was the most effective. **Clark et al**. (**1994**) also followed up on the athletes' symptoms after 15 months and found that misinterpretations of bodily sensations were the most common recurring symptoms. This result suggested combining BFB training with CR; the combination increased breathing control and diminished irrational beliefs in a competitive context, which is expected to show better self-regulation skills for psychophysiological states (**Clark et al., 1994**). Athletes often experience anxiety in diverse ways, with unique cognitive patterns contributing to their distress. The integration of CR allows for a more individualized intervention, tailoring cognitive strategies to the specific cognitive challenges each athlete faces alongside the physiological feedback from BFB.

In total, athletes should be equipped with cognitive strategies and skills for regulating physical reactions to anxiety and stress that can hinder optimal performance. Based on a psychophysiology approach, we developed a programme consisting of CR and HRV BFB breathing training to reduce anxiety and increase self-regulation for one squash athlete who suffered from an anxiety disorder. We aimed at quantitative and qualitative evaluation of the programme that we developed for the athlete, and we hypothesised that the psychophysiology intervention programme would result in emotion regulation changes in the athlete's HRV, anxiety level, and cognitive skills
The specific research hypothesis based on the purpose of the study is as follows.

H1: The psychophysiological intervention programm is expected to increase resting HRV.

H2: Psychophysiological intervention programme is anticipated to decrease anxiety levels.

H3: Psychophysiological intervention programme is expected to enhance participants' cognitive-emotional regulation abilities.

MATERIALS AND METHODS

Case Study

This study's limited sample size to one participant is attributed to the unique nature of the research focus. This approach allows for an in-depth and detailed analysis of individual responses, contributing valuable insights into the specific phenomenon under investigation. While a larger sample size is typically sought for generalizability, the emphasis here is on the depth of understanding gained from an intensive examination of a singular case, providing context-specific findings.

Jenny (pseudonym), the participant in this study, was an 18-year-old squash athlete on the Korean national team. She had been experiencing anxiety in competitive contexts (e.g., national championship) in the past year; the competitive contexts caused psychophysiological problems that resulted in poor performance. Jenny described several panic episodes marked by difficulty in breathing, dizziness, rapid heart rate, sweating, and a fear of losing consciousness during competitions. She experienced breathing problems repeatedly while she was sleeping or practicing in the gym as well. A medical check-up indicated no physiological causes for Jenny's symptoms. Based on her statements and medical results, we concluded that her anxiety symptoms were caused by dysfunctional beliefs about competition and her lack of physical coordination in stressful situations.

This case study followed ethical standards and received approval from the Kyungpook National University Industry Foundation in South Korea with reference number [KNU-2021-0157]. Participant provided informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

HRV BFB and CR Intervention Programme

HRV BFB training

Jenny was attended the intervention programme during the off-season. she maintained a consistent schedule of visiting the lab twice a week. this consistent attendance and the systematic

upkeep up uniform conditions provides a robust foundation for assessing the intervention's impact.

The HRV programme included 10 sessions, including a pre- and a post-test, with each session lasting 20 minutes and taking place at the same place and time. After we obtained consent from the participant, her coach and her parents, she completed two questionnaires to measure her psychological states and was equipped with biosensors for measuring her baseline psychological (i.e., stress level, sleep quality, mood) and physiological states (i.e., heart rate, temperature, skin conductance, breathing patterns), including competitive anxiety and HRV. These psychophysiological values for her baseline were measured not for the analysis but for supplementary reference information. We explained all the procedures to Jenny and educated her on how to do abdominal respiration. Prior to the programme starting, we measured her physiological states for 10 minutes during natural breathing to set up a baseline for comparison.

While Jenny performed breathing training, we obtained her physiological state using a BFB device (Peak Performance Suite, Thought Technology Ltd.). She was seated on a comfortable chair in a silent laboratory, and she wore the sensors on her left hand and abdomen; the sensors were calibrated while she adapted to the laboratory environment. At the beginning of the session, we explained how the heartbeat and other physiological data were detected by each sensor to capture HRV and RR, which were displayed on a screen in real-time. At each session, we collected Jenny's baseline data as she breathed naturally for 10 minutes; then she was instructed to follow the HRV BFB breathing training (i.e., abdominal respiration to follow a breathing pace bar by inhaling through the nose and exhaling through the mouth for 10 minutes) to regulate her psychophysiological states. We explained to Jenny the changes in thedata shown on the screen. We asked her to describe the feelings she had felt during the BFB training and her psychophysiological changes in order to qualitatively evaluate any improvements in her self-regulation. Jenny had to do breathing training at home; thus, we gave her a portable Emwave 2 breathing training device (Heart Math Inc.) and told her to do it three times a day.

CR intervention

CR. After each session of HRV BFB training, we applied approximately 30 minutes of CR. Initially, we educated Jenny on distinguishing between cognitive and somatic symptoms in stressful situations, not only so she could recognise her anxiety symptoms as reactions to the triggers of stressful situations but also so she could recognise that most of her anxiety symptoms were caused by negative thoughts and cognitive errors. CR consisted of the following three phases: First, a focus on awareness aims to bring to consciousness experiences of disconcerting thoughts during practice and competition; for this study, Jenny described her emotions, negative thoughts, and physical symptoms during stressful situations she had experienced. Second, focusing on appraisal identifies cognitive errors such as overestimation, dichotomous thinking, personalisation, and catastrophising. In the last phase, "alternative," people rethink certain situations and consider alternative ways to settle disputes.

Demographics

For her demographic information, Jenny completed a questionnaire including items related to personal characteristics (e.g., age, gender), health problems (e.g., medical history, injuries, mental illness), and athletic experience (e.g., winning record in competitions, psychological skill training, and BFB training).

HRV. We recorded HRV with the Peak Performance Suite that utilised electrodes connected to multi-modality encoders (Biograph ProComp Infiniti Encoder-8 channel, Thought Technology Ltd., Canada). The system was able to calculate HRV from the heart rate data derived from the blood volume pulse signals, which again shows changes in the ANS. We conducted the analyses by time and frequency, and the monitor displayed the real-time frequency domain results (VLF, LF, and HF) only; the system automatically stored the time domain results (SDNN, RMSDD) in the computer. We used LF power in normalised units (LF[ms2]/(total power[ms2]−VLF[ms2]) from 0.04 to 0.15 Hz, HF power in normalised units (HF[ms2]/(total power[ms2]−VLF[ms2]) from 0.15 to 0.4 Hz, and the LF/HF ratio in this study. For the time domain indices, we extracted and compared the pre/post SDNN and RMSSD.

CSAI-2. The CSAI-2 is a sport-specific state anxiety scale developed by **Martens et al.** (**1990**). It consists of a total of 27 items measuring three components: cognitive anxiety, somatic anxiety, and self-confidence. Each item is rated on a 4-

CERQ. The CERQ was developed by **Garnefski et al**. (**2002**). It consists of a total of 36 items measuring the following nine cognitive emotion regulation components: positive refocusing, positive reappraisal, refocus on planning, putting into perspective, acceptance, rumination, self-blame, other-blame, and catastrophising. Items on the CERQ are answered on a 5-point Likert scale ranging from 1 (almost never) to 5 (almost always), and each scale component consists of four items, for a possible score ranging from 4 to 20 for each component. In previous research on cognitive emotion regulation strategies, all subscales had high reliability, with Cronbach's alpha ranging between 0.75 and 0.87 (**Garnefski & Kraaij, 2007**).

Data Analysis

First, we quantitatively analysed the HRV changes by pre- and post-intervention data as mean ± standard deviation using Microsoft Excel. We also assessed the qualitative study data using content analysis, which entails interpreting meaning from interview data to identify important and meaningful aspects. At the end of each session, we rated Jenny's overall experiences, including her thoughts and opinions about the HRV BFB and the CR. We collected this descriptive data with three questions asked during a 10- or 15-minute session at the same place where the BFB training sessions occurred; a researcher asked follow-up questions when a response was bland:

Q1. Did you experience any positive aspects from the intervention?

Q2. Did you experience any negative aspects from the intervention?

Q3. Did you experience anything unusual? (body, emotions, thoughts)

RESULTS

Jenny described mostly the benefits of the psychophysiological intervention; the only negative aspect she cited was functional errorswith the Emwave2 device. Jenny described mostly the benefits of the psychophysiological intervention; point Likert scale from 1 (not at all) to 4 (very much so), and the total for each subscale ranges from 9 to 36. Cronbach's alpha coefficients for the CSAI-2 range from 0.80 to 0.88 (**Lane et al., 2008**), which shows that it is very reliable.

the only negative aspect she cited was functional errors with the Emwave2 device. From her responses, we established that we appeared to have achieved our three goals: a) increasing the young athlete's awareness of her own mind and body; b) teaching her efficient breathing and psychological stability; and c) increasing her mind and body abilities. Below, we further discuss our findings, including comments directly from Jenny and both the quantitative and qualitative changes in Jenny's indicators from baseline to the end of the intervention. Changes in her negative thoughts, her ability to control herself (self-regulation), and her overall experiences with HRV BFB training were some of the qualitative results.

Quantitative Changes

HRV

SDNN reflects variability in individual components over a recording period and, as such, can represent total variability (**Politano et al., 2008**). Short-term or momentary increases in SDNN within a normal range could imply more effective activation between the SNS and PNS (**Roberto & Attilio, 2018**), which can be interpreted as effectively coping with internal and external stresses. Jenny showed a higher SDNN, from 336.87 ms2 to 339.53 ms2 at the end of the HRV BFB training than her initial reading with natural breathing. The RMSSD, which is well-known as a PNS activation index, also increased after the intervention, from 648.17 to 652.91 ms2 (Figure 1). Compared with Jenny's baseline values, normalised LF power increased and normalised HF power decreased with natural breathing (Figure 2). The LF/HF ratio reflects the balance between the SNS and PNS, and this ratio increased from 1.97 to 3.80 ms2 by the end of the HRV BFB training.

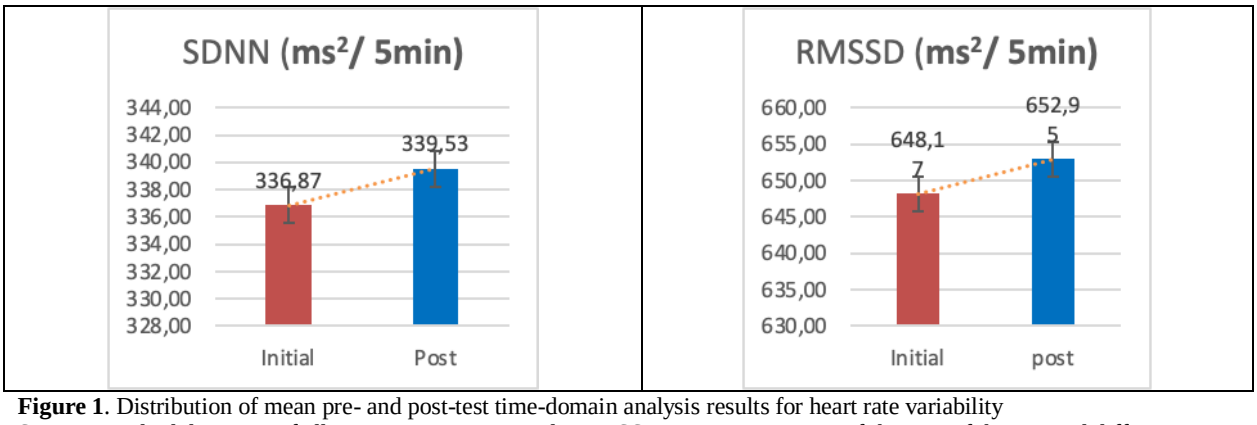

Figure 1. Distribution of mean pre- and post-test time-domain analysis results for heart rate variability
SDNN, standard deviation of all respiration rate intervals; RMSSD, root mean square of the sum of the squared differences between adjacent normal respiration rate intervals.

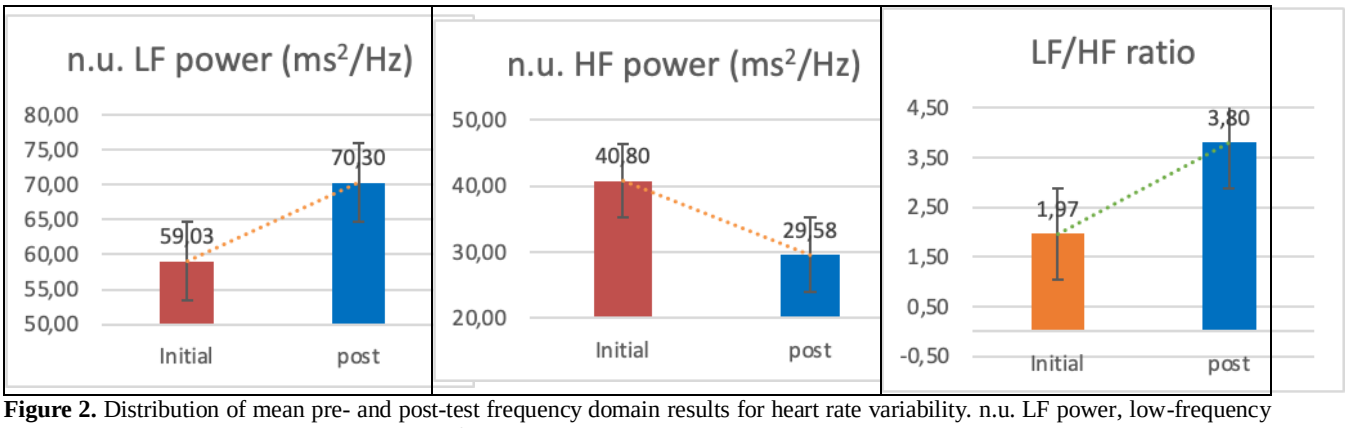

Figure 2. Distribution of mean pre- and post-test frequency domain results for heart rate variability. n.u. LF power, low-frequency power normalised units; n.u. HF power, high-frequency power normalised units; LF/HF ratio, balance between the low and high frequency bands.

Psychological state.

Jenny's scores on the CSAI-2 for both somatic (from 28 to 23) and cognitive (from 23 to 15) competitive state anxiety were much lower after the HRV BFB training. After the intervention, her state confidence in sports increased from 19 to 24 (Figure 3). Figure 4 displays the improvements in Jenny's cognitive emotion regulation. Her scores increased for the CERQ domains of putting things into perspective (from 7 to 11), refocusing on planning (from 14 to 16), positive refocusing (from 9 to 12), positive reappraisal (from 14 to 17) and acceptance (from 12 to 18). After the intervention, her scores decreased in the areas of self-blame (from 19 to 17) and catastrophising (from 20 to 12).

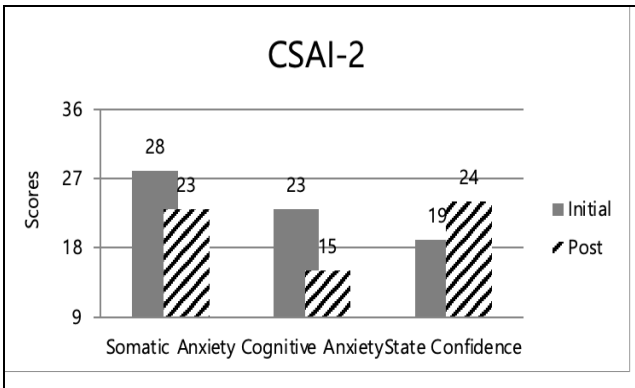

Figure 3. Pre- and post-test competitive state anxiety scores (range:9–36). CSAI-2, competitive state anxiety inventory-2

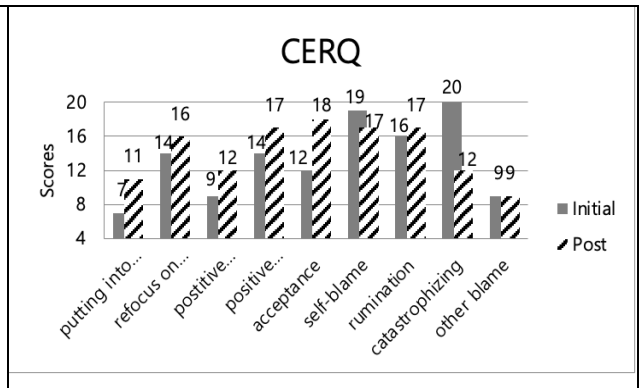

Figure 4. Pre- and post-test cognitive emotion regulation scores (range:4–20). CERQ, cognitive emotion regulation questionnaire.

Qualitative Changes

HRV BFB. Jenny reported her subjective feelings about her physiological and psychological changes after the intervention. She particularly highlighted how she was better at controlling her physiological reactions to stress through breathing.

"I think HRV BFB is helpful... After I am finished, I feel much lighter than before. It helped me to be aware that I am able to control myself." (Session 3)

"I did the breathing training three times a day with Emwave2 at home. Honestly, I couldn't feel any dramatic changes yet, but I could tell you that I've slept like a baby these days." (Session 4)

"It used to be difficult to breathe when I was under too much stress. Since I started BFB training, my daily breathing pattern has changed in a good way. The best advantage of it is that I can see my physiological state in real-time. Through the feedback, I can breathe slower and deeper than before." (Session 6)

"I used to be careful at every moment of my breathing. I was too sensitive and felt keenly about my body's condition. Right now, I have confidence in being able to control my body." (Session 8)

"I don't have breathing problems anymore. When I had too much stress, I used to feel uncomfortable breathing smoothly, but I can handle it now. Before starting the competition or waiting for my turn, breathing training can be a good method for performance." (Session 9)

CR. Jenny also expressed that she had become better able to regulate her cognition. For instance, she tried to change her negative thoughts in a positive way to regulate her physical and mental state to help her performance:

"I thought that anxiety always had bad effects on my performance. So I hated it. From now on, I feel like I can see the good side of anxiety." (Session 2)

"I've never had specific strategies to change my negative thoughts and anxiety symptoms before. After writing CR, I could find different points of view. So, I feel like some negative parts have already been solved." (Session 3)

"When I felt too sensitive or someone made me nervous, I couldn't do anything for myself. I just tried to be patient. These days, I am trying to find myself in a state of balance and am changing my thoughts positively." (Session 5)

"It was the best experience to learn about how to change my own emotions. I can also have different points of view and control my emotional state in a positive way. That experience has given me more confidence in my ability to play squash." (Session 9)

DISCUSSION

The HRV BFB and CR programme based on psychophysiological approaches intended to improve self-regulation in a female squash athlete who suffered from competitive anxiety. Jenny, the participant of this study, was able to control her physiological and psychological state better due to this intervention programme. This helped decrease her state anxiety and improve her cognitive emotion regulation.

We observed differences in HRV indices in both the time and frequency domains between the initial and post-test indicators. Specifically, both SDNN and RMSSD as time domain indices were higher after the intervention. Greater HRV is generally associated with better balance of the ANS, which regulates negative psychological states such as stress, depression, and anxiety (**Lagos et al., 2008; Reiner, 2008; Beckham et al., 2013**), and a higher SDNN reflects greater HRV and physiological resilience against stress (**Kim et al., 2018**). In contrast to SDNN, RMSSD reflects markers of the PNS, which are highly correlated with HF, and HRV BFB training activates the PNS as well (**Lagos et al., 2008; Lehrer & Gevirtz, 2014**). **Muller et al**. (**2020**) applied HRV BFB training for five days to a 24-year-old female triathlete and found higher RMSSD after the training. In a similar study, **Gross et al**. (**2017**) found higher RMSSD and psychological confidence in an elite female shooter after resonant frequency BFB training. Consistent with these earlier studies, our data also presented positive relationships between HRV measured in the time domain and the psychological variables. That is, increased HRV could predict more regulated states (**Thayer et al., 2010; Prinsloo et al., 2014; Mueller et al., 2020**).

In addition, in the frequency domain of HRV, we observed changes in Jenny's LF, HF, and LF/HF ratio at the end of the intervention. LF is interpreted as activation of the SNS, which is related to increased stress or anxiety (**Appelhans & Luechen, 2006; D'Ascenzi et al., 2014; Kim & Min, 2015**). In contrast, HF reflects PNS, which is a relaxed state. A high LH/HF ratio indicates high SNS or low PNS activation (**Kim & Min, 2015**).

Theoretically, low HRV or increased LF is associated with negative responses to stress and anxiety (**Kim et al., 2017; Morales et al., 2019**). However, our study showed a contradictory result. After the intervention, LF increased and HF decreased, which resulted in a larger LF/HF ratio. **Lagos et al.** (**2008**) similarly reported higher total HRV and LF but lower HF during HRV BFB training. Dziembowska et al. (2016) also investigated the effects of a stress management programme based on rhythmic breathing with a BFB device. Dziembowska et al. divided 41 healthy male athletes into two groups and applied HRV BFB training to the experimental group in 10 sessions of 20 minutes. HRV indices changed significantly in only the experiment group, in which LF power and total power were elevated while HF power declined.

Fluctuations in HRV indices are expected during HRV BFB training because of changes in breathing patterns. Normal HRV BFB programme have paced breathing in the lower frequency band (**Lehrer et al., 2003**), and a slow breathing rate causes overlapping of HF and LF, which can lead to misapprehension of the LF power (**Strano et al., 1998**). Overall, it is clear that the BFB programme we designed helped the athlete improve breathing regulation and physiological and psychological state control.

Jenny demonstrated positive changes in anxiety reduction and adaptive strategies for cognitive emotion regulation, and these results are supported by the results of **Beck et al.** (**1992**), who studied 33 panic disorder patients. Those patients were randomly assigned to focused cognitive therapy (FCT) or brief supportive psychological therapy (BSP) for 12 weeks, and the FCT group showed significantly fewer panic symptoms and less general anxiety after the treatment than did the BSP group. These changes in anxiety levels and cognitive emotional strategies can be considered positive effects of CR.

An anxiety disorder or panic attack is caused by a catastrophic misinterpretation of bodily sensations. Indeed, in one cognitive treatment study (**Salkovskis et al., 1991**), two patients who presented with misinterpretations of bodily sensations and dysfunctional beliefs showed no changes until the cognitive treatment was applied. Among the cognitive emotion regulation and anxiety measures in this study, catastrophising and cognitive anxiety decreased considerably after the intervention. This result confirmed that CR is effective for changing negative mindsets, consistent with an earlier finding by **Clark et al.** (**1985**). These authors reported decreases in panic attacks among 18 panic disorder patients with two weeks of breathing training and cognitive reattribution training. In total, findings suggest that combining BFB and CR can support ANS balance and enhance self-regulation in the body and mind.
As observed in the results, implications for the sport field is profound, as the integrated programme can potentially aid in managing performance-related stressors and optimizing mental resilience.

In summary, the study's results contribute valuable insights to the sports field by highlighting the practical applications of the integrated programme in improving athletes' anxiety reduction and cognitive-emotional regulation. Understanding that the combination of Biofeedback and Cognitive Regulation (CR) can lead to decreased anxiety levels and improved cognitive-emotional strategies provides a valuable tool for optimizing athlete performance. Furthermore, sport psychologists can develop an expanded psychological programme to implement the combination of BFB and CR in supporting Autonomic Nervous System (ANS) balance and promoting self-regulation in both the body and mind.

The results of this study have significant implications; however, there are some limitations. This is a case study to see the changes of the participant with a support from the qualitative analysis mainly, however the quantitative results have limitations to interpret with higher statistical power. This limitation suggests a further study with a larger samples to enhance validity and reliability on the effect of the intervention programme. This is the first attempt to combine two interventions, HRV BFB and CR, to deal with psychological issues. The overall findings suggest this programme is effective for athletes in reducing competitive anxiety and enhancing skills of emotional regulation.

Conflicts of Interest

All other authors report no conflicts of interest relevant to this article.

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Ethical Clearance

Ethical approval for this study was obtained from the Kyungpook National University Industry Foundation in South Korea (KNU-2021-0157). The need for the study was explained and informed written consent was obtained from the participant. In addition, results of all the test parameters after the psychophysiology intervention programme were given to the participant.

Author Contributions

Study Design, BK and SH; Data Collection, HK; Statistical Analysis, BK; Data Interpretation, HK and BK; Manuscript Preparation, BK and SH; Literature Search, BK, and HK. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

An Analytical Study of the Change in Some Biomechanical Indicators of Steeplechase (1-2-7-8) in the 400m Steeplechase for Elite Runners Under 20 Years Old

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Abstract
The aim of this study is to analyze the changes in the values of some biomechanical indicators (1- 2- 7-8) of steeplechase in the 400m steeplechase for elite runners under the age of 20. In this study, 8 athletes (age: 19.2 ± 0.98; height: 1.87 ± 0.05) were analyzed in the men's 400 m steeplechase. Analysis of variance test was used to compare differences between male athletes in terms of independent variables; significance was set at $p < 0.05$. As Result; the distance before the hurdle that, there is a non-significant value between the first hurdle and the second hurdle ($p>0.701$). As for the distance variable after the barrier, it turns out that there are significant differences in the first And the seventh, eighth (sig to Hurdle 1, $p<0.013$; $p<0.003$). As for the variable of the height of the body's center of gravity, the differences were not significant between the first and second and in the seventh And the eighth hurdles ($p>0.141$; $p>0.256$). But, We identified significant differences between other hurdles groups. As for the angle tangent variable, the results appeared significant for all the differences between the hurdles except for the difference between the seventh and the eighth barrier. In Conclusion, it is recommended to focus on training physical abilities according to performance and within bends, to train to maintain running rhythm, and to focus on speed and endurance exercises.

Keywords
Biomechanical Indicators, Hurdle Step, 400m Hurdles Race

INTRODUCTION

The 400 m hurdles (400 m-H) competition involves running over 10 obstacles set up at 35 m intervals. Compared to the 110 m hurdle race, overcoming obstacles on a curved track requires different techniques, such as regulation of stride length, tempo and stride patterns. Undoubtedly, performance in the 400 m is related to running ability in the 400 m race. However, Iskra and Pietrzak (2016) stated that even world-class 400 m-H athletes do not have the best personal records in 400 m-H runs. For this reason, 400 m-specific techniques such as stride adjustment and obstacle crossing in bends are thought to be important. During the race, maximum speed occurs between the first and third hurdles and then gradually decreases (**Ditroilo, 2001; Yasui et al., 2008**). Therefore, it can be concluded that the approach section, which is the acceleration phase from the start to the first obstacle, is an important stage for increasing the maximum speed. In fact, there is a strong correlation between maximum speed, approach speed and performance at 400 m (**Yasui et al., 2008**). Additionally, **Karube et al**. (**2003**) stated that athletes emphasize the first obstacle regardless of their performance level and gender, and that the athlete's emotion also shows the importance of th approach. In this approach section, athletes accelerate and adjust their steps. Move to the ideal takeoff position to clear the first obstacle around the bend. Then athletes need to

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maintain their speed to achieve high performance throughout the race (**Ozaki et al., 2019**).

High hurdle racing is one of the most technically demanding athletic events, and biomechanically hurdle racing is a combination of a cyclic sprint and a non-cyclic span of ten hurdles with a height of 1,067 m. Hurdle racing can be divided into the following stages: running to approach the first obstacle, overcoming obstacles and rhythm between obstacles, and running away from the last obstacle towards the finish line. Therefore, a proper steeplechase technique is a complex combination of various running and jumping kinematics. In addition, the hurdler must demonstrate a high level of sprinting skill, excellent flexibility in the hip joint, coordination, balance, dynamic perception, elastic strength and a high level of technical knowledge (**Salo, 2006**). Therefore, athletes, coaches and professionals are constantly looking for opportunities to improve high hurdle performance by focusing on show jumping technique with particular emphasis on kinematic and kinetic analysis (**Coh et al., 2020**).

Most coaches can resort to modern methods of assessing a runner's level in training units to find gaps where the runner's kinetic technique is improved. These methods include the use of force and speed sensors throughout the race distance, as well as imaging with special fast cameras with kinetic analysis programs that output biomechanical indicators that give a digital and graphical concept of the athlete's level. It improves the runner's physical abilities that do not fall to the competitive performance level, making the training process systematic and rational without losing sports training time (**Amara et al., 2019**). Steeplechase is a complex technical event that requires a high level of physical conditioning. In fact, sprint speed, intersegmental coordination, reactive power and excellent technical skills are the most important physical fitness elements that must be regularly developed and routinely implemented in training programs to be successful in the race (**Coh and Zvan, 2018**). In particular, the technique of overcoming the obstacle represents one of the most decisive factors that determine the outcome of the competition (**Sidhu and Singh, 2015**).

The science of biomechanics is one of the sciences that adds the character of standardized biomechanical indicators of the hurdles step (1- 2- 7- 8).

training for researchers and coaches, as well as accurately selecting weak points for runners, and this is what is adopted in higher level training. Considering that running strides depend entirely on how to reach the obstacles at the same speed and with a good hurdle stride without reducing the speed level, the 400 m-H running competition is considered one of speed, endurance races and precise kinetic performance (**Ozaki et al., 2019; Iskra, and Pietrzak , 2016**). This is done only through training to overcome the initial obstacles with as much of the same kinetic performance as possible of the final obstacles. It requires examining the biomechanical indicators of the hurdle steps in which the hurdler can maintain his kinetic performance level. Therefore, the importance of research in finding these indicators to know the level of success of runners and any rises and falls in them. Indicators during performance phases give the coach a graphical indication of both the training and the level of success (**Otsuka and Isaka, 2019**).

Considering that ten obstacles are present in the 400m-H race, the obstacles are distributed over the race distance and each obstacle constitutes a step within the performance distance, and the kinetic performance in the obstacle step is mastered throughout the passing speed and ensures the protection of the obstacle, a championship in the 400 m hurdles race at the Iraqi Athletics Championships The levels of runners varying between one and the other, the fact that passing in the least amount of time, therefore shortening the total race time, and the fact that the two researchers are experts on running races were noticed here. To investigate this problem in depth for the same athletes and to investigate the effect of the hurdle step on the kinetic performance level at certain distances in order to reach the cause of the rise and fall in the kinetic level of the hurdle step and therefore its effect on the hurdle step.

Purpose

The aim of this study is to analyze the changes in the values of some biomechanical indicators (1- 2- 7-8) of steeplechase in the 400m steeplechase for elite runners under the age of 20.

Research hypotheses

There are no statistically significant differences between the values of some

MATERIALS AND METHODS

The researchers used the descriptive approach in the style of correlational relations due to its suitability to the objectives of the research and the closest to solving the research problem.

Research Approval

Data were collected as part of the at the Ministry of Youth and Sports Athletics Stadium in Baghdad. This case study followed ethical standards and received approval from with reference number [No.10/144 and date 2/08/2023]. Participant provided informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

Participants

The research population consisted of 400 m hurdlers under 20 years of age, elite participants of the Iraq Championships, the second stage of which will be held in 2022. In this study, eight athletes (age: 19.2 ± 0.98; height: 1.77 ± 0.05) were analyzed in the men's 400 m steeplechase (Table 1). The research sample of the participants was chosen consciously, and the degrees they achieved (first, second and third) are given in detail in Figure 1.

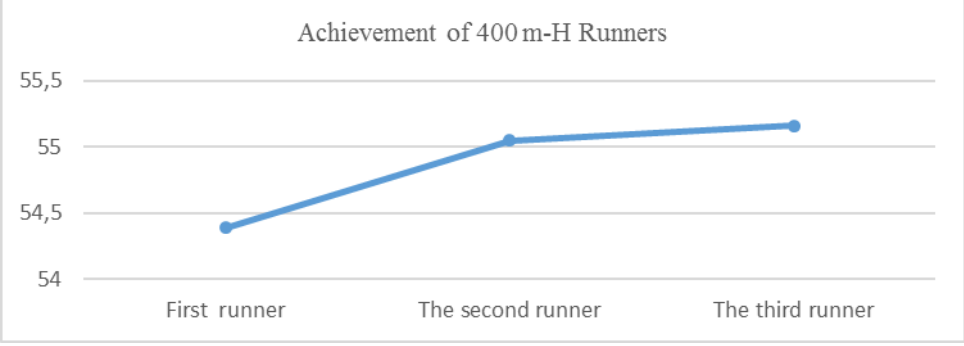

Figure 1. The best time achieved by the participants in the 400m steeplechase

Table 1. Anthropometric characteristics of participants

Variables	Descriptive Statistics		
	Means	Standard deviation	Skewness
Age (year)	19.22	0.986	-0.06
Height (cm)	1.77 ±0.05 m	0.587	0.10
Body mass (kg)	65.00 ±0.05 kg	0.894	0.58
Gender	Male (n=8)		

Data Collection

All data; It was collected using the International Information Network (Internet), Personal interviews, Tests and measurements, Registration form and information dump, Biomechanical laws and equations and Kinetic analysis program (kinovea).

Procedure of Measurements

Three-dimensional (3D) kinematic analyses of the hurdling sequences were performed over the entire 400-m distance (i.e., 4 hurdles) with ten mutually synchronized digital cameras [Shutter speed 1/240th of a second and sample rate 60 Hz] with wide conversion lens [× 0.6; 45.5 × 29 mm]. Cameras were placed in pairs 8,5-m away and 1.10-m above the floor with an angle of 60° and 120° for the first and the second camera, respectively. Each pair of cameras permitted the analysis of 1-2-7-8 hurdles (figure 1).

The first camera (1 hurdles): photographing the first checkpoint

The second camera (2 hurdles): filming the second checkpoint.

The third camera (7 hurdles): photographing the seventh checkpoint.

The fourth camera (8hurdles): photographing the eighth checkpoint

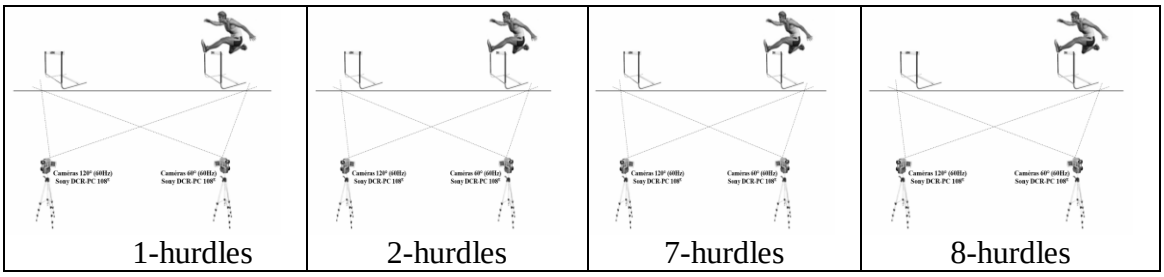

Figure 2. Procedure of Measurements

Procedures

400m hurdles achievement test (**Muhammad Abadi Abdul-Khafaji, 2003**): Its aim: to measure the total time, as well as all biomechanical indicators related to the research. Conducting a 400-meter hurdles run test in accordance with international law, with video filming procedures as follows: The fast video cameras for the analysis of the mechanical indicators of the hurdles step were placed on the hurdless within the two curves perpendicular to each hurdles. The distance before the hurdle (the ascent distance) for the four hurdles under discussion: it is measured directly through the process of kinetic analysis, which is determined by measuring the distance between the places of the runner's foot's back support to the vertical projection of the hurdle crossbar. The distance after the hurdles (landing distance) for four hurdless under discussion: It is measured directly through the kinetic analysis process, which is determined by measuring the distance between the vertical projection of the hurdle beam and the front support of the runner's foot.

The height of the body's center of gravity above the hurdles for the four hurdless under study: It is measured directly through the process of kinematic analysis by determining the highest height of the center of gravity of the runner's body vertically from above the hurdles to the ground at its highest height above the hurdles to the vertical projection of the hurdles beam. Tangent of the angle of inclination of the runner's apex of the curve: (**Sareeh Abdul Karim, 2009**). The mean of the tangent angle of inclination was extracted after identifying the runner's speed for the total step of the hurdles and dividing it by the ground acceleration and the radius according to the following equation:

$$\text{Tangent angle of inclination} = \frac{\text{speed}(2)}{\text{Ground acceleration x radius}}$$

Experimental Design

The two researchers conducted the test on 15/11/2022 at (4) in the afternoon with the help of the assistant work team, as the research test included a test of running a distance of 400 m / hurdles on the athletics track - Ministry of Youth and Sports - Baghdad and conducting video imaging to measure biomechanical indicators For each hurdles in question, After that, the imaging was taken for processing by the kinetic analysis program, which the researchers agreed to use among other analysis programs (kinovea) for its ease of use and the most agreed upon by the kinetic analysis specialists, and then extracting data on Excel to treat it statistically, and then prove the hypotheses and achieve the research goals.

Statistical analysis

All statistical analyses were carried out using SPSS Statistics 26 (IBM SPSS, Inc., Chicago, IL). Data were reported as mean ± standard deviation (SD) and confidence intervals at 95% level (95% CI).

Effect size (d) was calculated using GPOWER software. Data were tested for normal distribution using Shapiro-Wilk's test. Analysis of variance test was used to compare differences between male athletes in terms of independent variables; significance was set at $p < 0.05$.

The researchers used Excel program to extract the following mathematical operation (**Al-Bayati and Sareeh Abdul-Karim Al-Fadhli. 2012**).

Difference ratio, convergence ratio (percentage) (first value - second value / first value X100), where the first value represents the value of the first curve and the second value represents the value of the second curve.

RESULTS

Table 2. The statistical description of the values of some biomechanical indicators of the research sample

Variables	Hurdles	X	SD
Distance Before the Hurdles	Hurdle1	1.9133	.06429
	Hurdle2	1.8967	.02082
	Hurdle7	1.8400	.07550
	Hurdle8	1.7467	.01528
Distance After the Hurdles	Hurdle1	1.1700	.02646
	Hurdle2	1.1433	.01528
	Hurdle7	1.2200	.01000
	Hurdle8	1.2367	.02082
High Center of Gravity of the Body	Hurdle1	18.6667	.57735
	Hurdle2	20.0000	1.00000
	Hurdle7	21.3333	1.52753
	Hurdle8	22.3333	.57735
Tangent of the Angle	Hurdle1	8.6667	.57735
	Hurdle2	9.6667	.57735
	Hurdle7	10.6667	.57735
	Hurdle8	11.0000	0.00000

Through the table (3) above, which shows the contrast between the four hurdles, which showed the presence of significant differences between them in the variables of the study, and to show the preference of the values of biomechanical indicators, a statistical method must be used to find them, so the researchers resorted to using (L.S.D) the least significant difference to indicate the preference of the differences between them.

Table 3. Shows the analysis of variance for some biomechanical indicators of hurdles (1, 2, 7, 8) in the study sample.

Tests	Source of Contrast	Sum of Squares	Degrees of Freedom	Mean of Squares	F Value Calculated	P Value	Type Sig
Distance Before the Hurdles	Between	0.051	3	0.017	6.462	0.016	Sig
	Inside	0.021	8	0.003			
Distance After the Hurdles	Between	0.017	3	0.006	15.356	0.001	Sig
	Inside	0.003	8	0			
High Center of Gravity of the Body	Between	22.917	3	7.639	7.639	0.010	Sig
	Inside	8	8	1			
Tangent of the Angle	Between	10	3	3.333	13.333	0.002	Sig
	Inside	2	8	0.250			

Through table (4) above, which shows the differences between the arithmetic mean of the three runners and the value (L.S.D) of some biomechanical indicators of the four hurdles, as it is evident through the first indicator (the distance before the hurdle) that there is a non-significant value between the first hurdle and the second hurdle because the values are in the distance before the hurdle ($p>0.701$). For the same variable, the differences between the first obstacle and the eighth obstacle were found to be significant (sig to Hurdle 1, $p<0.004$), Similarly, the second obstacle

and the eighth obstacle were found to be significant (sig to Hurdle 2, p<0.007).

As for the distance variable after the barrier, the differences were non-significant between the first and the second barrier (p>0.126) but it turns out that there are significant differences in the first And the seventh, eighth (sig to Hurdle 1, p<0.013; p<0.003). At the same time, there are significant differences in the second And the seventh, eighth (sig to Hurdle 1, p<0.001; p<0.000).

As for the variable of the height of the body's center of gravity, the differences were not significant between the first and second and in the seventh And the eighth hurdles (p>0.141; p>0.256). But,We identified significant differences between other hurdles groups.

As for the angle tangent variable, the results appeared significant for all the differences between the hurdles except for the difference between the seventh and the eighth barrier (Table 4).

Table 4. Shows the difference between the means and the value of (L.S.D) for some biomechanical indicators of the four hurdles

Tests	Groups	Difference Between The Means X	P Value	Type sig
Distance Before the Hurdles	Hurdle 1-2	0.016	0.701	Non sig
	Hurdle 1-7	0.073	0.118	Non sig
	Hurdle 1-8	0.166	0.004	**sig to Hurdle**1
	Hurdle 2-7	0.056	0.213	Non sig
	Hurdle 2-8	0.150	0.007	**Sig to Hurdle**2
	Hurdle 7-8	0.093	0.056	Non sig
Distance After the Hurdles	Hurdle 1-2	0.266	0.126	Non sig
	Hurdle 1-7	-0.050	0.013	**Sig to Hurdle**1
	Hurdle 1-8	0.066-	0.003	**sig to Hurdle**1
	Hurdle 2-7	0.076-	0.001	**sig to Hurdle**2
	Hurdle 2-8	0.093-	0.000	**sig to Hurdle**2
	Hurdle 7-8	0.016	0.318	Non sig
High Center of Gravity of the Body	Hurdle 1-2	1.333-	0.141	Non sig
	Hurdle 1-7	2.666-	0.011	**sig to Hurdle**1
	Hurdle 1-8	3.666-	0.002	**sig to Hurdle**1
	Hurdle 2-7	1.333-	0.141	Non sig
	Hurdle 2-8	2.333-	0.021	**sig to Hurdle**2
	Hurdle 7-8	1-	0.256	Non sig
Tangent of the Angle	Hurdle 1-2	1-	0.040	**sig to Hurdle**1
	Hurdle 1-7	2-	0.001	**sig to Hurdle**1
	Hurdle 1-8	2.333-	0.000	**sig to Hurdle**1
	Hurdle 2-7	1-	0.040	**sig to Hurdle**2
	Hurdle 2-8	1.333-	0.011	**sig to Hurdle**2
	Hurdle 7-8	0.333-	0.438	Non sig

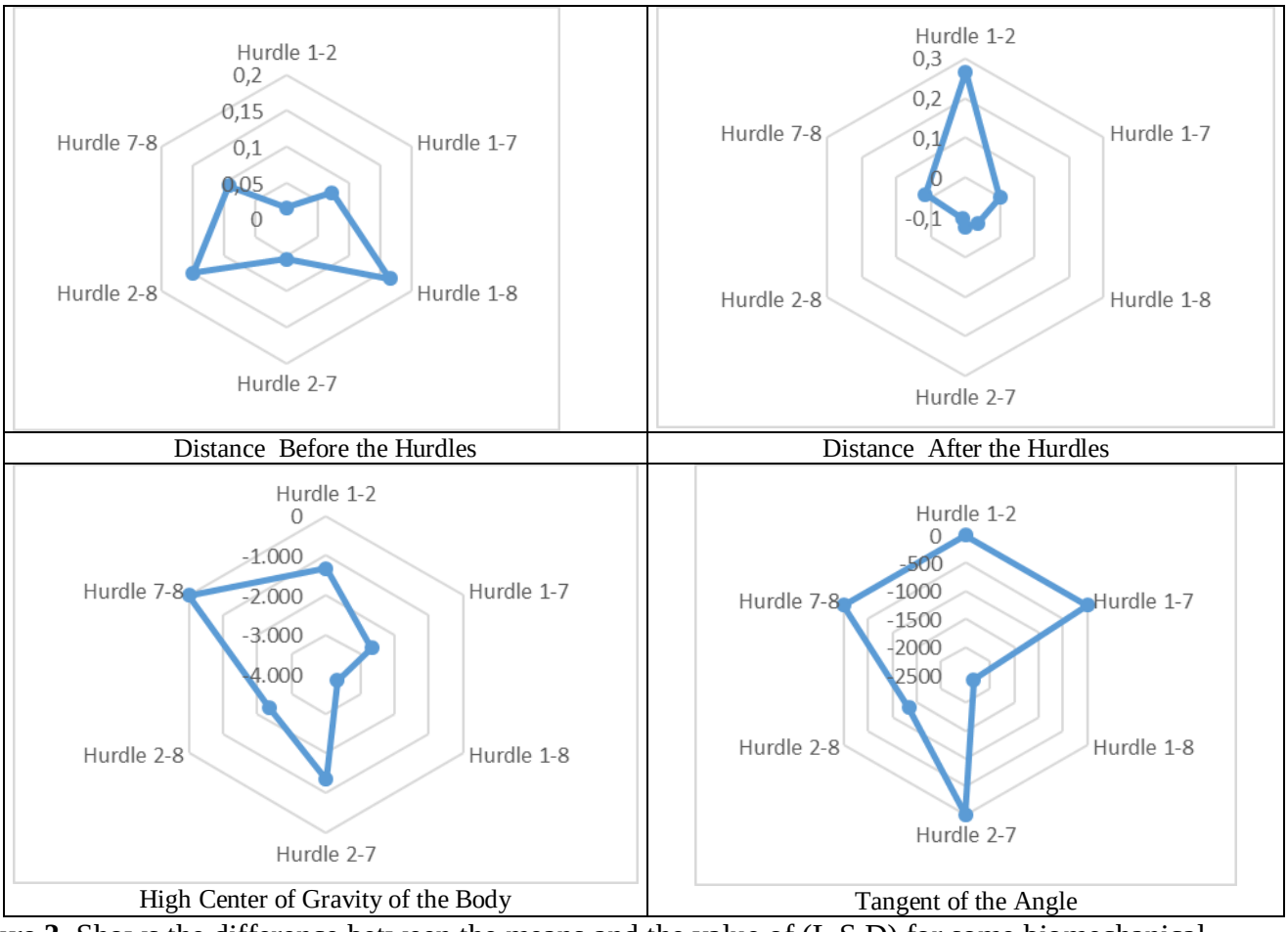

Figure 3. Shows the difference between the means and the value of (L.S.D) for some biomechanical indicators of the four hurdles

DISCUSSION

Hurdle events are part of the athletics program at the Olympic Games and all other outdoor major championships. Athletes must overcome ten obstacles over designated distances, making the event extremely technical as hurdlers attempt to minimize contact with each barrier while maintaining forward speed. Previous studies have focused on one and/or a maximum of three obstacles with kinetic or kinematic analysis (**Bezodis et al, 2019**). Therefore, the current study can be considered unique in that it examines both biomechanical and kinematic variables of the change in 400 m steeplechase performance (1-2-7-8 hurdles).

Results indicated that; through table (4) above, which shows the differences between the arithmetic mean of the three runners and the value (L.S.D) of some biomechanical indicators of the four hurdles, as it is evident through the first indicator (the distance before the hurdle) that there is a non-significant value between the first hurdle and the second hurdle because the values are in the distance before the hurdle The same barrier in the two hurdles with a small difference that was not sensed by the statistical method, and this indicates that the crossing of the first barrier was at the same speed as the crossing at the second barrier, because the variable speed is directly effected with the distance indicator according to the speed law, and here the steps are fixed and with a constant contact time and flight time in all steps up to the barrier The second, and this is what the researchers agree on with what was stated by "It is noted that there is a change in speed caused by the contact of the foot with the surface of the ground, and this contact, if it is for a long time, causes an unwanted momentary stop, and this stop causes a change or decrease in speed, i.e. the appearance of differences in speed"(**Al-Fadhli. 2009**).

This is evidence that the elite runners are distinguished by maintaining speed rates in the first curve. As for the same variable, the differences between the first hurdle and the eighth

hurdle were significant, and this indicates that the distance before the hurdle for the first hurdle was greater than the distance for the eighth hurdle, and this indicates a decrease in the average speed. However, slightly, causing the runner to reduce the distance of the ascent before the barrier to control the effective technique over the barrier without an increase in the crossing time. One study, in an analysis of hurdle runners using three-dimensional (3D) videography (50 Hz), found that absolute descent and recovery stride lengths at the national standard (0.03 and 0) differed little between men and women. Additionally, a 3D study using a higher sampling rate would allow greater precision in identifying specific events such as takeoff and touchdown, which could provide a more accurate assessment of kinematic and spatiotemporal aspects of steeplechase performance such as stride lengths and transition time (**Hanley et al., 2021**).

As for the distance variable after the barrier, the differences were non-significant between the first and the second barrier, and this indicates that the runner has the same compatibility for this distance, and this indicates the preservation of the endurance of the muscle strength responsible for pulling the leading leg beyond the barrier, but it turns out that there are significant differences in the seventh barrier And the eighth, and this indicates that the runners do not have the endurance of strength for these distances, and this is what works to reduce the effectiveness of the muscles to work with strength and speed to pull the leading foot directly after the barrier, and here the coaches must take into account the strength endurance training for this distance in order to work to reduce the passing time and thus Reducing completion time. The basic training task for the athlete includes the ability to maintain an adequate step pattern, that is, the number of steps that ensure a minimum loss of speed when subsequent segments are passed between obstacles (**Iskra ve Coh, 2011**). During hurdle racing, split times are measured as touchdown split times, separated by the moment the front foot touches down. Intergroup comparisons in 400 m hurdles races have reported that the faster hurdlers' finish times, the faster their touch down times in the second half of the race (**Breizer and Korchemny, 1990; Otsuka and Isaka, 2019**).

As for the variable of the height of the body's center of gravity, the differences were not significant between the first and second hurdles, because the runner is characterized by high passing speed, high compatibility, and good competitive capacity, which causes the same height values between the two hurdles. This also indicates that their coaches focus in their training on the distance of the first arc, and this is what We find it from close results in all biomechanical indicators, as well as non-significant differences between the differences for the seventh and eighth hurdles, and this indicates a decrease in the average speed for a distance before the eighth hurdle until the distance after the eighth hurdle. In other words, the speed plateau, and here the runner tries to maintain the speed without increasing it as a result of the close physical capabilities between the elite runners At the local level, after the distance of the eighth hurdle, it begins to gradually decrease until the finish line, and from here the coaches must focus on this distance in their training and the presence of hurdles to take advantage of the special physical capabilities with the rhythm of the hurdles and to stay away from free exercises without hurdles, as mentioned ": The hurdles runners should not spend a lot of time on sprint training without hurdles, because the hurdles running rhythm (movement weight) is not similar to the sprinting rhythm in short distances" (**Ibrahim. 1992**).

Claiming that horizontal speed is one of the most important factors, based on obstacle clearance analysis, and therefore loss should be minimized; otherwise the working time will be reduced. In addition, the athlete's take-off distance and landing distance are also important in order to overcome the obstacle as quickly and biomechanically effective as possible (**Salo, and Grimshaw,1997**). As for the variable the height of the body's center of gravity, the correct positioning of these two points determines the optimal flight trajectory, which is reflected in the flight time, in which the body's center of gravity should be as short as possible. According to **Coh and Zvan** (**2018**) and **Bubaj et al.** (**2008**) These two conditions are a prerequisite for the optimal flight path of the Body's center of gravity.

This optimal path results in shorter flight time. In addition to the correct position, the kinematic-dynamic structure of take-off and landing is also important as it directly affects the speed of obstacle clearance (**Chin-Shan et al., 2020; Amara et al., 2017**). To summarize the above considerations, following the main criteria for an optimal obstacle clearance technique

include horizontal speed, height of the Body's center of gravity during takeoff, rear foot speed, flight time, height of the Body's center of gravity during landing, and contact time (**Park et al., 2011**).

As for the angle tangent variable, the results appeared significant for all the differences between the hurdles except for the difference between the seventh and the eighth barrier. The researchers attribute this significance to the presence of the first barrier at the top of the curve and passing it at a high speed, and we know that the high speed in the curve requires a greater inclination to the interior as a result of the effect of the centrifugal force towards Thus, the runner's inclination towards the inside increases when passing the first barrier, and the presence of the eighth barrier at the end of the curve in the area of contact with the rectum, and here the concentrated repulsion action on the runner decreases, and thus the inclination decreases, and this shows the significant differences between the two hurdles, while we find in the seventh and eighth hurdles there are non-significant differences And for the same reason in the previous variable, as a result of the runners' attempt to maintain the ideal maximum speed in the performance endurance zone, although the results were not of high values, but they are close, and from here the coaches must emphasize running at a steady rhythm and at a high speed, and emphasize on passing one leg after controlling the rhythm of the distances in order to It shows us similar biomechanical indicators, regardless of the physical abilities that must be based on the training curriculum from the point of view of the researchers on biomechanical indicators. It is difficult to analyze 400 m hurdles kinematics in terms of movement structure. Running straight sections and turns, changing the forefoot, and unpredictable changes in the way of negotiating obstacles due to increased fatigue demand are particular indirect (non-competitive) tools for movement analysis. Researchers have mostly focused on changes in the center of gravity during obstacles (**Przednowek et al., 2016**). Additionally, kinetic and kinematic results are widely used to help improve the training and performance of athletes.

And this is indicated by "The method of running differs in the curve from that in the straight, so all parts of the body must take the appropriate mechanical positions, which differ from those that it takes in the case of running in the straight, and it aims primarily to resist the centrifugal force, so it The more the player tries to increase his speed in the curve, the more resistance he exerts against the centrifugal force, and to overcome this force, the body in the case of running in the curve must take a position that is completely different from that in the straight line, if both the instep of the left and right feet turn inwards (towards the edge interior of the curve field) to assist with steering during running,As for the body, it also inclines towards the inside (left side) in order to relatively reduce the radius of the sphere in order to increase the diagonal acceleration (towards the center) in order to maintain the tension force towards the inside, just as the right shoulder rises above the left shoulder, and the head also tilts slightly inward. Extending the movement of the right arm while the range of movement of the left arm close to the inner edge of the curve field decreases " (**Khawla Ibrahim, AK. 2012**).

Conclusiıons

Through the results of the differences, it became clear that there is a decrease in the values of the biomechanical indicators in the seventh and eighth barrier, indicating a decrease in the rate of speed. Through the results between the differences between the circles of the biomechanical indicators, it is inferred that the rate of speed training for the runners in the presence of hurdles is low compared to the percentage of endurance speed in the absence of hurdles. Through the results between the mean differences of the biomechanical indicators of the distance variable before and after the barrier, there is a weakness in the force tolerance of the muscles responsible for pulling the leading leg.

Recommendations

Emphasis on training physical abilities according to performance and within curves. Emphasis on training within the rhythm of the same man passing to maintain the running rhythm. Emphasis on performing speed endurance exercises with hurdles.

Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Committee

Data were collected as part of the at the Ministry of Youth and Sports Athletics Stadium in Baghdad. This case study followed ethical standards and received approval from with reference number [No.10/144 and date 2/08/2023].

Author Contributions

Study Design, ME, AN; Data Collection, ME, AN; Statistical Analysis, ME; Data Interpretation, ME, AN; Manuscript Preparation, ME, AN; Literature Search, AN; All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Prevalence of Substance Abuse Among University Undergraduates

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Abstract
The study investigated how many university students in private, state, and federal institutions abuse chemical substances. It also compared the three types of institution to know where abuse of substances is more prevalent. The population for the study were all university undergraduates from Ekiti State. The sample is made up of 450 respondents' selected using simple randomization and purposive sampling technique with 115 participants from private institutions, 165 from state owned institutions and 170 participants from federal institutions. A Google Form questionnaire tagged Prevalence of Substance Abuse Scale (PSAS) was created, validated and used for data collection. Results; No significant difference could be determined in terms of gender on the prevalence of substance abuse among undergraduate students ($F(1, 448) = 0.581$, $p < .05$). A significant difference was detected in terms of age ($F(3, 447) = 0.088$, $p < .05$). It revealed a non-significant effect on the prevalence of substance abuse among undergraduates across different universities (private, state, and federal) ($F(2, 447) = 0.084$, $p < 0.05$).
It was suggested that universities should have an active counselling centre with trained counsellors to help people who struggle with substance abuse. Counsellors should work with the National Drug Law Enforcement Agency (NDLEA) to hold events like awareness campaigns, seminars, and workshops to enlighten students about the negative effects of substance abuse..

Keywords
Substance Abuse, Undergraduates, Prevalence, Counselling

INTRODUCTION

Psychoanalysts described the affective components of moral development as a product of the Id, ego, and superego. It is believed that a morally mature individual should not get stalked by the irrational id that seeks the immediate gratification of instinctive needs but rather possess a superego that is moralistic enough to monitor the rational ego's thoughts and deeds. Youth with mature personalities are therefore expected to resist the temptations to violate moral or cultural norms and develop a sense of self–esteem that prevents negative behaviours. Unfortunately, moral decadence and unhealthy habits, which often begin during adolescence (**Mangerud et al., 2014**), are on the rise, as youth, especially university undergraduates, are getting more involved in social menace or immoral behaviours that deviate them from societal norms. Such deviant behaviours include substance abuse, drug addiction, cybercrime, cultism, gender violence, hooliganism, etc. (**Makinde et al., 2020**). Some psychoactive substances are used for curative purposes; however, they become abused when they are taken regularly without a medical doctor's prescription (**Onoyase, 2019**).

Substance abuse is almost becoming a normal phenomenon among adolescents and young adults and the challenges arising from its intake are becoming a prevalent global concern

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(Oparaduru & Okoye, 2022). Substance abuse is mostly acute among the youth; with institutions of higher learning (which was much revered in the past) becoming a fertile ground for substance abusers and drug addicts. Substance abuse is defined as the intentional consumption of chemical substances, mind-bending substances, or performance-enhancing substances for non-therapeutic or non-medical purposes, which may result in physical, mental, emotional, or social harm to the consumer (Onah, 2023,Onoyase, 2019). They are chemical substances that, when consumed or administered to the body system, it alters mental processes such as perception, consciousness, cognition, mood, and emotions with the proportion of use reaching epidemic levels in some parts of the world with varieties of negative consequences such as accidents, untimely deaths, health issues, cybercrimes, ritual killings, unwanted or untimely pregnancies and poor academic performances among others (Alozai & Sharma, 2022). They can make them violent, depressed, and behave strangely. Chemical substances are bad for the health of young adults, especially university students. Chemicals can also hurt their breathing and their nerves. Substance-induced disorders happen when someone is intoxicated or going through withdrawal from a substance. These disorders can also cause mental health problems like psychotic disorders, bipolar disorder, depressive disorder, anxiety disorder, obsessive-compulsive disorder, sleep disorders, sexual problems, delirium, and problems with thinking and memory. Recently, substance-induced disorders have become more common among college students. This could have a big impact on how they act and feel, and could also make it harder for them to do well in school (Ho et al., 2019)

Studies have shown that substance abuse is a long-lasting issue in tertiary institutions particularly universities because of things that propel students to do it. **(**Anyama, Jimoh, 2022; Ofuebe, et al. 2020; Jacob and Adegboyega, 2017**)** identified availability of substances in the open market, pressure from peers, poor interpersonal relationships with others, adjustment issues, academic and financial pressures, lack of fundamental knowledge about the harmful effects of drugs, lack or poor parental guidance, strained relationship with parents, poor academic achievements in school, teacher's negative attitude to work and parental illiteracy among other variables as factors predisposing youths to substance abuse. Youths across cultures use substances as a means of reducing tension, having fun, challenging parental and other adults' authority, curing social acceptability, frustration, and poverty, and showcasing their financial capability. Pressure from peers, poor relationships with others, and adjustments to academic and financial pressures are other reasons why youths abuse substances.

Studying substance abuse, researchers found that many tertiary institution students commonly use drugs or alcohol. In a study in Benue State, Nigeria, they looked at how many people in colleges, polytechnics, and universities were abusing drugs. They found that the average amount used was higher than what they expected (Onoyase, 2019). Marijuana was the substance that people abused the most. The next popular substances were prescription stimulants, hallucinogens, opioids, and cough syrup **(**Johnston et al., 2015) (United Nations Office on Drugs and Crime, 2018). On the other hand (Anyanwu et al., 2016) reported that with a frequency rate of 29.0%, alcohol is the most commonly abused substance. Cocaine had the lowest rate of abuse at 2. 1%, while cannabis was the most abused. Following cannabis, tobacco and locally brewed alcohol were also frequently abused according to (Essien, 2010). The facts sheet from the United Nations Office on Drugs and Crime (UNODC), the drugs most often injected by youth are pharmaceutical opioids, followed by cocaine and heroin. In simple words, more men than women inject drugs. Also, women are more likely to inject heroin than men. When women who abuse drugs by injecting them are more likely to do risky sexual activities than men, so their chances of getting HIV and other infections increase. When people use drugs and alcohol too much, men are more likely to become addicted than women. Men are more likely to try different illegal substances and are also more likely to go to the hospital or die from taking too much of these chemical substances. However, women are more likely to have strong desires for drugs and start using them again after trying to quit. However, men and women are equally likely to develop a substance use disorder (Fox et al., 2014, National Institute on Drug Agency, 2020, Smith, 2014).

The prevalence of substance abuse across institutions of higher learning is an indication that stakeholders should not cross fingers and allow the monster eat deep into educational system. Therefore, assessing the patronage of counselling services as a preventive measure or intervention for the prevalence of substance abuse in tertiary institutions, **King'ori,** (**2020**) reported that 78% of counsellors indicated that their students were aware and utilizing counselling services with 22% not aware of counselling services. Report also revealed that students in private owned institutions patronizes counselling services than those in public institution (**Omoyemiju, 2022**) a situation which may be linked to the quality control measures that are often put in place by such institutions.

Statement of the Problem

Substance abuse among youths most especially those in the University seems to be a constantly evolving phenomenon that necessitates frequent assessments and reassessments in order to nip the problem in the bud. Smoking tobacco, drinking alcohol, and using illegal drugs can make user sick and can even cause death during teenage years and as one get older. The university's response to substance abuse problems and understanding the effectiveness of policy and intervention efforts relies on having accurate and trustworthy data. That's why this research is important. This study looks at how common it is for university students in Ekiti State to misuse drugs and alcohol. The research also shows how common substance abuse is among different types of institutions, age groups, and genders.

Research Questions

1. Is substance abuse more prevalent among male university undergraduate students than female undergraduate students?
2. At what age group is substance abuse very prevalent among undergraduate students in tertiary institutions?
3. What is the prevalence level of substance abuse among Universities undergraduate students?

Research Hypotheses

1. There is no significant difference in the prevalence of substance abuse among undergraduates based on gender.
2. There is no significant difference in the prevalence of substance abuse among undergraduates based on age.
3. There is no significant difference in the prevalence of substance abuse among the three types.

MATERIALS AND METHODS

A descriptive research design was employed for the study, a process that requires gathering data and analyzing information on the current situation of the topic under investigation. The population for the study were all university undergraduates from Ekiti State. A sample of 115 participants from Private institutions, 165 from state owned institutions and 170 participants from federal institutions made up the 450 respondents selected for the study. The researcher used a simple random and purposive sampling technique to select the sample. Simple random in the sense that all participants who were from Ekiti State were given the chance of been selected. Purposive in that only responses from undergraduates from Ekiti Sate were considered for analysis from the cluster.

The issue of ethical considerations in research is held with high levels of importance, especially when the study involves human beings (**WMA, 2013**). Voluntary participation permission of all the participants was obtained by the researcher from the participants and necessary precautions were taken to protect the rights of the participants. They were duly informed of the purpose of the study. The researcher assured the participants of their anonymity and confidentiality of the information provided. They were instructed not to include their names and matriculation number and that the information provided would be used only for research, and they approved.

A self-developed structured Google form questionnaire tagged: Prevalence of Substance Abuse Scale (PSAS) was created, validated and used for data collection by the researcher. The questionnaire is sectionalized into two, A and B. Section A contains demographic information of the participants while Section B contains questions on the prevalence of substance abuse among university undergraduates. The instrument was

adjudged to have face and content validity by three tests and measurement experts. It was further subjected to a reliability test to determine its consistency for the purpose for which it was developed. The instrument, therefore yielded 0.81 Cronbach's alpha reliability coefficient. The instrument was sent to different students' online WhatsApp groups to find out how many students were using drugs, and if there were any differences between boys and girls when it came to drug abuse and to establish the difference in substance abuse based on age. The questionnaire items were rated on four scales (1= Strongly Disagreed, 2= Disagreed 3= Agreed and 4 = Strongly Agreed) Responses were received electronically while only responses from undergraduates from Ekiti Sate were purposively considered for analysis. The data collected were subjected to data analysis using mean, standard deviation, weighted mean, analysis of variance. The reference cutoff was a weighted mean of 2.50 (4 + 3 + 2 + 1 = 10/4). Any mean below 2.50 is regarded as disagreeing with the item, while any mean above 2.50 is agreeing with the item.

RESULTS

Descriptive Analysis

Research Question 1

Is substance abuse more prevalent among male undergraduate students than female undergraduate students in tertiary institutions?

Table 1 details the frequency tabulation of the 450 respondents (male 297 (66%) and 153 (34%) female) selected for the survey. There are 45 (39.1%) female respondents and 70 (60.9%) male respondents from private university, 112 (67.9%) male respondents and 53 (32.1%) female respondents from state university, and 115 (67.6%) male respondents and 55 (32.4%) female respondents from federal university.

Table 1. Demographic characteristics and respondents responses to prevalence of substance abuse in frequency and percentages

	Variable	Private Frequency/ Percentage (%)	State Frequency/ Percentage (%)	Federal Frequency/ Percentage (%)	Total Frequency/ Percentage (%)
Gender	Male	70 (60.9%)	112 (67.9%)	115 (67.6%)	297 (66%)
	Female	45 (39.1%)	53 (32.1%)	55 (32.4%)	153 (34%)
	Total	**115 (100%)**	**165 (100%)**	**170 (100%)**	**450 (100%)**
Age	11 – 15	6 (5.2%)	9 (5.5%)	4 (2.3%)	19 (4.2%)
	16 – 25	67 (58.3%)	98 (59.4%)	112 (65.9%)	277 (61.6%)
	26 and above	42 (36.5%)	58 (35.1%)	54 (31.8%)	154 (34.2%)
	Total	**115 (100%)**	**165 (100%)**	**170 (100%)**	**450 (100%)**

Research Question 2

At what age group is the prevalence of substance abuse very rapt among undergraduate students in tertiary institutions?

According to the respondents' age distribution in Table 1, 19 (4.2%), 277 (61.6%), and 154 (34.2%) of the respondents, were between the ages of 11 - 15. 16 – 25 and 26 and above respectively. The private university has 6 (5.2%) respondents in the 12-15 age group, 67 (58.3%) respondents in the 16 – 25 age group, and 42 (36.5%) respondents in the 26 and above age group. For the state university, 9 (5.5%) respondents in the 12-15 age group, 98 (59.4%) respondents in the 16 – 25 age group, and 58 (35.1%) respondents in the 26 and above age group. In federal university, respondents from age 11-15 accounted for 4 (2.3%), followed by respondents from age 16-25 which accounted for 112 (65.9%) while those aged 26 and above accounted for 54 (31.8%).

Research Question 3: What is the prevalence of substance abuse among universities undergraduate students?

Table 2. Mean and standard deviation on the prevalence of substance abuse among universities undergraduate students

		N=115			N=165			N=170		
	University	Private			Stat			Federal		
	Substance	Mean	SD	Decision	Mean	SD	Decision	Mean	SD	Decision
1.	Cocaine/Crack	3.00	0.67	Agreed	2.63	1.18	Agreed	2.97	0.96	Agreed
2.	Alcohol	3.23	0.54	Agreed	3.01	0.86	Agreed	3.39	0.67	Agreed
3.	Cigarette	2.49	1.08	Disagreed	2.27	0.44	Disagreed	2.43	0.68	Disagreed
4.	Caffeine	2.45	1.13	Disagreed	2.44	1.04	Disagreed	2.19	0.78	Disagreed
5.	Heroine	2.32	1.26	Disagreed	2.39	0.98	Disagreed	2.23	1.44	Disagreed
6.	Opium	2.14	1.29	Disagreed	3.23	0.71	Agreed	2.10	1.61	Disagreed
7.	Tramadol	3.09	0.65	Agreed	3.66	0.77	Agreed	3.23	0.54	Agreed
8.	Marijuana	2.55	0.98	Agreed	2.42	1.00	Disagreed	2.42	1.04	Disagreed
9.	Codine	2.48	1.46	Disagreed	2.33	0.99	Disagreed	2.41	1.22	Disagreed
10.	Gegemu	2.71	0.96	Agreed	2.61	0.59	Agreed	3.09	0.59	Agreed
11.	Dry feaces	2.00	1.02	Disagreed	2.39	0.98	Disagreed	2.52	0.92	Agreed
12.	Formaldehyde	2.46	1.06	Disagreed	2.48	0.97	Disagreed	2.07	0.76	Disagreed
13.	Cough Syrup	3.92	0.38	Agreed	2.72	0.89	Agreed	2.81	0.88	Agreed
14.	Paint thinner	2.78	0.88	Disagreed	2.46	1.15	Disagreed	2.47	1.08	Disagreed
15.	Refnol	2.96	0.57	Agreed	2.75	0.94	Agreed	2.85	0.70	Agreed
16.	Shisha	2.65	0.66	Agreed	3.29	0.69	Agreed	3.04	0.92	Agreed
	Grand Mean	2.78			3.04			3.12		

The result in Table 2, shows that the grand mean of 2.78 for respondents from private universities, 3.04 for respondents from state universities, and 3.12 for respondents from federal universities indicates the prevalence of substance abuse among the sampled university undergraduates. This means that these students abuse these substances to alter their behaviours or gain acceptability among their colleagues. The abuse of the following substances (alcohol, tramadol, cough syrup, refnol, shisha and gegemu) were found to be highly prevalent. Gegemu is a local herb cultivated for its effectiveness as anti-termite but when the leave is cut and squeezed, the juice acts as stimulant. The availability and cheapness may attest to why students abuse it. It was also shown that formaldehyde and dry feaces were the least abuse substance among the undergraduates.

Hypothesis One

There is no significant difference in the prevalence of substance abuse on the basis of undergraduate students' gender.

Table 3: ANOVA table for prevalence of Substance Abuse on undergraduate gender

Source of Variation	Sum of Squares	df	Mean Square	Cal. F-ratio	Critical F-ratio
Between Groups	16.107	1	16.107	0.581	3.000
Within Groups	12420.998	448	27.725		
Total	12437.105	449			

*P < 0.05

The analysis of variance (ANOVA) revealed a nonsignificant effect of gender on the prevalence of substance abuse among undergraduate students, as indicated by the F-statistic (F(1, 448) = 0.581, p <.05).

Hypothesis Two

There is no significant difference in the prevalence of substance abuse on basis of undergraduate students' age group.

Table 4: ANOVA of the prevalence of Substance Abuse among universities students age group

Source of Variation	Sum of Squares	df	Mean Square	Cal. F-ratio	Critical F-ratio
Between Groups	6.918	3	2.306	0.088	3.000
Within Groups	11712.008	447	26.201		
Total	12437.105	449			

*P < 0.05

The analysis of variance (ANOVA) revealed a nonsignificant effect of age on the prevalence of substance abuse among undergraduate students, as indicated by the F-statistic (F (3, 447) = 0.088, p < .05).

Hypothesis Three

There is no significant difference among students in private, state, and federal universities on the prevalence of substance abuse.

Table 5. ANOVA table for prevalence of Substance Abuse on university undergraduates

Source of Variation	Sum of Squares	df	Mean Square	Cal. F-ratio	Cal. F-ratio
Between – Group	4.676	2	2.338	0.084	3.000
Within – Group	12443.368	447	27.838		
Total	12448.044	449			

*P < 0.05

The analysis of variance (ANOVA) revealed a nonsignificant effect of the type of university (private, state, and federal) attended on the prevalence of substance abuse among undergraduate students, as indicated by the F-statistic (F(2, 447) = 0.084, p < .05).

DISCUSSION

The findings of this study have shown that the abuse of substances is prevalent among undergraduates irrespective of the type of ownership of the institution they attend (Private, State, or Federal) as shown in calculated F-ratio in table 3. The collated results revealed a grand mean of 2.78 for private universities, 3.04 for state universities, and 3.12 for federal universities which were found to be high when compared with the benchmark of 2.50. These results corroborate the findings of (Manzoor et al., 2023; Onoyase, 2019) in her study where she evaluated substance abuse among higher education students in Colleges of Education, Polytechnics, and Universities with a grand mean result of 2.61, 3.33, and 3.07 respectively, findings which were higher than the benchmark of 2.50. The high number of young students abusing substance may happen because they are excited and energetic, and because the influence of their friends who are also doing it and they want to fit in.

They may also do it because they like the feeling of being independent and not having their parents watching over them, which they experience during their time in secondary school. The study found that people abused alcohol the most, followed by tramadol, cough syrup, cocaine, shisha, and gegemu (a local herb). This contradicts what **Johnston et al** (**2015**) said. In 2018, UNODC studies found that marijuana was the most commonly used drug, followed by prescription stimulants, hallucinogens, opioids, and cough syrup. The study does not agree with **Essien** (**2010**) who found that cannabis, followed by tobacco and locally brewed alcohol, were the most common illegal drugs used by students. The outcome agrees with **Anyanwu et al.** (**2016**) that alcohol was the substance most commonly abused, with a rate of 29. 0% Cocaine was the least abused substance, with a rate of 2. 1%. Many people drink alcohol too much because it is easy to find and doesn't cost much.

Examining the variation in how often people misuse drugs or alcohol in different types of places. Table 3 suggests that there was no significant difference between the people who participated from private, state, and federal universities. However, state institutions had the highest average score of 3. 33, followed by federal institutions with a score of 3. 07, and private institutions with a score of 2. 78. Additional findings shows that most of the respondents from public universities live outside of the campus, while those from private universities live on campus where the rules prohibit the use of substances. The research found that there was no significant difference in gender abuse of substances as shown in table 4. Results showed that male undergraduate students are more likely to use drugs and alcohol compared to female undergraduate students. The findings showed that more men than women use alcohol, tramadol, cocaine, gegemu, and refnol. However, female college students from different schools tend to abuse cough syrup, shisha, tramadol, and cocaine more frequently. The findings supports previous studies that found men are more likely to have problems with alcohol and illegal drugs, leading to hospitalization and death. Women, on the other hand, are more likely to struggle with cravings, relapses, and using prescription drugs without a

medical reason (**Fox et al., 2014; National Institute on Drug Abuse, 2020; Smith, 2014**).

The study also showed that the age of undergraduates did not make a big difference in their substance abuse. The study showed that young men and women between 16 and 25 years old use drugs more than older people. The age range mentioned here is from teenage years to early adulthood. During this time, students, usually in university, are curious and eager to try new things. This can make them more likely to engage in harmful behaviours like substance abuse. Additional information from the comments of the participants showed that counselling services in universities are available with patronage at a very low ebb, and many students do not utilize the available counselling services as expected.

Conclusion

The study found that many college students have a serious problem with drug and alcohol use, and it is causing significant health issues for them and the public. Substance abuse is common in different types of places, among both males and females, and across different age groups. Men were more likely to abuse alcohol, tramadol, and refnol, while women were more likely to use cough syrup with codeine and shisha. It was found that younger students, aged 16 to 25, use drugs and alcohol more than older students. Additionally, students who live off campus are more likely to engage in substance abuse compared to those living on campus. Even though people all around the world are worried about drug and alcohol abuse, there is still not enough help and education being provided in counseling services and colleges.

Recommendations

Substance abuse can have serious results if not taken care of properly. To deal with the problem of many undergraduates abusing substances, here are some suggestions that might help.

- The university needs to create a counselling centre right away. This centre would have professional counsellors who would help students with substance abuse problems and also give support to those who have been affected by substance abuse.
- The university should prohibit the sale of illicit substances that can be bought without a prescription, such as cigarettes, codeine, tramadol, and cough syrup, on campus. Using a cough syrup with an ingredient called dextromethorphan alongside certain medications like monoamine oxidase inhibitors can cause high fever, seeing things that are not real, intense excitement, or being in a deep sleep-like state.
- Guidance counsellors can work together with the University health service providers and the National Drug Law Enforcement Agency (NDLEA) to plan programmes like drug awareness campaigns, seminars, and workshops. These events will help educate and make students aware of the harmful effects of substance abuse on their physical and mental health.
- Each university can adopt the National Drug Laws, such as the Ekiti State Gender-Based Violence (Prohibition) law, which allows for punishment of people caught using drugs. There needs to formulate rules that will stop people from selling and using substances at the university and nearby areas.
- The university should try hard to create more housing for students on campus. It is easier to keep an eye on and manage students who live on campus compared to those who live off-campus.
- Regular health check-ups, such as getting a blood test after coming back from holidays, can be done at the university health centre to find out if someone is abusing chemical substances. Knowing about blood screening and the possible punishment can stop some students from abusing substances.

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Conflict of Interest

The researcher declares that in the course of the research, there was no commercial or financial relationships existed that could be construed as a potential conflict of interest.

Ethical Statement

An approval on ethical clearance certificate with reference number CERAD/URTC/ECC-BOUESTI/STA/Vol.010 dated 17th January 2023 was collected from the Centre for Research and Development (CERAD) Ethics Assessment Committee of Bamidele Olumilua University of Education, Science, and Technology Ikere Ekiti.

Researchers' Contribution Statement

Research Design; Statistical analysis; Preparation of the article; The entire process of Data Collection was carried out by the author.

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RESEARCH ARTICLE

Mapping the Muscle Mass: A Birds-Eye View of Sarcopenia Research Through Bibliometric Network Analysis

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Abstract
Sarcopenia, characterized by progressive age-associated loss of skeletal muscle mass and function, has emerged as an impending public health threat. This bibliometric analysis elucidates the knowledge landscape of sarcopenia research by synthesizing growth trajectories, collaborative networks, and intellectual structures within the literature. Scientific publications spanning 1993–2023 were retrieved from the Web of Science and Scopus databases. VOSviewer, Biblioshiny, and ScientoPy software tools facilitated visualization and analysis of bibliometric trends. Results showed that after a seminal 2010 consensus definition paper, sarcopenia publications increased over 20-fold by 2021, following an initial gradual growth and then exponential expansion. China led in output volume; however, Western nations exhibited higher international collaboration. Prolific institutions clustered within Asia and Europe, although Australian and Canadian centers were also represented, reflecting expanding global networks. Core journals were dispersed across clinical medicine, gerontology, and nutrition. A co-occurrence network analysis of keywords delineated three predominant research domains: physical disability, muscle diagnostic metrics, and clinical prognostic outcomes. Keywords like “mobility” in the disability domain reflect sarcopenia's functional impacts. This novel perspective comprehensively maps sarcopenia's evolving knowledge landscape, despite limitations in incorporating citations and text mining. Practical contributions include identifying key areas for further research, including consolidating diagnostic methods through collaborative initiatives, exploring lifestyle interventions, and investigating sarcopenia across diverse specialties. By elucidating trends in growth, collaboration, and intellectual structure, this analysis offers data-driven perspectives to strategically combat this expanding public health challenge. The synthesis of publication trends provides both a novel scientometric perspective and practical insights to inform future sarcopenia research and guide public health policy.

Keywords
Bibliometric, Geriatric, Sarcopenia, Scopus, Web of Science

INTRODUCTION

Sarcopenia, the progressive age-linked loss of skeletal muscle mass and function, has emerged as a major geriatric syndrome with growing impacts on older populations (Papadopoulou, 2020). As global demographics increasingly skew toward older societies, sarcopenia is poised to become a formidable public health burden. Consequently, research on this condition has rapidly expanded over the past two decades. As global populations rapidly age, sarcopenia threatens to impose an immense burden on healthcare systems and economies worldwide.

However, research progress has been stymied by fragmentation across disciplines and lack of synthesis on knowledge frameworks, growth trends, and collaborative links. A comprehensive bibliometric analysis is urgently needed to integrate these disjointed elements into a coherent landscape, illuminating directions and opportunities to propel this field forward (Kaiser & Kuckertz, 2023). Mapping growth trajectories, contributor networks, conceptual themes, and

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research foci will discern mature versus nascent domains, crystallizing priorities for research, policy, and practice. Elucidating sarcopenia's knowledge topology through scientometric techniques is crucial to consolidate diagnostic methods, catalyze lifestyle interventions, and inform practitioner guidelines. As sarcopenia exerts escalating impacts on patient health and healthcare costs, gaining a birds-eye perspective of literature patterns has become imperative to strategically inform policies and programs. This analysis constitutes a critical first step toward integrating sarcopenia's intricate knowledge landscape to address this burgeoning public health challenge.

Therefore, this study harnesses bibliometric analysis to illuminate publication trends, knowledge topics, and structural patterns within sarcopenia research. Specifically, this analysis addresses four central questions: (i) What are the historical and current publication volume patterns in sarcopenia research, and what is the growth trajectory over time? (ii) What are the predominant subject categories, countries, and institutional affiliations associated with sarcopenia publications? (iii) Which core journals publish sarcopenia research and what are their most influential papers shaping this field? (iv) What are the common keyword themes and topics in sarcopenia publications based on author keyword analysis, and which new or rising themes have gained prominence recently?

Elucidating publication, citation, collaboration, and conceptual motifs can highlight maturity levels across research domains. Findings can differentiate established niches from nascent territories within the sarcopenia literature. The knowledge architectures discerned can inform research priorities moving forward. This bibliometric analysis constitutes a pivotal step toward synthesizing the intricate landscape of sarcopenia knowledge and steering future growth within this critical geriatric syndrome. The visualized mappings and analyzed growth trends will provide data-driven insights to guide sarcopenia researchers and clinicians in addressing persistent gaps.

MATERIALS AND METHODS

This study harnessed bibliometric analysis to elucidate publication trends, research foci, and knowledge configurations within sarcopenia literature. Searching in September 2023 using the following keywords: TITLE (“sarcopenia”) for both Wos and Scopus databased. Scientific publications spanning 1993-2023 were extracted from Web of Science (WoS) and Scopus databases. Preprocessing excluded non-article document types, yielding 12,904 papers (6,141 from the WoS and 6,763 from Scopus).

Fig. 1 shows the study flowchart. Duplicate papers were identified through matching titles, authors, and publication years and merged to generate a corpus of 7,106 unique papers (6,089 from the WoS and 1,017 from Scopus). ScientoPy, Biblioshiny and VOSviewer tools enabled bibliometric analyses (**Ruiz-Rosero, Ramirez-Gonzalez, & Viveros-Delgado, 2019**).

Publication trends were gauged using normalized citation counts, collaborative authorship patterns, and longitudinal growth trajectories. Science mapping delineated conceptual connections and research clusters via keyword and citation co-occurrence (**Azliyana, et al., 2023**). Network visualization through VOSviewer illuminated relationships and intellectual structure.

Keyword co-occurrence network mapping revealed thematic concentrations and proximities. Topic novelty was determined using the average publication years of linked keywords. This multi-faceted bibliometric approach provides data-driven perspectives into growth behaviors, collaborations, conceptual associations, and knowledge clusters defining the sarcopenia research landscape.

RESULTS

What are the historical and recent publication volume trends in sarcopenia research, and what is the growth trajectory in this field over time?

Fig. 2 shows the data from Web of Science (WoS) and Scopus, research output on sarcopenia began in the 1990s but remained low until the 2000s. Growth accelerated in the last decade, with publications rising steeply from 55 documents in 2010 to 1,115 in 2021 in WoS.

A key development identified was the 2010 consensus paper “Sarcopenia: European consensus on definition and diagnosis” by Cruz-Jentoft et al. in Age and Ageing. With 7,960 citations in WoS, this paper established standardized criteria and

sparked growing research interest in sarcopenia in the 2010s.

Another influential early paper was "Invited review: Aging and sarcopenia" by Doherty in the Journal of Applied Physiology in 2003, with 1,294 citations in Scopus. This review of the etiology and consequences of age-related muscle loss helped establish sarcopenia as a distinct disease entity. In instant, while sarcopenia research originated in the 1990s, growth accelerated after influential consensus and review publications in the 2000s. The field saw exponential growth in the last decade, with annual output rising by over 20 times in WoS between 2010 and 2021. This reflects the expanding research and clinical interest after the standardization of the condition.

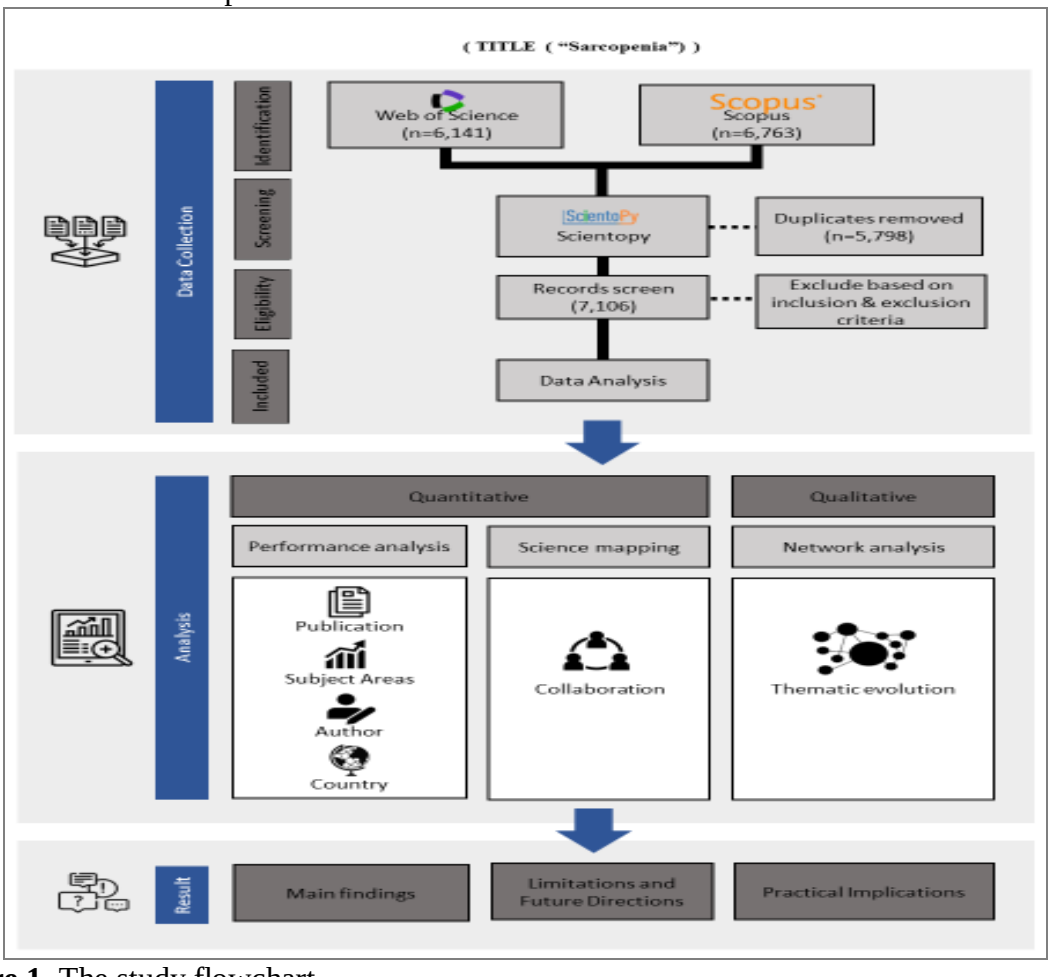

Figure 1. The study flowchart

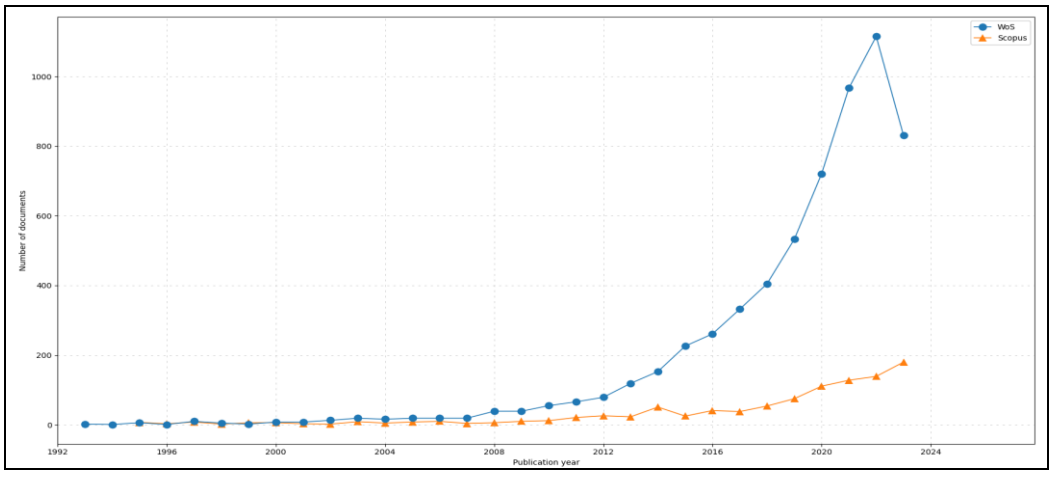

Figure 2. The research outputs and volumes

What are the top subject categories, countries, and institutional affiliations associated with sarcopenia publications?

Fig. 3(a) shows the top 10 subject categories based on the provided dataset. By far the dominant category is 'Geriatrics & Gerontology', with 1,656 documents representing 26% of all sarcopenia publications. This indicates sarcopenia's recognition as a key age-related condition.

The second most common subject area is 'Nutrition & Dietetics' with 948 documents or 15% of publications. This highlights the critical role of nutrition in mediating sarcopenia.'General & Internal Medicine' ranks third with 696 documents or 11% of the total, signaling sarcopenia's status as a condition affecting overall health in aging populations. Other top categories include 'Oncology' at 7% of documents, reflecting sarcopenia's impact on cancer outcomes, and 'Endocrinology & Metabolism' at 7%, indicating associations with hormonal changes.

'Surgery, Gastroenterology & Hepatology', 'Science & Technology, Research & Experimental Medicine', and 'Orthopedics' round out the top 10 categories, cumulatively comprising 18% of all sarcopenia research. Thus, it is clearly shown that sarcopenia literature is concentrated within gerontology, clinical medicine, and lifestyle disciplines, befitting an age-associated condition with nutritional and mobility implications. The subject distribution provides insights into how sarcopenia is framed in scientific research.

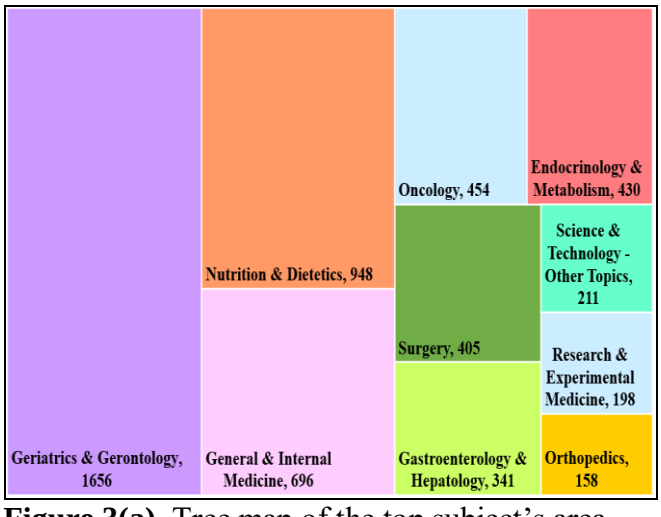

Figure 3(a). Tree map of the top subject's area

Next, Fig. 3(b) presented an analysis of the top corresponding author countries for sarcopenia publications. China has the highest output with 166 documents and 23% frequency, though only 4 documents are internationally collaborative.

The US ranks second with 73 documents and 10% frequency but has a higher international collaboration ratio at 0.11. Brazil follows with 45 documents but a high international collaboration ratio of 0.2. Japan and Korea are nearly tied with 41 documents each and 6% frequency, but Korea has a higher collaboration ratio of 0.073 vs. 0.024 for Japan.

Italy (27 documents, 4% frequency) and Spain (26 documents, 4% frequency) have similar output, but Italy's collaboration ratio is higher at 0.222 vs. 0.115 for Spain. The UK and Germany round out the top countries with 24 and 21 documents, respectively, and collaboration ratios below 0.1. Therefore, it clearly revealed that China dominates in sarcopenia publication volume but collaborates little internationally. The US and Brazil have the most international co-authorships proportional to output. Asian countries like Japan and Korea are active but collaborate less abroad. European nations like Italy and Spain are also major contributors but do more cross-country work.

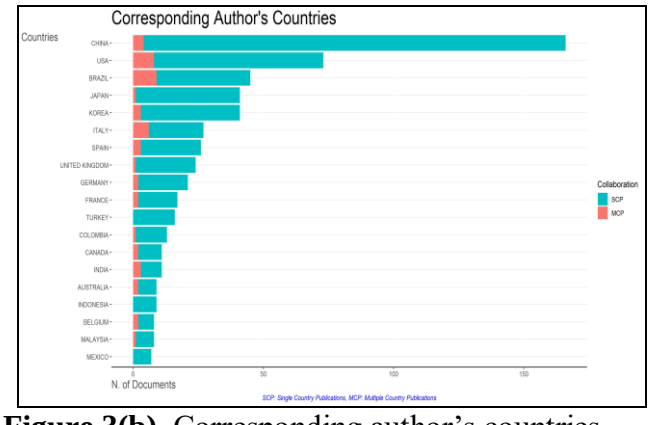

Figure 3(b). Corresponding author's countries

Fig. 3(c) shows that Univ Cattolica Sacro Cuore in Italy tops the list with 123 documents, making it the leading institutional contributor to sarcopenia literature. Sichuan University in China ranks second with 116 documents, leading among Asian institutions. The University of Melbourne in Australia follows closely with 103 documents, making it the prime institutional hub for sarcopenia research in the Australasia region. Seoul National University and Yonsei University, both from South Korea, take the next spots with 88 and 85 documents, respectively, making them major producers from the Asian region. Japan's

National Center for Geriatrics and Gerontology is another key Asian institution with 71 documents. The University of Liege in Belgium, with 69 documents, is the leading European institution besides Italy's Università Cattolica Sacro Cuore. The University of Southampton in the UK follows with 64 documents. Wenzhou Medical University in China and the University of Alberta in Canada round out the top 10 with 62 and 60 documents, respectively. In summary, the top sarcopenia research institutions are concentrated in Italy, China, Australia, South Korea, and Japan, along with contributions from Belgium, the UK, and Canada. Italy and China harbor several prolific centers.

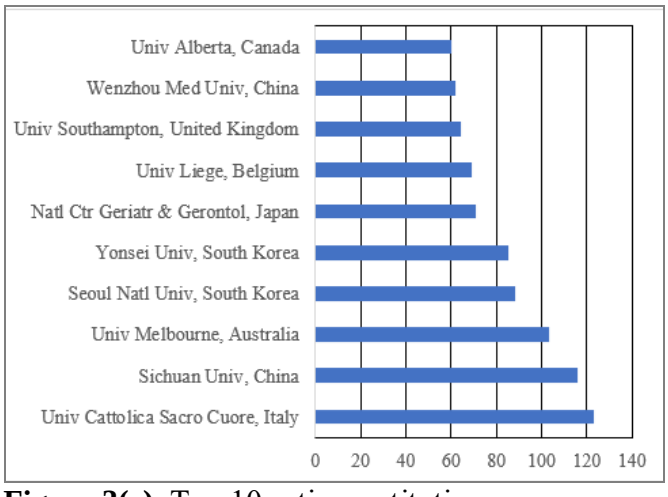

Figure 3(c). Top 10 active ınstitutions

What are the core journals publishing sarcopenia research and what are the top-cited papers from these journals that have shaped the field?

Table 1 presents an analysis of the top 10 active journals publishing on sarcopenia, along with their top-cited papers. The journal Nutrients published the most sarcopenia articles, with 199 papers. Its top-cited paper from 2017 discussed the gut-muscle axis in sarcopenia. With 197 papers, the Journal of Cachexia, Sarcopenia, and Muscle was second most active. Its top-cited 2016 paper presented the SARC-F diagnostic questionnaire. Other prolific journals were the Journal of Nutrition, Health, and Aging (129 papers), BMC Geriatrics (116 papers), and the Journal of the American Medical Directors Association (109 papers). Their landmark studies covered etiology, assessment tools, and consensus guidelines. Additional leading journals were Aging Clinical and Experimental Research, Experimental Gerontology, Journals of Gerontology A, and Scientific Reports. Their influential articles focused on nutrition, mechanisms, diagnosis criteria, and reference values. The Journal of Clinical Medicine rounds out the top 10 with 88 papers. Its top 2018 study presented exercise interventions.

To update, sarcopenia literature is dispersed across nutrition, gerontology, and clinical journals. Common themes in their milestone studies include consensus definitions, diagnostic methods, mechanisms, and lifestyle factors like diet and exercise. The active publishing venues highlight sarcopenia's multidisciplinary nature.

What are the common keyword themes and topics in sarcopenia publications over time based on author keyword analysis, and what new or emerging themes have gained prominence recently?

This study utilized bibliometric mapping to visualize the knowledge structure and research themes in sarcopenia literature. The title and abstract fields of publications from 1993–2023 were analyzed to discern key topics based on keyword frequencies. The binary counting method was applied with a threshold of at least 100 occurrences for the inclusion of terms. Of the 82,118 terms extracted, 407 crossed the threshold criteria. Relevance scores were calculated for each of the 407 terms based on metrics like average citations and average normalized citations. 60% of the most relevant terms, amounting to 244 keywords, were selected for mapping.

Co-occurrence network mapping was conducted on these 244 keywords in VOSviewer to identify clusters and connections between sarcopenia research themes. Occurrence analysis allows discernment of both established and emerging topics by weighing frequent keywords as well as rising terms. The visual mapping provides an aggregated overview of the intellectual landscape of sarcopenia literature over the last two decades. See Fig. 4.

Thematic clusters were delineated based on the proximity of keyword nodes, revealing core subject domains. The insights from this bibliometric mapping can elucidate prevalent areas of sarcopenia research as well as potential gaps to guide future work. Thus, there are three major clusters: (i) *physical function and disability*, (ii) *body composition and muscle metrics* and (iii) *clinical outcomes and prognosis*.

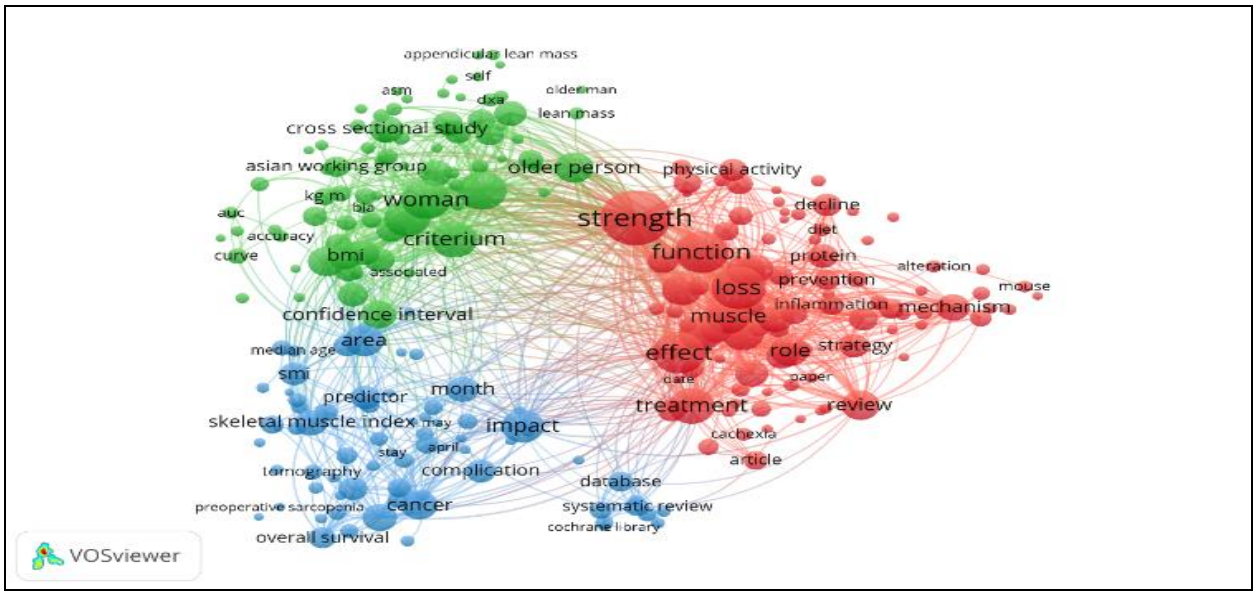

Figure 4. The occurrence analysis is based on the author's keywords from Vosviewer

Cluster 1 (Red): Physical Function and Disability

This large red cluster centers around sarcopenia's impacts on physical function and disability. Keywords like "gait speed", "walking", "mobility", "physical performance", and "disability" feature prominently, highlighting research on how sarcopenia affects ambulation, movement, and disability. Seminal studies in this group evaluate gait speed cutoffs to identify sarcopenic individuals at risk for mobility impairments (**Fujiwara & Wakabayashi, 2017; Salama et al., 2022**). Others examine links between sarcopenia and difficulty performing daily activities, increased falls, and loss of independence (**Duggan, Knight, & Romero-Ortuno, 2023; Roberto et al., 2023**). This reflects sarcopenia's significant burden on physical abilities and quality of life in older adults.

Cluster 2 (Green): Body Composition and Muscle Metrics

The green cluster contains keywords related to techniques for measuring muscle and body composition. Terms like "dual energy x-ray absorptiometry", "bioimpedance analysis", "skeletal muscle mass", and "skeletal muscle index" are central, emphasizing research on muscle mass quantification. Key studies assess optimal cut points and reference ranges for appendicular lean mass and skeletal muscle mass index. According to **Kawakami et al. (2022)** in their findings that fat-free mass index (FFMI) can be used as a simple surrogate marker for appendicular skeletal muscle mass index (ASMI) in screening for low muscle mass in sarcopenia. In addition, they also suggested that the FFMI cutoff values for predicting low muscle mass are <18 kg/m2 in men and <15 kg/m2 in women (**Kawakami et al., 2022**). This cluster highlights debates around techniques and thresholds for defining sarcopenia based on muscle mass. Standardizing these metrics is crucial to diagnosis and gauging severity. As further supported, different methods and terminologies hinder the diagnosis of sarcopenia, and normalization of muscle mass for body size and fat mass is important (**Walowski et al., 2020**).

Cluster 3 (Blue): Clinical Outcomes and Prognosis

Keywords in the blue cluster revolve around relating sarcopenia to clinical outcomes, like "length of hospital stay", "postoperative complications", "mortality", and "poor prognosis". Major publications investigate sarcopenia as a predictor of outcomes like hospitalization, post-surgery complications, and mortality in diseases (**Catherine Van Dongen et al., 2022; Ángela Santana Valenciano et al., 2023**). In fact, current evidence reports that sarcopenia was found to be a significant predictor of mortality in kidney transplant recipients (**Akihiro Kosoku et al., 2023**). This shows the growing recognition of sarcopenia's prognostic value across clinical settings and its impacts on healthcare utilization. In summary, the clusters capture sarcopenia's

multifaceted implications for physical ability, muscle wasting, and adverse health outcomes. The keyword groupings provide insights into active research themes concerning sarcopenia in older populations.

Table 1. The top 10 active journals and their cited papers

Journal	TP	Publisher	Cites Core 2022	SJR 2022	SNIP 2022	Most Cited Paper
Nutrients	199	Multidisciplinary Digital Publishing Institute (MDPI)	9.0	1.291	1.550	Aging Gut Microbiota at the Cross-Road between Nutrition, Physical Frailty, and Sarcopenia: Is There a Gut-Muscle Axis? (Ticinesi et al., 2017)
Journal of Cachexia Sarcopenia And Muscle	197	Wiley-Blackwell	13.0	2.159	2.243	SARC-F: a symptom score to predict persons with sarcopenia at risk for poor functional outcomes (Malmstrom, Miller, Simonsick, Ferrucci, & Morley, 2015)
Journal of Nutrition Health & Aging	129	Springer Nature	8.0	1.269	1.410	Sarcopenia: Its assessment, etiology, pathogenesis, consequences and future perspectives (Rolland et al., 2008)
Bmc Geriatrics	116	Springer Nature	5.1	1.127	1.546	Sarcopenia in daily practice: assessment and management (Beaudart et al., 2016)
Journal of The American Medical Directors Association	109	Elsevier	9.6	1.794	1.970	Sarcopenia in Asia: Consensus Report of the Asian Working Group for Sarcopenia (Chen et al., 2014)
Aging Clinical And Experimental Research	105	Springer Nature	7.3	0.982	1.306	Nutrition, frailty, and sarcopenia (Cruz-Jentoft, Kiesswetter, Drey, & Sieber, 2017)
Experimental Gerontology	101	Elsevier	6.7	0.937	1.017	The contribution of reactive oxygen species to sarcopenia and muscle ageing (Fulle et al., 2004)
Journals of Gerontology Series A-Biological Sciences And Medical Sciences	92	Oxford University Press	9.9	1.703	1.522	The FNIH Sarcopenia Project: Rationale, Study Description, Conference Recommendations, and Final Estimates (Studenski et al., 2014)
Scientific Reports	89	Springer Nature	7.5	0.973	1.312	Skeletal muscle cutoff values for sarcopenia diagnosis using T10 to L5 measurements in a healthy US population (Derstine et al., 2018)
Journal of Clinical Medicine	88	Multidisciplinary Digital Publishing Institute (MDPI)	5.4	0.935	1.179	The Effects of Group and Home-Based Exercise Programs in Elderly with Sarcopenia: A Randomized Controlled Trial (Tsekoura et al., 2018)

DISCUSSION

This bibliometric analysis provides a comprehensive visualization of sarcopenia literature's evolution, growth trends, research landscapes, and knowledge structure over the past two decades. Findings reveal the field's exponential expansion since an influential consensus definition paper in 2019 (Cruz-Jentoft et al., 2019). China leads in publication volume, though advanced economies like the US and Brazil show higher international collaboration, reflecting global recognition. Core journals span clinical medicine, gerontology, and nutrition, publishing seminal studies on consensus guidelines (Cruz-Jentoft et al., 2019), diagnostic methods (Malmstrom & Morley, 2013), and mechanisms (Marzetti, Anne Lees, Eva Wohlgemuth, &

Leeuwenburgh, 2009). The identified themes highlight established areas like physical function and emerging topics like obesity's role.

Sarcopenia research grew slowly until a landmark European consensus definition in 2010 (Cruz-Jentoft et al., 2019) provided standardized criteria, catalyzing exponential growth in publications. China contributes the highest volume, but lower international collaboration compared to Western countries, indicating research silos (Chen, Li, Ho, & Chau, 2021). Prolific institutions reside in Asia and Europe, led by Italy's Cattolica Sacro Cuore University. But Australian and Canadian centers also feature, showing widening global networks.

Keyword mapping identified three major clusters – physical disability, muscle metrics, and clinical outcomes. Disability keywords like "gait speed" and "mobility" reflect sarcopenia's impacts on function (Chun De Liao, Chen, Tsan Hon Liou, Lin, & Huang, 2022). Muscle metrics terms highlight debates regarding body composition techniques and cut-offs (Hilmi et al., 2019).

Clinical outcomes keywords signal growing prognostic value beyond geriatrics, like in cirrhosis (Liu, Ji, & Nguyen, 2023). This encapsulates sarcopenia's expanding significance beyond aging into wider specialties.

These findings reveal priority areas for future sarcopenia research. Consolidating muscle metrics and etiology requires more collaborative international studies (Delmonico & Beck, 2016). Exploring interventions through exercise trials and lifestyle factors can enhance clinical practice (Li et al., 2019). Thus, it is believed that the translating prognostic value and diagnoses across specialties via cross-disciplinary investigation is crucial for disseminating sarcopenia management.

This bibliometric analysis comprehensively synthesizes sarcopenia research growth, collaborations, and knowledge foundations, addressing the critical need for integration in this multifaceted field. The visualized knowledge topology sheds new light on maturity levels across domains, delineating strategic opportunities to accelerate this literature. Growth trajectory benchmarking indicates sarcopenia is transitioning from a niche focus toward an established, rapidly expanding field.

The findings spotlight gaps in lifestyle interventions, diagnostics, and translation while informing research priorities to fill these gaps. In particular, consolidated diagnostic techniques can facilitate clinical adoption. By elucidating conceptual themes, international links, demographics, and core journals, this analysis equips stakeholders with a roadmap to build upon established foundations while pioneering high-potential areas. It makes significant contributions toward integrating sarcopenia's intricate knowledge landscape and steering strategic growth at a pivotal juncture. This bibliometric mapping pave the way for transformative advancements in sarcopenia research, practice, and policy by cataloging the state of this emerging literature.

Limitations include incomplete analysis of citation trajectories and semantic content. Future bibliometric work can probe deeper into intellectual base linkages using citation network analysis. Text mining using semantic tools can provide more nuanced topical clusters and contextual insights. Nevertheless, this study's broad bibliometric approach provides value in visualizing the sarcopenia research landscape to direct future efforts. Subsequent analyses can leverage alternative techniques for deeper insights into knowledge structures.

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Dısclosure Statement

No conflict of interest was reported by the author.

Ethıcs Statement

Ethical approval is not required for this bibliometric paper because it involves the analysis of existing literature and doesn't involve human or animal subjects.

Author Contrıbutıon

Azliyana Azizan contributed to the study by participating in its conception and design, data collection, analysis, drafting the article, and its critical revision, ultimately granting final approval for publication.

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RESEARCH ARTICLE

Cluster Method: Effects on Performance in Handball

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Abstract
The aim of this study was to examine the effects of six week traditional and cluster training method applied in female handball players on speed, strength and throwing power. 32 handball players participated in this study. 16 athletes were assigned in the Cluster Training Group (CTG), 16 athletes in the Traditional Training Group (TTG). The training continued for six weeks, three days a week, during the preparation period of the annual training program. Both groups practiced leg extension/flexion, pulldown, butterfly, bench press, deep squat. The CTG performed 80% of repetition maximum (1RM), 4 repetitions with a 20-second rest, total of 12 repetitions and 2 sets. The TTG, on the other hand, performed 80% of 1RM, 12 repetitions, 2-3-minute rest between sets, and again 2 sets. At the beginning and end of the training, 10 and 20 m speed, hand grip strength, standing long jump, vertical jump, throwing speed, squat and bench press performance measurements were recorded. A statistically significant difference was found in the performance values within the group ($p<0.05$). A statistically significant difference was found between groups in the vertical jump and standing long jump ($p<0.05$). There was no statistically significant difference between groups in terms of the other performances ($p>0.05$). As a result, it was seen that the cluster method was effective on the development of the jump force. Considering the difference between cluster and traditional training methods, we can say that the cluster method provides more advantages than the traditional method in branches that require explosive strength.

Keywords
Cluster Training Method, Handball, Strength, Performance

INTRODUCTION

In handball, it is necessary to have a physical effort capacity that can resist violent contacts and short/high-intensity physical actions during trainings and games (**Bragazzi et. al., 2020**). In addition to technical and tactical skills, muscle strength and power (maximal isometric power) cannot be ignored in order to achieve success in both men's and women's handball (**Cherif et. al., 2016; Kohlmeier, 2015**).

Experiencing numerous high-intensity physical actions during the competition requires a high level of strength, which is to be maintained for a long time. Maximal strength, power, speed, endurance, and the Throwing speed are essential factors for success in elite handball (15). Throwing speed is very important in branches such as handball, baseball, throwing speed, and volleyball where overarm shots are dominant (**Andrade et. al., 2016**). The power produced during the shot will also affect the throwing speed. The ability of the player to dispose of the ball is directly related to the speed of the shot (**Debanne & Laffaye, 2013**). However, the strength in the arm should be evaluated not only with the upper extremity, but also with the throwing technique, the harmony of the body parts at this time, and the strength of the lower extremity.

The factors that determine performance in handball are explosive features such as strength, jump (vertical or horizontal), and speed (10 and 20 m sprint time). In handball, performance should be evaluated by measuring variables such as muscle

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strength, speed, and resistance (**Marques et. al., 2011; Póvoas et. al., 2014**).

The training methods to be applied in the training program play an important role. A plan prepared according to the purpose prevents over-training, provides adaptation, increases the motivation of the athlete, and increases the performance output. In the preparation of the training program, the intensity, frequency, scope, and type of the exercise vary depending on the feature and method to be developed. Newer methods lead to faster improvement in performance, but the more familiar an athlete is with the training, the slower the improvement in performance (**Hodges et. al., 2005**)

Traditional strength training can be characterized as exercises involving the general physiological adaptation of the body. This adaptation can be examined in two parts as neurological and morphological. Neurologically, it covers neurological factors such as muscle synchronization, motor unit activation, reflex tendons, and corpuscles. Morphologically, it includes changes in muscle size, muscle hypertrophy, muscle fibers, and muscle structure. In traditional strength training, the structure of a set requires performing it in a continuous fashion with no rest between each repetition of the set. In other words, it is the continuous application of repetitions by interrupting them with long rest intervals. In such a set structure, a 10-30 second repetition rest interval is used between each repetition performed (**Haff et. al., 2003**). As an example, in a set designed based on the classical method, 80% of 1RM training plan can be 6 repetitions, 3 sets, and a 1-2-minute rest between sets.

The variety in training is necessary for the athletes both to get used to their personal tasks more easily and to improve their performance quickly by keeping them away from overloads. Various parameters such as the number of repetitions, the number of sets, and the variety of movements can be used to make variety in training. Making changes in the structure of the set has recently been studied by sports experts. The newest approach to the structure of the set is the Cluster method (CM) method.

In CM, you have a pre-set training intensity and weight load. CM is a technique that emerged to slightly reduce the metabolic fatigue that occurs during traditional “no rest” sets. It is a method in which a set is divided into sets and a short rest interval is performed. In practice, the purpose of short rests (10-30 seconds) between repetitions is to provide efficient rests between repetitions and to ensure that the next repetition gives higher quality results. Due to the rests between repetitions and sets, more power output is achieved with the same load intensity compared to the traditional training method. During strength training, it causes less neuromuscular fatigue than the traditional set method, increases the nervous systems muscle contraction level, and prevents power losses. It has been observed that CM is more effective than RM and there is more strength development especially in vertical jump (**McArdle et. al., 2010; Sancez-Moreno et. al., 2016**).

Variable rest intervals can be used in the cluster method, or the resistance can be changed in each or several repetitions of the set depending on the purpose. In this method, unlike the traditional method (RM), the aim is to give short rest intervals between loads, to prevent injuries, and to replenish phosphocreatine stores (**Cin et. al., 2021**).

Creatine phosphate is the main high-energy, phosphate-storage molecule of muscle. In rested muscle, creatine phosphate is the predominant form; its maximal concentration is five times higher than that of ATP (**Kohlmeier, 2015**). For these reasons it is important to give short rest intervals between loads. When studies conducted so far are examined, effects of the cluster method on these performance parameters in handball has not been researched yet, to the best of our knowledge.

The aim of this study was to examine the effects of a six-week traditional and cluster training method administered in female handball players on speed, strength, and throwing power.

MATERIALS AND METHODS

Study participants

Thirty-two elite female handball players voluntarily participated in this study. Athletes were given detailed information about the study, an "informed consent form" was filled, and their consent was obtained. Research procedures were carried out in accordance with the human research ethical standards of the 2008 Principles of the Declaration of Helsinki. The demographic characteristics of the athletes are given in Table 1.

Table 1. Demographic characteristics of athletes

Variables	CTG			TTG		
	Range		Mean±Std.Dev.	Range		Mean±Std.Dev.
Height (cm)	164	184	173.35±5.66	1.69	1.85	1.74±0.03
Weight (kg)	52	78	64.71±6.54	58	80	67±6.23
Age (year)	20	30	24.21±2.87	18	38	26.20±6.16
Sport age (year)	10	20	13.85±2.74	8	31	15.73±6.76
NationalAthletes	3	75	34.64±20.89	2	150	34.8±41.95

Study organization

In order to minimize the fatigue factor in all the athletes in our study, physical exercise was discouraged for 24 hours before the measurements. A 15-minute general warm-up protocol was just before the study. Standard food and fluid intake was maintained throughout the training. Beverages containing caffeine were prohibited for 4 hours before measurements and no food was consumed 2 hours before. All athletes slept at least 7 hours per night during the training period and verbal encouragement was used for maximum effort throughout the training period. Sixteen athletes were randomly assigned to the CTG and 16 athletes to the TTG. The training continued for six weeks, three days a week, during the preparation period of the annual training program. Both groups practiced leg extension/flexion, pulldown, butterfly, bench press, and deep squat movements. The CTG performed 4 repetitions of 20 seconds rest in 80% of 1RM, totaling 12 repetitions and 2 sets (Table 2). On the other hand, the TTG applied 2 sets of 12 repetitions, resting 2-3 minutes between sets in 80% of 1RM. Data were collected just before and after the 6-week period (10 and 20 m sprint, hand grip strength, standing long jump, vertical jump and speed, squat and bench press).

Table 2. Cluster and traditional training

				Rest	
Group	Intensity	Number of repetitions	Set	Rest between repetitions	Rest between sets
CM	80% of 1 max rep	4x3 (12)	2	20 sec	5 min
TM	80% of 1 max rep	12	2	-	2-3 min

Data collection

The height of the athletes was measured bare feet with a Sega brand height measuring instrument with a sensitivity of 0.01 cm. A Baster brand scale with a precision of 0.1 kg was used for body weight measurement. The 10 m and 20 m speed measurements of the athletes were measured using the Microgate Witty photocell, with a precision of 0.01 second. The start and finish lines were clearly marked with cones. Each athlete completed two runs with a 3-minute rest period between sprints. Each athlete performed two rapid training tests with a rest period of 3 minutes in between. The best performance of the two repeated sprint tests was recorded.

For hand grip strength, right and left hand grip strength was measured using a digital hand dynamometer (CAMRY). The athletes grasped the measuring instrument for 2 seconds while standing, with their arms straight and without touching any part of their body to the dynamometer. Athletes practiced with each hand twice (alternately right and left) and rested for 1 minute between trials and their best values were recorded.

A tape measure was used for standing long jump measurement. The starting line was determined and a 3-m tape measure with 1-cm interval was fixed. The athlete stood without touching the starting line and jumped forward with both legs and the last point of contact with the body was measured from the front of the jump line. The athletes did not cut contact with the ground before jumping during the long jump. Each athlete repeated the jump twice and the best value was recorded. An Optojump Next® device was

used for vertical jump measurement (Microgate, Bolzano, Italy). Device installation and data acquisition were carried out in accordance with the manufacturer's recommendations. The athletes were asked to kneel down at the highest possible speed and jump vertically, keeping their hands at the waist, their knees fully extended, and their body in an upright position. Each athlete repeated the movement twice and the best value was recorded.

Throwing speeds were measured with the Speed Sport Radar brand radar instrument. The ball throwing speeds of the handball players were measured by standing behind the 7m line with the dominant (D) arm. The handball players were asked to shoot at the highest speed they could apply, and the best value was recorded by having each athlete perform twice.

Statistical analysis

Regarding the normal distribution assumptions of the 1st and 2nd measurement of the variables, all variables were found to have a normal distribution (p value > α=0.05) and parametric tests were used in the analysis. Statistical properties of the variables, such as mean and standard deviation, according to groups and measurements are presented. Normality assumptions of the variables were examined with the Kolmogorov-Smirnov test. Parametric tests were used since the variables had a normal distribution (p value > α=0.05). The analyses between the 1st measurement and the 2nd measurement within groups were made with the Paired Sample t Test. The analyses of differences between the two measurements and between the groups were made with the Independent Sample t Test. The IBM-SPSS-21 program was used in the analysis of the data.

RESULTS

Table 3. Relationship between CTG and TTG performance values

Variables		CTG			TTG		
		Mean±Std.Dev.		Sig.	Mean±Std.Dev.		Sig.
Left hand grip strength (kg)	M 1	31.575	4.027	0.000*	31.774	3.669	0.000*
	M 2	35.213	3.152		33.956	3.634	
Right hand grip strength (kg)	M 1	34.742	3.986	0.000*	34.273	3.572	0.000*
	M2	39.113	4.341		37.175	3.491	
Vertical jump (cm)	M 1	31.919	4.009	0.000*	30.389	3.579	0.000*
	M 2	36.063	3.494		31.818	3.105	
10 m speed (sec)	M 1	1.933	0.102	0.000*	1.298	0.052	0.012*
	M2	1.859	0.106		1.931	0.055	
20 m speed (sec)	M 1	3.412	0.125	0.023*	3.481	0.1	0.010*
	M 2	3.348	0.159		3.437	0.091	
Standing long jump (m)	M 1	1.892	0.16	0.000*	1.898	0.165	0.546
	M2	2.011	0.106		1.914	0.161	
Throwing speed (km/h)	M 1	67.188	3.692	0.000*	65.625	3.649	0.000*
	M 2	71.375	3.052		67.938	3.821	
Squats (kg)	M 1	144.438	16.967	0.000*	111	17.662	0.000*
	M2	165.831	16.221		126.963	20.778	
Bench press (kg)	M 1	55.056	4.699	0.000*	46.388	5.808	0.000*
	M 2	71.094	7.303		59.056	6.066	

(p value> α=0.05)- M: Measurement

A statistically significant difference was found between M 1 and 2 in left-right hand grip strength, vertical jump, 10m-20m sprint, standing long jump, throwing speed, squat and bench measurement results in both groups (p=0.000 <α= 0.05) (Table 3).

Table 4. Performance values between groups

	Group	Mean±Std.Dev.	Sig.	Difference
Left hand grip strength	CTG	3.638±2.583	0.076	-
	TTG	2.183±1.823		
Right hand grip strength	CTG	4.375±2.253	0.068	-
	TTG	2.902±2.145		
Vertical jump	CTG	4.144±1.756	0.000*	1>2
	TTG	1.429±1.31		
10m speed	CTG	0.074±0.063	0.306	-
	TTG	0.049±0.069		
20m speed	CTG	0.064±0.101	0.514	-
	TTG	0.044±0.061		
Standing long jump	CTG	0.119±0.094	0.007*	1>2
	TTG	0.016±0.105		
Throwing speed	CTG	4.188±2.949	0.053	-
	TTG	2.313±2.272		
Squat	CTG	21.394±8.646	0.048	-
	TTG	15.963±6.03		
Bench press	CTG	16.038±5.336	0.068	-
	TTG	12.669±4.7		

(p value> α=0.05)

According to the differences of the variables between the 1st and 2nd measurements and the results of the independent samples t-test performed between the groups, a statistically significant difference was found between the groups regarding the vertical jump and the standing long jump ($p=0.000 <\alpha=0.05$, $p=0.007 <\alpha=0.05$). No statistically significant difference was found between the groups regarding the other performances ($p=0.076> \alpha=0.05$, $p=0.068 > \alpha=0.05$, $p=0.402 > \alpha=0.05$, $p=0.306 > \alpha=0.05$, $p= 0.514 > \alpha=0.05$, $p=0.053 > \alpha=0.05$, $p=0.048 < \alpha=0.05$, $p=0.068 > \alpha=0.05$). The differences found were due to the cluster group. The performance difference (vertical jump and standing long jump) between M 1 and 2 of the CTG was more (effective) than that in the TTG (Table 4).

DISCUSSION

In this study, it was determined that CM and RM strength training increased performance in both groups. When the performance differences between the groups were examined, CM was significantly more effective than RM in vertical jump and standing long jump.

Artacho et al. (**2018**) divided 19 athletes into two groups as CM group and RM group and applied the countermovement jump exercise for 3 weeks. The effects of CM on strength and velocity were examined. As a result of the study, while the CTG showed an increase in both speed and strength performance, there was no statistical difference in the TMG. **Cin et al.** (**2021**) conducted a study in elite volleyball players and stated that CMG showed higher significant gains in 1RM strength, sprint time, vertical jump, and agility compared to TMG. **Zarezadeh Mehrizi et al.** (**2013**) reported that CM applied in 22 male soccer players for 3 weeks showed higher strength improvements than TM, whereas higher gains were noted in the development of 90° knee flexion in RM. **Moreno et al.** (**2014**) emphasized that coaches had their athletes do 2-5 jumps with a 27-45 seconds rest and they argued that this will reduce fatigue and allow more eccentric sequential reloads. **Haff et al.** (**2018**) emphasized the importance of the number of sets and repetitions in training as well as rest intervals to achieve the highest efficiency in training, and argued that short rests between repetitions will have a positive effect on performance. In their study, the TMG applied 1 set of 5 repetitions with clean pull exercise and the CMG applied 5 sets of 1 repetition with 30 seconds of rest between sets, and they concluded that the average power outputs were much higher in the CMG. Asadi and Ramirez (Asadi Ramírez-Campillo) examined the effects of plyometric exercises applied 2 days a week for 6 weeks on standing long jump performance. In the study, the CMG applied 5 sets of 10 repetitions, with 30-second rests between repetitions and 90-second rests between sets, whereas the TMG applied 5

sets of 20 repetitions with 2-minute rests between repetitions.

In our study, there was an increase in performance in both training methods applied in bench press and squat exercises, but there was no difference in performance increase between the two methods. **Lawton et al.** (**2006**) performed the bench press exercise in their study with 12 basketball players and 14 football players and classified the athletes as TMG and 3 different CMG groups. In the TMG, there was a decrease in strength with each repetition, but there was no significant difference between CMGs. Again, **Davies et. al.** (**2022**) examined bench press performance in a study they conducted in 20 trained athletes for six weeks. The CMG performed 6 sets of five repetitions at 85% 1RM, with 30 seconds rest between repetitions, and a 3-minute rest between sets. The GMG performed three sets of five repetitions at 85% 1RM with a 5-minute rest between sets. They found that bench press exercise in CM did not have any muscle performance advantage over TM. **Tufano et al.** (**2016**) studied the squat exercise with 20 athletes performing strength training in their acute effect study. They divided the athletes into three groups as traditional, cluster 2, and cluster 4. The athletes applied the traditional method with 3 sets of 12 repetitions with a rest of 120 seconds between sets. Cluster 2 method was applied as 3 sets of 3 repetitions with a 120-second rest between sets. Cluster 4 method was applied with 3 sets of 6 units of 2 repetitions with a 120-second rest between sets and a 30-second rest between repetitions. As a result, cluster 4 performed in two repetitions yielded statistically better results compared TM results; it yielded statistically better results in some parameters compared to cluster 2 results, which was performed in four repetitions. It provided better results in terms of performance compared the rest of the groups.

Oliver et al. (**2015**) examined the squat exercise in two groups as TM and CM in the study they conducted with 24 students. Students performed TM with 4 sets of 10 repetitions with a rest of 120 seconds between sets. They applied CM with 4 sets of 2 units of 5 repetitions with a 90-second rest between sets and a 30-second rest between repetitions. They stated that CM produced more power than TM.

In another study, **Haff et al.** (**2003**) had 8 athletes and 5 weightlifters perform clean pulls. They were divided into three separate groups as traditional, cluster 1, and undulating cluster. The power output performance of the three groups was evaluated. While there was a decrease in power output (peak power) in the traditional setting, Cluster 1 maintained its peak power at each repetition. In the method where the intensity parameter between repetitions changed (Undulating Cluster), power output changed according to the intensity of repetition.

Hansen et al. (**2011**) applied the squat jump exercise in 20 rugby players. They divided the athletes into four groups as TM, CM 1, CM 2, and CM 3. As a result of the study, it was seen that CMs performed better than TM at the highest power and highest speed values, while CMs with less repetitions were more effective. **Latella et al.** (**2019**) stated that acute resistance exercises with CM maximize neuromuscular performance, especially reduce speed and power loss.

Sports scientists argues that changing the traditional set structure by dividing the number of sets more and shortening the rest time between sets will be more effective in the development of quick strength (**Bompa, 2017; Haff et. al., 2008**). As a result, in this study, it was seen that the Cluster method was effective on the development of jump force and explosive force. Considering the difference between cluster and traditional training methods, it can be concluded that CM provides more advantages than TM in branches that require explosive strength. In maximal strength training in handball, the cluster method has a positive effect on jumping force and explosive force performance and the applicability of this method in handball is supported. Nevertheless, although the benefits of the cluster method are strongly suggested in the literature, we can say that more comprehensive studies are needed by considering the differences in age, sports age, gender, number of groups, and exercises performed in sports branches.

Conflict of interest

The authors declare no conflicts of interest. No financial support has been received.

Ethics Committee

This study was approved by Zonguldak Bülent Ecevit University Non-Interventional Research Ethics Committee on 02.11.2022 with decision number 2022/19.

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Author Contributions

Study Design, SE, NE; Data Collection, SE; Statistical Analysis, NE; Data Interpretation, SE, NE; Manuscript Preparation, SE, NE; Literature Search, SE, NE. The published version of the manuscript has been read and approved by all authors.

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RESEARCH ARTICLE

The Effect of The Strength of The Center Muscles on Improving the Level of Technical Performance of Some Stability Movements on the Mat of Floor Movements

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Abstract
The purpose of this research was to determine whether some stability exercises performed on the floor exercise mat to increase core strength would improve the technical application level of students. Method: A sample of 39 young male students from a university (age = 22.1±1.2 years, height = 170.3±6.5 cm, weight 65.2±8.7 kg, Body Mass Index = 22.5±2.8) participated in the study. The participants were into the control group (n=19) and experimental group (n=20) completed pre-tests and post-tests. The CS was assessed by the Stability Movement Push-ups, Abdominals, Back, Pull-ups, Headstand. The results of the paired samples t-tests show that the experimental group had a significant improvement in the mean scores for all four movements on the post-test compared to the pre-test. The mean score for the push-ups increased from 4.9±1.2 to 7.5±1.3 ($t(14)=-10.78$, $p<0.001$), the mean score for the abdominals and headstand increased from 4.6±1.0 to 7.0±1.2 ($t(14)=-10.14$, $p<0.001$), the mean score for the back and handstand increased from 4.8±1.1 to 6.9±1.2 ($t(14)=-7.86$, $p<0.001$), and the mean score for the pull-ups increased from 4.7±1.0 to 7.3±1.1 ($t(14)=-11.47$, $p<0.001$). Since the p values of the four movements are lower than 0.001, it is seen that there is a statistically significant difference between the scores obtained in the pre-test and the scores obtained in the post-test. According to the results, working out the core muscles may help enhance the technical execution of stability exercises performed on the mat or floor.

Keywords
Center Muscles, Technical Performance, Stability Movements, Mat, Floor Movements

INTRODUCTION

Core stability (CS) is the ability to control the position and movement of the trunk over the pelvis; Therefore, it has an important function on postural control. Recently, exercises that strengthen and stabilize the core musculature have become part of conditioning programs for recreationally physically active individuals as well as competitive athletes. These exercises are often performed alone or in combination with body strengthening exercises under stable and unstable conditions. The intervention usually lasts 4 to 8 weeks; twice a week, lasting 25–45 minutes and 60–75 minutes when part of a warm-up. It is performed as part of the standard training program (**Kumar And Zemková, 2022; Sannicadro et al., 2017**).

Training programs that focus on improving core muscle strength, muscular endurance, and postural and core stability have also been found to improve functional movements and therefore athletic performance. While core strengthening exercises increase the activation of local stabilizers and global mobilizers and facilitate the transfer of muscle power, core stabilization exercises improve

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control of the lumbar spine. **Luo et al** (**2022**), A recent systematic review by also showed that overall movement control and force transfer to the terminal segment during athletic tasks can be optimized with core strength exercises; Therefore, they should be included in daily training routines.

Additionally, since these exercises provide stability to the core musculature for effective control of body movements and force production in the lower extremities, its deficiency or imbalance can increase fatigue and reduce muscular endurance, leading to greater susceptibility to injuries. In athletic environment, CS involves dynamically controlling and transferring large forces from the upper and lower extremities through the core to maximize performance and promote efficient biomechanics (**Cabrejas et al., 2022; Barr et al., 2007**).

Movements that need stability are an essential component of a wide variety of different types of physical activity, including sports, dance, and gymnastics. These motions call for a very high degree of coordination, as well as balance and the ability to maintain control over the body's center of mass. The body's weight is concentrated at the center of mass, which is found at the body's midline and corresponds to the place at where the center of mass is situated. The center of gravity and the center of mass are both names for the same location. A collection of muscles known as the center muscles is responsible for controlling the location of the center of mass. The transverse abdominis, the rectus abdominis, the internal and external obliques, and the erector spinae are all considered to be part of these muscles. These muscles are very important for the stabilization of the spine, the maintenance of posture, and the regulation of movement.

The link between the strength of the core muscles and the capacity to execute stability movements has been the subject of investigation in a number of different research. For instance, a research conducted by **Willardson et al.** (**2009**) discovered that a six-week training program that concentrated on strengthening the core muscles resulted to a considerable improvement in the execution of stability exercises among college-aged women. This finding was based on the participants' ability to execute the motions. In a similar vein, a research conducted by **Behm et al.** (**2005**) found that older people' stability and balance improved after participating in a training program that concentrated on strengthening the core muscles for a period of four weeks.

Previous study has indicated that strengthening the core muscles may enhance the performance of stability movements; however, there is currently a paucity of research on the particular influence that strengthening the core muscles has on the technical performance of stability exercises on the mat or floor motions. Moreover, the power of the core muscles is essential while doing different stability activities on the floor mat. The amount to which the strength of the core muscles impacts the technical execution of these motions, however, has not been well researched. As a result, there is a need to explore the influence of core muscle strength on the technical execution of stability exercises on the floor mat. Therefore, this research aims to evaluate the influence that the strength of the center muscles has on enhancing the technical performance of stability movements on the mat of floor exercises.

MATERIALS AND METHODS

Participants

The study population will consist of all students enrolled in the College of Physical Education and Sports Science at Palestine Technical University - Kadoorie during the academic year 2021/2022. The total number of students in the population is 236, according to the records of the Student Affairs Deanship. The participants in the study were 39 students majoring in physical education at the College of Physical Education and Sports Science, Palestine Technical University Kadoorie during the academic year 2022. Thirty nine male students were randomly divided into two groups (Table 1). Experimental group 1 underwent core strengthening training and group 2 was the control. Participants were informed about the main purpose of this study and related procedures. They were examined by a qualified physician and all of them were fit for participating in this study. Participants were free to withdraw their consent if they felt any discomfort during training programs. There were no dropouts in this study. The procedures followed were in accordance with the ethical standards on human experimentation stated in compliance with the 1964 Helsinki Declaration and its later amendments. This research has been approved by the Scientific and Technical Committee Ethical

Committee of the College of Physical Education and Sports Sciences, Palestine Technical University -khdoorie in 17Sep.2023.Additional precautions were taken by the investigator(s) to protect the volunteers in this study. The following were the criteria for inclusion in the study: no history of musculoskeletal ailments or conditions that might limit their ability to do the exercises; no present involvement in any regular exercise program; and no previous experience with stability movements on the mat or floor movements.

Table 1. Characteristics of participants (Mean ±SD)

Variable	Experimental Group	Control Group
Age (years)	22.1±1.2	21.8±1.4
Height (cm)	170.3±6.5	169.8±5.8
Weight (kg)	65.2±8.7	64.8±7.9
Body Mass Index(kg/m²)	22.5±2.8	22.6±2.4

Experimental Protocol

Group 1 underwent core strengthening training that included exercises such as Exercises that targeted the rectus abdominis, the transverse abdominis, the internal and external obliques, and the erector spinae were included in the program. The push-ups, the abdomens, the handstand, the headstand, the back and the pull-ups were among of the exercises that were performed (3–4 sets of each exercise with 8-12 repetitions per set). The increase in training load reflected individual capacity to respond and adapt to particular exercise. Interventions were administrated for a duration of 6 weeks. The number of sessions per week was confined to three alternative days and each session lasted 45 minutes a day. Experimental group underwent their respective training program simultaneously under the supervision of the research scholar. Control group 2 was not exposed to any conditioning program (**Kumar & Zemková, 2022**).

The technical performance of the participants in stability movements was evaluated by administering a pre-test and a post-test that comprised four activities. These movements were the push-ups, the abdomens, the handstand, the headstand, the back and the pull-ups. The exercises were carried out on a mat that was placed on the floor, and the participants were given the instruction to hold each movement for as long as they could while still preserving their correct form. The execution of each movement was graded using a grading system that assigned points based on whether or not the body was aligned properly, whether or not the core was stable, and whether or not the movement was controlled. There was a maximum score of ten points available for each movement. After the training program, both groups will be reassessed for their level of strength of the center muscles and technical performance of stability movements on the floor mat (Rahimi et al., 2020).

Measurements

Instruments and Testing Procedures

The researchers measured the power of the core muscles using a digital dynamometer (produced by Lafayette Instrument, located in Lafayette, Indiana, United States). In order to guarantee that the dynamometer would provide accurate results, it was calibrated before each test. The participants were instructed to lie face down on the floor with their knees bent and their feet planted firmly on the surface. They were given the instruction to bring their shoulders up off the floor while maintaining touch with the floor with their lower backs. The dynamometer was positioned such that it was resting on their belly, and they were given instructions to tense their abdominal muscles as forcefully as they could for a period of three seconds. There were three separate measurements collected, and the mean value was the one that was utilized for the study.

Statistical Analyses

The data were analyzed using version 25 of the SPSS program. For the purpose of describing the characteristics of the research sample, descriptive statistics were used. Participants' descriptive data are presented as mean ± standard deviation (SD). Descriptive data from the inferential analysis are the estimated marginal means with a 95% confidence interval (CI; lower limit to upper limit). Comparing the mean scores

of the experimental group with the control group on the pre-test and the post-test was accomplished via the use of independent samples t-tests. Comparing the average scores of the experimental group on the pre-test and the post-test was accomplished via the use of paired samples t-tests. The threshold for statistical significance was established at $p < 0.05$.

RESULTS

Table 1 summarizes the features of the sample utilized in the experiment. Body mass index, height, age, and weight did not vary substantially between the control and experimental groups.

The results of the pre-test and post-test for both the experimental group and the control group are shown in Table 2, together with the mean scores and standard deviations for each group. The findings of the independent samples t-tests indicate that the experimental group and the control group did not significantly vary from one another on the pre-test. On the post-test, however, there were discernible differences between the performance of the experimental group and that of the control group in each of the four motions. The experimental group had significantly higher mean scores than the control group for the push-ups ($t(28)=3.48$, $p=0.002$), the abdominals and headstand ($t(28)=3.16$, $p=0.004$), the back and handstand ($t(28)=2.83$, $p=0.008$), and the pull-ups ($t(28)=3.05$, $p=0.005$).

Table 2. Mean scores and standard deviations of the experimental and control groups on the Pre-Test and Post-Test.

Movement	Pre-Test Scores Experimental	Post-Test Scores Experimental*	Pre-Test Scores Control	Post-Test Scores Control
Push-ups	4.9±1.2	7.5±1.3*	4.8±1.1	5.4±1.1
Abdominals	4.6±1.0	7.0±1.2*	4.4±1.0	4.8±1.0
Back	4.8±1.1	6.9±1.2*	4.7±1.0	5.1±1.0
Pull-ups	4.7±1.0	7.3±1.1*	4.6±1.0	5.2±1.0
Headstand	4.6±1.0	7.0±1.2*	4.4±1.0	4.8±1.0
Handstand	4.8±1.1	6.9±1.2*	4.7±1.0	5.1±1.0

(*) indicates a substantial variation among between the control and experimental groups at $p<0.05$.

The results of the paired samples t-tests show that the experimental group had a significant improvement in the mean scores for all four movements on the post-test compared to the pre-test. The mean score for the push-ups increased from 4.9±1.2 to 7.5±1.3 ($t(14)=-10.78$, $p<0.001$), the mean score for the abdominals and headstand increased from 4.6±1.0 to 7.0±1.2 ($t(14)=-10.14$, $p<0.001$), the mean score for the back and handstand increased from 4.8±1.1 to 6.9±1.2 ($t(14)=-7.86$, $p<0.001$), and the mean score for the pull-ups increased from 4.7±1.0 to 7.3±1.1 ($t(14)=-11.47$, $p<0.001$).

Based on these findings, it seems that training for core muscular strength has the potential to considerably enhance the technical execution of stability exercises performed on the mat or floor. The fact that there were statistically significant differences in the post-test scores of the experimental and control groups for each of the four motions suggests that the improvement in technical performance was brought on by the strength training in the center muscles and not by any other variables.

Effect Sizes (Cohen's d) on the Pre-Test and Post-Test for the Experimental Group and the Control Group are presented in Table 3.

Table 3. The impact values (Cohen's d) of both control and experimental groups on the pre-and post-tests.

Stability Movement	Effect Size (Cohen's d)
Push-ups	2.4 (very large)
Abdominals	3.4 (very large)
Back	2.8 (very large)
Pull-ups	4.7 (very large)
Headstand	2.9 (very large)
Handstand	3.5 (very large)

The results of the pre-test and post-test for each of the four stability movements are shown in Table 3, together with the effect sizes, as measured by Cohen's d, for both the experimental and control groups. Taking into consideration the degree to which the two groups' mean scores vary from one another, the effect size estimates the magnitude of the difference between the two sets of results. When comparing the two groups, an effect size that is huge suggests that there is a considerable difference between them, whereas an effect size that is little implies that there is just a minimum difference.

Both the experimental and control groups had comparable levels of technical ability at the beginning of the research, as shown by the fact that the effect sizes for the pre-test scores of the experimental and control groups were minor for all four movements. On the other hand, the effect sizes for the experimental group were big for all four actions on the post-test, which indicates that the center muscle strength training led to a considerable improvement in the technical performance of the participants.

The effect size for the push-ups in the experimental group came in at 2.4, suggesting that it had a very significant impact on the group. It was determined that the experimental group had an effect size of 3.4 and 3.5 for the abdominals and handstand, respectively, which indicates a very substantial effect size. A very substantial effect size was indicated by the fact that the effect size for the back and headstand in the experimental group was 2.8 and 2.9, respectively. The effect size for the pull-ups in the experimental group came in at 4.7, suggesting that it had a very big impact on the results.

Based on these findings, it seems that the strength training of the core muscles had a strong and considerable influence on the technical execution of stability exercises performed on the mat and floor. The fact that the center muscle strength training had such a significant influence on the participants' ability to do all four actions is supported by the fact that the effect sizes for those activities were rather substantial. The paired samples t-test is shown in Table 4.

Table 4. Paired samples t-test results for the experimental group.

Stability Movement	Mean Pre- Test Score	Mean Post-Test Score	Paired Samples t-test p-value
Push-ups	15.2	22.8	<0.001
Abdominals	12.4	21.6	<0.001
Back	14.5	22.2	<0.001
Pull-ups	11.1	20.5	<0.001
Headstand	11.3	20.6	<0.001
Handstand	13.7	22.1	<0.001

*p<0.05

The outcomes of the paired samples t-test conducted on the group that participated in the experiment are shown in Table 4. This test makes a comparison between the scores acquired for each of the four stability movements during the pre-test and the scores obtained during the post-test. The pre-test scores and the post-test scores of the same group are used as examples in the paired samples t-test, which is a statistical test that compares the mean scores of two related samples, such as the pre-test and post-test scores. This test is used to determine whether or not there is a significant difference between the two sets of scores.

According to the results of the paired samples t-test, the experimental group's mean scores on the post-test for all four movements were significantly higher than their mean scores on the pre-test. These findings were shown to be the case when comparing the pre-test and post-test scores. This was true for both the pre-test and the post-test, therefore this conclusion may be drawn. It seems that there was a statistically significant difference between the scores that were received during the pre-test and those that were gained during the post-test since the p-values for all four movements were lower than 0.001, which indicates that there was a statistically significant difference between the two sets of scores. The findings of the paired samples t-test indicate that the experimental group's mean scores on the post-test for all four movements were substantially higher than their mean scores on the pre-test. This was the case for both the pre-test and the post-test. The p-values for all four motions were lower than 0.001, suggesting that there was a statistically significant difference between the scores obtained during the pre-test and those

obtained during the post-test. The mean pre-test scores ranged from 11.1 for the pull-ups movement to 15.2 for the push-ups movement. The mean post-test scores ranged from 20.5 for the pull-ups movement to 22.8 for the push-ups movement. This indicates a substantial improvement in the technical performance of all four stability movements after the center muscle strength training. The large differences between the mean pre-test and post-test scores, combined with the statistically significant p-values, provide strong evidence that the center muscle strength training had a positive effect on the technical performance of stability movements on the mat of floor movements. The paired samples t-test results indicate that the improvement in technical performance was not due to chance or other factors, but rather to the center muscle strength training. These findings provide even more credence to the hypothesis that strengthening one's core muscles via resistance exercises might enhance one's ability to execute technically demanding stability movements on a mat or floor. The fact that the participants' overall performance on the post-test significantly improved when compared to their performance on the pre-test suggests that the participants' ability to execute the actions was improved as a result of the participants' participation in the center muscle strength training.

DISCUSSION

The purpose of this research was to determine whether or not increasing the strength of the core muscles may improve the technical execution of stability exercises performed on a mat or floor. In comparison to the group that served as the control, the members of the experimental group demonstrated a substantial rise in their level of technical performance throughout the stability movements. According to **Hassan** (**2017**), **Chang et al.** (**2020**), and **Suner-Keklik et al**. (**2021**), strengthening the core muscles may have a beneficial influence on the technical execution of stability exercises performed on the mat or floor.

The six-week training program that concentrated on developing the core muscles was responsible for the observed increases in the experimental group's technical performance, which may be ascribed to the fact that the program was designed to strengthen the core muscles. Exercises that targeted the rectus abdominis, the transverse abdominis, the internal and external obliques, and the erector spinae were included in the training program (**Park and Park, 2019**). By strengthening these muscles, individual may increase the body's capacity to regulate and stabilize itself during stability exercises. These muscles play an important role in maintaining the stability of the spine and in regulating movement (**Marani et al., 2020**).

The discovery that the strength of the center muscles has a favorable correlation with the technical execution of stabilization movements has important repercussions for the avoidance of injuries. Injuries, especially to the lower back and spine, are more likely to occur when a person's core muscles do not have sufficient strength. Stability movements are often utilized in physical activities and sports (**Xu and Peng, 2020**). Individuals may lower their risk of injury and enhance their ability to conduct stability movements in a safe and effective manner by increasing the strength of their core muscles via the use of workouts that specifically target those muscles.

Moreover, the findings of this research indicate that core muscular strength is an important factor in determining overall fitness as well as performance in physical activities. A high degree of stability and balance is required for many different types of physical activity, including sports and exercise. Increasing the strength of your core muscles with certain workouts will help improve the overall physical performance and may lead to gains in other areas as well, such as the speed, agility, and power (**Glave et al., 2016**).

In addition, the discovery that focused core strengthening exercises may have a considerable influence on technical performance even after only a relatively short amount of time has practical implications for coaches, trainers, and people who are looking to enhance their physical performance. The training regimen that was employed in this research lasted for just six weeks, which suggests that people may achieve considerable gains in both the strength of their core muscles and the technical execution of their movements in a very short amount of time.

These findings have significant repercussions for the development of training regimens suitable for people of varying degrees of physical fitness and ability. The results of this research, which focused on healthy guys, may be relevant to people of diverse genders, ages, and levels of fitness. Exercises that focus on strengthening the core muscles may be beneficial for those who are healing from injuries, as well as those who want to enhance their general fitness and performance. These exercises can be integrated into training routines. The activities that were employed in this research, such as headstand, handstand, pull-ups, push-ups, back, and abdomens, are not only simple to do, but they also need very little equipment and can be done at home or in a gym environment.

The findings of this study are in line with those of other studies, which found that exercising and strengthening the core muscles may enhance the performance of stability movements. For instance, a research that was carried out by **Cugliari and Boccia** (**2017**) discovered that a training program that focused on the core muscles and lasted for a period of six weeks was able to increase an individual's ability to do the these exercises. In a similar vein, a research that was conducted by **Zemková and Zapletalová** (**2021**) discovered that a training program that lasted for four weeks and concentrated on the core muscles increased the performance of the bird dog exercise. The results of this research have significant practical significance for coaches, trainers, and athletes who are participating in activities that demand stability movements on the mat or floor motions. They are able to enhance the technical performance of their athletes and lessen the chance of injury by including exercises in their training regimens that focus on the core muscles. In conclusion, the findings of this research provide compelling evidence that the strength of the core muscles is favorably connected with the technical execution of stability exercises performed on the mat or floor. It is possible to increase one's capacity to maintain good body alignment, stability, and control when participating in physical activities by strengthening the core muscles via the use of specific exercises. This may lead to better performance as well as a decreased chance of injury. These results have substantial repercussions for athletes, coaches, and trainers, as well as for those who are interested in improving both their general fitness level and their physical performance. Exploring the potential advantages of core strengthening exercises for persons of varying ages, fitness levels, and genders should be a focus of future study. This research should also evaluate the ideal time and intensity of core strengthening activities for enhancing stability movements

Conclusion

The results of this study provide evidence to support the idea that strengthening the core muscles may improve the technical execution of stability exercises conducted on a mat or floor. The outcomes of this study were found to be significant. According to the findings, a training program that consists of exercises that target the rectus abdominis, the transverse abdominis, the internal and external obliques, and the erector spinae may lead to significant improvements in the performance of stability movements. The program lasts for six weeks and focuses on exercises that target these muscles. The rectus abdominis, the transverse abdominis, the internal and external obliques, and the erector spinae are the muscles that are strengthened by these workouts. These improvements have the potential to have practical implications for coaches, trainers, and athletes who engage in workouts on the mat or floor that necessitate stabilizing movements.

This research has a number of limitations, the most notable of which are its limited sample size and the absence of a lengthy follow-up period to evaluate the stability of the gains in technical performance. In this research, we were solely interested in the impact that center muscle strength training had in the short term on the level of technical execution of stability exercises on the mat and floor movements. There is a need for more research to study not just the long-term impact that center muscle strength training has on stability and balance, but also the effects of other parameters that may affect the performance of stability movements, such as flexibility and coordination. In addition, the participants in our research were all young adults who were in good health and had no previous history of musculoskeletal injuries or conditions. It is possible that people who already had an injury or ailment before to beginning strength training for their core muscles might see a different influence on the degree of technical execution of stability exercises. In next research, the influence of core muscle strength training on stabilization movements for persons of varying health conditions should be investigated.

Our research demonstrates that training for strength in the core muscles may be an effective intervention for enhancing the level of technical performance of stability exercises on the mat or floor. These findings have consequences for practice, and they recommend that such training should be pursued. Center muscle strength training may be included into training programs for athletes who undertake stability movements by coaches and trainers. Center muscle strength training can also be beneficial for people who wish to enhance their stability and balance.

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No funding agencies were reported by the authors.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Ethics Committee

This research has been approved by the Scientific and Technical Committee Ethical Committee of the College of Physical Education and Sports Sciences, Palestine Technical University -khdoorie in 17Sep.2023 The study was conducted in accordance with the Principles of the Declaration of Helsinki

Author Contributions

Author's Planned Workflow: AN and RB; Study Design: AI, Data Collection: MO, Statistical Analysis: AB, Data Interpretation, Manuscript Preparation, Literature Search: AN, RB, AI, MO and AB

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RESEARCH ARTICLE

A Comparison of the Immediate Effects of Chiropractic Thoracic High-Velocity Low-Amplitude Manipulation Applied Supine and Prone on the Autonomic Nervous System

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Abstract
Thoracic manipulation is one of the spinal manipulative treatment methods frequently used by clinicians. However, when carrying out this task, several methods could be preferred. This study aimed to compare the immediate effects of supine and prone thoracic high-velocity-low-amplitude chiropractic manipulations on the autonomic nervous system. The study included 62 healthy and volunteer participants aged 18-45 years. Participants were randomly assigned to supine and prone manipulation groups. Both groups, heart rate variability data were obtained with the Elite HRV CorSense device for 1 minute before the application, systolic and diastolic blood pressures were measured, pulse and saturation values were recorded. After the measurement, supine chiropractic manipulation was applied to the mid-thoracic region and the same measurements were repeated. Heart rate variability data were analyzed with Elite HRV application, pulse rate, saturation, systolic and diastolic blood pressure values were recorded, and the results were statistically evaluated. In the intra-group comparison, LF/HF ratio increased in the prone group (p=0.025). When the difference between the groups was analyzed, the change in LF/HF ratio was found to be statistically significant between the two groups (p=0.008). The effect of prone application on the autonomic nervous system was found to be higher than supine application. This study revealed that prone and supine thoracic chiropractic HVLA application was effective on OSS in healthy individuals and that the efficiency of prone manipulation was significantly higher.

Keywords
Chiropractic, Autonomic Nervous System, Spinal Manipulation, Parasympathetic Nervous System

INTRODUCTION

Thoracic manipulation techniques are frequently applied with a chiropractic focus all over the world. Understanding the mechanisms and effects of these techniques is important for proper patient selection and correct technique selection (**Erdem et al.2021; Sener et al. 2021**). There are few studies in the literature investigating the effects of prone and supine thoracic manipulation (**Cakir et al. 2019; Tsegay et al. 2022**). Several studies show that thoracic manipulation has several neurophysiological effects. These effects include excitation of the sympathetic chain, mechanical hypoalgesia, decreased neural mechanosensitivity, increased pain tolerance and normalization of muscle activity (**Lascurain-Aguirrebena et al., 2016**).

Throughout the history of chiropractic, the treatment of visceral disorders has been adopted as a field of study, with an emphasis on the autonomic nervous system (**Gatterman, 2005**). From the earliest studies of chiropractic to the present day, there has been increasing evidence that manipulation of specific spinal segments can reduce the symptoms of visceral disorders. There are

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studies indicating that the autonomic nervous system (ANS) is affected in various ways by thoracic manipulation (**Sillevis et al., 2011; Sillevis et al., 2021**). Studies have shown increased parasympathetic activity, decreased heart rate and blood pressure, and increased proprioceptive input as a result of lumbar and lower thoracic spinal manipulations. In addition, thoracic manipulation has been reported to cause changes in blood pressure, skin temperature, heart rate, pupil diameter on the ANS (**McDevitt et al., 2022; Ward et al., 2015; Jowsey et al., 2010**). Results have also shown that the immune and endocrine systems are also affected by spinal manipulation (**Carnevali et al., 2020; Sampath et al., 2017**).

Although studies have shown that thoracic manipulations have an effect on the autonomic nervous system, it is not known whether the technique of application makes a difference. Therefore, we conducted this study to compare the immediate effects of prone and supine chiropractic HVLA thoracic manipulation on the ANS.

MATERIALS AND METHODS

This study followed to all relevant sections of the Declaration of Helsinki and was carried out in accordance with ethical standards. Ethics committee approval numbered 2022-186 was obtained from Bandırma Onyedi Eylül University Health Sciences Non-Interventional Research Ethics Committee on 12.01.2023. Our study was registered with the number NCT05850910. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures. Participants were informed about the study and provided written informed consent.

Participants

The study included 62 healthy volunteers. Participants were divided into two groups by simple randomization method via random.org website. Thoracic manipulation was applied to both groups, the first group prone and the second group supine. The G Power 5.1.9.4 program was used to determine the sample size and the Type 1 error (alpha) was calculated as 0.05 and the power of the test (1-beta) was calculated as 0.8. A total of 58 people were calculated for each group, 29 in total. photoplethysmography. This program allows for the quick collection of RMSSD, SDNN, LN, In case of dropout, 31 in each group and 62 in total were included in the study (**Sener et al. 2021**).

Patients between the ages of 18 and 45 who were without mechanical limitations as determined by an examination of the thoracic region and without palpable discomfort, as well as those who had tumors, infections, injuries, inflammatory disorders, neurological and vascular issues, were included.

Design

Patients with tumors, infections, traumas, inflammatory illnesses, neurological and vascular problems, as well as those who were between the ages of 18 and 45 and were without mechanical restricts as determined by an examination of the thoracic region and without palpable discomfort, were included.

The supine application group (Group 1) was asked to cross their arms in front of their torso while the participant was lying on their back. The arm of the practitioner was placed in a half fist on the opposite side of the individual's torso in the mid-thoracic region. In this position, the spinous process coincided with the space in the center of the half fist, while the thoracic processes coincided with the fingertips and the tenar region. With the other hand of the practitioner supporting the patient's elbows, HVLA thrust is applied from front to back.

In the prone application group (Group 2); the participant positions his/her hands freely from the side of the treatment table while lying prone. The practitioner is positioned next to the patient with the hypothenar part of the hands over the thoracic processes in the mid-thoracic segment. From this point, a high-speed, low-amplitude thrust is applied from the back to the front.

Blood pressure, heart rate, and 1-minute HRV were all monitored following the intervention, and the findings of each measurement were recorded. Using an Omron M2 (HEM-7121-E) model sphygmomanometer, blood pressure and pulse were measured before and after the application. Systolic and diastolic blood pressures were recorded.

Before and after the thoracic manipulation, each subject conducted 1-min HRV measurements using the Elite CorSense equipment (Figure 3.3). The Elite HRV app was used to evaluate the measurements. The data is monitored by the Elite CorSense HRV program using a technique called

PNN50, and LF/HF ratio data on a single screen, making it easy to use (Chhetri et al., 2022).

Statistical Analyses

Statistical Package for Social Sciences (SPSS) Version 20.0 (SPSS inc. Chicago, IL, USA) was used for data analysis. Data expressed in numbers were expressed as n (%) and data expressed in measurements were expressed as arithmetic mean ± standard deviation (X±SD). Statistical significance level was accepted as $p<0.05$ in all analyses. Depending on the properties of the data, several methodologies were used to conduct statistical analysis. Student's t-tests were used to compare means between two groups for normally distributed variables. Additionally, correlation analysis using the Pearson and Spearman coefficients were carried out to look at the connections between continuous variables. In cases where the data did not meet the assumptions of normality, non-parametric tests like the Mann Whitney-U test were used to compare group differences.

RESULTS

There were 31 individuals total in both groups: 20 women and 11 men in the prone group and 21 women and 10 men in the group that was supine (Figure 1). When demographic information was compared between the groups, there was no significant difference ($p>0.05$) (Table 1).

Table 1: Compares the demographic data of the different groups.

	Group1 (n=31)	Group2 (n=31)	P
Age	26.00±5.66	23.96±3.61	0.097
BMI(kg/cm^2)	22.69±3.25	22.48±3.30	0.800
Gender	21 Female / 10 Male	20 Female / 11 Male	**0.011**

Kg: kilogram, cm: centimeters, p<0,05

Pulse rate, systolic and diastolic pressure decreased in both groups after the application but were not statistically significant. The values of HRV values before and after supine and prone thoracic manipulation are given in the table. RMSSD and LF values increased after both supine and prone manipulations. However, this increase was not statistically significant ($p>0.05$). There was not a significant difference between the groups in RMSSD, LF and HF variables ($p>0.05$). While there was not a significant change in the LF/HF ratio in the supine group ($p>0.05$), a significant increase was observed in the prone group ($p<0.05$). There was a significant difference in the LF/HF ratio between the groups ($p<0.05$).

Table 2: Before and after intra- and inter-group manipulation application

	Group1			**Group2**			
	Pre-Application	Post-Application	P	Pre-Application	Post-Application	p	p
Pulse	82.32±12.92	81.77±13.84	0.546	86.51±11.88	85.41±10.07	0.373	0.717
SBB	112.96±13.71	111.67±15.45	0.314	117.74±13.07	111.93±13.38	0.010	0.072
DBB	75.41±10.07	73.83±10.46	0.212	78.32±10.52	73.58±9.43	0.032	0.231
RMSSD	54.57±22.85	61.04±28.56	0.134	52.04±22.19	55.73±26.71	0.364	0.634
LF/HF	2.80±2.68	2.05±1.74	0.106	2.05±1.42	2.86±2.36	**0.025**	**0.008**
LF	2479.37±2353.89	2999.32±3855.65	0.891	1855.15±1575.67	2475.37±2455.22	0.153	0.307
HF	1445.94±1847.48	1943.37±2322.15	0.299	1422.72±1466.40	1179.06±1214.24	0.710	0.877

p<0,05.
RMSSD:Root mean square of successive differences SDNN: Standart deviation of normal normal intervals LN:Natural logaritm PNN50:Percantage of normal normal intervals LF: Low frekans HF: High Frekans, *SBB: Sistolik Blood Pressure DBB: Diastolic Blood Pressure,*

DISCUSSION

In this study, the impacts of thoracic chiropractic HVLA in the prone and supine positions on the ANS in healthy participants were examined. Data collected at the conclusion of the study demonstrated that the prone group had higher LF/HF ratios and lower systolic and diastolic blood pressures. These outcomes, however, lacked statistical significance. The LF/HF ratio indicated a significant difference between the two groups when the change between the groups was evaluated. **Wirth and et. al** (**2019**) investigated the neurophysiological effects of spinal manipulative therapy with HVLA thrust in their systematic study. They discovered that stimulation of the upper or lower thoracic or lower cervical segments increased the sympathetic to parasympathetic ratio (LF/HF ratio). This can be associated to the segment used because the T5 segment's effects on the lumbar segments were insignificant. We came to the conclusion that modification of the middle and lower thoracic segments may not have an impact on HRV because the preganglionic fibers of the cardiac plexus largely branch from the T3-T4 spinal segments. In our research, we found that while there was no significant change in the supine group, the LF/HF ratio increased significantly in the prone group with mid-thoracic manipulation (**Wirth et al., 2019**).

The effects of a single spinal manipulation on cardiovascular autonomic activity and pressure pain threshold were studied by **Picchiottino et al**. (**2020**) According to the study of 41 participants, a single spinal manipulation of the thoracic spine had no appreciable impact on autonomic activity. **Picchiottino et al.** (**2019**) [17] investigated at the acute effects in ANS activity of spinal manipulation therapy given to spinal or peripheral joints in their systematic study. This study, which included 29 investigations, found that several forms of mobilization significantly increased sympathetic nerve activity both immediately and shortly. HVLA procedures, on the other hand, have no noticeable impact on the ANS. Results for a particular sector, however, were not recorded. Systolic and diastolic blood pressure, indicators of parasympathetic nervous system activity, were reduced in our study by prone application at the T6-T7 level, but the results were not statistically significant (**Picchiottino et al. 2020**).

Araujo et al. (**2019**) investigated the effects of spinal manipulative therapy on the ANS in their systematic review. Including 18 studies, it was reported that vertebral mobilization caused an increase in sympathetic activity regardless of the region of application (cervical, thoracic or lumbar spine). Continuous natural apophyseal shifts were reported to have no effect on the ANS, and manipulation practices were found to give conflicting results. It was stated that the inclusion of studies with low level of evidence may cause this contradiction. We applied mid-thoracic chiropractic HVLA manipulation in healthy subjects and found that ANS was affected in favor of parasympathetic activity. The reason for this difference may be that a specific level was not studied, or symptomatic individuals were included in the study (**Araujo et al., 2019**).

Roura et al. (**2021**) evaluated the effect of manual therapy interventions on the ANS in their systematic review. In the study, which included 12 systematic reviews, the findings showed that manual therapy can be effective on both sympathetic and parasympathetic systems. However, the results obtained from the included studies were found to be inconsistent due to their methodological rigor and differences in how they were measured. In a systematic review, Navarro-**Santana et al**. (**2020**) evaluated the effects of joint mobilization on changes in clinical signs of sympathetic nervous system activity. As a result, moderate clinical evidence was found indicating a sympathetic stimulating effect of joint mobilization (**Roura et al., 2021**). In our study, we found a significant change in the LF/HF ratio from HRV values as a result of prone mid-thoracic chiropractic manipulation. This change indicates that it causes an immediate effect in the direction of increased activity of the parasympathetic nervous system.

In a randomized controlled -blind pilot investigation, **Rogan et al**. (**2019**) assessed the effects of thoracic spinal manipulation on the autonomic nervous system. In this study, 12 healthy volunteers had two days of prone and supine thoracic spinal mobilization to the T6-T12 regions. Blood pressure, heart rate, pulse, and skin perfusion were all monitored. On the majority of secondary variables, prone mobilization had a stronger impact than supine mobilization. It has been demonstrated that prone application may raise the pulse rate and HRV HF and LF/HF ratios. In our investigation, we subjected several subjects to supine and prone

manipulation of T6-T7 segments. Similar to this study, we found a greater and significant change in parasympathetic values in the prone group compared to the supine group. In our study, an increase in the LF/HF ratio was found among the

In a randomized controlled double-blind pilot investigation, **Rogan et al.** (**2019**) assessed the effects of thoracic spinal manipulation on the autonomic nervous system. In this study, 12 healthy volunteers had two days of prone and supine thoracic spinal mobilization to the T6-T12 regions. Blood pressure, heart rate, pulse, and skin perfusion were all monitored. On the majority of secondary variables, prone mobilization had a stronger impact than supine mobilization. It has been demonstrated that prone application may raise the pulse rate and HRV HF and LF/HF ratios. In our investigation, we subjected several subjects to supine and prone manipulation of T6-T7 segments (**Rogan et al., 2019**).

In a placebo-controlled trial, Rodrigues et al. examined the immediate impact of manual treatment administered to the upper thoracic spine on cardiovascular autonomic regulation. A significant increase in RMSSD and HF values, which indicate parasympathetic activity, was observed in the spinal manipulation group. Only the spinal manipulation group reported significant improvements in the sympathetic activity indicators LF and LF/HF ratio. In neither group was there a noticeable distinction in the blood pressure response. The results of the two studies are comparable in that we observed an increase in the LF/HF ratio in our study as a result of prone mid-thoracic chiropractic HVLA manipulation. The results of our blood pressure tests are comparable (**Rodrigues et al., 2021**).

Using HRV data, in their study, **Çakır et al.** (**2019**) examined the immediate impact of chiropractic thoracic manipulations on the ANS. While there were significant increases in LF power, SNS Index, and Stress Index values in the experimental group, there were significant decreases in RMSSD, HF power, PNS Index, and PNN50 values, which indicate parasympathetic nervous system activity. There was not a significant alteration in the parameters in the placebo group. In contrast, we determined that intermediate thoracic manipulation produced parasympathetic effects in our investigation. Which section they used in their HRV values. They suggested that pulse, HF and LF/HF ratio may increase. We are of the opinion that such a difference may occur due to the larger number of subjects in our study (**Rogan et al., 2019**).

investigation was not made clear. The applied section may determine how the two applications differ from one another. Again, they examined people with mechanical constraints in their study, whereas we used healthy people (**Çakır et al., 2019**).

Conclusion

As a result of the study in which we compared the immediate effects of supine and prone mid-thoracic chiropractic manipulations on the ANS, only a statistical increase in the LF/HF ratio was found after the prone manipulation. As a result, the immediate effect of prone mid-thoracic chiropractic HVLA manipulation on the ANS is higher. One of the limitations of our study is that we focused solely at immediate effects in the middle thoracic region in healthy individuals. Different outcomes may be seen with applications to the cervical, upper and lower thoracic, lumbar, and sacral regions. Spinal manipulation may have distinct impacts on the ANS in people with pain and mechanical restrictions than it does in healthy people. When it comes to the study's advantages, contrasting the results of manipulations performed in various postures and adding to the body of knowledge will help chiropractors select the most effective method.

Conflict of Interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Statement The approval of the Scientific

Research Ethics Committee of Bandırma University obtained for the study 2022186.

Author Contributions

Study Design, BEP; Data Collection, YA, and BEP; Statistical Analysis, HG; Data Interpretation, YA, HG; Manuscript Preparation, YA, BEP, HG; Literature Search, YA, BEP, HG. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

The Effect of Intermittent and Continuous Instantaneous Strength Training on Biomechanical Ability, Technical Performance and Long Jump Success in Athletics

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Abstract
The use of discrete and continuous instantaneous strength training is a modern method that can develop the level of mechanical ability and achieve development in some biomechanical variables. The aim is to identify the use of continuous and discrete and continuous instantaneous strength, in developing the explosive ability, and the technical performance according to some biomechanical variables, and its direct impact on the development of the achievement of the Athletics for advanced in the long jump, the researcher hypothesized that there are significant statistical differences in the explosive ability and the technical performance According to some biomechanical variables and the achievement of the Athletics for advanced in the long jump, the researcher used the experimental method on a sample of (11) jumpers, representing the total research community. The research was applied to a sample of (8) jumpers From the National Center for Sporting Talent (Athletics for advanced) for applicants aged (17-21), for the season (2022-2023). Result: An increase in strength and speed was determined due to the use of special exercises using arm and leg weights. As a result of the measurements, Approach speed (Pre-test: 8.01±0.15; post-tes: 9.97±0.57), The Cruising Angle (Pre-test: 21.60±0.852; post-tes: 23.10±0.721) and Measurement pushing force (Pre-test: 23.10±0.721). test: 156.23±11.6; post-test: 310.12±37.7), High Jump (Pre-test: 5.75±0.21; post-test: 6.10±0.04) it was determined that there was an increase. In conludes; the researcher concluded that it is necessary to pay attention to technical performance during the performance of athletics activities.

Keywords
Technical Performance, Mechanical Ability, Biomechanics, Long Jump

INTRODUCTION

Long jump is a flexible sport that combines periodic and non-periodic. The combination of good physical fitness and professional sports skills guarantees long jumpers to achieve excellent results (Al-Zubaidi, 1999). The explosive power of the muscles plays a very important role in movement. Improving explosive power training is the top priority for our long jumpers (**Zong, 2023**). The long jump consists of 4 phases: running phase, take-off phase, flight phase and landing phase (**Kamnardsiria et al., 2015; Alwan et al., 2023**). Long jump performance depends not only on a fast horizontal speed at the end of the run, but also on take-off technique and landing on the sandy area. Successful long jump athletes pay close attention to these stages because they affect the distance of the long jump, especially the running stage, which is the first stage of the long jump (**Alyaseri et al., 2023**). Each of these stages has its own unique cinematic characteristics in terms of performance, requiring the contestant's full attention and concentration (**Vazini Taher et al., 2021**).

Strength is a very important component of overall physical fitness because it is the driving force of every physical activity (**Nurul İhsan. 2018**). **Tangkudung and Puspitorini** (**2012**)

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suggest: Strength can be divided into three forms: maximum force, elastic force and force endurance. Maximum force is the greatest force/muscle produced by contraction, without determining how fast a movement can be performed or how long it can take to perform the movement. Additionally, Syafrudin (**2012**) argues that strength is the ability of the muscles or pulling the muscles to overcome the load or resistance (resistance), both the load in the body's own sense, such as jumping due to the lifting of the body, and external loads, such as weightlifting.

Power, one of the important factors of athletic performance, has a time component and refers to the mechanical quantity defined as the temporal ratio of work done (power = work/time) and generally depends on the ability to create the maximum possible force (maximum force) (**Newton and Kraemer, 1994**). In other words, if two athletes have similar maximum forces, the person applying the force at a higher speed (or in a shorter period of time) will have a distinct advantage in the performance of anaerobic movements (**Salih, 2022; Idrees & Salih, 2022**). Performance success of many athletic actions is often a matter of how much force is applied to objects (such as the ground, ball, or sports equipment); Success during a particular athletic workout completed in a short period of time depends on the athlete's power efficiency capacity (**Stone et al., 2023**).

The rate of concentric contraction of a muscle is inversely proportional to the applied load or external force. The contraction rate of the muscle is highest when the applied force is zero. When the force increases to a level equal to the maximum force straining the muscle, the rate of contraction becomes zero. In other words, as the weight increases, the force produced by the muscle increases and the movement speed decreases (**Bartlett, 2007**). Athletic jumps are specific cyclic-acyclic movements that require a high level of motor, specific motor and functional abilities from competitors despite good performance of techniques. Additionally, all jumping disciplines contain the appropriate morphological profile (height, weight, BMI, age) of their specific athletes. It is often said that jumpers are of high growth and relatively low weight, have long legs, long and slender muscles, and their muscular structure is dominated by white muscle fibers. Long jump is an athletic discipline with a fast-strong character and belongs to a group of distance jumps, including the triple jump and horizontal jumps according to the trajectory of the body center (**Pavlović, 2016; Smajlović, 2010**). The starting speed of running is as important as the strength of the lower extremities that provide the final jump, so the result depends on speed, jumping ability and movement technique (**Jaitner, 2001**). In top-level long jump athletes, the capacity to generate and apply significant amounts of force quickly plays a fundamental role (**Slawinski, 2017**).

The application of scientific foundations and technology in the sports field is carried out through conducting more research and studies to detect the ideal methods and exercises for the development of achievement (**Flayyih & Khiari, 2023; Nikkeh et al., 2022**), The science of biomechanics detect errors by analyzing sports movements and benefiting from mechanical laws, which is one of the basic duties of coaches, To benefit from it in training, which is related to the variables of strength, speed, and the mass of the athlete to develop athletic achievement. Many of the speed and strength training exercises that jumping coaches recommend through their training programs are weight-based. Although some exercises do not match the level of skill ability, it is seen from previous research that the use of different deep jumping methods (horizontal - vertical) to improve physical capacity and biomechanical properties is effective for athletes (**Dobbs et al., 2015**).

From Athletics the long jump effectiveness is considered one of the competitions that most need analysis and scrutiny in its stages. The technical performance of this competition depends on the capabilities and biomechanical variables to achieve the best achievement. The development of the mechanical stages of technical performance contributes effectively to achieving the optimal technique. The long jump depends on the physical requirements and a high level of skill, the good linking of the mechanical and motor capabilities of the skill, during the performance to achieve the best achievement, including the approach speed, the cruising angle, and the measurement Pushing force. The researcher noticed that preparing trainings discrete and continuous instantaneous strength, taking into account the individual differences between the jumpers, that the interest in the biomechanical variables during the technical

performance because of their significant impact on the development of the mechanical ability helps in the development of achievement of the effectiveness the long jump, so a preparation was made Exercises discrete and continuous instantaneous strength, and their impact on the develop of the mechanical ability, and the technical performance according to some biomechanical variables and the achievement of the applicants in the long jump.

Research objectives to Identifying the values of the mechanical ability of the arms and legs and some biomechanical variables and achievement of the advanced in the long jump, Preparing the effect of exercises discrete and continuous instantaneous strength to develop the mechanical ability of the arms and legs and the technical performance according to some biomechanical variables and the achievement of the research sample. and to identify the effect of exercises discrete and continuous instantaneous strength to develop the mechanical ability of the arms and legs and technical performance according to some biomechanical variables.

Research hypotheses

There are differences between the tests for the development of the mechanical ability of the arms and legs and some biomechanical variables and the achievement of the applicants in the long jump.

Research limits

The In their study, researcher focused on the research sample being from the jumpers of the National Center for the Care of Athletic Talent for Athletics for advanced in the long jump the season (2022-2023)

- Researcher worked in her study for the period from (5-1-2023) until (25-3-2023).

- The program was conducted in the halls of the Iraqi Ministry of Youth and Sports - the capital Baghdad.

MATERIALS AND METHODS

The used the experimental approach with a (one group) design.

Participants

A total of 11 athletes (age: 20±1.3; height: 190 ±3.5; weight: 85 ±5.2) voluntarily participated in this study. Before initiating the study, all participants were informed in detail about the purpose of study, test procedures, potential risks and benefits of the research and then the participants signed an approval document indicating that they would participate in the study voluntarily. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures. Ethical approval of the study was obtained from Ministry of Education, Iraq Ethics Committee at the board meeting dated 20.03.2023 and numbered 17-09-2023 Ref. 216. NO. 1, 2023.

The participants identified the jumpers of National Center for the Care of Athletic Talent for the Athletics for advanced in the long jump, aged (17-21) years, their number is (11) jumpers for the sports season (2023-2022) - (the sample "it is the part that represents the community of origin on which the researcher conducts the entire focus of his work)", (**Mahjoub، 1993**). The sample was chosen by the intentional method and by (8) jumpers, with a percentage of (72.73) % of the research community, The chosen were (3) Jumpers to conduct the exploratory experiment (Table 1).

Table 1. Paerticipants physical characteristics

Variable	(n = 11) (M ± SD)
Age (years)	20±1.3
Height (cm)	190 ±3.5
Weight (kg)	85 ±5.2
BMI (kg/cm^2)	24 ± 2.9

Study Design

Measurements

Means, tools and devices used for this study are mentioned as follows:

- Arabic and foreign sources and references
- observation and experimentation
- A Lenovo laptop with the use of (Kenova) program to determine biomechanical indicators.
- One (1) camera holder
- Adhesive tape

One (1) manual electronic calculator Two (2) manual stopwatches-

A balance, a medical scale, to measure mass and length -). Flags - red and white) number (2 -A legal field for the long jump

Power platform

Field Research Procedures

Define Rsearch Parameters

The search variables were measured (approach speed, the cruising angle, and the

measurement Pushing force, by placing a camera to the left of the jumper, at a height of (1.35 m), from the center of the ascent plate, the field of photography was (8 m), the scale of the drawing was determined by the length of the leg for each jumper.

FD:Flight Distance, EP: Explosive Power, IPT: Instant Push Time

Figure 1. Long jump measurement tools

Tests used in the research

Test (medicine ball throw), weighing (2 kg), for the maximum distance (**Al-Zubaid, 1999**). From a standing position, the player throws the ball with his hands to the maximum distance while allowing one step to be taken before throwing. The player must touch the ground while throwing, and gives the tester two attempts. The best result is calculated and the distance (in meters), and its time is calculated, as the pushing time is calculated. The momentary moment of the arm is from the moment the arm moves with the ball until the moment the ball is left. The power (in watts) is calculated according to the following law:

$$\text{Explosive force (For Arms)} = \frac{(\text{Mass of the Arm} + \text{Mass of the Ball}) * \frac{\text{Flight Distance}}{\text{Flight Time}}}{\text{Instant Push Time}} \text{ (newton's)}$$

$$\text{Then apply the Power law: } \frac{\text{Explosive power X Distance}}{\text{Time}}$$

Long jump stability test

The purpose: measuring the muscular ability of the legs and torso from the long jump.

specifications (**scholich & Kreis, 1982**)

The player stands with the feet slightly apart and the arms high. He swings the arms forward down behind with the knees bent in half and the torso inclined forward. From this position, the arms swing forward strongly with the extension of the legs along the torso and push the ground with the feet, strongly in an attempt to jump forward the farthest distance Possible.

Testing instructions

The distance of the jump is measured from the starting line (the inner edge) until the last trace left by the player near the point where the heels touch the ground. The attempt is canceled in case of imbalance and must be repeated.

Recording

The tested player has two attempts to score the best of them.

Recording method

Using the analysis program (Kenova) to extract the power.

$$\text{Explosive Power (For Legs)} = \frac{\text{Body mass x 9.8 x } \frac{\textit{Flight Distance}}{\textit{It's Time}}}{\text{Instant Push Time}} \text{ (Newton's)}$$

$$\text{Explosive Ability (For Legs)} = \frac{\text{Power x Jump Distance}}{\text{Jump Time}} \text{ (Watt)}$$

Long jump achievement test

The purpose: measuring the horizontal distance of the meter and its part.

Tools used: force platform device.

Performance method: The player stands at a distance of (30-40 m) from the board and performs an approximate run, presses on the device, and rises in the air to the end of the movement.

Recording: The horizontal distance traveled by the player in the air is calculated by meters and its part. And he is given three attempts to calculate the meaning.

Exploratory experience

The first experiment was conducted on a sample of (3 jumpers) from the National Center for the Nurturing of Athletic Talent the Athletics for advanced in the long jump from outside the research sample, on Thursday (5-1-2023) at four o'clock in the afternoon, in the halls of the Ministry of Youth and Sports, the experiment was conducted To find out and find (maximum value - stresses - frequencies - times).

Experimental Procedures

Pre-tests:

The pre-examinations for the tests were conducted on Thursday (12/1/2022) at four o'clock in the afternoon, the tests were conducted and the conditions for the tests were confirmed in terms of the assistant work team, time, place and tools And devices, so that all similar conditions can be provided when conducting post-tests.

Special exercises used in the research:

The training started on Saturday (14/1/2023), and will continue until Thursday (23-3-2023).

Preparing strength training commensurate with the nature of the competition so that it is similar to the competition.

The exercises are applied in the main section of the training unit during the period of special preparation, for a period of ten weeks, at the rate of three training units per week, and the number of training units is (30) training units.

Training days: Saturday - Monday – Thursday-

Training intensity ranges from 90-100%

load waves (1:3).

Use the interval and repetitive training method

The intensity was determined according to the repetitions

Using weights in the arms and legs with a weight ranging between (3-8) kg

The exercises are given at the time of the main section and range between (50-60) minute.

Post tests:

After completing the exercises, the post-tests were conducted on Saturday (25-3-3023) , in the athletics in the Ministry of Youth and Sports. The same conditions were created in Devices and tools - Implementation method - Work team.

Electronic computing processing:

The analysis program (Kenova) was used in (AVI) format, and the biomechanical variables were extracted directly from the movie taken of the tested player during the performance of the long jump event.

Biomechanical variables:

Approach speed: It is the (time it takes) to travel a distance (the last 10 m) to the approach board

The cruising angle: It is the angle confined between the intersection of the straight line connecting the center of gravity of the body at the moment of leaving the board with the horizontal line parallel to the ground and towards the front. It is measured in degrees.

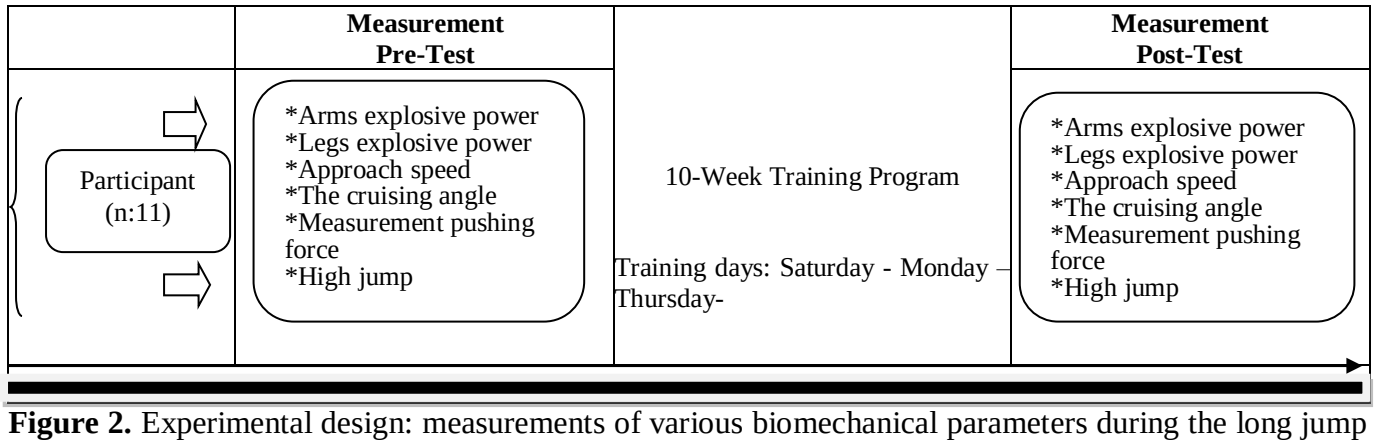

Figure 2. Experimental design: measurements of various biomechanical parameters during the long jump testing at pre and subsequent to the interventions

Table 1. 10-week training program of participants

Main section time (53 min)								
Exercise Name	Mass.Kg	İntensity	Repetitions	Rest		Repetition Time (S)	Exercise Time Minutes	Total Time İs İn Minutes
				Repetition	Exercise			
Running a distance of (30m) from the flying position	78	90%	4	3m	6m	3.64	9.24	15.24
	75					3.66	9.24	15.24
	77					3.58	9.24	15.24
						3.69	9.25	15.25
						3.74	9.25	15.25
Run a distance of (50m)	78	90%	4	3.30m	6m	6.80	10.35	16.35
						6.85	10.36	16.36
	88					6.75	10.35	16.35
						6.88	10.36	16.36
						6.94	10.36	16.36
Jumping on barrier (9) with a standard height	0	90%	4	2m	5m	12	6.8	11.8
Leaping from stability	0	90%	4	2.30m	-	5	7.63	7.63

Statistical analysis

In the descriptive analysis data is reported as means ± standard deviations and percentage of changes. Physical characteristics before the intervention were tested for difference between the groups with unpaired t-tests. Test data was examined for normality with Shapiro Wilk test and for homogeneity of test. If normality of data was presenta two way mixed analysis of variance (factors: group, time, and interaction (group vs. time)) was performed. Results were considered significant when $p<0.05$. IBM SPSS statistics version 22.0 package was used.

RESULTS

Display and discussion of the mechanical ability of the two tests, analysis and discussion:

Table 2. shows that the results appeared significant in the explosive ability, depending on both the mass and the distance, as a result of the use of special exercises through the use of weights with arms and legs and special exercises for strength and speed.

Table 2. Mean - standard deviation - difference of the means, calculated (t) value for the mechanical ability of arms and legs

Mechanical Ability	Measuring Unit	Test	M	SD	D m	SD	t value calculated	Sig.
Arms Explosive Power	Watt	Pre- Tests	2810.71	2732.15	770.33	547.99	4.76	Moral
		Post- Tests	3581.04	2419.55				
Legs Explosive Power	Watt	Pre- Test	84.65	71.34	33.89	19.14	5.01	Moral
		Post- Test	118.54	69.50				
Note / (T) calculated at (7) degree of freedom and error probability (0.01) = 3.60								

As a result of the measurements, Approach speed (Pre-test: 8.01±0.15; post-tes: 9.97±0.57), The Cruising Angle (Pre-test: 21.60±0.852; post-tes: 23.10±0.721) and Measurement pushing force (Pre-test: 23.10±0.721). test: 156.23±11.6; post-test: 310.12±37.7), it was determined that there was an increase (Table 3).

Table 3. The mean - standard deviation - standard deviation of the differences - calculated (t) value - significance level for some biomechanical variables

Variables	Measuring Unit	Test	M	SD	D M	SD	t Value Calculated	Sig.
Approach speed	m/sec	Pre- Tests	8.01	0.15	1.96	0.93	5.94	moral
		Post- Tests	9.97	0.57				
The Cruising Angle	Degree	Pre- Tests	21.60	0.852	1.5	0.93	4.55	moral
		Post- Tests	23.10	0.721				
Measurement pushing force	Kg	Pre- Tests	156.23	11.6	153.89	72.95	5.97	moral
		Post- Tests	310.12	37.7				
note / t at the degree of freedom (7) and the probability of error (0.01) = 3.60								

As a result of the measurements, it was determined that there was an increase in High Jump (Pre-test: 5.75±0.21; post-test: 6.10±0.04).

Table 4. The mean - calculated (t) value - difference of the means - standard deviation of the differences - significance level for the achievement of the long jump

Achievement	Measuring Unit	Test	M	SD	D M	SD	t Value Calculated	Sig.
High Jump	Pre- Tests	Degree	5.75	0.21	0.35	0.22	4.49	moral
	Post- Tests		6.10	0.04				
note / t at the degree of freedom (7) and the probability of error (0.01) = 3.60								

DISCUSSION

The goal of the long jump is to reach a landing spot or jumping platform as far as possible. Jump distance is measured from the push board to the closest distance to the landing position formed by the body part. A long jumper with good limb muscle strength is highly supportive of success in long jump sports. As explained, strength is the basic ability of physical conditions, especially the strength of the leg muscles (**Antoni et al., 2019**). The long jump technique is based on a natural and fairly easy movement; here the jumper strives for more speed (horizontal component horizontal throw), which transforms the reflection into a longer-distance jump (ballistic curve inclined throw). The ratio of the horizontal component (start-up speed) and the vertical component (reflection speed, flash) is related to 2:1. The effect of horizontal and vertical components directs the body and ensures that the elevation angle is between 18°-26°. This means that the decrease in angle (β) increases as a result of movements (R) that decrease the angle of elevation (α). Keeping all this in mind, a long-lapse reflection should only be performed at top speed and to the limit after the moment of verticality. Studies by some authors have confirmed the inverse relationship of horizontal and vertical body center elevation. As horizontal speed increases, vertical speed decreases and vice versa.

Table 2. shows that the results appeared significant in the explosive ability, depending on both the mass and the distance, as a result of the use of special exercises through the use of weights with arms and legs and special exercises for strength and speed, and this is confirmed by (**Adel Abdel-Basir 1999**) " The strength characterized by speed plays a role Important as one of the basic characteristics of the components of physical preparation that characterize sports activities" (**Ali, 1999**). The use of a group of vertical and wide jumping exercises with the additional weight. The jumping exercises affected the sample, and (**Mohammed Hassan Allawi and Abu Ela Ahmed 1984**) confirms that "the muscular ability to stretch contributes to increasing the speed of the motor performance of the used exercises" (**Muhammad & Abdel, 1984**).

The exercises used to develop explosive ability at the highest speed, and this stimulates the nervous system to perform quickly. The quality of the approved exercises using separate and continuous momentary strength training has an effective effect in developing research variables using resistance exercises with weights, and the exercises used are similar to the performance requirements during competition For the purpose of benefiting from the effects of these exercises to

achieve the required ability, this was confirmed by (**Abu El-Ela Ahmed 1992**)" that the ability training needs a high speed during the exercises in order to obtain a better motor performance during the competitions" (**Abdel Fattah, 1992**).

The study sample has developed in the speed of approach, as the effectiveness of the long jump requires the acquisition of the maximum horizontal transitional speed appropriate to carry out the ascent and flight to achieve the longest horizontal distance, and the horizontal speed is of great importance to achieving achievement in this activity. For the purpose of obtaining high speed in the approach run and obtaining high speed, gradient acceleration is permitted, starting from the first step and ending with the maximum speed when ascending (**Rogers, 2000**) **.** The significant results showed in the variables of the body's launch angle and the momentum. These two variables are among the important variables in the effectiveness of the long jump. From this angle, it is possible to predict the level of achievement for the jumper, as well as determine the horizontal and vertical components. It is affected by the angle of rise and the speed of the performance of the approach stage and pushes the plate strongly and the high speed to get at a flight height suitable for the center of gravity, as it helps the jumper to achieve an appropriate flight angle and achieve a good jump distance .

The researcher believes that there is a correlation between the processes of absorption and propulsion when performing the jump, and that the arms have a good effect in achieving the transfer of the resulting momentum to the trunk, and determining the appropriate angles for the rest of the body parts, which achieves the lowest values of the body's own inertia, this is confirmed by (Mohammed Hassan Allawi and Abu Al-Ala) There are some factors that work to develop and develop speed, which are the formative properties of muscle fibers, their ability to relax, and the ability of the muscle to stretch and viscosity (**Allawi & Abdel, 1984**).

Training leads to an increase in the distance and height of flight, this is due to the development of the mechanical capabilities, as the continuation of the body's flight is evidence of the amount of effective force thrust exerted by the jumper. Creating suitable conditions for performance, the researcher agrees with what was indicated by (Sarih Abdul-Karim Al-Fadhli) that the results of some research indicated that long jumpers with high levels outperform those with weaker levels in this aspect (i.e. negative momentum change) (**Al-Fadhl, 2010**).

The reason for this is as a result of the application of separate and continuous momentary strength training and in a correlated with biomechanical variables The organization of training and the application of training units in the correct manner and attention to gradation in intensity, and the beginning from the shorter distances to the longer ones that contribute to improving the research variables, this is what was confirmed by (**Qasim Hassan and Mahmoud Abdullah, 1987**) "The training unit and the upward rise of its intensity and volume, depending on the most confident level of training" (**Hussein & Abdullah, 1987**). The achievement variable is related to the parts of the body in order to take suitable positions for the motor performance of the jumper. This variable is affected in the process of linking (approaching speed, departure angle and momentum). Whenever the movement is without any stops or intersections in the body parts, an appropriate starting angle and high momentum, the achievement increases This What is confirmed by (Ammar Makki Ali, 2005) "The development that accompanied all the variables gave an indication of increasing the efficiency and consistency of work between the joints of the body and the working muscles, and thus the production of greater force which leads to an increase in the achieved achievement" (**Ali A. M., 2005**).

Conclusion

There is a development in mechanical ability. There is a development in the variables of the Approach speed - the cruising angle of the body - and Measurement pushing force. The different exercises have an effective impact in develop the mechanical ability of the arms and legs and some biomechanical variables for the technical performance of the long jump effectiveness of athletics.

Recommendations

Emphasis on the continuity of training with discrete and continuous instantaneous strength training, as it has a great role in the jumper getting a good achievement. The trainers, when carrying out the training process, should pay attention to the aspects of technical performance according to the biomechanical variables that serve the achievement. Emphasizing the use of analysis to

find out the points of error and weakness and giving appropriate training. Conducting a similar study that takes other variables and other skills from different athletics activities.

Conflict of interest

There are no conflicts of interest between fellow authors, including financial and non-financial relationships.

Ethics Committee

This study was performed by adhering to the Helsinki Declaration. Ethical approval of the study was obtained from Ministry of Education, Iraq Ethics Committee at the board meeting dated 20.03.2023 and numbered 17-09-2023 Ref. 216. NO. 1, 2023.

Author Contributions

Planned by author: Study Design, Data. Collection, Statistical Analysis, Data. Interpretation, Manuscript Preparation, Literature search. All authors have read and approved published version of the manuscript.

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RESEARCH ARTICLE

Application of Naive Bayes Algorithm for Physical Fitness Level Classification

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Abstract
The implementation of physical fitness tests requires adequate facilities, so technology is needed to make it easier without having to provide facilities. The purpose of this study is to make it easier to get the results of a person's physical fitness level using age, gender, height and weight data through an intelligent system using the naïve Bayes algorithm without having to do a physical fitness test. This research is included in the Experimental research. The method used in this study used machine learning and classification with the naïve Bayes algorithm. Data analysis techniques use probability by using data tests and evaluations. The evaluation used uses accuracy. The population in this study was 100 college students. Training model scheme 98 and test 2 get an accuracy value when training is 100%, on testing an accuracy value of 50%. The best model is used as a reference in predicting new data, using 5 new data where 3 data already know the VO2Max value with the same prediction value and actual value, then 2 new data are not yet known VO2Max value, the 4th data gets a value of 44.2 and the 5th data gets a value of 33.2. The results of VO2Max testing using the naïve Bayes algorithm are declared accountable. Contribution to future research is to multiply research datasets to improve accuracy and improve user interface quality through development research.

Keywords
Bayes Algorithm, Intelligent System, Physical Fitness, Sport Technology, Vo2Max

INTRODUCTION

Sport is a body activity that aims to increase endurance to stay physically and spiritually fit (**Prasetya, 2021; Purwanto & Burhaein, 2021; Susanto et al., 2022a**). This life move causes a diminish in one component of physical wellness, to be specific cardiorespiratory wellness or what is regularly alluded to as the most extreme oxygen volume level. Wear could be a human require that's the most component and is exceptionally powerful within the arrangement of a solid soul (otherworldly) and physical (body or body). Each human who frequently does sports exercises will have way better otherworldly and physical wellbeing than people who seldom or never do sports exercises (**Burhaein, Demirci, et al., 2021; Syahri et al., 2023**). Perseverance is one of the vital components of physical condition and can be said to be the establishment for creating other physical conditions. The pattern of sports activities should be structured and planned to obtain good results. The physical abilities and skills of each person are different, so the basis for the implementation of sports activities must consider various things to obtain effective results. Sports

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activities have three objectives (**Burhaein, Tarigan, et al., 2021; Phytanza et al., 2023**), namely: 1) education, which means sports that are carried out as part of the educational process and continue to obtain knowledge through sports activities that have been prepared through a certain curriculum. 2) Achievement, which is a sport that fosters sportsmen in a planned, tiered, and sustainable manner that aims to achieve certain achievement goals. 3) Recreation, which is a sports activity carried out by the community with hobbies and abilities in accordance with community conditions for health, fitness, and excitement. Of these various goals, sports achievements are a very promising alternative to one's life. Because in addition to getting health, you will also get promising finances.

Sports achievements became one of the goals that society dominated because. Sports achievements become a very promising alternative to one's life. Because in addition to getting health, you will also get promising finances. Sports achievement is the optimal result achieved by a sportsman in the form of ability and skill in completing tasks, both in team and individual competitions (**Jannah et al., 2021; Susanto et al., 2022b**). Many things must be done to achieve optimal achievement, including skills, intelligence, personality, and most importantly a person's physical condition. VO2 Max can also be called maximum oxygen consumption or maximum oxygen uptake or aerobic capacity (**Laishram Santosh Singh, 2022**). VO2Max can be measured in several ways, namely a 12-minute running test, a 15-minute running test, a multi-stage running test (bleep test), and a Harvard step test. Talking about sports achievements cannot be separated from the physical condition of athletes. One way to determine the need for the maximum amount of oxygen when doing physical exercise is to measure VO²Max, namely Maximum Oxygen Volume.

Artificial intelligence or artificial intelligence is a field of science from computer science (technology) that mimics human behavior (**Jamaaluddin &; Sulistyowati, 2021**). To identify a person's VO2Max Prediction without bringing in his person or testing needs an expert system or expert system to make predictions, in other words, the researcher intends to adopt the experience of someone who is accustomed to calculating VO2Max Prediction with features of gender, weight, height, age, bleep test.

The problem that occurs is the constraints of the VO2Max measurement program as a basis for measuring athletes' physical fitness as one of the foundations of sports achievement. Various student activities, both academic and non-academic, are obstacles to the VO2Max measurement process. For this reason, we tried to make a VO2Max measurement application with the Naive Bayes Algorithm system for Physical Fitness Level Classification. Athlete Physical Fitness Data can be obtained by knowing by analyzing a person's height and weight to be able to get VO2Max data as a benchmark for Athlete Physical Fitness. This will certainly make it easier for us to predict a person's physical fitness without doing certain tests.

Some studies that use expert systems for expert prediction systems built in detecting covid-19 using naïve Bayes algorithms get able to make predictions according to the truth. Research conducted to detect symptoms of diabetes using the naïve Bayes algorithm obtained an accuracy value of 100%. Research in predicting oxygen before cycling using the ANN algorithm has achieved reliable accuracy (**Diseases et al., 2018; Insani & Son, 2018; Borror et al., 2019**).

MATERIALS AND METHODS

Physical Fitness

Physical Wellness or regularly called physical wellness could be a person's capacity to carry out every day exercises without encountering noteworthy weariness, and still have vitality saves to do other startling things (**Catur & Mujiriah, 2021; Winata & Mujirah, 2021**). Physical fitness in everyday life is the ability of a person to do certain body activities, without experiencing fatigue or fatigue that is significant after carrying out an activity, so that there is still residual energy to carry out other activities. In addition, the exercises carried out need to involve components in physical fitness related to health, namely: flexibility, power, endurance, VO2 max, and body composition.

VO²Max

VO2 Max can also be called maximal oxygen consumption or maximal oxygen uptake or aerobic capacity (**Laishram Santosh Singh, 2022**). VO2Max can be measured in several ways, namely the 12-minute running test, the 15-minute running test, the multi-stage running test (bleep

test), and the Harvard bench test (Harvard step test). Talking about sports achievements cannot be separated from the physical condition of athletes. One way to determine the need for the maximum amount of oxygen when doing physical exercise is to measure VO²Max, namely Maximum Oxygen Volume. VO2 max is a form of evaluation of a person's physical condition. VO²Max describes the level of effectiveness of the body to get oxygen, then channeling it to muscles and other cells using use it in the form of energy, where at the same time the body removes metabolic waste that can inhibit physical activity. Someone who has a high VO²Max will tend to be able to do more activity than people who have a lower VO²Max so the greater a person's VO²Max, the better they are in accepting and dealing with physical work. Someone who has good endurance and stamina has a high VO2 max value.

Performance Coaching

Sports coaching and sports achievement development are carried out and directed to achieve sports achievements at the regional, national, and international levels carried out by the parent sports organization at the central and regional levels. Sports achievements can be achieved by requiring good management or management, effectiveness in carrying out activities is a demand for every organization to achieve goal. The implementation of the development of organizational achievements is one way to be able to carry out systematic and structured development. One institution that plays a lot of role in the contribution of athletes is Higher Education, at that age, it is a golden age in the formation of sports achievement, so the Student Activity Unit (UKM) in the field of sports must continue to be encouraged to support student contributions in improving sports in the region through sports achievements. Higher education has a focus on student activity units in the field of sports The student activity units in the field of sports include: Football UKM, Futsal UKM, Handball UKM, Pentaque UKM, Badminton UKM, Volleyball UKM, Rugby UKM, etc. Coaching in university sports organization units should need to be maintained, including organizational structure, financing, and training programs. The training program itself was created to measure the progress of athletes' skills and physical condition in college. With good physical condition, it is expected that the athlete's performance will be well maintained as well. A good physical condition is in line with a person's VO2Max, the better a person's VO2Max ideally has a good physical condition.

Artificial Intelligence

Artificial intelligence or artificial intelligence is a field of science from computer science (technology) that imitates human behavior (Jamaaluddin & Sulistyowati, 2021). Human indicators, rules, calculations and decisions are closely related to the definition of an expert system (**Goldberg, 1989**). Expert system is a branch of artificial intelligence (**Goldberg, 1989**). AI can make decisions quickly in all aspects (**Li, 2023**) with human-like rules and calculations. AI can serve in the fields of pharmaceutical, economic, technological, agricultural, social, and military (**Jamaaluddin & Sulistyowati, 2021**).

The field of phapharmacy/ health self is used for hospital logistics decisions and deciddecisionsractical work (**Jamaaluddin & Sulistyowati, 2021**). In economics, it is used to decide in taking financial credit. In social life, AI caadaptpt how familiarity generates trust (**Cristina et al., 2023; Horowitz et al., 2023**). As well as human attachments, rules, calculations, and decisions. Rules and calculations are definitions of algorithms (**Goldberg, 1989; Donald E. Knuth, 1977**). AI and ES must have algorithms in finding a decision (**Donald E. Knuth, 1977**).

Algoritma Naïve Bayes

Algortima was first proposed by Al-Khawarizmi who was a mathematician, astronomer and geographer in the 9th century AD (**Influence et al., 2023**). Algorithms are mathematical procedures or rules created to provide alternative solutions (**Knuth, 1977**). An algorithm is a compound control structure that is limited, abstract, effective, imperatively given, achieving certain goals under given conditions (**Hill, 2015**). Algorithms must have input criteria, outputs, have clear directions and have limitations with their role methods with fundamental algorithms, flow charts, pseudo code (**Knuth, 1977**).

The Naïve Bayes Classifier is a classification method rooted in Bayes' theorem. The main feature of this Naïve Bayes Classifier is the exceptionally solid presumption of freedom from each condition (**Wibawa et al., 2018**). In Bayes' theorem, if there are two separate events

(e.g. A and B), then Bayes' theorem is formulated as follows:

$$P(A|B) = \frac{P(A)}{P(B)} P(B|A)$$

Bayes' theorem is often developed in view of the enactment of the law of total probability, as follows:

$$P(A|B) = \frac{P(A)P(B|A)}{\sum_{1=1}^{n} P(A|B)}$$

$$dimana\ A_1 U\ A_2 U \ldots Un=S$$

To explain the Naïve Bayes theorem, it is important to note that the classification process requires a number of clues to determine what class is suitable for the analyzed sample. Therefore, the above Bayes theorem is adjusted as follow:

$$P(C|F_1 \ldots F_n) = \frac{P(C)P(F_1 \ldots F_n|C)}{P(F_1 \ldots F_n)}$$

Where variable C speaks to lesson, whereas variable F1... Fn speaks to the characteristic characteristics of the clues required to perform the classification. So the equation clarifies that the chance of section of tests with certain characteristics in lesson C (back) is the chance of course C showing up (Wibawa et al., 2018).

Evaluasi Algoritma

Evaluation of the algorithm is needed to determine the performance of the algorithm (Fadjeri et al., 2020). However, in this study it was used to find out the prediction results from training data and testing data. The evaluation in this study uses *accuracy* (Armstrong, n.d.).

The *accuracy* formula is as follows

$$Accuracy = \frac{a+d}{a+b+c+d}$$

(Santra & Christy, 2012)

Accuracy or accuracy is widely used in algorithm evaluation.

METHODS

The method used in this study uses two parts, namely the machine learning method and the classification method with the naïve Bayes algorithm (Borror et al., 2019). Naive Bayes algorithms are used in machine learning and classification because naïve Bayes algorithms get the best accuracy from research (Woollam et al., 2020; Diseases et al., 2018; Insani & Putra, 2018). Machine learning is a method of receiving and analyzing input data to then be able to predict the output value of the research dataset (Zignoli et al., 2020).

Participants

Research participants are subjects who voluntarily give consent to participate in a scientific study. Participants became a source of data that researchers used to gather research information from a variety of backgrounds, including various age groups and genders. Before participating in a study, participants are usually provided with complete information about their research objectives, procedures, risks, benefits, and rights. Participants gave voluntary consent after understanding the information from the researcher. The population in this study was students who participated in the Student Activity Unit in the field of sports. The sample in this study was students who participated in Football, Futsal and Volleyball sports totaling 100 students.

Based on the letter of determination of ethical clearance regarding the determination of the validity of fitness research data of participants of the Student Activity Unit in the field of sports, it is declared valid for research. The research subject has given in-depth, informational, and voluntary consent before engaging in the research. Researchers are responsible for ensuring that research subjects fully understand the objectives, methods, risks, and benefits of research carried out in accordance with the Helsinki Statement. Additional precautions were taken by the investigator(s) to protect the volunteers in this study.

Data Collection Tools

Data collection for this study is age, sex, weight and height data involving a series of steps to obtain accurate and representative information. Participants fill in biodata by showing an identity card (KTP) or other identity to find out gender and age. Height measurement with a calibrated stadiometer, while for weight measurement with a calibrated scale.

The data collection tool in this study was using the Beep Test. A method of measuring physical fitness that involves running back and forth between two points on a track according to a certain tempo. As time goes by, the tempo will increase, and participants should try to keep running according to the specified tempo. When participants can no longer keep up with the tempo or reach the line at the allotted time, the test is

stopped, and fitness levels are measured based on the last stage successfully achieved.

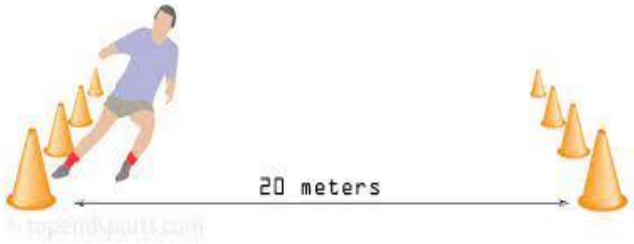

Figure 1. Implementation of beep test
Source: (Wood, 2023)

Design Test

Test design refers to the process or data collection techniques including height data, weight data, and physical fitness data using the Beep Test.

1. Participants fill out a statement of willingness.
2. Participants fill in their age and gender biodata by showing an identity card (KTP) or other personal identification that indicates student status.
3. Participants measure height with a calibrated stadiometer.
4. Participants measure their weight with a calibrated scale.
5. Participants are given an understanding of the technical implementation of physical fitness tests with beep tests.
6. Prepare test takers to be tested.
7. Prepare the tools needed, namely, multi-stage fitness audio, cones, whistles, stationery, paper, and a stopwatch.
8. The officer records the results of the achievement of the physical fitness test.

Training Intervention

The treatment was carried out several times until it got the highest accuracy score in machine learning using native bayes algorithms. The 100 data will be divided into training data and testing data. With the best scheme at least 90% data training and 10% data testing and several treatment schemes to get the highest accuracy value

Classification is done with new data with methods that have been obtained in the best machine learning mode. Data analysis techniques use probability (naïve Bayes) using data testing and evaluation. The evaluation used uses accuracy, and then the explanation is seen in Figure 1.

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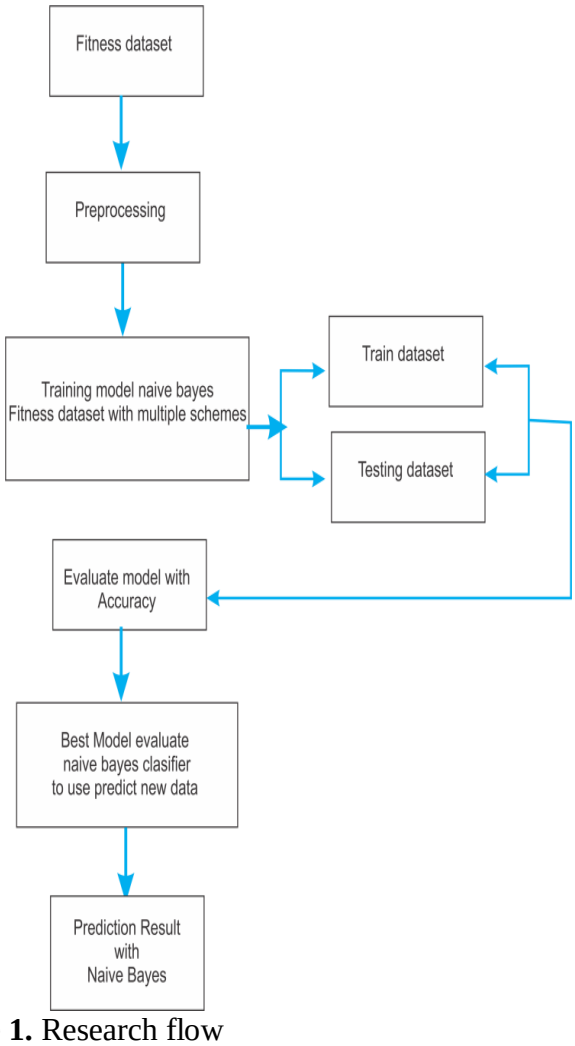


Figure 1. Research flow

In table 1 there are 100 data with features gender, height, weight, bleep test result, age, and VO2Max prediction. The 100 data will be a reference in machine learning in artificial intelligence with the Naive Bayes algorithm. Once machine learning is done, VO2Max prediction testing with new data that is not from the 100 sections can be done.

Statistical Analysis

Evaluation of the algorithm is needed to determine the performance of the algorithm (**Fadjeri et al., 2020**). However, in this study it was used to find out the prediction results from training data and testing data. The evaluation in this study uses *accuracy* (Armstrong, n.d.).
The *accuracy* formula is as follows

$$Accuracy = \frac{a+d}{a+b+c+d}$$

(Santra & Christy, 2012)
Accuracy or accuracy is widely used in algorithm evaluation

Table 1. The research dataset

No	Gender	Height	Weight	Bleep Test Result	Age	VO_2Max Predictions
1	Man	162	57	11.2	20	50.8
2	Man	160	64	11.7	21	52.2
3	Woman	159	50	7.5	17	38.2
4	Man	175	61	9.3	20	44.2
5	Man	170	78	6.1	19	33.2
*	*	*	*	*	*	*
*	*	*	*	*	*	*
*	*	*	*	*	*	*
99	Woman	170	59	4.7	14	28.7
100	Woman	170	59	4.5	15	27.6

Source: Primary Data

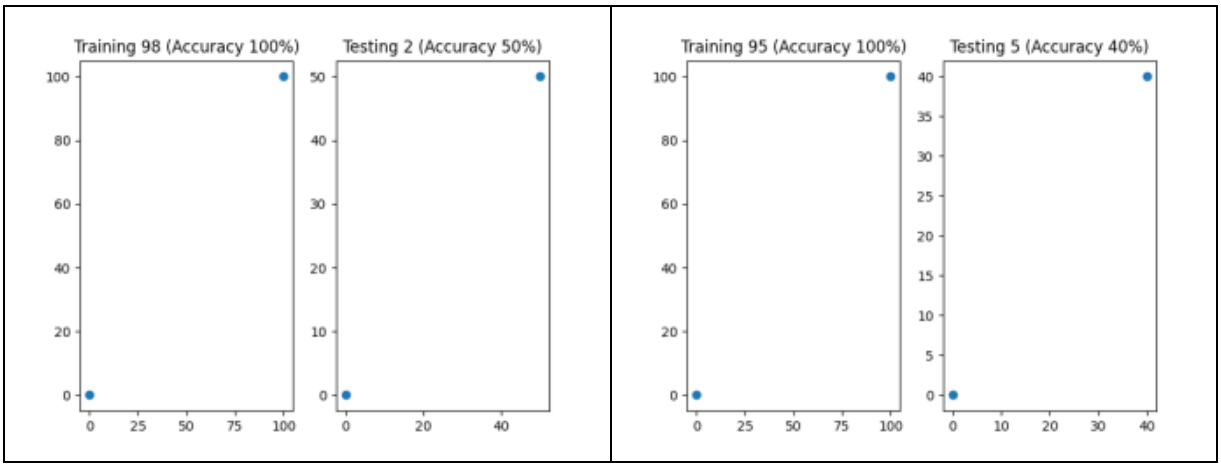
RESULTS

With the division for machine learning obtained results, 90 data training, and 10 data testing got 25% accuracy results and averrage 62,5%. Data 99 data train 1 data test gets error accuracy results, data 95 data train 5 data testing gets 40% accuracy results and averrage 70% . Data 98 data train 2 data testing gets 50% accuracy results and averrage 75 %. With these results, for testing new data using 98 training division data and testing data 2.

Table 2 describes the machine defense scheme with 100 data in table 1. From this scheme, researchers used a scheme of 98 data training and 2 data testing with an average accuracy result of 75%. The results of such machine learning are used for prediction of new data using naïve bayes algorithms.

Table 2. Results by model/ schematic

Data	Categori	Model/Schematic		
		Training	Testing	Accuracy
Data (100)	Training	90	10	100%
	Testing	90	10	25%
	Training	95	5	100%
	Testing	95	5	40 %
	Training	98	2	100%
	Testing	98	2	50 %
	Training	99	1	100%
	Testing	99	1	Error



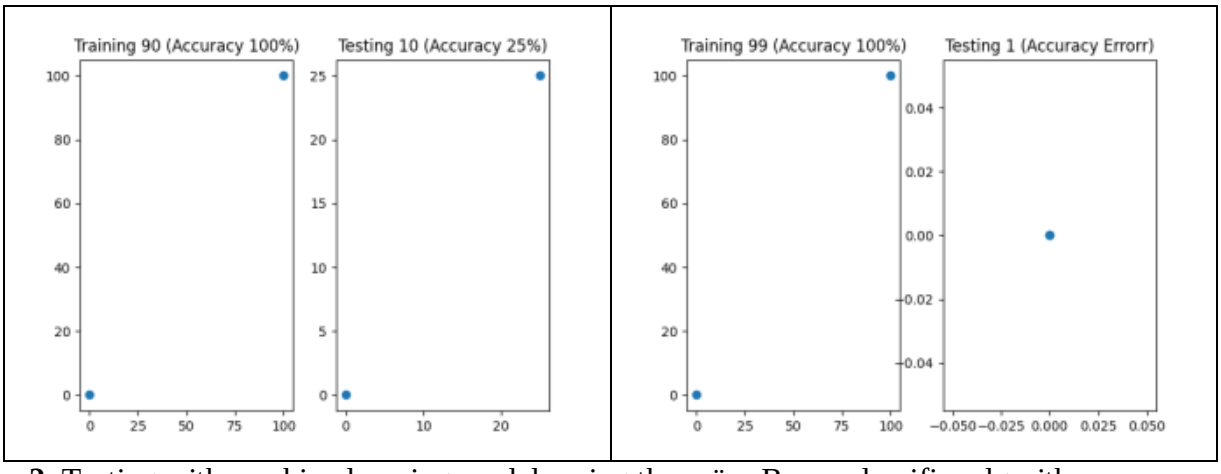


Figure 2. Testing with machine learning models using the naïve Bayes classifier algorithm

Source: Primary Data

Testing: with a machine learning model using the naïve Bayes classifier algorithm Researchers prepared 5 test datasets (new data) that were not included in the training data with 3 data already known VO2max Prediction values and 2 data unknown VO2Max PREDICTION values.

Table 3. Results reviewed actual values

No	Gender	Height	Weight	Bleep Test Result	Age	VO_2Max Predictions	Actual
1	Man	162	57	11.2	20	50.8	50.8
2	Man	160	64	11.7	21	52.2	52.2
3	Woman	159	50	7.5	17	38.2	38.2
4	Man	175	61	9.3	20	44,2	New data
5	Man	170	78	6.1	19	33,2	New data

Source: Primary Data

By looking at the table, it can be stated that of the 3 data that display the actual value is already known and is not part of the data from the initial 100 data, getting the appropriate value between the prediction and the actual. The VO2Max 2 prediski value of the new data gets values of 44.2 and 33.2.

Compared to previous research (**Ilham Insani et al., 2018**), This study used several machine learning schemes to get the best schema model by getting an overall accuracy value of 100% training with several models. Compared (**Zignoli et al., 2020**) which uses the ANN algorithm, this research has a more complete data set feature and the prediction evaluation results are better with an average training evaluation of 100%.

DISCUSSION

Sports are physical activities or games that are carried out with the aim of improving physical skills, health, fitness, and/or achieving competitive achievements. Sports can be divided into categories based on the main purpose or focus of the activity. The two main categories are "health sports" and "achievement sports. Fitness is a type of sport that is oriented to improve physical and general health, without focusing on a high level of competition (**Burhaein, 2022**). The main goal of health sports involves the maintenance and improvement of one's physical condition and general health. Achievement sports include sports that are played at a high competitive level. Athletes in achievement sports often train intensively and participate in competitions to achieve the highest achievements. The type of sport that is widely practiced by the community is achievement sports.

Achievement sports can involve a single individual or a team, and often have certain rules or guidelines. "Sports achievement" refers to sports activities that are performed with a focus on achieving the highest level of performance or outstanding achievement. Achievement sports often involve athletes training and competing at highly competitive levels, whether on a regional, national, or even international scale. TLET in sports of achievement focuses on developing and refining their technical, physical, and tactical skills with a high level of rigor (**Singh, 2022**). Intensive and structured training is an integral part of an athlete's preparation of achievement. It includes physical exercises, technical exercises, and game strategies. Athletes in achievement sports need to maintain optimal physical and mental fitness. It involves a careful exercise plan, good recovery, and a strong mental strategy.

Physical fitness plays a key role in an athlete's achievements. Physical fitness involves an optimal level of health and performance of the body, and contributes to the achievement of achievements both in sports and in everyday life (**Catur & Mujiriah, 2021; Winata & Mujirah, 2021**). With good physical fitness, it is expected to be able to contribute to the achievement of one's sports achievements. Therefore, to find out the level of physical fitness of athletes should be measured periodically. Physical fitness measurement has difficulties in its implementation because it requires time, energy, and adequate facilities. For this reason, it is necessary to make new breakthroughs related to measuring one's physical fitness more easily and accurately. Intelligent systems with machine learning and classification with naïve Bayes algorithms are a measure of a person's physical fitness without having to carry out physical fitness tests, only by entering age, gender, weight and height data.

The Naive Bayes algorithm is one of the classification methods used in machine learning. Although commonly used for text classification, Naive Bayes can also be applied in the context of physical fitness. This study provides findings that the results of this study are an application system that can detect a person's physical fitness just by entering age, gender, weight and height data without conducting a physical fitness test.

The importance of Naive Bayes algorithms in physical fitness depends on a number of factors, including the type of problem at hand, the nature of the available data, and the purpose of the analysis. Naive Bayes have very strong assumptions about feature independence, which may not always correspond to real-world circumstances. Therefore, the use of Naive Bayes should be carefully considered depending on the characteristics of the data and the purpose of the analysis. If your physical fitness dataset has complex dependencies between its features, perhaps other models such as logistic regression or decision trees can provide better results. The results of the study provide findings andconclusions are that the Application of Naive Bayes Algorithm for Physical Fitness Level Classification can be used to predict VO2Max with 100% accuracy. Training model scheme 98 and test 2 get an accuracy value when training is 100%, on testing an accuracy value of 50%.

This is in accordance with the theoretical concept with thetreatment naïve bayes carried out several times until obtaining the highest accuracy score in machine learning using native bayes algorithms. 100 data will be divided into training data and testing data. With the best scheme at least 90% data training and 10% data testing and several treatment schemes to get the highest accuracy value (**Jamaaluddin & Sulistyowati, 2021**).

Refer to the main Foundation of The field of phapharmacy/ health self is used for hospital logistics decisions and decide decision practical work (**Jamaaluddin & Sulistyowati, 2021**), then the results of this study concluded that the Smart system-based measuring instrument using the Naife Bayes algorithm can be used as a measuring instrument to determine one's physical fitness accurately. Next is related to the limitations and advantages of naïve bayes. The limitations of the research are on intelligent system applications that are still desktop and data input still using exel microsof. For further research, it is expected to use a more practical and flexible application based on Android. Naive Bayes algorithms tend to be simple and fast in training and prediction. This makes it suitable for problems that require efficient solutions and can be implemented quickly

Conclusions

The conclusion is that the Application of Naive Bayes Algorithm for Physical Fitness Level Classification can be used to predict VO2Max with 100% accuracy. Training model scheme 98 and test 2 get an accuracy value when training is 100%, on testing an accuracy value of 50%. The

best model is used as a reference in predicting new data, using 5 new data where 3 data already know the VO2Max value with the same prediction value and actual value, then 2 new data are not yet known VO2Max value, the 4th data gets a value of 44.2 and the 5th data gets a value of 33.2. The results of VO2Max testing using the naïve Bayes algorithm are declared accountable. The limitation of this study is that the research dataset was only for 100 participants which had an impact on the testing accuracy rate of 50% and the system was still in desktop form. Contribution to future research is to multiply research datasets to improve accuracy and improve user interface quality through development research.

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Conflict of Interest

We declare that this article we wrote is not involved in any particular conflict of interest.

Ethics Statement

This study was performed by adhering to the Helsinki Declaration. Ethical approval of the study was obtained from Universitas ma'Nahdkatual Ulama Kebumen Ethics Committee at the board meeting dated 20.03.2023 and numbered 17-06-2023 Ref. 0617079003, 2023.

Author Contributions

Study Design, EB; Data Collection, EB, AF and IPW; Statistical Analysis, EB, AF and IPW; Data Interpretation, EB, AF and IPW; Manuscript Preparation, EB, AF and IPW; Literature Search, EB, AF and IPW. All authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Positive Effect of Sand-Based Plyometric Jump Training on Increasing Muscle Strength and Power in Young Student-athletes

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Abstract
Muscle strength and power are considered fundamental components of successful athletic performance. However, what type of training method is effective and efficient in increasing muscle strength and power has not been well resolved. Therefore this study aimed at analyzing the effects of five weeks of sand-based plyometric jump training on improving muscle power and strength. The pretest-posttest randomized experimental design was conducted on student-athletes which then classified into three groups: the plyometric knee tuck jump (TJ, n=11), hurdle jump (HJ, n=11), and control (C, n=11). Subjects in TJ and HJ groups were assigned to five weeks of plyometric exercise, comprising 15 sessions in total, with intensities ranging from 80% to 100%. Data were obtained using NordBord and Force Decks prior to and after they completed the whole set of exercises. Data were analyzed using SPSS 23 and presented descriptively in mean and standard deviation. Paired sample t-test and one-way ANOVA were done to compare the differences between groups. Five weeks of TJ and HJ resulted in similar improvements in strength and power ($p \leq 0.05$). However, statistically significant between groups differences at the post-test were noted for HJ ($p=0.000$) in favor of both measured variables. Based on these findings, it was concluded that plyometric training in general increased strength and power of muscle leg better than conventional training.

Keywords
Athletic Performance, Hurdle Jump, Muscle Power, Plyometric Training, Tuck Jump

INTRODUCTION

A number of underlying physical condition components may contribute to physical fitness, which strength being one the most important factors, thus become the key role for maximum achievement in any sport requiring explosive action (**Alemdaroğlu et al., 2013; Maio Alves et al., 2010; Suchomel et al., 2016**). Therefore, explosive strength is considered as a fundamental components of successful athletic performance (**Silva et al., 2019**). However, other components such as power also plays important role that influences performance in various type of sport (**Marwat et al., 2022**). Muscular power allows a given muscle to exert a greater magnitude of work in the same time, or the equal amount of work in shorter time, which is important for jumping,

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sprinting (Peterson et al., 2006; Silva et al., 2019), and making quick changes of direction (CoD) (Saeed, 2013). Therefore, many researchers and coaches have been concerned with the type of training methods that is effective to use to increase power as well as strength (Wang et al., 2022).

Plyometric training, which follows the form of human movement (Wang et al., 2022), has been widely applied to enhance explosive athletic performance and regarded as one of the most effective training methods for its comprehensive neuromuscular and motor control benefit (Putera et al., 2022). It applies the mechanism of "stretch-shortening cycle" (SSC) to change the elastic potential energy in the lengthening phase (i.e. eccentric) to kinetic energy in the shortening phase (i.e. concentric) of the same muscle and tissue in the shortest possible time (Pardos-Mainer et al., 2021; Ramirez-Campillo et al., 2018; Wang et al., 2023). Because plyometric training includes muscle lengthening, it also increases flexibility (Silva et al., 2019), stimulates more stored elastic energy in the muscle (Kubo et al., 2007), and increases the amount of muscle units, resulting in higher firing frequency (Pienaar & Coetzee, 2013) and joint proprioception (Swanik et al., 2016). Additionally, recent studies in last decade have observed that the combination of plyometric training and other exercise program such as strength training, is able to optimize muscular power, vertical jump performance, and acceleration in general (Mazurek et al., 2018; Putera et al., 2023; Slimani et al., 2016). Thus, plyometric training especially in lower limb can be applied in almost all type of sports (Haff, 2015).

The aforementioned of plyometric training effectiveness can be improved by modifying several variables such as intensity, volume, and the type of jump (Ramirez-Campillo et al., 2018). However, some environment-related variables such as the type of practice plane or surface (e.g. hard surface, grass, sand, water, etc) should also be taken into account during developing the plyometric training program (Chen et al., 2023; Ramirez-Campillo et al., 2020; Sanchez-Sanchez et al., 2022; Wahba & El Nahass, 2017). Previous study done by (Impellizzeri et al., 2008) compared the effect of plyometric training done on grass vs sand surface in improving vertical jump. The result showed that sand surface significantly induced higher jump improvement (9.25%) compared to grass (5.02%), but greater increase in sprint ability was observed for grass compared to sand surface (27.86% vs 25.07%). Another study found that the improvement in countermovement jump, CoD, and sprint ability were in favour of combined-surface plyometric training (sand, wood, land-dirt, tartan-track, gym mat) compared to single surface (grass) that both were done for 8 weeks (Ramirez-Campillo et al., 2020).

Previous meta analyses have explained that type of surface may cause the training outcomes to vary, however, the most effective type of surface for plyometric training has not been decided until now, especially among team-sports (Ahmadi et al., 2021). In addition, many longitudinal studies on the effect of plyometric jump training on physical performance have been documented in recent years, however, less is known about the acute effect of different type of jump exercises on strength and power of muscle leg. Besides, recent studies in few decades have shown that the effect of plyometric training was influenced by the type of jump (Ramirez-Campillo et al., 2020), thus, an investigation into this could be helpful to coaches in adjusting training program in accordance with the principles of training, and it would also provide fresh and pertinent information regarding this topic. Therefore, the purpose of this study was to investigate the acute effect of sand-based plyometric training on increasing power and strength of student-athletes.

MATERIALS AND METHODS

Participants

This research used pretest-posttest randomized experimental design, involving 33 student-athletes as participants. The inclusion criteria applied on this study were: (1) age 18-24 years old; (2) male students; (3) an active undergraduate student majoring at sport-coaching education (4) free from any chronic conditions, respiratory disease, or injury that would have impact on their ability to run the exercise; (5) no participation in any other training program outside this study; and (6) willing to complete the whole training sessions. All participants were informed the details of training protocol and instructed to avoid heavy or high-intensity activity at least 24 hours before the test. Then, each participant was classified into experimental groups who received an intervention using sand-based plyometric tuck

jump (TJ, n=11) and hurdle jump (HJ, n=11), and control group (C, n=11). All participants had been explained the aims and objectives of this research and voluntarily and consciously provided a statement of consent by filling out and signing an informed consent. The study was done in accordance with the research policy procedures of Universitas Negeri Surabaya and and approved by the Health Research Ethics Committee, Faculty of Public Health Universitas Airlangga, Surabaya, Indonesia No. 156/EA/KEPK/2022.

Training protocols

Plyometric training was done three times a week for five weeks (15 sessions) on non-consecutive which days, namely Monday, Wednesday, and Friday (**Hariyanto et al., 2022**). At the beginning of each training, participants completed each for 5 minutes of warm-up and cool-down lower-body stretching **(Pranoto et al., 2023**), then continued with the plyometric training done in 3 sets of 12-15 reps and rest between sets 60 seconds. Plyometric training was performed with maximum intensity (80-100% 1RM) with progressively improved intensity every two weeks. All sessions were thoroughly monitored and recorded in the exercise logbook for each subject.

All participants were also measured the peak force of power and strength of muscle leg before (pretest) and after (posttest) the last training period. The measurements were performed using portable NordBord (Vald Performance, Newstead, Australia) to measure strength and ForceDecks (Vald Performance, Newstead, Australia) for power testing, both operated according to the manufacturer's recommendations. Power measurement was done by performing a jump on the device's force plate. Subjects performed three attempts of countermovement jump (CMJ) with a 30-second break between each jump. Peak force was considered as the maximum force generated before take off **(Chavda et al., 2018; Sarvestan et al., 2020**). The measures of jumping height (cm) and jumping peak power (W) were recorded. All measurements were done by an experienced laboratory technician.

Prior to the first session, the main sociodemographic (age) and anthropometric variables (body weight, height, body mass index, oxygen saturation, blood pressure, resting heart rate) were measured as baseline characteristic. Bodyweight was assessed using digital scale (Omron HN-289, Osaka, Japan) at the nearest 0.1 kg. Portable stadiometer (Seca 213, Seca Ltd., California, US) was used to measure standing height. Resting heart rate (HR) was monitored using a polar heart rate monitor (Polar H10 Bluetooth Heart Rate Sensor & Fitness Tracker, Kempele, Finland), and blood pressure was measured using a digital blood pressure meter (Omron Deluxe HEM-8712, Osaka, Japan).

Statistical analysis

All measured variables were presented descriptively as means and standard deviations (SD). After normality test was verified using Saphiro-Wilk test, then paired t-test was done to analyse the differences in measured variables before and after the training was conducted. One-way Anova was applied to examine group differences between TJ, HJ, and C. Further post-hoc analysis was performed using Least Significant Different (LSD) post-hoc test to find out which pairs were different. Differences between groups were considered statistically significant for $p \leq 0.05$. All statistical evaluations were performed using GraphPad Prims 9.0 for Mac (GraphPad Software Inc., San Diego, USA) and SPSS 23 for Windows (SPSS Inc., Chicago, USA).

RESULTS

A total of 33 males student-athletes, with the average age (19.48 ± 0.50 years), had normal body mass index (20.90 ± 1.35 kg/m^2), normal blood pressure (systolic: 115.23 ± 5.48 mmHg; diastolic: 74.50 ± 5.12 mmHg), normal resting heart rate (66.32 ± 5.88 bpm), and normal oxygen saturation (96.23 ± 1.15 %) participated in this study. From Table 1, it can be obtained that baseline characteristic of participants in all groups were equally homogenous ($p \geq 0.05$). All participants have completed the whole training programs for five weeks. There were neither injury of lower limb nor spine, and no drop out reported during the experimental period.

Table 1. Baseline characteristic

Variable	C	TJ	HJ	*p*-value
Age (years)	19.27 ± 0.46	19.63 ± 0.50	19.54 ± 0.52	0.222
Height (cm)	168.27 ± 5.76	171.72 ± 5.33	173.54 ± 4.15	0.065
Weight (kg)	55.18 ± 4.60	56.81 ± 5.01	53.81 ± 3.70	0.304
BMI (kg/m^2)	21.19 ± 1.44	21.51 ± 1.72	20.82 ± 0.76	0.079
SBP (mmHg)	115.80 ± 3.71	114.80 ± 7.98	115.10 ± 4.33	0.752
DBP (mmHg)	75.25 ± 3.56	76.10 ± 4.69	75.60 ± 3.98	0.591
HR (bpm)	65.90 ± 5.23	64.82 ± 4.99	65.76 ± 6.31	0.145
SpO_2 (%)	97.00 ± 1.25	97.50 ± 1.65	97.40 ± 1.43	0.430

Description: BMI: Body mass index; C=Control group; DBP: Diastolic blood pressure; HJ: Plyometric tuck jump group; HR: Heart rate; SBP: Systolic blood pressure; SpO_2: Oxygen saturation; TJ: Plyometric hurdle jump group. All data were presented in mean and standard deviation (mean±SD).

Figure 1 disclosed the comparison result in muscle power and muscle strength pre and post-subjects performed plyometric jump training. We observed significant differences in the experimental group where five weeks of plyometric jump training that was performed on sand increased muscle power and strength ($p \leq 0.05$). The highest improvement of muscle power was found in HJ which increased from 4152.82±519.02 watt to 4768.64±718.82 watt (Delta (Δ) = 615.82±314.71 watt; percentage increase with pre = 14.66±6.423 %). The greatest improvement was also seen in strength for HJ, from 116.45±20.47 kg to 135.82±21.28 kg (Δ = 19.37±10.98 kg; percentage increase with pre = 14.21±7.57 %) (Figure 2).

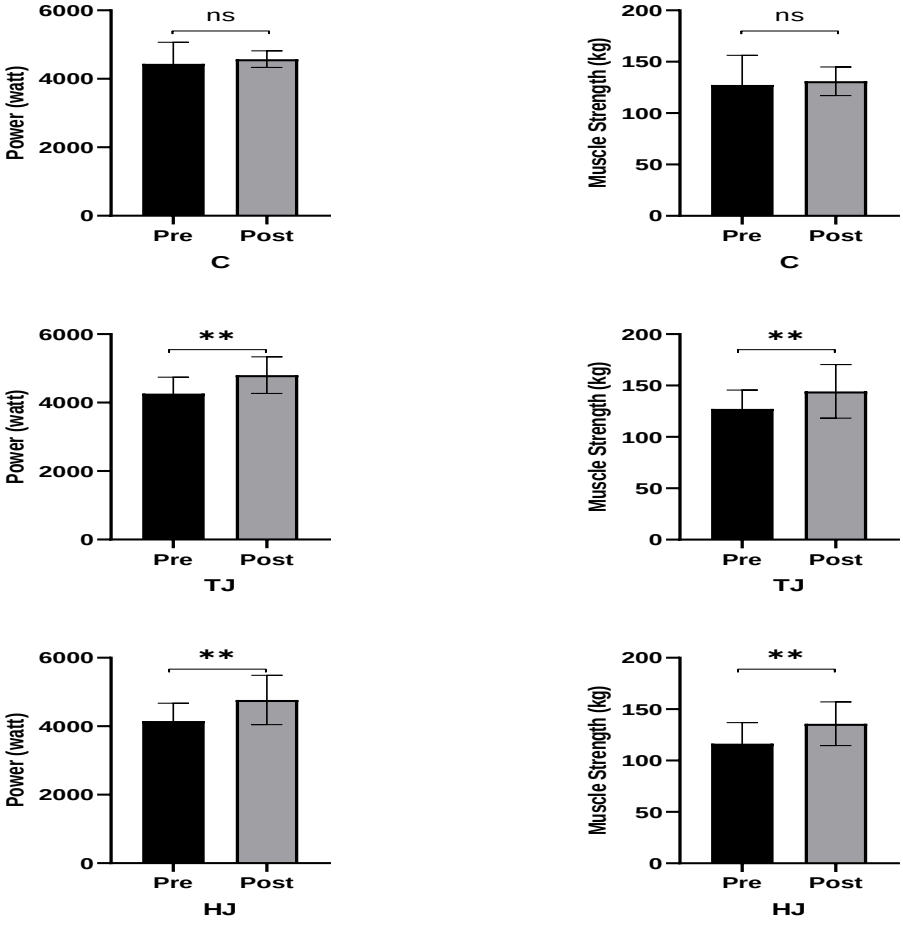

Figure 1. Analysis of power and muscle strength in all groups. C=Control group; TJ: Plyometric hurdle jump group; HJ: Plyometric tuck jump group. All data were presented in mean±SD. p-value is obtained by paired sample t-test. (ns) Not significant. (**) Significant at pre ($p \leq 0.001$).

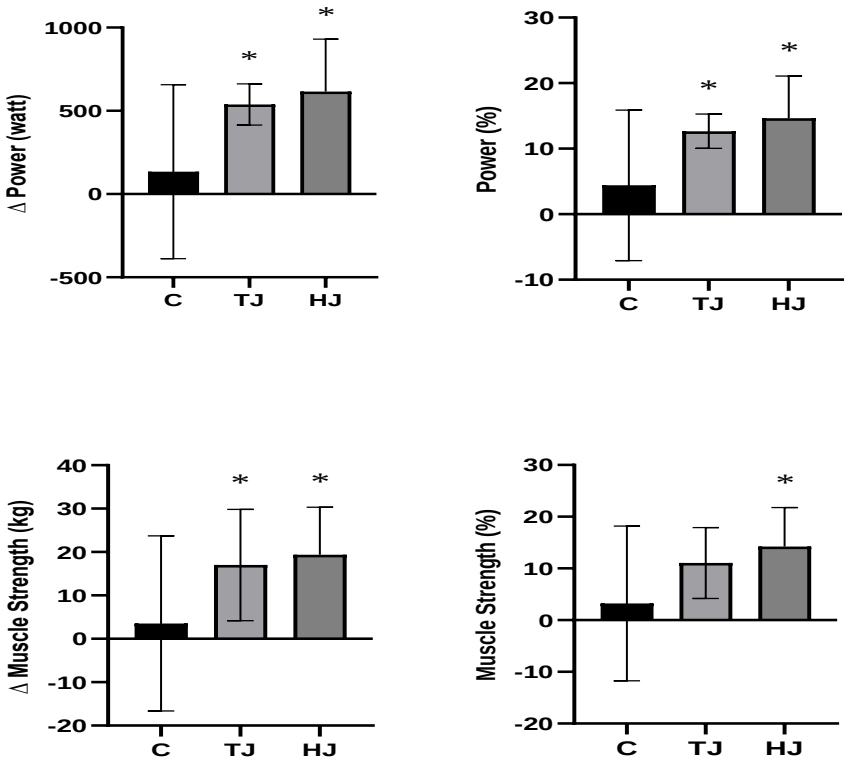

Figure 2. The differences of power and muscle strength between groups (C vs. TJ vs. HJ). (*) Significant at Control (C) ($p \leq 0.05$).

DISCUSSION

Previous experimental studies regarding the effect of plyometric trainings on individuals discovered that PT contributes to the increase of sport performance as well as improve several health parameters (**Hariyanto et al., 2022**), such as lowering fat mass and optimizing bone health when integrated with daily training routines **(Wang & Zhang, 2016**). This study revealed that plyometric jump training done on sand was effective to increase power and strength of muscle legs in student-athletes. Our hypothesize that higher gains would occur in experimental group compared to control group was clearly seen in present study, as the given plyometric jump trainings resulted in significantly greater increase in both measured variables by the fifth week. The highest improvement was reported in HJ group, where a change of 14.83% and 16.63% indicated that significant adaptation in power and strength was occurred after five weeks of treatment. The finding of present study was supported by previous investigation conducted by **Putera et al**. (**2023**) where six-week of plyometric training significantly enhanced muscle power and strength of lower limb in young adults. Another study also reported small but significant increase in strength after subjects was given plyometric training with an intensity of 60-80% HRmax for five weeks (**Hariyanto et al., 2022**). The same results have also been observed that plyometric training also significantly increases strength, agility, and speed in quadriceps and hamstring muscles before and after plyometric training compared to non-plyometric training group (**Elnaggar et al., 2019**).

Plyometric training applies the mechanism of continuous SSC, which comprise of eccentric followed immediately by concentric phase of the muscle (**Bulqini et al., 2023; Hariyanto et al., 2022; Putera et al., 2022; Silva et al., 2019**). Because of this continuous repeated cycle, **Kobal et al.** (**2017**) in their research has made clear that PT can lead to greater improvement in physical performance in fatigue-free state. In line with that, other study stated that plyometric exercise done in only one session was sufficient to change muscle-tendon characteristics by modifying neuromuscular activity which in turn caused tendon to lengthen and shorten more frequently than fascicles (**Hirayama et al., 2012**). Different from the acute effect of other trainings, PT will escalate the performance of SSC exercises differently, with muscle tendon unit (MTU)

behavior changes in a favorable way, adjusting to the change of tendon stiffness and muscle strength (**Fouré et al., 2010; Wu et al., 2010; Hirayama et al., 2017**). Tuck jump (TJ) and hurdle jump (HJ) that were done in experimental groups were able to shorten the muscle transition from eccentric to concentric phase, which will also improve jumping ability and support the muscle's capacity for explosive movements that increase power and strength of muscle leg (**Louder et al., 2015**). In addition to that, because plyometric exercise involves muscle lengthening, it may also enhance the amount of elastic energy that is stored in the muscles (**Kubo et al., 2007**), induce more muscle units (**Pienaar & Coetzee, 2013**) which lead to a higher (neural) firing frequency, and enhance joint proprioception (**Swanik et al., 2016**).

Significant increase in measured variables was found in all groups, but we observed that HJ gained largest increase compared the rest of groups. It might be explained that jumping over hurdles requires more effort and better coordination than usual jumping **(Healy et al., 2020**) or traditional countermovement jump (**Cappa & Behm, 2011**). The urge to overcome an obstacle like a box or a hurdle might affect the SSC mechanism, resulting in adjusment of concentric and eccentric jump parameters, which may eventually influence the resultant training adaptations over time (**Janikov et al., 2023**). However, present study did not investigate concentric and eccentric parameters further which become limitation of this study.

Present study confirmed that both types of plyometric training increase muscle power and muscle strength in student-athletes, but plyometric hurdle jump training is more effective in increasing sport performances than plyometric knee tuck jump training. This study found a positive relationship between increased muscle strength and muscle power. Given that improvements are roughly equivalent for both type of plyometric training, it is crucial to take into account the reduction in soreness or injury in athletes when using different kind of jump training to supplement conditioning training.

Acknowledment

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Conflict of interest

The authors declared to have no conflict of interest. In addition, no financial support was received.

Ethics Committee

All procedures for this study were approved by the Health Research Ethics Committee, Faculty of Public Health Universitas Airlangga, Surabaya, Indonesia (Ethical Approval No. 156/ EA/ KEPK /2022).

Author Contributions

Study Design; OW-HS, Data Collection; OW-AK-SHPP-AMS, Statistical Analysis; AP Data Interpretation; AP, Manuscript Preparation; OW-AMS-AP, Literature Search; OW-AK-SHPP. Authors have read and agreed to the published version of the manuscript.

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RESEARCH ARTICLE

Association Between Hearing Loss Suspect with Diabetes and Arterial Hypertension Risk Under Different Body Composition Phenotypes: Results from the Chilean National Health Survey 2016-17

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Abstract
Purpose: 1) To characterize the glucose and blood pressure control in HLS adult participants based on four body composition phenotypes models from the Chilean National Health Survey 2016-17. 2) to associate the HLS and body composition phenotypes (based on calf and waist circumference [WC]) with arterial hypertension and diabetes markers. Method: A quantitative cross-sectional study based on the Chilean National Health Survey 2016-17, reporting adults with/without HLS based on four different phenotypes was carried out by the epidemiological group of the Institute of Rehabilitation and Exercise Sciences of the Universidad Andres bello, Chile (ICER-UNAB). Groups were as follows; Low skeletal muscle [SMM] and high waist circumference [WC] (Lsmm−Hwc, *n*=278), Low SMM and low WC (Lsmm−Lwc, *n*=479), High SMM and high WC (Hsmm−Hwc, *n*=2140), and High SMM and low WC (Hsmm−Lwc, *n*=2709). The primary outcomes were fasting plasma glucose, systolic, and diastolic blood pressure. Findings: In systolic blood pressure, there were significant differences between each Lsmm−Hwc (150 vs. 123 mmHg), Lsmm−Lwc (140 vs. 123 mmHg), and Hsmm−Hwc vs. the Reference group (145 vs. 123 mmHg, all *P*<0.0001). Systolic blood pressure reported significant Group x HLS interaction *F* (3.33), *P*=0.019, ES 0.004. In diastolic blood pressure, there were significant differences between each Lsmm−Hwc (74 vs. 72 mmHg) and Hsmm−Hwc vs. the Reference group (76 vs. 72 mmHg, both *P*<0.0001). Diastolic blood pressure reported significant Group x HLS interaction *F* (4.49), *P*=0.004, ES 0.005. Chilean adults with HLS, low SMM and high waist circumference shows a higher systolic and diastolic blood pressure.

Keywords
Body Composition, Hearing Loss, Quality of Life, Diabetes, Arterial Hypertension

INTRODUCTION

Considering the different and potential causes of hearing loss (HL) in adults, the natural ageing of the auditory system (**Tang, Tran, Dawes, & Gopinath, 2023**) and prolonged exposure to high noises are commonly the two main factors described in the HL process (**Elshaer, Meleis, & Mohamed, 2023**). Worryingly, more than 65% of people over 60 years old suffer from

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some degree of hearing loss (i.e., independently of their congenital, permanent, bilateral, or unilateral HL cause); however, the prevalence increases dramatically in 15% of those aged 60, and 80% among those aged ≥80 years old (**Goman & Lin, 2016**). It has been described that 62.7 million Americans have some degree of HL (i.e., moderate, or high grade) (**WHO, 2021b**); however, it is increased by ~10% in >15 aged population that suffer from any disability (i.e., from sensory, hearing, or visual disability). Indeed, literature has reported that HL disability represents ~8.2% of total disabilities (**WHO, 2021b**).

Independently of the HL origin and prevalence, together with the physical health disabilities that HL is related to, other health-related quality-of-life (QoL) detriments are also characteristic of adults with some degree of HL or hearing loss suspect (i.e., a self-report of some degree of hearing loss without a clinical diagnosed). Moreover, other conditions such as lower postural stability (**Foster, Williams, Timmer, & Brauer, 2022**), cognitive impairment, dementia (**Azeem et al., 2023; Tamblay et al., 2023**), depression (**Baiduc, Sun, Berry, Anderson, & Vance, 2023**), and poor QoL have been associated with populations with HLS as well (**Dillard et al., 2023**).

Reductions in the capacity for adhering to and maintaining daily living activities that could protect cardiometabolic health (i.e., decreased capacity to maintain regular physical activity such as walking or running, to associate with other peers by limited social possibilities associated with HLS) are common aspects related to poor QoL (**Goodwin, Hogervorst, Hardy, Stephan, & Maidment, 2023; Kuo, Di, Ferrucci, & Lin, 2021**). Furthermore, the reduction in physical activity levels in adults with HLS is usually related to more time in sedentary activities, and these populations could face less possibility the cardiometabolic conditions usually associated with the ageing process, such as diabetes and HTN (**Goodwin et al., 2023**). Thus, when adults declare HLS, they could probably be at major risk of modifying their body composition (i.e., increasing body fat, and reducing their skeletal muscle mass) and thus more at risk for acquiring comorbidities such as being overweight or obesity condition (**Curhan, Eavey, Wang, Stampfer, & Curhan, 2013**). So far, a previous study involving (n=62.421) women reported that adults with HL showed a higher body mass index (BMI) and higher waist circumference (WC) characteristically; meanwhile, peers that walk at least 2 h per week have shown an inverse association with a minor HL prevalence (**Curhan et al., 2013**). Therefore, physical inactivity (i.e., do not adhere to international physical activity guidelines of at least 150 to 300 min of low-to-moderate PA per week), or 75 to 150 min of vigorous PA per week (Tsao et al., 2023)) and sedentary time usually increase adiposity (i.e., by BMI and body fat increases) (**Croll et al., 2019**), contributing to skeletal muscle mass (SMM) decrease and SMM loss (sarcopenia), in addition to lower glucose and blood pressure control, leading for diabetes and arterial hypertension risk (**Park et al., 2022**).

So far, changes in body composition have been linked with HLS in the adult population, which leads to a greater risk of suffering from cardiometabolic diseases such as diabetes and arterial hypertension (HTN). Likewise, Samocha-**Bonet et al.** (**2021**) highlight that in older adults diagnosed with diabetes, the incidence of HL increases twice. Moreover, several studies have also reported a significant association between HL and a higher prevalence of diabetes and HTN (**Helzner et al., 2011; McKee, Stransky, & Reichard, 2018; Samocha-Bonet, Wu, & Ryugo, 2021**). Several investigations (**Bener et al., 2017; Gioacchini et al., 2023; Meneses-Barriviera et al., 2018**) have reported epidemiological data about adults with HLS and the association with cardiometabolic diseases; however, no studies have established these associations in Chilean population, especially the relation of HLS with diabetes and HTN risk.

On the other hand, it is interesting to mention a recent preclinical study in animal models from (**Park et al., 2020**) that suggests the acceleration of the ageing process (by increasing oxidative-stress-induced mitochondrial dysfunction, promoting hypoxia or increasing the exposure to high-fat diet) was significantly associated with high HL risk.

Concerning this, characterize the different body composition phenotypes (i.e., high, or low SMM, by calf circumference; and high or low body fat, by WC or their combinations) and their association with diabetes and HTN markers in the adult Chilean population with HLS would

contribute to clinical practice and prevention is little information regarding the cardiometabolic risk in terms of HTN and diabetes prevalence in the population with HLS, being relevant to describe the characteristics and lifestyle of the population with HLS where their body composition phenotypes could play a role in preventing additional or major comorbidities, and above considering the role of a low SMM and higher body in the worse of the glucose control (i.e., diabetes), and impairment of the cardiovascular health (i.e., HTN).

Therefore, this study aims: 1) to characterize the glucose and blood pressure control in HLS adult participants based on four body composition phenotypes models from the Chilean National Health Survey 2016-17 (NHS16-17) and 2) to associate HLS and body composition phenotypes (based on calf and waist circumference) with arterial hypertension and diabetes markers.

MATERIALS AND METHODS

This cross-sectional study is based on the NHS16-17, a prevalence, multi-stage, and representative study developed at home, using random, stratified-by-conglomerates methods, that include urban and rural areas (**Minsal, 2017**).

strategies for improving QoL. Additionally, there

Participants

Considering the total NHS16-17 sample of (*n*=6.233) participants, the present study included (*n*=5.632) participants that were associated by each phenotype-modelled group and by the categories of "no hearing loss suspect" (No-HLS) and "hearing loss suspect" (HLS). The final sample was then determined according with four different body composition phenotypes using each SMM and CC variations, as follows; Low SMM and high WC (Lsmm-Hwc, *n*=140 [category No-HLS, *n*=94; HLS, *n*=46]), Low SMM and Low WC (Lsmm-Lwc, *n*=242 [category No-HLS, *n*=154; HLS, *n*=88]), High SMM and High WC (Hsmm-Hwc, *n*=1076 [category No-HLS, *n*=742; HLS, *n*=334]), and High SMM and Low WC (Hsmm-Lwc, *n*=1358 [category No-HLS, *n*=1078; HLS, *n*=280]). The study protocol was approved by the Ethical Committee of the Escuela de Medicina de la Pontificia Universidad Católica de Chile (16-019), and all participants signed an informed consent, date: ENS16-17. The study design can be seen in (Figure 1). The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

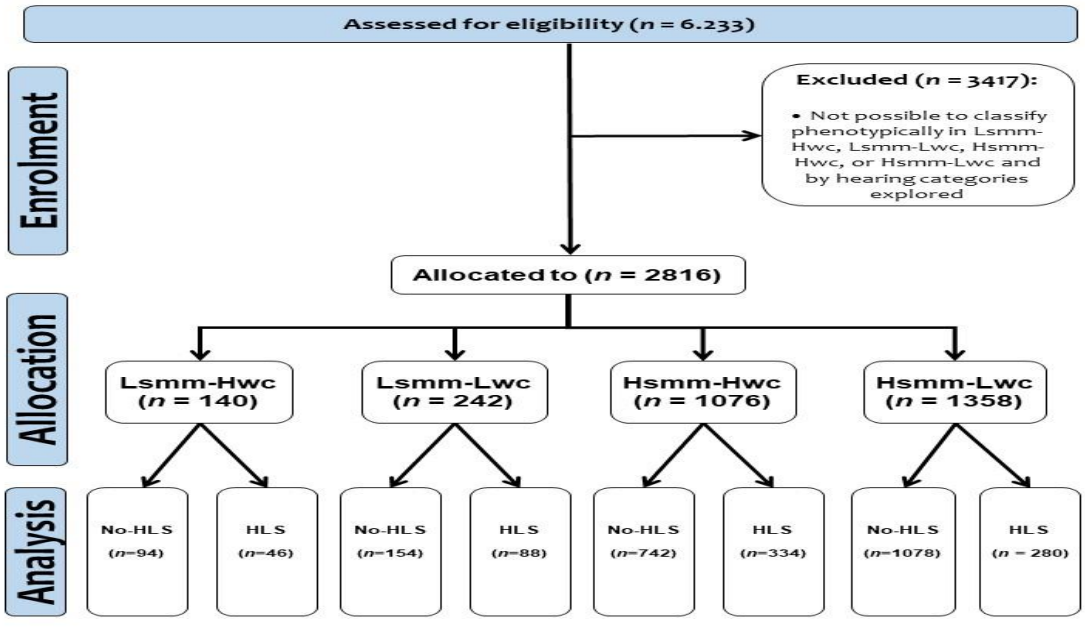

Figure 1.The study design

Body composition phenotypes

The participants were grouped by four phenotypes according to a different SMM level (i.e., based on the 'calf circumference' outcome) and adiposity (i.e., based on the 'waist circumference' outcome) that are reported in the NHS16-17.

The four groups of phenotypes (Lsmm-Hwc, Lsmm-Lwc, Hsmm-Hwc, Hsmm-Lwc) were modelled using the cut-off point of 34 cm to 'calf circumference' for men, and 33 cm for adult women that have demonstrated high sensitivity (80.0%) and specificity (84.6%) (Pagotto, Santos, Malaquias, Bachion, & Silveira, 2018). The WC was categorized as 'higher' WC (men ≥90 cm, women ≥80 cm), or 'low' WC (men <89 cm, women <79 cm), as previously used (Rolland et al., 2003). For both CC and WC outcomes, a professional nurse used an inextensible tape for the measurement applied at each participant's home. On the other hand, the No-HLS or HLS condition was categorized using the data population that reported suffering (or not) of HLS, using the question included in the NHS16-17 as follows; "Do you consider that you normally hear in both ears?".

Diabetes and arterial hypertension markers (main outcomes)

Fasting plasma glucose (FPG) and glycated haemoglobin were measured in fasting conditions (i.e., 8 h) by professional nursing, similar to those reported in previous studies (**Álvarez et al., 2023**). To detect the diabetes risk, there was reported the odds ratio (OR) statistical parameter to detect the risk of suffering or not some condition, such as diabetes and HTN risk, by the categorization of the question; 'diabetes suspects in fasting state', with categorical answers 'Yes' or 'Not', included in the NHS16-17.

On the other hand, to the HTN risk, the systolic (SBP) and diastolic (DBP) were measured in the left arm three times, and the average of these attempts was registered. We used the American Heart Association 2018 blood pressure categorization; 'Normal BP' was defined as SBP/DBP less than 120/80 mmHg, 'elevated blood pressure' (Ele) as SBP/DBP 120-129/80 mmHg, 'stage 1 HTN' as SBP/DBP 130-139/80-89 mmHg, and 'stage 2 HTN' as SBP/DBP ≥140/90 mmHg (Whelton et al., 2018). These measurements were carried out by an automatic monitor (OMRON^{TM}, model HEM 7114, Tokyo, Japan) similar to previous studies of the NHS16-17 (**Petermann, Duran, et al., 2017**), and were applied by professional nursing at-home conditions. In addition, to detect the HTN risk, we also reported the OR statistical parameters, and used the question; 'Arterial hypertension suspects', with categorical answers 'Yes' or 'Not', included in the NHS16-17.

Secondary cardiometabolic risk factors (Secondary outcomes)

Total cholesterol (Tc), low-density lipid cholesterol (LDL-c), high-density lipid cholesterol (HDL-c), and plasma triglycerides (Tg) were measured and classified following the National Cholesterol Education Program NCEP ATP-III criteria (NCEP, 2002). The 25-OH vitamin D2+D2 outcome was included as a mineral content marker, and gamma (GGT) and pyruvic glutamyl transferase (PGT) were analyzed as non-alcoholic fatty liver disease markers. Free thyroxine and thyroid stimulating hormone (TSH) were analyzed as markers of 'hypothyroidism', C-Reactive protein was included as a marker of 'inflammation', and finally, microalbuminuria was included as a marker of kidney damage.

The weight was measured by a digital electronic scale OMRON^{TM}, model HN 289 (OMRON Corporation, Kioto, Japon), (sensitivity of 100 g, maximum weight capacity of ~150 kg), where height and waist circumference were assessed by an inextensible tape, similar as previously (**Concha-Cisternas et al., 2023**). The BMI was calculated using weight and height information from international institutions (**WHO, 2000**).

Cardiovascular risk score estimation

The cardiovascular risk was categorized by scale punctuation in 'low' (0-4 points), 'moderate' (5 to 9 points), and 'high cardiovascular risk' (≥10 points) using the metabolic syndrome outcomes (SBP, DBP, FPG, HDL-c, and Tg), including tobacco habit, alcohol consumption, dyslipidemia, sleep patterns, as well by the three questions included as follows; a) in the self-report on acute myocardial infarction ¿Has a doctor or physician ever told you had or suffered a heart attack? Being the prevalence from those who answered "Yes"; b) the question for the self-reported prevalence of stroke "Has a doctor or physician ever told you had or suffered a stroke? or had or suffered a stroke or cerebral thrombosis (or stroke)?", and c) the question about the self-reported prevalence of peripheral venous disease "Has a doctor or physician ever told you had or suffered from peripheral vascular disease or to the arteries in your legs?" (**MINSAL, 2018**). However, we reported only the risk of suffering from 'moderate' and high CVR' in this study.

Statistical analysis

Data for continuous outcomes are shown as mean and (95%CI), and for categorical outcomes as frequency (*n*=) and (%), percentage. The normality was tested using the Shapiro-Wilk test. For continuous outcomes, the interaction of the four phenotypes groups (Lsmm-Hwc, Lsmm-Lwc, Hsmm-Hwc, and Hsmm-Lwc) with HLS categories was tested using univariant analyses ANOVA (Groups; HLS; and Groups x HLS). Moreover, using multinominal logistic regression, we calculated the risk for suffering from diabetes, HTN, MetS, 'moderate' and 'high' cardiovascular risk by the OR and showed the information as mean and (95% CI). The Wald Chi-square was reported and the pseudo-McFadden R^2 were reported for predicting each dependent outcome. Additionally, we calculated the effect size (ES) using Cohen's *d* test (Hopkins, Marshall, Batterham, & Hanin, 2009) corrected for small samples (<20 subjects) (Hedges & Olkin, 2014), with threshold values at 0.20, 0.60, 1.2, and 2.0 for small, moderate, large, and very large effect sizes, respectively. These analyses were adjusted by geographic area, region, sex, and age. All statistical analyses were developed using the SPSS™ software 25 version for Windows (IBM SPSS Inc., Chicago, IL, USA).

RESULTS

The general characteristics of No-HLS vs. HLS group revealed significant differences in outcomes age (*diff*. 10.4 y, *P*<0.0001), height (*diff*. 2 cm, *P*<0.0001), weight (*diff*. 2.1 kg, *P*=0.003), FPG (*diff*. 3.4 mg·dL), SBP (*diff*. 6 mmHg, *P*<0.0001), PGT (*diff*. 1.7 UI·L, *P*=0.035) microalbuminuria (*diff*. 1.85 mg·dL, *P*=0.007) and PA_{VI} (*diff*. 6.2 min·week, *P*=0.002) (Table 1). No significant differences were detected between No-HLS vs. HLS group in outcomes BMI, WC, CC, HbA1c, DBP, Tc, LDL-c, HDL-c, Tg, vitamin D2+D3, GGT, PGT, free thyroxine, TSH, CRP, PA_{MI}, PA_{LI}, handgrip muscle strength (Table 1).

Table 1. General characteristics of adult participants of the chilean national health survey 2016-17.

Outcomes	No-HLS	HLS	No-HLS *vs.* HLS
(*n* =)	4929	1304	
Age (y)	46.7 (46.1; 47.2)	57.1 (56.1; 58.1)	***P*<0.0001**
Height (cm)	160.0 (159.7; 160.2)	158.0 (157.5; 158.6)	***P*<0.0001**
Weight (kg)	74.0 (73.5; 74.4)	71.9 (71.0; 72.8)	***P*=0.003**
BMI (kg·m^2)	27.2 (26.9; 27.4)	27.0 (26.6; 27.4)	*P*=0.451
WC (cm)	93.6 (93.1; 94.0)	93.9 (93.1; 94.7)	*P*=0.535
CC (cm)	35.1 (34.8; 35.4)	34.8 (34.3; 35.2)	*P*=0.191
FPG (mg·dL)	99.3 (98.2; 100.4)	102.7 (100.5; 104.9)	***P*=0.007**
HbA1c (%)	6.3 (6.2; 6.4)	6.5 (6.3; 6.6)	*P*=0.098
SBP (mmHg)	126 (125; 126)	132 (131; 133)	***P*<0.0001**
DBP (mmHg)	75 (74; 75)	74 (74; 75)	*P*=0.773
Tc (mg·dL)	181.1 (179.6; 182.6)	182.4 (179.6; 185.2)	*P*=0.422
LDL-c (mg·dL)	104.6 (103.4; 105.8)	105.5 (103.1; 107.8)	*P*=0.529
HDL-c (mg·dL)	47.7 (47.2; 48.1)	48.2 (47.3; 49.1)	*P*=0.311
Tg (mg·dL)	144.0 (140.6; 147.3)	143.7 (137.3; 150.1)	*P*=0.934
D2+D3 (ng·mL)	19.8 (19.5; 20.2)	19.3 (18.7; 19.9)	*P*=0.158
GGT (UI·L)	32.0 (30.2; 33.8)	34.4 (30.9; 37.8)	*P*=0.229
PGT (UI·L)	25.3 (24.6; 26.0)	23.6 (22.3; 25.0)	***P*=0.035**
TSH (ng·dL)	3.97 (3.46; 4.47)	4.14 (3.20; 5.09)	*P*=0.746
FT (ng·dL)	1.20 (1.18; 1.21)	1.20 (1.17; 1.23)	*P*=0.806
C-RP (mg·L)	0.45 (0.38; 0.52)	0.40 (0.29; 0.51)	*P*=0.431
Microalb	2.86 (2.21; 3.50)	4.71 (3.52; 5.89)	***P*=0.007**
PA_{VI} (min·week)	3.5 (2.8; 4.2)	6.1 (4.6; 7.6)	***P*=0.002**
PA_{MI} (min·week)	4.0 (3.5; 4.6)	4.2 (3.1; 5.3)	*P*=0.749
PA_{LI} (min·week)	12.7 (12.2; 13.2)	12.2 (11.2; 13.2)	*P*=0.431
HGS (kg)	52.1 (46.8; 57.5)	59.5 (52.3; 66.7)	*P*=0.108

Data are shown as mean and (95% CI). Groups are described as; (No-HLS) No hearing loss suspect. (HLS) Hearing loss suspect. (BMI) Body mass index. (WC) Waist circumference. (CC) Calf circumference. (FPG) Fasting plasma glucose. (HbA1c) Gluyated hemoglobin. (SBP) Systolic and (DBP) Diastolic blood pressure. (Tc) Total cholesterol. (LDL-c) Low-density lipoprotein. (HDL-c) High-density lipoprotein. (Tg) Triglycerides. (D2+D3) Vitamin D2+D3. (GGT) Gamma glutamil transferase. (PGT) Piruvate glutamil transferase. (TSH) Tirostimulant hormone. (FT) Free thyroxine. (C-RP) C-Reactive protein. (Microalb) Microalbuminuria. (PA_{VI}) Vigorous-intensity physical activity. (PA_{MI}) Moderate-intensity physical activity. (PA_{LI}) Light-intensity physical activity. (HGS) Handgrip muscle strength. Bold values denote significant differences by groups at $P \leq 0.05$.

There were significant differences in FPG between each Lsmm−Hwc (112.5 vs. 93.6 mg·dL, $P<0.0001$), Lsmm−Lwc (95.8 vs. 93.6 mg·dL, $P<0.021$), and Hsmm−Hwc vs. the Ref. group (112.3 vs. 93.6 mg·dL, $P<0.0001$) (Figure 2A). Significant Group interaction was reported in FPG $F(22.10)$, $P=0.015$, ES 0.957 (Figure 2A). In HbA1c, no significant interactions were found (Figure 2B). In SBP, there were significant differences between each Lsmm−Hwc (150 vs. 123 mmHg), Lsmm−Lwc (140 vs. 123 mmHg), and Hsmm−Hwc vs. the Ref. group (145 vs. 123 mmHg, all $P<0.0001$) (Figure 2C). SBP reported significant Group x HLS interaction $F(3.33)$, $P=0.019$, ES 0.004 (Figure 2C). In DBP, there were significant differences between each Lsmm−Hwc (74 vs. 72 mmHg) and Hsmm−Hwc vs. the Ref. group (76 vs. 72 mmHg, both $P<0.0001$) (Figure 2D). DBP reported significant Group x HLS interaction $F(4.49)$, $P=0.004$, ES 0.005 (Figure 2D).

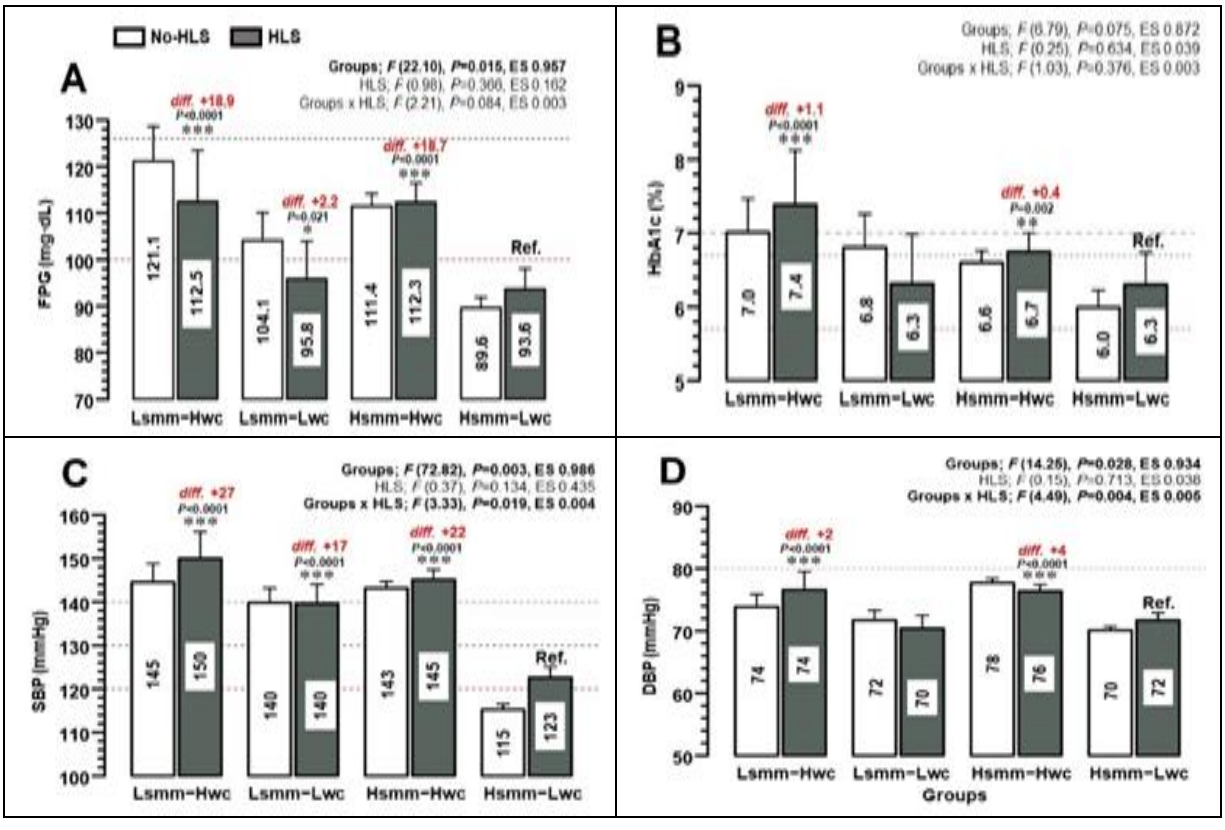

Figure 2. Diabetes (A, B) and arterial hypertension (C, D) markers in Chilean adult participants of the National Health Survey 2016-17, described by four body composition phenotypes and by a different condition of hearing. Groups are described as low-skeletal muscle mass and high waist circumference phenotypical model (Lsmm−Hwc), low-skeletal muscle mass and low waist circumference phenotypical model (Lsmm−Lwc), high-skeletal muscle mass and high waist circumference phenotypical model (Hsmm−Hwc), and high-skeletal muscle mass and low waist circumference phenotypical model (Hsmm−Lwc), Reference group (Ref.). Categories are described as: (HLS) hearing loss suspect. (No-HLS) No hearing loss suspect. Outcomes are described as; (FPG) Fasting plasma glucose. (HbA1c) Glycated hemoglobin. (SBP) Systolic blood pressure. (DBP) Diastolic blood pressure. (*diff.*) Differences vs. Ref. group. (*) Denotes significant difference vs. Ref. at $P<0.05$. (**) Denotes significant difference vs. Ref. at $P<0.01$. (***) Denotes significant difference vs. Ref. at $P<0.0001$.

In the lipid profile outcomes, there were significant differences in Tc between Lsmm−Hwc vs. the Ref. group (201.5 vs. 182.6 mg·dL, *P*<0.0001) (Figure 3A). A significant Group x HLS interaction was reported in Tc *F*(3.44), *P*=0.016, ES 0.005 (Figure 3A). In LDL-c, no significant interactions were found (Figure 3B). In HDL-c, there were significant differences between Hsmm−Hwc vs. the Ref. group (46.3 vs. 52.8 mg·dL, *P*<0.0001) (Figure 3C). Significant Group interaction was reported in HDL *F*(3.44), *P*=0.016, ES 0.005 (Figure 3C). In Tg, there were significant differences between Lsmm−Hwc (163.7 vs. 116.3), and Hsmm−Hwc vs. the Ref. group (145.3 vs. 116.3 mg·dL, *P*<0.0001) (Figure 3D). Significant Group interaction was reported in Tg *F*(18.69), *P*=0.019, ES 0.949 (Figure 3D).

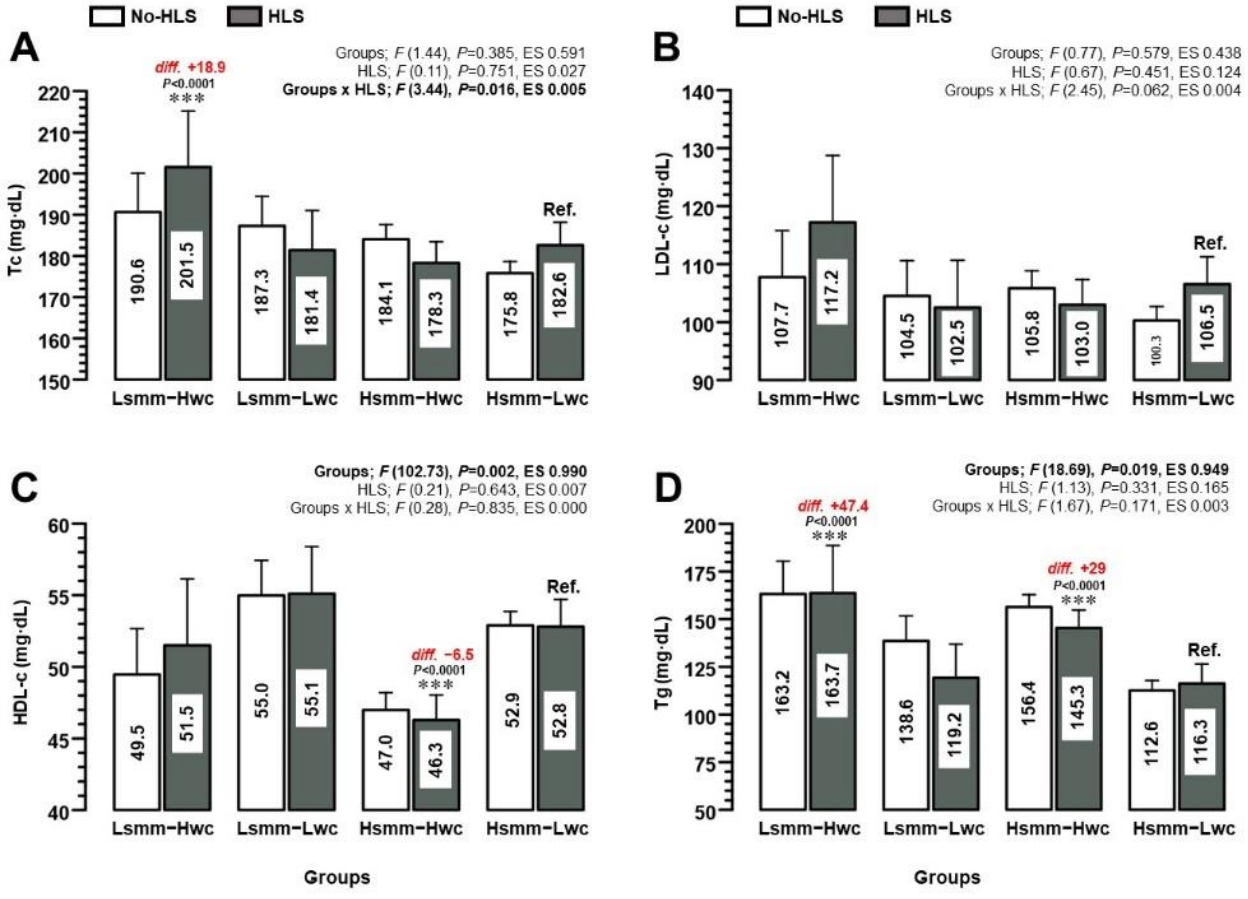

Figure 3. Hypercholesterolemia/dyslipidaemia markers in Chilean adult participants of the National Health Survey 2016-17, described by four body composition phenotypes and by a different condition of hearing. Groups are described as: low-skeletal muscle mass and high waist circumference phenotypical model (Lsmm−Hwc), low-skeletal muscle mass and low waist circumference phenotypical model (Lsmm−Lwc), high-skeletal muscle mass and high waist circumference phenotypical model (Hsmm−Hwc), and high-skeletal muscle mass and low waist circumference phenotypical model (Hsmm−Lwc), Reference group (Ref.). Categories are described as HLS. (No-HLS) No hearing loss suspect. Outcomes are described as; (Tc) Total cholesterol. (LDL-c) Low-density lipoprotein. (HDL-c) High-density lipoprotein. (Tg) Triglycerides. (*diff.*) Differences vs. Ref. group. (***) Denotes significant difference vs. Ref. at *P*<0.0001.

There were significant differences in GGT between Hsmm−Hwc vs. the Ref. group (14.6 vs. 3.2 UI·L, *diff*. +11.4 UI·L, *P*=0.004) (Figure 4D). A significant Group x HLS interaction was reported in TSH *F*(3.44), *P*=0.016, ES 0.005 (Figure 4A). There were significant differences in PGT between Hsmm−Hwc vs. the Ref. group (24.7 vs. 18.0 UI·L, *diff*. +6.7 UI·L, *P*<0.0001) (Figure 4B). Significant Group interaction was reported in PGT *F*(148.942), *P*=0.001, ES 0.993 (Figure 4B). There were significant differences in TSH between Lsmm−Hwc vs. the Ref. group (36.3 vs. 27.2 UI·L, *diff*. +9.7 UI·L, *P*<0.0001) (Figure 4D). A significant Group x HLS interaction was reported in GGT *F*(4.16), *P*=0.006, ES 0.018 (Figure 4D).

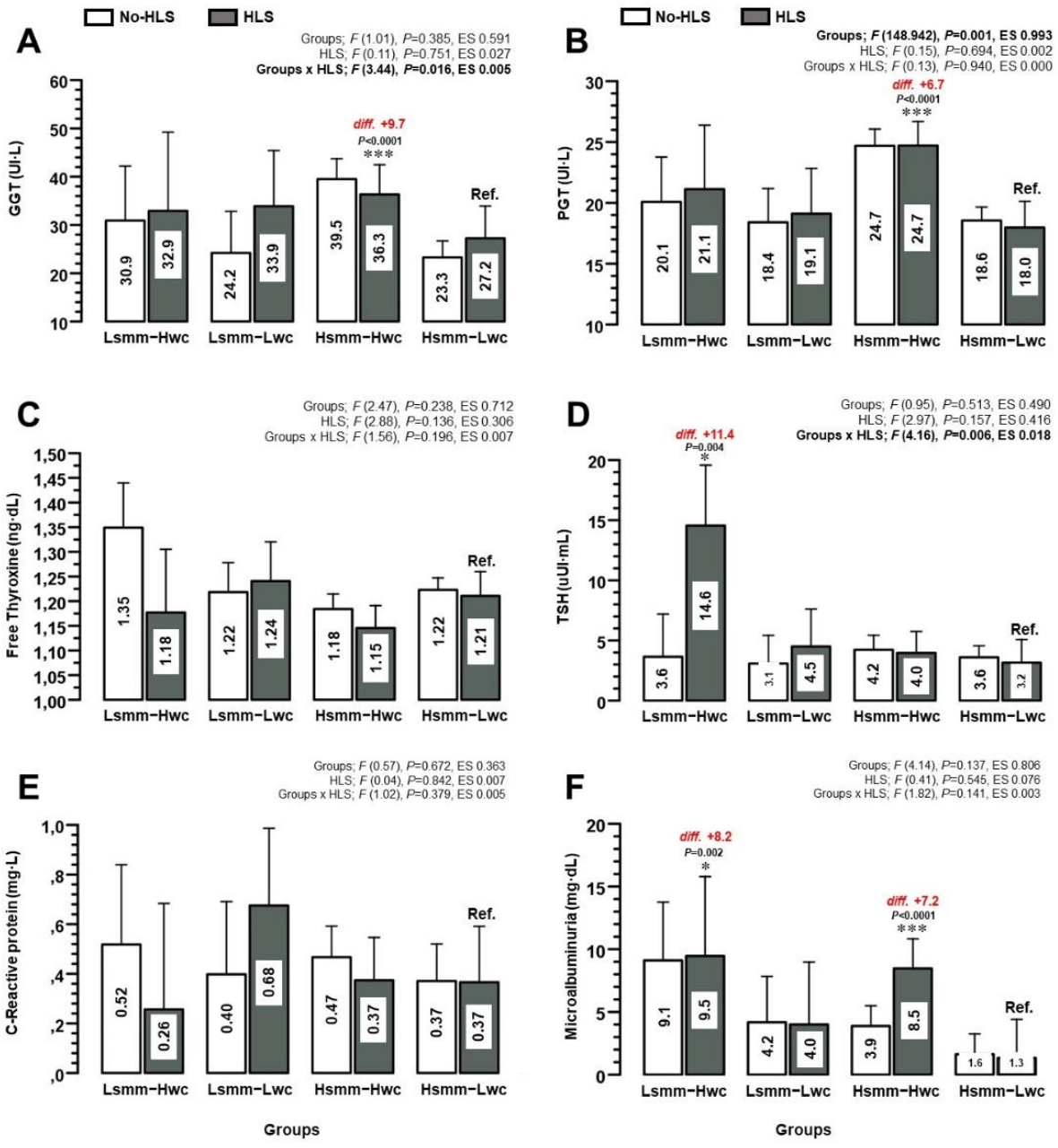

Figure 4. Non-alcoholic fatty liver disease (A, B), hypothyroidism (C, D), inflammation (E), and kidney disease markers (F) in Chilean adult participants of the National Health Survey 2016-17, described by four body composition phenotypes and by a different condition of hearing. Groups are described as low-skeletal muscle mass and high waist circumference phenotypical model (Lsmm−Hwc), low-skeletal muscle mass and low waist circumference phenotypical model (Lsmm−Lwc), high-skeletal muscle mass and high waist circumference phenotypical model (Hsmm−Hwc), and high-skeletal muscle mass and low waist circumference phenotypical model (Hsmm−Lwc), Reference group (Ref.). Categories are described as HLS. (No-HLS) No hearing loss suspect. Outcomes are described as; (GGT) Gamma glutamyl transferase. (PGT) Pyruvic glutamyl transferase. (TSH) Thyroid-stimulating hormone. (*diff.*) Differences vs. Ref. group. (*) Denotes significant difference vs. Ref. at $P<0.05$. (***) Denotes significant difference vs. Ref. at $P<0.0001$.

For diabetes suspect, there was a significant association between models 1 (β 0.251, $P=0.024$; OR 1.28), model 2 (β 1.952, $P<0.0001$; OR 7.03), model 3 (β 1.315, $P<0.0001$; OR 3.72), and model 4 (β 1.917, $P<0.0001$; OR 6.79) with diabetes diagnosed (Table 2). For HTN suspect, there was a significant association between models 1 (β 0.367, $P<0.0001$; OR 1.44), model 2 (β 2.436, $P<0.0001$; OR 11.43), model 3 (β 1.838, $P<0.0001$; OR 6.28), and model 4 (β 2.443, $P<0.0001$; OR 11.50) with HTN diagnosed (Table 2). On the other hand, for 'Hypercholesterolemia' risk, there was a significant association between models 2 (β 0.708, $P<0.001$; OR 2.03), model 3 (β 0.484, $P=0.006$; OR 1.61), and model 4 (β 0.319, $P=0.004$; OR 1.37) (Table 2). For 'MetS' risk, there was a

significant association between models 2 (β 2.268, *P*<0.0001; OR 9.65), model 3 (β 0.667, *P*<0.0001; OR 1.94), and model 4 (β 2.484, *P*<0.0001; OR 11.9) (Table 2). For 'High CVR', there was a significant association between models 1 (β 0.483, *P*=0.001; OR 1.62), model 2 (β 3.072, *P*<0.0001; OR 21.59), model 3 (β 1.922, *P*<0.0001; OR 6.83), and model 4 (β 2.962, *P*<0.0001; OR 19.34) (Table 2). Finally, for 'NAFLD' risk, there was a significant association between model 2 (β 0.503, *P*=0.023; OR 1.65), and model 4 (β 0.533, *P*<0.0001; OR 1.70) (Table 2).

Table 2. Multinominal logistic regression with odds ratios by each phenotype group and according to the risk for suffering different cardiometabolic conditions.

Outcomes	β	SE	Wald	McFadden Pseudo R^2	OR (95%CI)	*p*-value
'Diabetes'						
Model 0: No-HL or Hsmm−Lwc	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	0.251	0.111	5.075	0.115	1.28 (1.03; 1.59)	***P*=0.024**
Model 2: Lsmm−Hwc	1.952	0.213	84.262		7.03 (4.64; 10.67)	***P*<0.0001**
Model 3: Lsmm−Lwc	1.315	0.197	44.424		3.72 (2.53; 5.48)	***P*<0.0001**
Model 4: Hsmm−Hwc	1.917	0.129	219.836		6.79 (5.27; 8.75)	***P*<0.0001**
'HTN'						
Model 0: 'No-HL' or 'Hsmm−Lwc'	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	0.367	0.101	13.208	0.218	1.44 (1.18; 1.76)	***P*<0.0001**
Model 2: Lsmm−Hwc	2.436	0.206	139.958		11.43 (7.63; 17.11)	***P*<0.0001**
Model 3: Lsmm−Lwc	1.838	0.150	150.897		6.28 (4.68; 8.43)	***P*<0.0001**
Model 4: Hsmm−Hwc	2.443	0.098	622.055		11.50 (9.49; 13.94)	***P*<0.0001**
'Hipercholesterolemia'						
Model 0: 'No-HL' or 'Hsmm−Lwc'	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	0.007	0.114	0.459	0.008	1.08 (0.86; 1.35)	*P*=0.498
Model 2: Lsmm−Hwc	0.708	0.219	10.471		2.03 (1.32; 3.11)	***P*<0.001**
Model 3: Lsmm−Lwc	0.484	0.175	7.655		1.61 (1.15; 2.28)	***P*=0.006**
Model 4: Hsmm−Hwc	0.319	0.112	8.119		1.37 (1.10; 1.71)	***P*=0.004**
'MetS'						
Model 0: 'No-HL' or 'Hsmm−Lwc'	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	−0.142	0.126	1.256	0.210	0.86 (0.67; 1.11)	*P*=0.262
Model 2: Lsmm−Hwc	2.268	0.241	88.486		9.65 (6.02; 15.49)	***P*<0.0001**
Model 3: Lsmm−Lwc	0.667	0.187	12.744		1.94 (1.35; 2.80)	***P*<0.0001**
Model 4: Hsmm−Hwc	2.484	0.124	402.632		11.9 (9.40; 15.27)	***P*<0.0001**
'High CVR'						
Model 0: 'No-HL' or 'Hsmm−Lwc'	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	0.483	0.142	11.616	0.169	1.62 (1.22; 2.13)	***P*=0.001**
Model 2: Lsmm−Hwc	3.072	0.330	86.611		21.59 (11.30; 41.23)	***P*<0.0001**
Model 3: Lsmm−Lwc	1.922	0.195	97.153		6.83 (4.66; 10.01)	***P*<0.0001**
Model 4: Hsmm−Hwc	2.962	0.150	391.320		19.34 (14.42; 25.94)	***P*<0.0001**
'NAFLD by higher GGT'						
Model 0: 'No-HL' or 'Hsmm−Lwc'	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	−0.189	0.113	2.802	0.012	0.82 (0.66; 1.03)	*P*=0.094
Model 2: Lsmm−Hwc	0.503	0.221	5.181		1.65 (1.07; 2.55)	***P*=0.023**
Model 3: Lsmm−Lwc	0.000	0.183	0.000		1.00 (0.69; 1.43)	*P*=0.998
Model 4: Hsmm−Hwc	0.533	0.107	24.755		1.70 (1.38; 2.10)	***P*<0.0001**
'NAFLD by higher PGT'						
Model 0: 'No-HL' or 'Hsmm−Lwc'	-	-	-	-	**1.00 (Ref.)**	-
Model 1: 'HL'	−0.019	0.139	0.019	0.018	0.98 (0.74; 1.28)	*P*=0.890
Model 2: Lsmm−Hwc	0.143	0.297	0.231		1.15 (0.64; 2.06)	*P*=0.631
Model 3: Lsmm−Lwc	−0.231	0.257	0.811		0.79 (0.48; 1.31)	*P*=0.368
Model 4: Hsmm−Hwc	0.651	0.132	24.372		1.91 (1.48; 2.48)	***P*<0.0001**

Data are shown as mean and (95%CI) for continuous outcomes and as frequency and (% percentage) for categorical outcomes. Groups are described as: (Lsmm−Hwc) Low-skeletal muscle mass and high waist circumference phenotypical model. (Lsmm−Lwc) Low-skeletal muscle mass and low waist circumference phenotypical model. (Hsmm−Hwc) High-skeletal muscle mass and high waist circumference phenotypical model. (Hsmm−Lwc) High-skeletal muscle mass and low waist circumference phenotypical model. (β) Beta. (SE) Standard error. (Wald) Wald chi-square. (OR) Odds ratios. (95%CI) 95% confidence interval. (HTN) Hypertension. (MetS) Metabolic syndrome. (CVR) Cardiovascular risk. (NAFLD) Non-alcoholic fatty liver disease. (PGT) Piruvic glutamyl transferase. (Ref.) Reference group.

DISCUSSION

The aims of this study were; 1) to characterize the glucose and blood pressure control in adults with HLS based on four body composition phenotypes participants of the Chilean NHS16-17, and 2) to associate the HLS condition and body composition phenotypes (based on calf circumference and waist circumference) with diabetes and arterial hypertension markers. The main finding of this study was that *i*) adults with HLS who report phenotypically Lsmm−Hwc show higher SBP (+27 mmHg), DBP (+2 mmHg), Tc (+18.9), GGT (+9.7), and TSH (+11.4), and *ii*) both HLS condition and the Lsmm−Hwc phenotype are significantly associated with higher risk for the suffering of diabetes (HLS OR 1.28; Lsmm−Hwc OR 7.03), and arterial hypertension (HLS OR 1.44; Lsmm−Hwc OR 11.43) (Table 2). These results were displayed with other relevant results, including that adults with HLS who report phenotypically Lsmm−Hwc show higher Tc (+18.9), GGT (+9.7), and TSH (+11.4), and both HLS condition and Lsmm−Hwc phenotype report a high cardiovascular risk (HLS OR 1.62; Lsmm−Hwc OR 21.59) (Table 2).

Comparing No-HLS vs. HLS, HLS adults were characteristically older (57.1 vs. 46.7 y), and showed elevated FPG (102.7 vs. 99.3 mg·dL) and SBP (132 vs. 126 mmHg) vs. No-HSL peers respectively (Table 1). In this line, the Chilean adult population increase their physical inactivity prevalence ~40-45 years old (**Garrido-Méndez et al., 2019**), being cardiometabolic diseases being more prevalent at older ages (**Petermann, Durán, et al., 2017**). From here, it is not surprising to find out that HLS who are mainly older persons also show more elevated FPG and SBP. Thus, although the ageing process is not a rule suffering of both HLS conditions as well as more elevated diabetes and HTN diseases, there is an urgent need for increasing health promotion and possibilities to maintain a healthy lifestyle in older adult populations.

Physical inactivity modulates body composition, promoting SMM loss, known as sarcopenia, and increasing adiposity as an obesity environment, summarized in a body composition phenotype of low SMM, and high adiposity, as in the case of the present study is represented by the high WC (i.e., Lsmm−Hwc phenotype). By contrast, physical activity promotes the maintenance of SMM and growing and low levels of adiposity, represented phenotypically by the Hsmm-Lwc phenotype as the reference group. Previous longitudinal literature studies from (Lee et al., 2012) have revealed that after 6-years of follow-ups, adults who increased their adiposity (By body fat percentage and BMI increases) were associated with a high risk for developing HTN, metabolic syndrome and hypercholesterolemia. By contrast, those who maintained cardiorespiratory fitness were associated with lower cardiovascular risk. However, this literature study does note reported populations with disabilities as HLS. Worryingly, in the present study, participants with a Lsmm−Hwc body composition phenotype reported higher SBP (+27 mmHg) and DBP (+2 mmHg), being the risk for suffering of HTN also higher in both HLS condition (OR 1.44) and more superior in those of Lsmm−Hwc phenotype (OR 11.43) (Table 2). Thus, from each side of the condition, for example, having HLS or an unhealthy body composition phenotype, there is a higher risk of developing HTN. Therefore, there is a need for longitudinal studies, particularly on how prevalent cardiometabolic diseases are in HLS populations.

The knowledge about HL and its association with mental health still needs to be improved. Few studies have established these associations, highlighting that adults and older adults with HL tend to show conditions such as depression more than those without HL (**West, 2017**). Likewise, it has been postulated that depression, with other multifactorial variables, promotes limitations in daily living activities in adults with HL, which could impact a healthy lifestyle (**West, 2017**). This negatively impacts adherence to physical

activities, increasing sedentary behaviour. Our results did not show differences between No-HLS vs. HLS subjects in physical activity levels of PA_{LI} and PA_{MI}, but HLS showed to practice more PA_{VI} (Table 1). However, these findings are not uncommon due to PA_{VI} is usually the minor physical activity modality practised during the week and reasonably could not influence modifying body composition as SMM or WC in adults.

On the other hand, future research from a more mechanistical more than associative approach is needed to determine whether an unhealthy body composition as the Lsmm−Hwc phenotype is a risk factor for HLS, or whether the presence of HLS leads to an unhealthy body composition phenotype. Identifying the clear direction of this relationship is relevant to promote 'health promotion' actions to reduce the HLS or at least to promote physical activity in populations with HLS looking to avoid additional comorbidities such as diabetes and HTN that clearly would decrease their health and QoL.

Some limitations of our work included that i) we did not measure clinically HL condition by pure audiometry and measured the physical activity level by standardized questionnaires (i.e., International PA questionnaire GPAQ, and not objectively measures by accelerometry equipment), where we used the self-reported information from the NHS16-17 of these outcomes, *ii*) the four body composition phenotypes were modelled using secondary outcomes of SMM and adiposity as were 'calf circumference' and 'waist circumference', but both outcomes are frequently used in clinical practice, and has a strong association with sarcopenia/skeletal muscle mass and body fat, *iii*) although we reported a significant association between HLS and several cardiometabolic markers, the effect sizes were relatively small, and iv) our HLS sample could be not directly to be representative of some specific adult groups as those adults who work in noise environments, due to construction sites, for example, are more likely to suffer of HL (**WHO, 2021a**). Some strengths are that *i*) the NHS16-17 is a representative study of the Chilean population, *ii*) the present study reports information about cardiometabolic risk in adults, and *iii*) this information could be useful for adjusting physical activity guidelines to populations with some hearing disabilities.

Chilean adults with HLS who report phenotypically a low skeletal muscle mass and high waist circumference are characterized by registering higher SBP (+27 mmHg) and DBP (+2 mmHg). Both HLS and Lsmm−Hwc isolated conditions represent a higher risk for suffering from diabetes and HTN and increase the cardiovascular risk in adults. Future studies should explore this association in a more longitudinal than cross-sectional manner as well as exploring those mechanisms underlying these relationship.

Conflict of interest

No conflict of interest is declared by tehe authors.

Ethics Committee

The Chilean National Health Surveys were funded by the Chilean Ministry of Health and led by the Department of Public Health of the Pontificia Universidad Católica de Chile. The Chilean National Health Surveys were approved by the Ethics Research Committee of the Faculty of Medicine at the same university.

Author contributions

Study Design, CA; Data Collection, CA, DT-R, LM; Statistical Analysis, CA; Data Interpretation, CA, DT-R, LM, CF-B; Manuscript Preparation, CA, DT-R, LM, CF-B, AR; Literature Search, All authors. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

All data information can be found freely accessed at the Epidemiological Unit of the Chilean Health Ministry at http://epi.minsal.cl/encuesta-ens-descargable

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