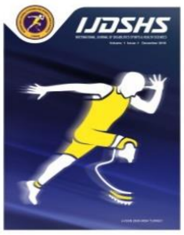

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RESEARCH ARTICLE

The Relationships with Maximal Aerobic Speed, Maximal Oxygen Uptake and Isokinetic Strength in Hearing Impaired Men's Handball Players

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Abstract
Study aim: This study aimed to analyze the relationships between weekly training frequency, changes in training duration, and Maximal Aerobic Speed (MAS), Maximum Oxygen Uptake (VO_2max), and Isokinetic Strength over an 8-week period (pre-season 8 weeks). Material and methods: Eighteen hearing-impaired handball players (age: 26.78±2.26 years; height: 177.76±4.40 cm; body weight: 64.94±2.73 kg, training experience 13.1±2.6 years) were positioned in defense and offense based on their playing positions and were monitored for 8 weeks. Repeated Measures ANOVA test was performed for the pre-test and post-test comparisons of defense and offense players, frequency and distribution is observed, average standard deviation, maximum, and minimum values were taken. Results: The analysis results revealed a significant large positive difference in the agonist/antagonist ratio in the right extremity ($p < 0.01$). Conclusion: Throughout the study, fluctuating changes in the numbers and durations of training sessions were observed to significantly increase and correlate with changes in the players' fitness status. There is a statistically significant difference between pre-test and post- test values for maximal oxygen consumption (VO_2max), maximal aerobic speed (MAS), and maximal heart rate (HRmax) ($p< 0.01$). However, the variability in the large positive difference in the agonist/antagonist ratio in the right extremity suggests that it cannot be solely explained by the number and duration of training sessions in terms of fitness level.

Keywords
Training, Maximal Aerobic Speed, Maximal Oxygen Uptake, Isokinetic Strength

INTRODUCTION

In recent years, technology-based training methods have been implemented in elite-level teams to enhance the quality of training sessions. The objectives of these training methods are to determine the internal and external loads imposed on athletes during training and to assess the acute and long-term effects of the training sessions (Zemkova & Hamar, 2014; Chukhlantseva 2019). The assessment of training quality within athletic performance involves physiological measurements of internal factors such as maximum oxygen consumption and maximal heart rate, as well as external factors based on physical measurements including distances covered at varying speeds, corresponding pace, accelerations and decelerations, sudden changes in direction, jump height, and the summation of these variables at maximal intensity. These assessments are conducted through athletic performance tests (Timmins & Saunders, 2014; Bourdon et al., 2017).

The impact of training on players varies from athlete to athlete in team sports. These differences can be attributed to various factors such as age, gender, training history, adaptation period to training, metabolic response time to training, training intensity, and frequency, leading to variations in reactions among athletes (Altavilla

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et al., 2017). Considering all these various factors, it is acknowledged that training loads, both internal and external, do not necessarily produce similar or identical physical and physiological outcomes among team sports players (Petridis et al., 2021). This variability can be attributed to the specific nature of team sports, where training methods such as running, variable-intensity games, and high-intensity sprints, particularly in sports like handball, exhibit fluctuations in both internal and external loads (Park et al., 2021). In light of this variability, the application of the same training intensity and volume may result in different loads for athletes. This insight can provide coaches, conditioning coaches, and sports researchers with valuable information: some athletes may require additional training, while others may risk overtraining due to high levels of internal and external loading (Práxedes et al., 2018; D'Isanto et al., 2019).

Handball, a dynamic game requiring various physical abilities such as speed, agility, endurance, and strength, often exhibits differences in multiple variables. Consequently, it is observed that the preseason training period and subsequent periods minimize variations in the athletic performance and fitness levels of handball players (Müller & Brandes, 2015). The quality of training conducted on handball players during preseason preparation and subsequent training periods is crucial. During these periods, the aim is to minimize variations in the athletic performance and fitness levels of players. With the improvement in training quality, enhancements can be observed in parameters such as heart rate, maximum heart rate, muscle strength, muscle endurance, maximum aerobic speed, and maximum oxygen consumption levels (Saavedra et al., 2018; Ivrasson, 2014).

In the sport of handball, various physical abilities such as strength, muscular endurance, maximal oxygen consumption, and maximal aerobic capacity are required. Strength plays a crucial role in movements such as smashes, serves, and blocks, requiring both upper and lower body strength (Wagner et al., 2017). Players need a strong body to effectively hit the ball and compete with opponents. Muscular endurance, on the other hand, is essential for withstanding the continuous, fast, and intense movements throughout the game. It enables players to resist fatigue and maintain their performance for extended periods (Tyshchenko et al., 2017). Maximal oxygen consumption (aerobic capacity) is vital for long-term endurance in sports like handball. It involves increasing players' maximal oxygen consumption to sustain energy levels throughout lengthy matches (Gorostiaga et al., 2006). Given that handball is a fast-paced and dynamic team sport, maximal aerobic capacity (aerobic endurance) is crucial for players. Improving maximal aerobic capacity can enhance players' endurance and performance (Milanović et al., 2018).

Researching the characteristics of hearing-impaired handball players is of great importance due to the high aerobic and anaerobic capacities required in handball, being a high-intensity team sport (Drake et al., 2017). The investigation of maximal aerobic speed, maximum oxygen uptake, and isokinetic strength holds significant importance in the realm of sports science, particularly concerning hearing-impaired handball players, as these physiological and physical parameters play crucial roles in determining the athletic performance and overall fitness levels of individuals engaged in competitive sports activities (İbrahim et al., 2017). Upon review of the literature, aerobic capacity has been identified as a characteristic encompassing all metabolic processes contributing to athletes' overall work capacity (Jagim et al., 2016). Consequently, maximal oxygen consumption (VO2 max) is widely utilized as a criterion for aerobic capacity and is employed in the physiological monitoring of hearing-impaired athletes, as well as in determining indicators of their anaerobic capacities (Mujika et al., 2018). However, it is noted that studies conducted on hearing-impaired handball players at both field and laboratory levels are limited (Cameron et al., 2018).

In recent years, there has been a growing recognition of the importance of applying scientific principles to enhance the performance of athletes with disabilities (Dafoe, 2007). Noteworthy advancements have been achieved through training studies utilizing various methods and approaches (Gorostiaga et al., 2006). These investigations appear to be particularly geared towards enhancing the performance and success of disabled athletes, particularly those with hearing impairments (Kejonen et al., 2003). The enhancement of performance among hearing-impaired handball players, influenced by hearing loss, is crucial for optimizing physical, physiological, and biomechanical components

(Billat et al., 2000). The objective of this study seems to be centered around increasing the maximal work capacity of hearing-impaired handball players and pushing the boundaries of athletes' performance. It is postulated that targeting the physical and physiological parameters examined in the study is advantageous, provided that the body is subjected to a high level of adaptive challenge. The structural and physiological adaptations observed in hearing-impaired handball players suggest that training regimens tailored to these athletes should involve specific activities tailored to the scope, intensity, and frequency of the training applied. In summary, this study aims to investigate: a) The relationships between maximal aerobic speed, maximal oxygen consumption, and isokinetic strength in hearing-impaired handball players. The results obtained will provide insights into specific training methods tailored to these parameters. b) The aim of the study was to examine the relationships between physical fitness and strength variables (parameters maximum oxygen consumption (VO_2max), maximum aerobic speed (MAS), anterior and posterior peak torques at 60˚/s) over an 8-week period in hearing-impaired handball players following an 8-week training process section which is at the end of template.

MATERIALS AND METHODS

Ethical Approval

This study followed ethical standards and received approval from the Çankırı Karatekin University (Health Sciences Ethics Committee) in Turkey with reference number (08/05/2023; 7). 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

During the 8-week training period, eighteen male handball players with hearing impairments (age: 26.78±2.26 years; height: 177.76±4.40 cm; body weight: 64.94±2.73 kg, training experience 13.1±2.6 years) were included in the study and observed.

Research design in the study

The hearing-impaired handball players participated in the deaf handball league affiliated with the Turkey Deaf Sports Federation during the 2023/2024 season. They played in the same team, and their playing positions within the team were distributed as follows: three were central playmakers, three were left playmakers, three were right playmakers, three were left wings, three were right wings, and three players were in the pivot position. The aim of the conducted study is to determine the cardiovascular fitness levels of hearing-impaired handball players through physical and physiological tests at the beginning and end of an 8-week training period, and to identify the relationships between these fitness variables over the 8-week process. The inclusion criteria for this research are as follows: not being a goalkeeper, participating in 75% of the training sessions during the eight-week period, not experiencing prolonged injuries, and not using alcohol or ergogenic supplements.

Hearing-impaired handball players participated in training programs prepared and designed by coaches and athletic performance coaches for eight weeks. Additionally, they did not engage in any other training programs. Before the study, players were informed about the design, structure, and content of the study, as well as the potential risks and benefits. Pre-study information was provided, and players declared their voluntary agreement to participate by signing informed consent forms that outlined the study conditions.

Experimental Approach to the Problem

This study, which commenced at the end of June and concluded at the beginning of September (over 8 weeks), was designed and implemented in the form of a pre-test-post-test experimental design (during the 8-week pre-season). The Timeline of the measurement in Table 1. For cardiovascular fitness assessments, players underwent pre-test evaluations within 1 day before the start of the 8-week period, and post-test evaluations were conducted within 48 hours after the conclusion of the 8-week training process. The fitness variations occurring in hearing-impaired handball players over the 8-week training period were also correlated in the study.

Pre- Workout Warm Up Protocol

The players underwent a 20-min warm up session led by a licensed strength and conditioning coach involving stretching, the classical warm-up procedure applied in the study includes 5 minute-jogging with 40-50% of the maximum heart rate, followed by 5 frontal-lateral hopping, 5 mobilization, 5 upper extremity static stretching exercises and familiarization with the test, respectively. The movements were applied for 2 sets and 15 seconds. In addition, players did a standard warm-up focusing on lower limbs which consisted of self- paced low-intensity running, lower-limb dynamic stretching, and reactive strength exercises before the tests.

Table 1. Timeline of the measurement

Days	Measurements
Sunday	Resting Day
Monday	(10:00) Height and Body Weight Measurement (16 :00) Aerobic Assesment
Tuesday	(10:00) Isokinetic Leg Strength test
Wednesday	Resting Day
Thursday	Resting Day
Friday	Resting Day

Table 2. Detailed training program (Hantău, 2021)

Days of the Week	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week	8th Week
Sunday	Resting Day	Resting Day	Resting Day	Resting Day	Resting Day	Resting Day	Resting Day	Resting Day
Monday	Resistance training	Resistance training	Sprınt Training	Plyometrıc Training	İnterval Training	Functional Training	Club Workouts	Club Workouts
Tuesday	Resistance training	Resistance training	Functional Training	Functional Training	İnterval Training	Functional Training	Club Workouts	Club Workouts
Wednesday	Resistance training	Resistance training	Functional Training	Functional Training	İnterval Training	Functional Training	Club Workouts	Club Workouts
Thursday	Resistance training	Resistance training	Functional Training	Functional Training	Club Workouts	Functional Training	Club Workouts	Club Workouts
Friday	Resistance training	Resistance training	Sprınt Training	Plyometrıc Training	Club Workouts	Functional Training	Club Workouts	Club Workouts
Saturday	Resting Day	Resting Day	Resting Day	Resting Day	Club Workouts	Club Workouts	Club Workouts	Club Workouts

Data collection tools

Anthropometric measurements

A stadiometer with a precision of ± 1mm (Holtain, UK) was used to measure the heights of the study group. Heights were measured with anatomical posture, barefoot, heels together, and the headboard touching the vertex point (Arslanoğlu et al., 2017). The body weights of the players (in kg) were measured using the Tanita BC 418 MA Professional Segmental body analysis system. The accuracy of the measurement tool was calibrated with a precision of 0.01 kg for weight. The measurements of the athletes were recorded in kilograms (kg) when they were barefoot, wearing only shorts and T-shirts.

Aerobic assessment

Aerobic capacity determination was conducted utilizing a stepwise incremental treadmill equipped with a direct calorimeter (Technogym, Skillrun Live 7000, Italy). The testing was carried out in a controlled laboratory environment maintained at a temperature range of 22-22°C and a relative humidity of 50-55%. A standardized warm-up protocol was employed, consisting of a 3-minute treadmill run at a speed of 8 km/h followed by 5 minutes of free stretching. The test protocol continued until exhaustion, with progressive increments of 0.5 km/h every 30 seconds at a constant incline of 2%. Exhaustio was defined as the point at which participants voluntarily declared their inability to maintain the predetermined pace (Malone et al., 2015). The treadmill incline remained fixed at 2% throughout the duration of the test.

Respiratory parameters were measured using an automatic gas analysis system (Fitmate Pro, Cosmed, Italy) (Gabbett, 2020). The device was calibrated before each measurement session according to the manufacturer's recommendations and operated in "breath by breath" mode with a 5-second averaging option. Calculation of participants' VO_2max values utilized three criteria: a sustained increase in speed while a plateau was observed in VO_2, a Respiratory Exchange Ratio (RER) value exceeding 1.10, and an estimated heart rate exceeding 95% of the maximum predicted heart rate based on the formula 220 - age. VO_2max was calculated as the average of the highest three values where at least two of these criteria were met (Daros et al., 2012). Heart rate monitoring during the incremental test was conducted using a heart rate monitor (H10, Polar, Finland), recording participants' heart rates every second and synchronized with a local system. The maximum heart rate (HRmax) attained during the exercise was recorded for each participant.

Maximal aerobic speed was determined based on the highest speed achieved during the incremental treadmill test. Pre- and post-observation period tests were conducted in the same facility, at the same hour, on the same day of the week, maintaining a stable temperature of 22°C and relative humidity of 50-55% (Campos et al., 2017).

The isokinetic strength

The test was conducted using the Cybex Norm isokinetic dynamometer (CSMI, Stoughton, Massachusetts, USA) following a standardized warm-up on a cycloergometer (Monark LC4, Sweden) for five minutes. Prior to testing, the anterior and posterior lower limb torques were gravity-corrected, and dynamometer calibration was performed according to the manufacturer's guidelines. Lower limb assessments were conducted randomly after participants received verbal and visual instructions and feedback from the evaluator. Players underwent two non-recorded trial sessions to become familiar with the testing procedure. Once familiarized, players were evaluated through five repetitions of concentric knee extensions and flexions at 60˚/sec, with a 10-second recovery period allowed between repetitions. Isokinetic strength ratios were calculated based on measurements of maximal anterior and posterior peak torques (Śliwowski et al., 2017).

Peak torque deficits between lower limbs were assessed by comparing the best trials of left and right lower limb extension and flexion. The following measures were utilized during statistical analysis: Extension Peak Torque at 60˚/s (EPT); Flexion Peak Torque at 60˚/s (FPTL); Extension Deficit (DE); Flexion Deficit (DF); and Agonist/Antagonist Ratio (Rag/An). The testing environment maintained a controlled temperature of 22°C and relative humidity of 50-55% during both pre- and post-training evaluations (Söyler et al., 2023).

Data analysis

The statistical analysis of the data was conducted using the SPSS 22.0 software package. Repeated Measures ANOVA test was performed for the pre- test and post-test comparisons of defense and offense players.

Table 3. Training sessions and time of training week during the 8-week period.

	W1	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**
Training sessions	5	5	5	5	6	6	6	6
Total time (min)	350	350	375	375	450	450	480	480

W: Week

RESULTS

When looking at Table 4; There is a statistically significant difference between pre-test and post- test values for maximal oxygen consumption (VO_2max), maximal aerobic speed (MAS), and maximal heart rate (HRmax) ($p < 0.01$).

Table 4. Within-group differences of VO_2max, and MAS, between pre- and post-period of training in handball players with hearing impairment

Variable	Position	M (Sd) pre	M (SD) post	P	
				Group*Time	Int.group
VO_2max (ml.kg.min)	playmaker	42.92±1.57	46.53±2.05	0.013	0.935
	pivot	42.78±1.26	46.63±1.47		
MAS (m/min)	playmaker	3.87±0.06	3.75±0.07	**<0.001**	0.341
	pivot	3.88±0.06	3.74±0.05		
HRmax (bpm)	playmaker	198.91±0.76	192.81±2.20	**<0.001**	0.89
	pivot	198.59±1.09	192.35±1.83		

VO_2max: maximal oxygen consumption; MAS: maximal aerobic speed; HRmax: maximal heart rate

When looking at Table 5; There is a statistically significant difference between pre-test and post-test values for EPT: Extension Peak Torque at 60˚/s; FPT: flexion peak torque at 60˚/s; L): left; R): right; DE: deficit at extension; DF: deficit at flexion; Rag/An: ratio agonist/antagonist $p < 0.01$). In the Agonist/Antagonist ratio Rag/An), offensive players statistically have a higher value than defensive players $p = 0.011$).

Table 5. Within-group differences of ısokinetic strength between pre- and post-period of training in handball players with hearing impairment

Variable	Position	M(Sd) pre	M(SD) post	P	
				Group*Time	Int.group
EPT(L) (Nm)	playmaker	288.14±2.14	279.50±2.34	<0.001	0.831
	pivot	287.87±4.05	279.11±3.13		
EPT(R) 8Nm)	playmaker	270.88±3.23	281.09±2.33	<0.001	0.505
	pivot	269.40±3.91	278.36±5.34		
DE (Nm)	playmaker	10.53±0.35	11.14±0.35	<0.001	0.504
	pivot	10.38±0.33	11.22±0.22		
FPT(L) (Nm)	playmaker	174.97±1.95	186.50±3.47	<0.001	0.230
	pivot	175.94±2.38	185.06±4.0		
FPT(R) Nm)	playmaker	183.77±2.68	188.11±1.63	<0.001	0.255
	pivot	183.67±1.57	188.98±0.79		
DF (Nm)	playmaker	7.44±0.21	7.97±0.19	<0.001	0.807
	pivot	7.45±0.14	8.00±0.04		
RAg/An(L) (%)	playmaker	42.89±1.18	47.87±1.10	<0.001	0.057
	pivot	44.52±0.25	47.99±1.19		
RAg/An(R) (%)	playmaker	42.36±0.96	42.71±1.04	<0.001	0.011
	pivot	41.59±0.40	42.52±0.52		

EPT: Extension Peak Torque at 60˚/s; FPT: flexion peak torque at 60˚/s; L): left; R): right; DE: deficit at extension; DF: deficit at flexion; Rag/An: ratio agonist/antagonist

When looking at Table 6 mean values ±SD) of basic somatic variables determined in handball players with hearing impairment.

Table 6. Mean values ±sd of basic somatic variables determined in handball players with hearing impairment

Variable	n	M sd)	Min	Max
Age (year)	18	26.78±2.26	22.00	29.00
Body Height (cm)		177.76±4.40	171.56	188.41
Body Height (kg)		64.94±2.73	60.50	69.80
Training experience (years)		13.1±2.6	9.00	16.00

DISCUSSION

Handball is a contact sport that requires both high anaerobic and aerobic capacity and top-level performance. Similar to other contact sports, in handball, high aerobic capacity comes into play along with anaerobic capacity during the game, enhancing players' recovery speed Granados et al., (2008). Changes in the number and duration of weekly training sessions are crucial in enabling players to meet the intensity and duration of the game more effectively. It is stated that the weekly monitored training frequency and durations in team sports contribute positively to players, leading to improved muscular endurance, enhanced fitness values, and positive momentum based on their positions in the game (Williams et al., 2017).

In based on the conducted studies, it is emphasized that stabilizing and optimizing the pre-season training load of team sports players, as well as monitoring the training load throughout the entire competition period, is crucial for considering the players' positions regarding aerobic assessment Coutinho et al., (2015). The objectives of this study are as follows: a) To investigate the relationships between maximal aerobic speed, maximal oxygen consumption, and isokinetic strength in deaf handball players, aiming to provide insights into potential training programs that could be designed based on the obtained results. b) To explore the relationships between physical fitness and strength variables among deaf handball players over an 8-week standard club training period, focusing on maximum oxygen consumption VO2max), maximum aerobic speed MAS), and anterior and posterior peak torques at 60˚/s.

In their study focused on team sports, Beltz et al. (2016), designed a weekly training program in which the training load increased progressively, with a 10% increase in the first 2 weeks, 15% in the subsequent 3rd and 4th weeks, 20% in the 5th and 6th weeks, and a 25% increase in the last 7th and 8th weeks. This gradual increase ensured a consistent elevation in training load each week, allowing players to be aware of their individual training loads. Wolpern et al. (2015), in their study implementing a systematic increase in weekly training hours, noted parallel increases between training hours and training load, resulting in improvements in muscular endurance, cardiovascular fitness values, and alleviation of monotony for players. Our research aligns with similar structured literature, demonstrating comparable and parallel results regarding training hours and training load.

During the preseason initial four-week period, weekly training frequency and duration ranged between 350-400 minutes, while in the last six weeks, it increased to approximately 450-600 minutes per week.

Analysis of the physical and physiological variables in the study revealed variations in maximal oxygen capacity based on maximal contraction and maximum heart rates, depending on training variables, over the 8-week period among hearing-impaired men's handball players. Additionally, linear correlations were observed between changes in endurance parameters based on training durations and heart rate (Nopianto et al., 2021). During handball matches, players typically exhibit heart rates ranging between 165 and 198 beats per minute. In a one-hour match, on average, players' heart rates reach approximately 85% of the maximum heart rate, with heart rates exceeding 80% of the maximum for approximately 70-75% of the match duration (Hammami et al., 2022).

Pre- and post-test evaluations conducted over the 8-week period in both groups indicated closely aligned values of VO2 max levels, maximum aerobic speed MAS), and maximum heart rate HRmax) during endurance running. This alignment is believed to be due to handball's reliance on cardiorespiratory fitness, with sustainability stemming from the development and maintenance of such fitness. Results suggested high oxygen capacity and cardiac output in both groups, leading to increased oxygen supply to working muscles and demonstrating possession of maximum oxygen pulse associated with continuity. Additionally, both groups exhibited faster recovery post-exercise associated with maximum aerobic speed.

The results indicated that players from both groups possessed similar aerobic capacities, as evidenced by basic indicators of aerobic capacity. It is inferred that players from both groups reached the highest level of maximum oxygen consumption rate, likely due to extensive field coverage and running technique contributing to running economy. Furthermore, the manual nature of handball play significantly influenced success. Considering field dimensions, the presence of short bursts followed by brief recoveries, and the importance of oxygen intake for recovery are crucial for regaining composure.

Bragazzi et al. (2020), states that aerobic capacity contributes to the ability of players to exert maximum effort during handball games, as well as to rapid recovery during low-intensity rest intervals, and is crucial in regeneration. The aerobic system can provide information for developing training and regeneration strategies to improve the performance of handball players and optimize their physical condition (Boraczynski & Umiaz, 2008). Such research is often used to create more effective training programs for athletes, reduce the risk of injuries, and enhance overall performance (Michalsik et al., 2013). Looking at the results obtained in terms of isokinetic strength; the similarity of the changes in fitness levels observed in both groups during the study has also led to similar results in terms of isokinetic strength. It can be said that the increase in weekly training durations is largely correlated with isokinetic peak torque during knee extension and the variation in the ratio of agonist/antagonist. Additionally, a significant superiority of the right lower extremity ratio agonist/antagonist) over the others is observed in terms of meaningful difference. Generally, in the handball training process, the division of the playing field into segments is believed to be beneficial for the increase in short and high-intensity movements sudden sprint, sudden deceleration, sudden changes of direction, etc.) and the development of handball-specific movements related to power. Moreover, similarities are observed between the increase in weekly training frequency and duration and the load-extension deficits. As a result, it is considered that the training process is a factor in complementing the deficits because in the case of deficits, the formation of a negative parameter between groups could have shown differences, and positive similarity is thought to stem from a closer resemblance to symmetry.

In a similar study, the relationship between medicine ball throwing and leg strength was investigated in a 6-week training program. The conclusion was that isokinetic strength and throwing speed increased equally (Andersen et al., 2018; Reader et al., 2015). In a different study conducted on elite young handball players, it was reported that different strength training programs showed significantly similar improvements in weekly training loads and durations over a 4-week period, with stationary and moving ball throwing speeds and leg isokinetics (Schwesig et al., 2016).

Aloui et al. (2021), examined the relationship between handball players' isokinetic shoulder strength and throwing speeds, determining that strength and throwing speed increased in parallel. In their analysis, Ignjatovic et al. (2012), investigated the correlation between isokinetic strength and various strength training regimens among handball players. They discovered that as the number of training sessions increased, handball players exhibited significantly greater improvements in performance tests. Furthermore, they noted that the ratio of agonist/antagonist muscles demonstrated a higher rate of development compared to other muscle groups. Similarly, Szymanski et al. (2007), conducted a 12-week study examining the effects of cross-training durations with different training programs involving moderate and heavy weights for both lower and upper extremities. They observed enhancements ranging from approximately 4% to 14% in the lower and upper extremities among player groups consisting of four distinct groups. Additionally, variations were noted in the ratio of agonist/antagonist muscle groups.

Conclusıon

This study conducted on deaf handball players holds great importance in examining the relationship between different training frequencies-durations and significant fitness variables, given the limited and restricted literature in this area. From this perspective, the current study also has some limitations. The sample situation is one of the main limitations. Analyzing the relationship by collecting data only from one team and obtaining feedback from players may affect the inferences of the current study. Looking at systematically conducted previous studies, it is observed that the same limitations exist in those studies as well. Monitoring and analyzing multiple deaf handball players and teams pose certain challenges. Fitness values obtained based on weekly training frequencies and durations are highly similar and correlated with heart rate measurements and maximum aerobic speed values. On the other hand, for the variable of isokinetic strength, more information and a larger sample size are required to explain the ratio of agonist/antagonist.

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The authors of this study have no conflict of interest with the issues addressed in study. No founding was received for the accomplishment of this field study. We thank hearing impaired men's handball players for helping in data collecting.

Conflict of Interest

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

Ethics Statement

This study followed ethical standards and received approval from the Çankırı Karatekin University (Health Sciences Ethics Committee) in Turkey with reference number (08/05/2023; 7).

Author Contributions

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

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