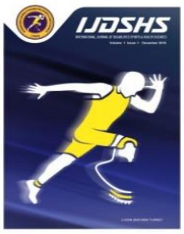

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RESEARCH ARTICLE

The Impact of Plyometric Resistance Training Implemented During the European Championship Preparation on Athletic Performance: A Case Study of the Youth Boxing National Team

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Abstract
The purpose of this study is to examine the effect of plyometric resistance training applied to the Turkish National Junior Men's Boxing Team during the European Championship preparation process. A total of 14 athletes from the Turkish National Junior Men's Boxing Team volunteered to participate in the study. The average age of the boxers was 17.57±1.04 years, the average height was 172.28±5.7 cm, the average weight was 72.14±2.9 kg, and the average body fat percentage was 20.47±1.15%. Participants engaged in a plyometric resistance training program prepared and scheduled by the researchers throughout the preparation camp. Various physical and biomotor parameters of all boxers (weight, BMI, body fat percentage, Squat, vertical jump, reaction time, grip strength, 5-meter speed, 10-meter speed, 40-meter speed, flexibility included) were measured at the beginning and end of the camp. Statistical analyses of all data were performed using the SPSS 22.0 statistical package program. Normal distribution analyses were conducted using the Shapiro-Wilk Test. Wilcoxon Test was used for the pre-test and post-test comparison of Body Mass Index and weight values, while the paired T-test statistic was used for the pre-test and post-test comparison of body fat percentage, Squat, vertical jump, reaction time, grip strength, 5-meter speed, 10-meter speed, 40-meter speed, and flexibility values. A significance value of $p < 0.05$ was accepted. Statistically significant changes were observed between pre- and post-camp changes. In conclusion, we suggest that a well-designed plyometric resistance training program may positively contribute to the physical and biomotor parameters of national junior male boxers before an important tournament during a preparation camp.

Keywords
Sports, Box, Physical Activity, Pliometrıc Power, Resistance

INTRODUCTION

It is Boxing, one of the oldest combat sports known to humankind, continues to captivate a broad audience today. Its enduring popularity stems from its focus on precise strikes and proper posture, both statically and dynamically, which are essential for achieving peak performance and gaining an advantage over opponents (Lopes-Laval et al., 2020). Boxing is regarded as a defensive art that demands skill and unwavering dedication to excel. It is founded on the core philosophy of delivering punches while adeptly evading incoming strikes. The physical demands placed on boxers are unmatched when compared to athletes in many other sports (Bianco et al., 2013). In addition to sparring with a partner, essential components of boxing training include shadow boxing, bag work, sandbag training, skipping rope, and a variety of static and dynamic exercises aimed at honing fundamental motor skills. These activities collectively contribute to the rigorous and demanding nature of the sport (Söyler et al., 2021; Özkan & Kumak, 2023). One of the most

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noteworthy and effective features that distinguishes boxing from other sports is its comprehensive engagement of the entire body during training sessions, fostering self-control, and cultivating a strong sense of self-confidence (Söyler & Çingöz, 2022). Given the dynamic nature of boxing matches, coaches must continuously refine and innovate training methodologies that emphasize motor skills development, aerobic and anaerobic conditioning, and muscular activities to provide valuable feedback. It is imperative to comprehend and strive to improve physiological capacities, particularly in individual sports that share similarities with boxing in terms of energy system utilization and cardiovascular response (Bruzas et al., 2014).

Indeed, physiological data, when examined within the context of sports, emerges as a vital instrument in crafting training protocols, maximizing athletic performance, and formulating strategic approaches for competitions (Sanchez Medina et al., 2010). In both boxing and other sports, performance hinges on various factors including power, anaerobic and aerobic energy capacity, speed, as well as neuromuscular functions such as technique, tactics, and psychology (Turner et al., 2011). Elite boxers meticulously prepare for matches by engaging in high-intensity training sessions (Amtmann et al., 2008). Due to its high level of dynamic and static attributes, boxing is considered a complex and highly demanding combat sport that can significantly impact certain physiological balances in the body (Satılmış et al, 2023). To achieve top performance in boxing, athletes today require a combination of various physiological, psychological, and biomechanical factors. Therefore, sports scientists acknowledge that effective methods and diverse approaches used in preparing elite athletes for competitions are more valid in modern sports understanding (Zileli and Söyler, 2018; Kayantaş and Söyler, 2020).

In the realm of sports science, research on resistance training has been a focal point, exploring its impact on body composition and its correlation with various physical parameters. In addition to physiological, psychological, and tactical considerations, body composition and the assessment of physical performance play pivotal roles (Söyler and Zileli, 2023).

Attaining peak athletic performance necessitates tailoring training regimens to the specific demands of the sport discipline. Nevertheless, physical fitness alone does not determine optimal training performance in sports. Several physical factors influencing training performance encompass height, weight, body composition, aerobic and anaerobic capacities, strength, speed, and flexibility, all of which are modulated by diverse training methodologies (Satılmış et al., 2023).

This study examines the effects of plyometric resistance training conducted during the preparation period for the European Championship on male boxing team athletes.

MATERIALS AND METHODS

Participants

This study involved 14 young male national boxers, with an average age of 17.57±1.04 years, heights of 172.28±5.7 cm, body weights of 72.14±2.9 kg, and body fat percentages of 20.47±1.15%.

Table 1. Baseline characteristics of the study subjects (n= 14)

	n	X	SD
Age (years)	14	17.57	.51
Height (cm)		172.28	6.63
Body Weight (kg)		72.14	4.38
Body Fat Percentage (%)		20.47	1.15

Mean(X), Std. Deviation (SD)

Procedures

Participants were provided with a minimum of 24 hours of complete rest before the assessment phase of physical parameter variables. They were explicitly instructed to refrain from using any medication or similar chemical substances on the day of testing and throughout the pre-test period. As part of the research application process, participants were briefed on the specialized program, which encompassed pre-testing and resistance training at the outset. Additionally, they were informed that tests would be conducted eight weeks later.

Warm Up Protochol

To ensure a safe and suitable preparation for the physical fitness tests, participants engaged in a standardized warm-up session lasting approximately 15 minutes. This warm-up routine comprised running, sprinting, multi-directional movements, and dynamic stretching exercises.

Ethics Statement

These participants were preparing for the Junior Men's European Championship while concurrently training in various boxing clubs. Ethical approval for the study was obtained from the Atatürk University Ethics Committee (Code: E-70400699-000 2200099753/ Date: 28.03.2022/ Decision: 37). Prior to enrollment, all volunteers were verbally briefed on the study's objectives, and written consent forms were duly obtained from each participant.

Data Collection Tools

Measurement of Height

Height measurements were obtained using a Holtain device from England. The measurements were taken with the individual's body weight evenly distributed on both legs, head positioned in the "Frankfort Horizontal Plane," arms placed by the sides of the body, and palms facing the thighs, while the participant remained barefoot (Piorkowski et al., 2009).

Body Weight and Body Fat Percentage

Body weight and body fat percentage were assessed utilizing a Tanita MC-780 body fat analyzer from Japan. These measurements were conducted in the morning prior to breakfast, following a period of fasting. Participants were attired in shorts and a t-shirt during the measurements. To ensure accuracy, any metal or ornamental accessories worn by the volunteers were removed. Subsequently, the participant being measured stood barefoot on the aluminum platforms of the analyzer while holding the hand electrodes. Prior to each boxer stepping onto the platform, the metal components of the platform in contact with the hands and feet were cleansed with a damp cloth (Khanna et al., 2006).

Vertical Jump

Participants underwent vertical jump measurements utilizing the Optojump Next® device developed by Microgate in Bolzano, Italy. Widely acknowledged for vertical jump testing, the OptoJump device has demonstrated validity and reliability (González -Badillo et al., 2017). During the active jump test, participants were instructed to squat as deeply as possible and subsequently execute a vertical jump with their hands free, knees fully extended, and body upright. Any separation of the hands from the waist or bending of the knees during the flight phase of the jump was deemed incorrect. For the Squat Jump test, participants were instructed to squat with their knees at a 90-degree angle and then execute a vertical jump without re-bending their knees. Bending of the knees during the flight phase of the jump was considered an incorrect movement. In the event of incorrect movements, the test was repeated. Vertical jump measurements were conducted twice, and the best result was selected for evaluation (Glatthorn et al., 2011).

Sit and Reach Test (Flexibility Test)

Participants begin by sitting on a flat surface with their legs extended and feet (barefoot) positioned against the Sit and Reach test box, which is placed vertically in front of the feet. With the trunk bent forward at the hips, participants attempt to reach forward with their hands in front of the body, ensuring that their knees remain unbent. They are instructed to reach as far forward as possible. At the furthest point reached, participants hold the position for 2 seconds, and the measurement is recorded. It is crucial to maintain straight knees throughout the test. The test is repeated twice, and the highest score achieved is recorded for evaluation (Arazi et al., 2014).

Reaction Time

Participants' reaction time was measured using a test device developed by Performanz, designed to assess upper extremity motor reaction and visual reaction levels while incorporating cognitive challenges. The device comprises 8 light switches and operates with a total of 24 stimuli, with 3 randomly illuminated lights on each reflector. The test starts and stops with the activation of the device (Franchini et al, 2019).

Speed

The transit times for 5m, 10m, and 40m were measured using the Fusion Sports Smart Speed Professional Performance photosels, with a chronometer system providing ±0.01 seconds precision (Zileli & Söyler, 2021).

Training Program

In the first phase, which lasted for the initial 4 weeks, each exercise was performed for 40 seconds, and the workouts were structured with 5 sets over 4 days per week. Moving into the 5th and 6th weeks, the program progressed to 6 sets over 5 days per week, with each set lasting 60 seconds. Rest periods between sets were set at 4 minutes. The exercises were performed in the following order: 1. Lunge (15 seconds on the right side, 15 seconds on the left side), 2. Burpee, 3. Jump Rope, 4. Push-up, 5. Plank, 6. Static Leg Raise, 7. Full Squat, 8. Jumping Jacks.

In the second phase, during the 7th and 8th weeks, the program intensified to 7 sets over 6 days per week, with each set lasting 90 seconds. Rest periods between sets remained at 4 minutes. The order of exercises, based on mixed work durations and repetition counts, was as follows: 9. Spinning (30 seconds), 10. Kettlebell Swing (20 reps), 11. Front Squat (10 reps), 12. Rope Slamming (30 seconds), 13. Deadlift (10 reps), 14. Kettlebell Lunge (20 reps), 15. Medicine Ball (10 reps on each side), 16. Bulgarian Bag Jump Squat (10 reps).

Table 2. Phases and variables of plyometric resistance training in boxing training program during the preparation period

	1st phase	**2st phase**	**3st phase**
Weeks	Weeks 1-4	Weeks 5-6	Weeks 7-8
Weekly Training Day	4 days	5 days	6 days
Rest Interval	4 minutes rest	4 minutes rest	4 minutes rest
Ex.Duration per Minute	40 seconds	60 seconds	90 seconds
Training Intensity	70%	80%	90%

Data Analysis

Statistical analysis of all obtained data was done by SPSS 22.0 statistical package program in computer. Normal distribution analyses were made with the Shapiro-Wilk test. Comparison of the pre-test and post-test scores of BMI and body weight data were analyzed by using the Wilcoxon Test. Comparison of the pre-test and post-test scores were analyzed by using the Paired T test. Significance value was taken as $p < 0.05$.

RESULTS

In this section of the study, statistical analysis results and interpretations of the data obtained are given.

Table 3. Physical characteristics of elite young male boxers (n=14)

	n	**X**	**SD**
Age (years)	14	17.57	.51
Body Height (cm)		172.28	6.63
Body Weight (kg)		72.14	4.38
BodyFat Percentage (%)		20.47	1.15

Mean(X), Std. Deviation (SD)

Table 4. Pre and post-training programme body composition and physiological parameters (n=14)

Parameters	Pre Test Mean (SD)	Post Test Mean (SD)	Std. Deviation Pre-post	t	P value
Body Weight (kg)	72.14	65.85	4.38-3.50	6.60	**.000***
Body Fat Percentage (%)	20.47	18.37	1.15-1.14	8.51	**.000***
Squat Jump (cm)	27.75	29.57	3.49-3.07	-3.4	**.005***
Vertical Jump (cm)	29.84	31.25	5.44-4.69	-2.5	0.24
ReaktionTıme (sn)	.51	.54	.85-.07	4.6.	**.000***
Grip Strength (left)	48.68	52.21	5.04-6.00	-7.0	**.000***
Grip Strength (right)	49.57	50.51	4.07-4.82	-2.0	0.62
5m (sec.)	1.47	1.14	.25-.12	4.90	**.000***
10m (sec.)	3.64	5.65	.34-.19	5.69	**.000***
40m (sec.)	5.65	5.10	.24-.11	7.45	**.000***
Flexibility (cm)	30.82	31.86	3.93-3.75	-4.2	**.001***

$p<0.05$

In terms of boxers' body composition, notable disparities were observed between pre-test and post-test assessments in body weight (p=0.00*; p>0.05). Similarly, significant differences were noted between pre-test and post-test measurements in body fat percentage (p=0.00; p<0.05). Upon evaluating the p-values of the means, it becomes apparent that this discrepancy is favorable, indicating an improvement in post-test scores. Significant differences were observed between pre-test and post-test scores in Squat performance ($p=0.005$; $p<0.05$). Upon considering the p-values of the means, it is evident that this difference is positive, favoring the post-test score.

However, no significant differences were found between pre-test and post-test scores in Vertical Jump performance ($p=0.24$; $p>0.05$). Regarding grip strength, significant differences were identified between pre-test and post-test scores in left hand grip strength ($p=0.00$; $p<0.05$). Conversely, no significant differences were observed between pre-test and post-test scores in right hand grip strength ($p=0.06$; $p>0.05$). Considering the p-values of the means, it is observed that the difference in left hand grip strength is positive, favoring the post-test score. There were significant differences between pre-test and post-test scores in Reaction Time ($p=0.00$; $p<0.05$). Upon considering the p-values of the means, it is observed that this difference is positive, favoring the post-test score.

Similarly, significant differences were also found between pre-test and post-test scores in the 5-meter sprint ($p=0.00$; $p<0.05$). Again, upon examining the p-values of the means, it is observed that this difference is positive, favoring the post-test score. There were significant differences between pre-test and post-test scores in the 10-meter sprint ($p=0.00$; $p<0.05$). Upon considering the p-values of the means, it is observed that this difference is positive, favoring the post-test score. Similarly, significant differences were also found between pre-test and post-test scores in the 40-meter sprint ($p=0.00$; $p<0.05$). Again, upon examining the p-values of the means, it is observed that this difference is positive, favoring the post-test score. Additionally, flexibility exhibited significant differences between pre-test and post-test scores ($p=0.00$; $p<0.05$). Upon considering the p-values of the means, it is observed that this difference is positive, favoring the post-test score.

The aim of this study was to investigate the impact of plyometric resistance training on athletes undergoing preparation for the European Boxing Championship. Fourteen male national boxers, all active licensed athletes in the field of boxing, volunteered to take part in the study. Various parameters of the athletes were evaluated through pre- and post-tests, and the collected data were analyzed and assessed

DISCUSSION

The aim of this study was to investigate the impact of plyometric resistance training on athletes undergoing preparation for the European Boxing Championship. Fourteen male national boxers, all active licensed athletes in the field of boxing, volunteered to take part in the study. Various parameters of the athletes were evaluated through pre- and post-tests, and the collected data were analyzed and assessed.

Significant differences were observed between the pre-test and post-test results of body weight measurements among the athletes participating in the study ($p<0.05$). Specifically, statistical significance was noted in the body weight measurements of the national boxers involved in our study ($p<0.05$). At the commencement of the preparatory camp, the average body weight of the boxers was recorded as 72.14 kg, whereas the measurement at the conclusion of the camp indicated an average of 65.85 kg (Table 3). Body weight stands as a pivotal factor contributing to athletic success, particularly in the sport of boxing (Davis et al.,2014). Notably, significant discrepancies in body weight values before and after a twelve-week training program, as applied to boxers with world and European rankings at the national team level, have been reported in previous research (Finlay et al., 2023).

In a study conducted on female boxers, it was observed that female national team boxers experience more rapid weight loss compared to professional handball players (Chaabène et al., 2015). Additionally, Savaş and Uğraş (2004) investigated the effects of an eight-week preseason training program on the physical and physiological characteristics of male collegiate boxers. They reported a decrease in body weight from an average of 78.33±12.26 kg to 75.67±10.61 kg (Savaş and Uğraş, 2004). Our findings align with the existing literature. The effects of plyometric resistance training implemented during the preparation camp preceding the championship, along with the controlled management of boxers' weight during this period, could elucidate these results.

A significant reduction in body fat percentages was observed among the national team boxers participating in our study ($p<0.05$). Upon examining the body fat percentage values of the national team boxers before the preparation camp, it is noted that the average body fat percentage decreased from 20.47% to 18.37% after the preparation camp, indicating a positive improvement (Table 3).

Contrastingly, Pala and Savucu (2011) reported in their study that there were no statistically significant differences in the average body fat percentage of the boxing group before the camp (12.32%) compared to after the camp (12.33%) (Pala and Savucu, 2011). Additionally, in a study comparing various physical parameters of national female boxers with professional handball players, it was found that the boxers had an average body fat percentage of 9.61% (Usher and Babraj, 2024).

In their study examining the effects of an eight-week preseason training program on the physical and physiological characteristics of university male boxing athletes, Savaş and Uğraş (2004) reported that the average body fat percentage decreased from 12.86±2.37% to 12.72±2.87%. When compared to elite boxers, the average body fat percentage of the Turkish Boxing National Team was found to be 16.76%, the Ukrainian Boxing National Team's average body fat percentage was 13.40% (Chaabène et al., 2015), the Azerbaijan Boxing National Team's average body fat percentage was 10.29%, and the Turkish Boxing National Team's average body fat percentage was 13.16% (Beyleroğlu, 1998). The disparities in the average body fat percentage values can be attributed to the fact that our study group consisted of youth female athletes.

When evaluating the squat performances of the national boxers participating in our study, a significant increase is observed (p<0.05). Upon reviewing the squat values of the national team boxers before the preparatory camp, the pre-test average increased from 27.75 to 29.50 after the preparatory camp, indicating a positive development (Table 3).

It is believed that the increase in squat performance among all athletes in the study resulted from the development associated with maximal strength within the plyometric resistance training included in the study. Plyometric training can be defined as an intermittent sport characterized by high-speed and power activity bursts (James et al., 2017; Brown et al., 2022). Therefore, plyometric resistance exercises are physiologically complex, involving a wide range of physical abilities (i.e., strength, power, speed, muscle endurance) and metabolic mechanisms (anaerobic and aerobic) during both training and competition (James et al., 2017). Elite-level boxers need to possess high levels of endurance, strength, and anaerobic power to utilize different foot techniques targeting the lower body effectively (James et al., 2016; Venckunas et al., 2022). These high physical and technical demands underscore the necessity of specialized strength and conditioning training programs for these athletes (Helms et al., 2017).

Boxing athletes heavily rely on the power generated from their legs to enhance upper extremity strength (Cid-calfucura et al., 2023). The three fundamental punches in boxing—direct punches, hooks, and uppercuts—each involve a triple extension where the ankle, knee, and hip extend to generate force from the ground. The athlete then transfers this force to the opponent by utilizing the kinetic chain, involving the trunk, shoulder, and arm joints to deliver punches. Our study results indicate a focus on different strength training on the lower extremities, which aligns with the necessity for this combination as demonstrated in studies by Cepulenas et al. (2011).

The study conducted by El-Ashker et al. (2004) showcased improvements in lower extremity strength and power values of boxing athletes after four weeks of strength conditioning training on seventeen active athletes at the competitive level (El-Ashker et al., 2004; Jukic et al., 2023). Our study results are consistent with the findings of this research.

The study results demonstrate a significant increase in vertical jump performance among the national boxing athletes who participated in our study (p<0.05). Upon examining the pre-training camp vertical jump values of national team boxers, it is observed that the pre-test average increased from 29.84 to 31.25 after the training camp, indicating positive improvement (Table 3). Explosive power serves as one of the performance indicators in strength-based sports like boxing (Omcirk et al., 2022). Vertical jump, particularly favored for assessing anaerobic power and capacity, holds great significance in boxing (Brindha and Nallavan, 2022). In a study involving elite boxers across different age groups (14-16 years), athletes were reported to have vertical jump values of 29.88 cm (Paul et al., 2011). Kıyıcı et al. (2016) and Bayraktar (2013) reported vertical jump values of 23.78 cm in their study on the boxing field. Furthermore, in a separate study conducted on elite male boxers, it was noted that training outcomes on speed and vertical jump abilities resulted in a positive increase in vertical jump values (Kıyıcı et al., 2016 & Bayraktar, 2013). Serin and Taşkın (2016) explored the relationship between anaerobic endurance and vertical jump in boxing and handball players and discovered a significant relationship ($p<0.05$), indicating that as vertical jump performance increased, anaerobic performance also improved (Serin and Taşkın, 2016). Pala and Savucu (2011) reported the vertical jump (cm) parameter for the Senior Men's Boxing National Team as 43.05 cm before the camp and 44.55 cm after, with the increase being statistically significant. Similar studies conducted on national team boxers revealed vertical jump measurements ranging from 39.57 cm to 47.82 cm at different times (Pala and Savucu, 2011). Based on our study findings, we can infer that athletes had a productive training camp period, achieving an increase in vertical jump parameters as mentioned above.

Conclusion

In conclusion, the plyometric resistance training implemented with the junior male national boxing team athletes during the preparation phase for the European Championship proved effective in enhancing various abilities, particularly jump ability duration. The incorporation of exercises targeting leg strength and power abilities during training sessions likely contributed to this effect. Additionally, a reduction in reaction time was observed, which may be attributed to exercises targeting arm strength and power abilities post-training sessions.

Throughout the camp period, the plyometric resistance training significantly improved motor characteristics and reaction time in the human body physiologically. It was evident that the type of activity influenced these characteristics at different levels. The short-term enhancement in reaction ability, considered a major expected effect of the applied training, can be credited to the training effect.

Moreover, the training regimen proved effective in increasing flexibility, possibly due to the inclusion of strength-intensive exercises focusing on strength and active force-related jumps. However, no significant difference was observed in right hand grip strength abilities, which may be attributed to the minimal inclusion of maximal force exercises in the training regimen for boxers with already high grip strength.

Considering the preparation process for the European Championship and the diverse needs of the national team boxers in terms of skill acquisition, the plyometric resistance training conducted during the preparation camp was evaluated in conjunction with all variables. Based on the study results, it is believed that the training regimen is effective in improving overall athletic performance.

Limitations and suggestions

Within the limitations of the study, it is important to mention the sample size. Our study consisted of fourteen participants.

However, if larger sample sizes can be achieved, it would provide preliminary information for future studies with a broader sample. Finally, our study has practical implications. Coaches of boxing athletes may consider using plyometric resistance training-based exercises throughout the preseason leading up to competitions. These exercises aim to improve neuromuscular variables, which could consequently impact competition outcomes.

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Conflict of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics Statement

These participants were preparing for the Junior Men's European Championship while concurrently training in various boxing clubs. Ethical approval for the study was obtained from the Atatürk University Ethics Committee (Code: E-70400699-000 2200099753/ Date: 28.03.2022/ Decision: 37). Prior to enrollment, all volunteers were verbally briefed on the study's objectives, and written consent forms were duly obtained from each participant.

Author Contributions

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

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