

Acute Effects of Squat and Core Exercises Using Elastic Bands on Post- Activation Performance Enhancement in Tennis Players: Control, Randomized, Crossover Trials

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Abstract

Background Resistance equipment is often used to achieve the post-activation performance enhancement (PAPE) effect; however, tennis players who are constantly in tournaments may not always have access to it. This study aimed to investigate the PAPE effects of resistance-band-based squat and core exercises on selected physical test parameters in tennis players.

Methods Fifteen male tennis players (14.86 ± 0.66 years) participating in international tennis tournaments completed three separate randomized experimental visits. At each visit, participants began with different warm-up protocols (jogging [Control], dynamic warm-up [DW], and dynamic warm-up + resistance band [DW + RB]). Then they performed a series of sport-specific tests (countermovement jump [CMJ], anaerobic power, squat jump [SJ], 5m, 10 sprints, 5-0-5 change of direction test [COD], and medicine ball forehand [MBFH] and backhand [MBBH] throw tests).

Results The findings showed that the DW + RB protocol produced statistically significant differences in CMJ, anaerobic power, MBFH, and MBBH test results compared to both CON and DW ($p < 0.05$). Although the DW + RB group showed an increase in SJ performance (CON 7.83% and DW 2.66%), there was no statistically significant difference compared to the other warm-up groups ($p > 0.05$). No statistically significant differences were observed between the groups in the sprint (5 m and 10 m) and the change of direction test results.

Conclusions The use of elastic bands after a dynamic warm-up resulted in improved core performance, essential for jumping and tennis, compared to other warm-up protocols. Therefore, warm-up activities involving elastic band-based exercises can be integrated into the traditional warm-up protocol before training or matches for players participating in international tennis tournaments.

Background

Tennis is an intermittent sport that requires multiple physical components, including sprinting, change of direction (COD), and strength, across matches of varying durations (1–5 h) [1]. To achieve top-level success in this sport, players must possess not only technical skills but also good physical fitness, including acceleration, power, and change of direction [2]. Coaches and players use various warm-up exercises to prepare these motor skills for training or competition [3]. Dynamic warm-up (DW) or ballistic warm-up exercises performed before athletic activity generally increase muscle temperature, facilitating physiological changes such as increased blood flow and optimized metabolic responses [4, 5]. Another alternative to general warm-up exercises is the improvement in voluntary muscle contraction after conditioning activities (CA) performed with maximal or submaximal loads (e.g., 60–85% of a 1 RM back squat) after the warm-up. This is defined as Post-Activation Performance Enhancement (PAPE). [6–8]. Although the mechanisms of action of PAPE have been implicated, including increased calcium sensitivity, phosphorylation of myosin light chains, and preferential recruitment of fast-twitch fibers, the exact mechanisms of PAPE remain incompletely understood [9, 10].

One key factor determining the positive effect of PAPE is the optimal balance between induced fatigue and potentiation after CA, which is necessary to achieve performance enhancement [11]. Although CAs performed at 70–90% of 1 RM in PAPE protocols have indicated positive effects on performance [12], some studies have reported deterioration in performance due to fatigue at these high intensities [13]. Although it has been stated that CAs performed at light resistances cannot sufficiently activate the motor units in the muscles [14], a recent meta-analysis reported that PAPE is effective on performance after CAs performed at 50%–85% of 1 RM in resistance exercises [6]. In some tennis studies, the PAPE protocol demonstrated that lighter loads are more effective for tennis-specific performance indicators [7]. Specifically, squatting at 60% of 1RM significantly improved maximal power output [15].

Studies demonstrating the positive effects of PAPE in the literature have frequently used free weights or resistance machines. However, because resistance bands provide both long and short-term improvements in force production by achieving maximum or near-maximal muscle contractions, they have been used as an alternative method to reveal the positive effects of PAPE [16–18]. A meta-analysis compared muscle activation using resistance bands and isoinertial resistance equipment. The study reported that EMG measurements with resistance bands did not differ from those with isoinertial resistance equipment; however, resistance bands tended to yield higher stabilizer EMG values [19]. This partially refutes the criticism that resistance bands cannot provide sufficient muscle activation. These results suggest that using resistance bands rather than resistance equipment or free weights may be an alternative for performing PAPE. A study in the literature found that CA applied with resistance bands at 3–5 RM improved participants' jumping and sprint performance [18]. A study involving handball players demonstrated significant improvements in jumping, sprinting, and free-throw performance after applying CA with resistance bands [17]. Because the participants in studies investigating the effect of PAPE were mostly adults participating in team sports, the literature has also highlighted the need for further research on the effects of PAPE on adolescent players participating in individual sports [20].

From an early age (e.g., U14), tennis players participate in tournaments held on specific weeks in specific regions around the world. In these tournaments, players compete in both singles and doubles matches throughout the day [21]. However, tennis players do not always have access to gyms during tournaments. Therefore, versatile, portable, compact, and relatively inexpensive resistance bands offer an alternative method for frequently traveling tennis players to induce the PAPE effect after a warm-up.

One solution to minimize fatigue while maintaining potency is the use of resistance bands for PAPE, which may be particularly suitable for adolescent players, as the literature recommends using lighter weights [22]. Therefore, the purpose of this study was to investigate the effects of squat and core CA performed with RB on jumping, sprinting, change of direction, and medicine ball throwing performance in tennis players. Our research hypothesis was that completing a dynamic warm-up before CA would significantly affect tennis players' performance scores.

Methods

Study design

This study used a randomized, controlled, crossover experimental design to investigate the effects of different warm-up protocols on several performance parameters in tennis players. All players underwent several practice sessions to familiarize themselves with the use of resistance bands, determine their individual loading intensity, and perform squats and core exercises. The players were also instructed to familiarize themselves with the experimental testing procedures. The research team randomly assigned participants to experimental visits, and the players received a 48-hour rest period between testing days. The participants were divided into control, dynamic warm-up (DW), and dynamic warm-up + resistance bands (DW + RB) groups. After completing the warm-up protocols, the players underwent a 4-minute passive rest, followed by the countermovement jump (CMJ), squat jump (SJ), 5-m and 10-m sprints, 5-0-5 change of direction (COD), and medicine ball throws (forehand and backhand). Participants were allowed to perform two tests for each test, and their best scores were recorded. The participants were given a 1-minute passive rest between repeated tests. All tests were conducted on an indoor hard-surface tennis court. A schematic diagram of the experimental procedure is shown in Fig. 1.

Participants

A G*power analysis was conducted to determine the sample size for this study. Assuming a significance level of 0.05, a power of 0.80, and a correlation of 0.70 across three replicate measurements, a sample size of at least 15 participants was calculated to detect medium effect sizes. The study results of Chen et al. [17], who examined CMJ, SJ, and COD and their physical parameters in a study using resistance bands, were used to determine the sample size. Fifteen male adolescent tennis players (mean $\pm$ SD: age: 14.86 ± 0.66 years; height: 1.72 ± 0.06 cm; body weight: 62.57 ± 4.67 kg, training age: 8.79 ± 0.58 ; BMI: 21.29 ± 1.41) who had international tennis rankings and participated in international tournaments volunteered for this study. All participants participated in tennis and conditioning training 6 days a week. Participants were asked to avoid high-intensity physical activity throughout the study and to maintain regular daily habits, including sleep, nutrition, hydration, and daily activities. Participants were also prohibited from consuming alcohol or caffeine or from taking any additional supplements during the study. Extra effort was made to ensure that the tests were conducted at approximately the same time of the day (10:00 AM–12:00 PM). All experimental procedures in this study adhered to the principles outlined in the Declaration of Helsinki. All participants and their parents or guardians were fully informed of the study protocol, potential risks and benefits, and provided written consent. The study was approved by the Sinop University Ethics Review Board (No. 10/255–276).

Procedures

Studies have shown that using the OMNI (0–10) scale to determine load intensity is beneficial for assessing load intensity [23]. Therefore, in this study investigating the PAPE effect, we used the OMNI (0–10) scale to determine the appropriate load intensity. Before the test, resistance bands of varying

tensions (green: 15 kg, yellow: 25 kg, orange: 35 kg, and red: 45 kg, Corenghi, Decathlon CO) were used to determine the load intensity for each participant. To measure the load applied to the squat using elastic bands, the resistance bands were fixed to the tennis players' shoulders, with the other ends placed under their feet. This tension provides variable resistance during squats. To measure the load applied to the core by the elastic bands, the participants assumed a lunge position with one leg forward (at a 90° angle), the rear leg back, and the knee on the floor. In this position, the participants grasped the middle of the resistance band with both hands, and the other end of the band was attached to a fixed point (an area fixed at the heel of the rear foot). In this position, participants were positioned to perform a forward pull in the sagittal plane and then to the right or left. This requires tennis players to engage their core and maintain balance. Bands representing each participant's OMNI 8 score (for squat and core) were determined before the tests, and the bands used by each participant were noted. A metronome (e.g., 4 s per squat) was used to establish the rhythm of the movement during the CAs.

Our study included the CON, DW, and DW + RB groups as indicated in Fig. 1. Participants in the CON group performed a 5-minute warm-up run (at a heart rate of 120 bpm), followed by 2 min of passive rest, and then completed performance tests. The other warm-up group, DW, performed a 5-minute warm-up run (at a heart rate of 120 bpm) followed by 2 min of passive rest. The participants then performed the DW exercise adapted by Ayala et al. [24]. The tennis players performed 6–8 minutes of DW exercises (i.e., straight leg march, forward lunge with opposite arm reach, forward lunge with an elbow instep, lateral lunge, trunk rotations, and multidirectional skippings) in 3 sets, from low to high, with a 15-second rest period between each set. For more detailed exercises, see Ayala et al. [24]. After the warm-up, the tennis players rested for 3 minutes and then completed the performance tests. In the DW + RB warm-up protocol, participants performed the DW protocol in the same manner and were then given 3 minutes of passive rest. The tennis players then performed three sets of 8 squats (4.5 minutes) and three sets of 8 core exercises (5 minutes) to scores of 8 on the OMNI scale (Fig. 2). Performance tests were conducted after a 4-minute passive rest period.

Measures

Sprint Test

The linear sprint test (5 m and 10 m) was conducted using the Smartspeed Pro timing system (Fusion Sport, Boulder, CO, USA). The tennis players performed a 10 m sprint while standing after hearing an audible signal. The time intervals (in seconds) for the first 5 m and the first 10 m of the sprint attempt were recorded for data collection [25].

Countermovement Jump and Squat jump Test

The countermovement jump test was conducted using a Smartjump system (Fusion Sport). The participants were asked to perform a countermovement to a depth that would allow for maximum jump height, with both hands placed on their hips. In the squat jump test participants were asked to hold their

squat position for ~ 3 s and then perform the jump. During both jumps, the participants were asked to maintain the extension of their hip, knee, and ankle joints while in the air. A 1-minute rest period was given between the repetitions [17]. Anaerobic power was calculated from participants' CMJ test results using the Lewis formula: Anaerobic Power (W) = $\{\sqrt{4.9 [\text{Body Weight (kg)}] \sqrt{\text{Vertical Jump (m)}}\}$ [26].

Change of Direction test

The 5-0-5 change of direction test was conducted using the Smartspeed Pro timing system (Fusion Sport, Boulder, CO, USA). To accelerate the participants, they ran 10 m, then 5 m, turned 180°, and sprinted 5 m back in the direction they came from to complete the test. This test is used in sports that frequently involve changes in direction, such as tennis [27].

Medicine Ball Throw Test

Medicine ball throw, a 3 kg medicine ball (Domyos, Decathlon CO) was used for the medicine ball throw (forehand and backhand). A study of adolescent tennis players' trunk rotation and flexion strength found a high correlation with their performance in forehand and backhand medicine ball throws [28]. Before the medicine ball throw, the participants were asked to grasp the ball with both hands, with their feet shoulder-width apart, and stand behind a designated line on the floor. They then threw the ball forward, using a technique similar to a forehand or backhand stroke in tennis. The throw distance was calculated in cm from the point where the ball first touched the ground.

Statistical Analyses

Before selecting the tests to be applied to the data obtained in the study, the Shapiro-Wilk normality test was applied to check whether the error terms showed a normal distribution. The differences between variables were analyzed using repeated-measures ANOVA. Differences between groups were assessed using the Bonferroni correction. The effect size index was calculated with the Eta-squared value (η^2) in the range of 0.00–1.00, and η^2 values were considered as 0.01-small, 0.06-medium, 0.14-large, and 0.20-very-large effect sizes [29]. Research findings are presented as mean and standard deviation (Mean $\pm$ SD), and statistical analysis and interpretation of the data were considered significant at a significance level of $p < 0.05$. SPSS 22.0 was used as the statistical package program for all statistical calculations.

Results

When the performance parameters of the three groups were compared (Table 1), no statistically significant difference was observed in sprint (5–10 m) and COD performance ($p > 0.05$). Furthermore, when the effect size was examined, a change/difference in performance values between the three groups was detected.

Table 1
5 m, 10 m and change of direction test results of different warm-up groups

Variables	CON	DW	DW + RB	f	p	η^2
	X $\pm$ SD	X $\pm$ SD	X $\pm$ SD			
5 m sprint (s)	1.28 $\pm$.17	1.22 $\pm$.17	1.29 $\pm$.20	1.755	0.207	.12
10 m sprint (s)	2.16 $\pm$.25	2.01 $\pm$.29	2.04 $\pm$.31	3.059	0.090	.19
COD (s)	2.57 $\pm$.14	2.48 $\pm$.20	2.51 $\pm$.21	2.149	0.160	.14
*(p < 0,05); X = mean; SD = standard deviation; CON = control group; DW = dynamic warm-up; DW + RB = dynamic warm-up + resistance band; COD = change of direction.						

When the performance parameters of the three groups were compared (Fig. 3), a statistically significant difference was found in the countermovement jump and anaerobic power parameters ($p < 0.05$). No statistically significant difference was found in the squat jump performance ($p > 0.05$). According to the obtained data, a statistically significant difference was found in the countermovement jump and anaerobic power parameters between the DW + RB and DW and CON groups, favoring the DW + RB group ($p < 0.05$). Furthermore, when the effect size was examined, a change/difference in performance values was detected between the three groups.

When the performance parameters of the three groups were compared (Fig. 4), a statistically significant difference was found in the forehand and backhand parameters of the medicine ball throw ($p < 0.05$). According to the data obtained, the statistical analysis showed a significant difference, with the DW + RB group achieving higher performance scores than the DW and CON groups on both forehand and backhand parameters of the medicine ball throw ($p < 0.05$). Furthermore, when the effect size was examined, a change/difference in performance values was detected between the three groups.

Discussion

This study aimed to investigate the effects of CA on the OMNI 8 scores of tennis players in terms of jumping, sprinting, change of direction, and MB throwing. The main finding of our study was that DW + RB produced statistically significantly different performance responses in CMJ, anaerobic power, and MB throwing tests compared to both CON and DW. Furthermore, players in the DW + RB group performed better on SJ performance (CON 7.83% and DW 2.66%) than players in the other groups; however, this difference was not statistically significant in the group analysis. However, no significant difference was found between the groups in terms of sprint and COD. Our results supported our hypothesis regarding the CMJ and MB throwing tests. To our knowledge, this study is one of the few to examine a comprehensive battery of performance tests in elite adolescent tennis players following different warm-up protocols (CON, DW, and DW + RB).

An athlete's power generation capacity is generally considered a key performance indicator of athletic success. In our study, after 4 min of passive rest following three sets of 8 repetitions of squats and core CA performed with a resistance band, significant results were observed in CMJ and anaerobic power performance. The SJ results showed a statistically significant trend compared to the other warm-up groups. The difference in both jump test results may be due to the muscle stretch-shortening cycle [30]. Overall, our findings suggest that a properly planned PAPE protocol can enhance fundamental athletic skills, such as jumping, without inducing additional perceptual fatigue. In the literature, significant effects on jump performance have been observed after completing CA at different intensities (5 RM or 75–90% of 1 RM) during PAPE protocols using various forms of resistance equipment [31, 32]. Similar to our study, studies using resistance bands have shown a significant difference in CMJ performance after squats performed at 3–5 RM [18]. A study involving handball players reported that CAs performed at specific intervals using resistance bands increased CMJ performance [17]. The positive effects of PAPE emerge from increased recruitment of motor units during CAs performed with resistance equipment, which, in turn, activate neuromuscular function, including improved intramuscular coordination [33]. Elastic bands, used as a resistance method, complement the length-tension relationship by requiring a gradual activation of high-threshold motor units, thus providing the highest motor unit activation in the most mechanically advantageous position within a movement, which may have facilitated the positive effect of PAPE [34–36]. In our study, the positive effect of PAPE was observed only in the DW + RB group, suggesting that using elastic bands as a warm-up before training or matches may be a more effective tool than resistance equipment [17, 18]. Furthermore, because CMJ results are strongly correlated with tennis performance, tennis players can implement this PAPE protocol to enhance their current performance, especially before matches [2].

Owing to the nature of tennis and the court's dimensions, a tennis player's acceleration performance is more important than their sprint speed [21]. One study reported that 89.2% of the total distance covered by tennis players during a match was achieved through acceleration-based sprints [37]. In our study, after performing three sets of 8 squats and three sets of 8 core CA, there was no loss of performance in the 5m and 10m acceleration scores; however, no statistically significant difference was found between the groups. Studies on PAPE acceleration have generally shown increases in 5m and 10m performance after 4 min of passive rest following squats performed at high-intensity loads (90% of 1RM) [38, 39]. However, since the positive effect of PAPE varies depending on the sporting branch or factors such as age, CAs applied at high loads in branches such as tennis can have a negative effect, especially on acceleration performance [13, 40]. Indeed, CA applied to tennis players was observed to negatively affect sprint (5m and 10m) performance following leg press exercise at 85% of 1RM [13]. However, another study conducted on tennis players reported that while no increase in sprint performance was observed after squats performed at 80% of 1 RM, interestingly, an increase in sprint (5m and 10m) performance was reported when squat + hip thrust exercises were applied together at lower loads at 60% of 1 RM [15]. Hip thrust is an exercise predominantly activated by hip extension and specific muscles and transferred to explosive, short-term activities, such as high-speed sprints. This exercise differs from our research results because it was applied to squats in this study [40]. Other studies using resistance bands for

sprinting have reported significant differences in sprint speed at 20 m [18] and 30 m [17]. Our current findings suggest that PAPE may vary across sprint phases (5–10 m and 20–30 m), which explains the differences in results. Therefore, when discussing the effects of PAPE on linear velocity during sprinting with resistance bands, it is essential to specify whether the potentiation is due to acceleration or maximum sprint speed [8].

Studies on COD performance with PAPE protocols have shown positive improvements in COD performance after leg press (5RM) [41] and back squat (60–90% of 1RM) CAs [42]. Studies involving tennis players have shown that COD performance deteriorates due to fatigue after leg press (85% of 1RM) exercise [13]. However, another study reported increases in COD performance after squat (70–90% of 1RM) CAs [12]. Our current findings indicate no positive or negative effects on performance after squat and core CAs exercises performed using resistance bands. Owing to the existing positive relationship between acceleration and COD [43], the lack of an increase in acceleration performance in our current findings is also thought to affect COD performance. Other studies using resistance bands have shown a significant effect on COD performance with squats (3RM and 5RM) [18] or plyometric (10% of body weight) CAs [44]. One reason our study's findings differ from those of this study may be due to the inclusion of adolescent players in the participant group. A PAPE study involving preadolescents, adolescents, and adults found that adults performed best [45]. Furthermore, a recent meta-analysis has indicated that PAPE can improve COD performance; however, the results may vary depending on factors such as age, branch, and the type of CA performed [20].

Previous studies have reported that a strong core structure positively affects tennis performance by enabling force transmission from the lower to the upper extremities via the kinetic chain [46, 47]. In our study, after applying squat and core conditioning with resistance bands, a statistically significant difference was observed in both the MBFH and MBBH throwing test results compared to the other warm-up groups. These findings confirm our hypothesis and provide some clues that more active core muscles may have a positive effect on tennis players' subsequent training or match performance [46, 47]. In a study with results parallel to our research findings, the authors reported significant effects on MB throwing speed and handball throw performance in handball players after core CA was applied using resistance bands [44]. Given the limited literature on core CAs in warm-up protocols, the effects of different PAPE protocols across athletic populations should be investigated in the future.

The current study had some limitations that should be acknowledged. The tennis players in this study were adolescent males with high-performance levels. Therefore, these results may not be valid for players of different genders and performance levels. Although studies investigating the effect of PAPE have different protocols in the literature, in our study, performance tests were conducted 4 min after squats and core CA with resistance bands at a score of 8 on the OMNI scale. Therefore, future studies should investigate the effect of PAPE at 4, 8, and 12 minutes after CA across different sports.

Conclusions

Although numerous studies investigating the PAPE effect exist in the literature, PAPE protocols involving adolescent players are limited. Furthermore, tennis players compete in tournaments across countries throughout the year. Therefore, players' access to fitness centers during each tournament is limited. Alternatively, using resistance bands to achieve the PAPE effect may present an opportunity for these players. In conclusion, squat and core exercises using elastic bands likely improved athletic performance (CMJ, anaerobic power, MBFH, and MBBH) in adolescent male tennis players compared to CON and DW. Considering these findings, there is some evidence supporting the use of elastic bands as an alternative to PAPE before training or matches.

Abbreviations

PAPE	Post-activation performance enhancement
CA	Conditioning activities
COD	Change of direction
CON	Control
DW	Dynamic warm-up
DW+RB	Dynamic warm-up + resistance bands
MBFH	Medicine ball throws forehand
MBBH	Medicine ball throws backhand
CMJ	Countermovement jump
SJ	Squat jump

Declarations

Authors' contributions

Conceptualization and design: MA, AM, and MÖ; Methodology: MA, AM and EG; Formal analysis and investigation: MA; Interpretation of the results: AM, ŞTS; Resources: ŞTS and MA; Writing – original draft preparation: MA, MÖ and AM; Writing – review and editing: MA, AM, ŞTS, MÖ and EG. All authors critically revised and approved the final manuscript.

Ethical statement

The study protocol was approved by the Sinop University Ethics Committee (No. 10/255-276) and was conducted in accordance with the Helsinki Declaration.

Data availability

Data are available upon request to the corresponding author at Abdioglu.

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The authors used Grammarly to assist with language editing. After using this tool, all authors reviewed the manuscript thoroughly and take full responsibility for its content.

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Competing interests

The authors declare no competing interests.

Consent for publication

Written informed consent was obtained from the participants (and/or their legal guardians) for publication of their data.

Ethics approval and consent to participate

All participants (and/or their legal guardians) provided written informed consent prior to participation.

Informed Consent

Informed consent was obtained from all participants (and/or their legal guardians) included in the study.

References

1. Kovacs MS. Tennis physiology. Sports medicine. 2007;37(3):189-98.10.2165/00007256-200737030-00001
2. Girard O, Lattier G, Maffiuletti NA, Micallef J-P, Millet GP. Neuromuscular fatigue during a prolonged intermittent exercise: Application to tennis. Journal of Electromyography and Kinesiology. 2008;18(6):1038-46.10.1016/j.jelekin.2007.05.005
3. Gelen E, Dede M, Bingul BM, Bulgan C, Aydin M. Acute effects of static stretching, dynamic exercises, and high volume upper extremity plyometric activity on tennis serve performance. Journal of sports science & medicine. 2012;11(4):600
4. Bishop D. Warm up I. Sports medicine. 2003;33(6):439-54.10.2165/00007256-200333060-00005
5. McGowan CJ, Pyne DB, Thompson KG, Rattray B. Warm-Up Strategies for Sport and Exercise: Mechanisms and Applications. Sports Med. 2015;45(11):1523-46.10.1007/s40279-015-0376-x.
6. Garbisu-Hualde A, Santos-Concejero J. Post-Activation Potentiation in Strength Training: A Systematic Review of the Scientific Literature. J Hum Kinet. 2021;78:141-50.10.2478/hukin-2021-

0034.

7. Germic A, Filipcic A, Paravlic A. Potential Benefits of Postactivation Potentiation Protocols on Tennis Performance: A Systematic Review. *Strength & Conditioning Journal*. 2025;47(2):169-83.10.1519/ssc.0000000000000852
8. Lockie RG, Lazar A, Davis DL, Moreno MR. Effects of postactivation potentiation on linear and change-of-direction speed: analysis of the current literature and applications for the strength and conditioning coach. *Strength & Conditioning Journal*. 2018;40(1):75-91.10.1519/ssc.0000000000000277
9. Hodgson M, Docherty D, Robbins D. Post-activation potentiation: underlying physiology and implications for motor performance. *Sports Med*. 2005;35(7):585-95.10.2165/00007256-200535070-00004.
10. Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Med*. 2009;39(2):147-66.10.2165/00007256-200939020-00004.
11. Seitz LB, Haff GG. Factors Modulating Post-Activation Potentiation of Jump, Sprint, Throw, and Upper-Body Ballistic Performances: A Systematic Review with Meta-Analysis. *Sports Med*. 2016;46(2):231-40.10.1007/s40279-015-0415-7.
12. Sole CJ, Moir GL, Davis SE, Witmer CA. Mechanical analysis of the acute effects of a heavy resistance exercise warm-up on agility performance in court-sport athletes. *Journal of human kinetics*. 2013;39:147.10.2478/hukin-2013-0077
13. Moreno-Perez V, Hernandez-Davo JL, Nakamura F, Lopez-Samanes A, Jimenez-Reyes P, Fernandez-Fernandez J, et al. Post-activation performance enhancement of dynamic stretching and heavy load warm-up strategies in elite tennis players. *J Back Musculoskelet Rehabil*. 2021;34(3):413-23.10.3233/BMR-191710.
14. Schoenfeld BJ. The mechanisms of muscle hypertrophy and their application to resistance training. *The Journal of Strength & Conditioning Research*. 2010;24(10):2857-72.10.1519/jsc.0b013e3181e840f3
15. Fernandez-Galvan LM, Prieto-Gonzalez P, Sanchez-Infante J, Jimenez-Reyes P, Casado A. The Post-Activation Potentiation Effects on Sprinting Abilities in Junior Tennis Players. *Int J Environ Res Public Health*. 2022;19(4).10.3390/ijerph19042080.
16. Aandahl HS, Von Heimburg E, Van den Tillaar R. Effect of Postactivation Potentiation Induced by Elastic Resistance on Kinematics and Performance in a Roundhouse Kick of Trained Martial Arts Practitioners. *J Strength Cond Res*. 2018;32(4):990-6.10.1519/JSC.0000000000001947.
17. Chen CH, Chang CK, Tseng WC, Chiu CH, Dai X, Ye X. Acute Effects of Different Warm-up Protocols on Sports Performance in Elite Male Collegiate Handball Players. *J Strength Cond Res*. 2022;36(8):2262-7.10.1519/JSC.0000000000003547.
18. Peng HT, Zhan DW, Song CY, Chen ZR, Gu CY, Wang IL, et al. Acute Effects of Squats Using Elastic Bands on Postactivation Potentiation. *J Strength Cond Res*. 2021;35(12):3334-

- 40.10.1519/JSC.00000000000003618.
19. Aboodarda SJ, Page PA, Behm DG. Muscle activation comparisons between elastic and isoinertial resistance: A meta-analysis. *Clinical Biomechanics*. 2016;39:52-61.10.1016/j.clinbiomech.2016.09.008
 20. Singh U, Connor JD, Leicht AS, Brice SM, Doma K. Acute effects of prior conditioning activity on change of direction performance. A systematic review and meta-analysis. *J Sports Sci*. 2023;41(18):1701-17.10.1080/02640414.2023.2293556.
 21. Fernandez-Fernandez J, Mendez-Villanueva A, Pluim B. Intensity of tennis match play. *British journal of sports medicine*. 2006;40(5):387-91
 22. Duchateau J, Enoka RM. Neural adaptations with chronic activity patterns in able-bodied humans. *Am J Phys Med Rehabil*. 2002;81(11 Suppl):S17-27.10.1097/00002060-200211001-00004.
 23. Naclerio F, Rodríguez-Romo G, Barriopedro-Moro MI, Jimenez A, Alvar BA, Triplett NT. Control of resistance training intensity by the OMNI perceived exertion scale. *The Journal of Strength & Conditioning Research*. 2011;25(7):1879-88.10.1519/jsc.0b013e3181e501e9
 24. Ayala F, Moreno-Pérez V, Vera-Garcia FJ, Moya M, Sanz-Rivas D, Fernandez-Fernandez J. Acute and time-course effects of traditional and dynamic warm-up routines in young elite junior tennis players. *PloS one*. 2016;11(4):e0152790.10.1371/journal.pone.0152790
 25. Yildiz S, Pinar S, Gelen E. Effects of 8-week functional vs. traditional training on athletic performance and functional movement on prepubertal tennis players. *The Journal of Strength & Conditioning Research*. 2019;33(3):651-61.10.1519/jsc.0000000000002956
 26. Daneshjoo A, Mokhtar AH, Rahn timer N, Yusof A. Effects of the 11+ and Harmoknee warm-up programs on physical performance measures in professional soccer players. *Journal of sports science & medicine*. 2013;12(3):489.10.1371/journal.pone.0050979
 27. Fernandez-Fernandez J, Granacher U, Sanz-Rivas D, Sarabia Marin JM, Hernandez-Davo JL, Moya M. Sequencing Effects of Neuromuscular Training on Physical Fitness in Youth Elite Tennis Players. *J Strength Cond Res*. 2018;32(3):849-56.10.1519/JSC.0000000000002319.
 28. Ellenbecker T, Roetert EP. Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *J Sci Med Sport*. 2003;6(1):63-70.10.1016/s1440-2440(03)80009-9.
 29. Alpar R. Spor, sağlık ve eğitim bilimlerinden örneklerle uygulamalı istatistik ve geçerlik-güvenirlik: Detay yayıncılık; 2010.
 30. Van Hooren B, Zolotarjova J. The difference between countermovement and squat jump performances: a review of underlying mechanisms with practical applications. *The Journal of Strength & Conditioning Research*. 2017;31(7):2011-20.10.1519/jsc.0000000000001913
 31. McCann MR, Flanagan SP. The effects of exercise selection and rest interval on postactivation potentiation of vertical jump performance. *J Strength Cond Res*. 2010;24(5):1285-91.10.1519/JSC.0b013e3181d6867c.

32. Mola JN, Bruce-Low SS, Burnet SJ. Optimal recovery time for postactivation potentiation in professional soccer players. *J Strength Cond Res.* 2014;28(6):1529-37.10.1519/JSC.0000000000000313.
33. Blazevich AJ, Babault N. Post-activation potentiation versus post-activation performance enhancement in humans: historical perspective, underlying mechanisms, and current issues. *Frontiers in Physiology.* 2019;10:1359.10.3389/fphys.2019.01359
34. Israel MA, McBride JM, Nuzzo JL, Skinner JW, Dayne AM. Kinetic and kinematic differences between squats performed with and without elastic bands. *The Journal of Strength & Conditioning Research.* 2010;24(1):190-4.10.1519/jsc.0b013e31819b7995
35. McMaster DT, Cronin J, McGuigan M. Forms of variable resistance training. *Strength & conditioning journal.* 2009;31(1):50-64.10.1519/ssc.0b013e318195ad32
36. McMaster DT, Cronin J, McGuigan MR. Quantification of rubber and chain-based resistance modes. *J Strength Cond Res.* 2010;24(8):2056-64.10.1519/JSC.0b013e3181dc4200.
37. Galé-Ansodi C, Castellano J, Usabiaga O, Casamichana D, editors. Metabolic power in tennis: New approach to understand the physical demands. *Journal of Strength and Conditioning Research.* IV International Conference; 2014.
38. Bevan HR, Cunningham DJ, Tooley EP, Owen NJ, Cook CJ, Kilduff LP. Influence of postactivation potentiation on sprinting performance in professional rugby players. *J Strength Cond Res.* 2010;24(3):701-5.10.1519/JSC.0b013e3181c7b68a.
39. Chatzopoulos DE, Michailidis CJ, Giannakos AK, Alexiou KC, Patikas DA, Antonopoulos CB, et al. Postactivation potentiation effects after heavy resistance exercise on running speed. *J Strength Cond Res.* 2007;21(4):1278-81.10.1519/R-21276.1.
40. Neto WK, Vieira TL, Gama EF. Barbell Hip Thrust, Muscular Activation and Performance: A Systematic Review. *J Sports Sci Med.* 2019;18(2):198-206.10.37766/inplasy2025.1.0115
41. Zois J, Bishop DJ, Ball K, Aughey RJ. High-intensity warm-ups elicit superior performance to a current soccer warm-up routine. *J Sci Med Sport.* 2011;14(6):522-8.10.1016/j.jsams.2011.03.012.
42. Okuno NM, Tricoli V, Silva SB, Bertuzzi R, Moreira A, Kiss MA. Postactivation potentiation on repeated-sprint ability in elite handball players. *J Strength Cond Res.* 2013;27(3):662-8.10.1519/JSC.0b013e31825bb582.
43. Stewart PF, Turner AN, Miller SC. Reliability, factorial validity, and interrelationships of five commonly used change of direction speed tests. *Scand J Med Sci Sports.* 2014;24(3):500-6.10.1111/sms.12019.
44. Chua MT, Chow KM, Lum D, Tay AWH, Goh WX, Ihsan M, et al. Effectiveness of On-Court Resistive Warm-Ups on Change of Direction Speed and Smash Velocity during a Simulated Badminton Match Play in Well-Trained Players. *J Funct Morphol Kinesiol.* 2021;6(4).10.3390/jfmk6040081.
45. McKiel A, Woods S, Gabriel DA, Vandenboom R, Falk B. Post-activation potentiation and potentiated motor unit firing patterns in boys and men. *Eur J Appl Physiol.* 2024;124(5):1561-74.10.1007/s00421-023-05377-z.

46. Fernandez-Fernandez J, Ellenbecker T, Sanz-Rivas D, Ulbricht A, Ferrautia A. Effects of a 6-week junior tennis conditioning program on service velocity. J Sports Sci Med. 2013;12(2):232-9

47. Martin C, Bideau B, Bideau N, Nicolas G, Delamarche P, Kulpa R. Energy flow analysis during the tennis serve: comparison between injured and noninjured tennis players. The American journal of sports medicine. 2014;42(11):2751-60.10.1177/0363546514547173

Figures

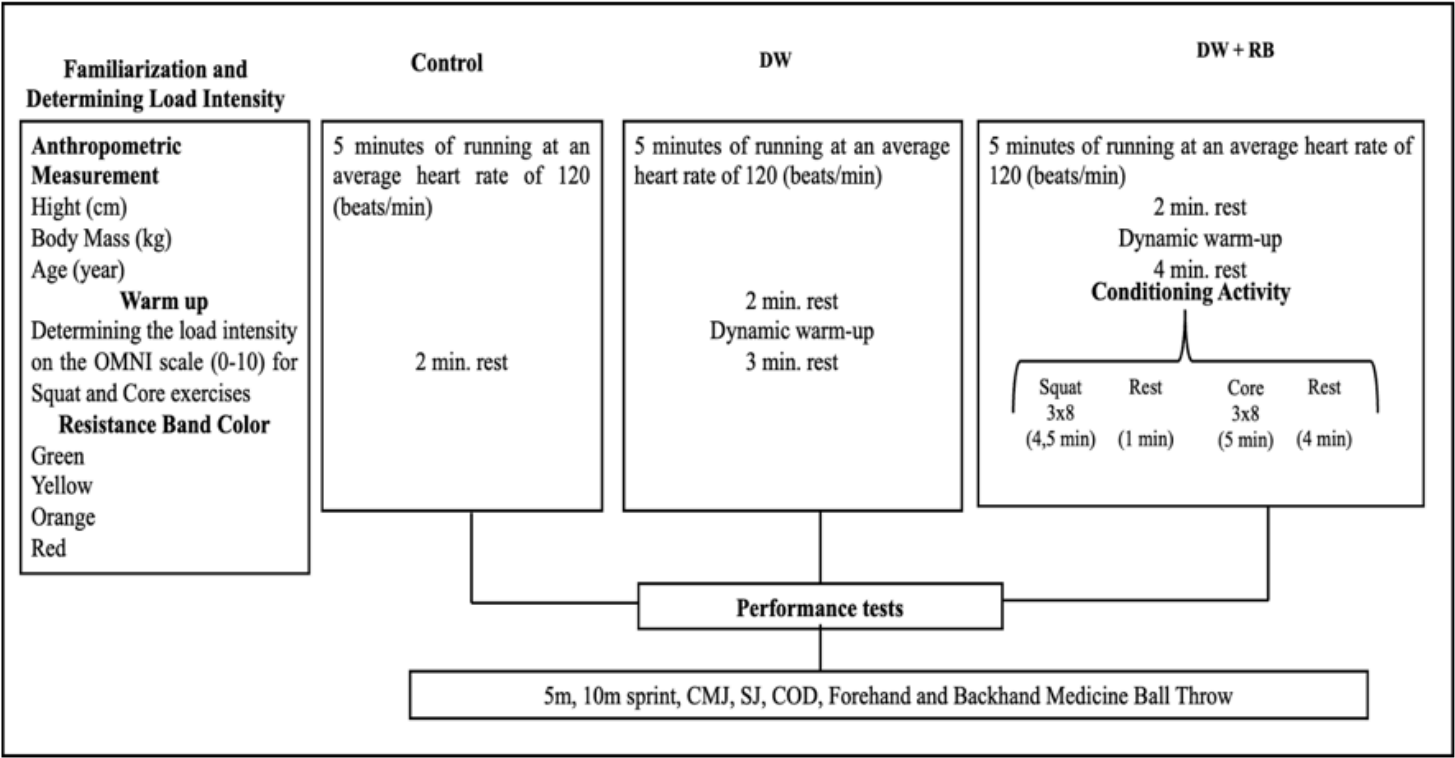


Figure 1

Experimental design

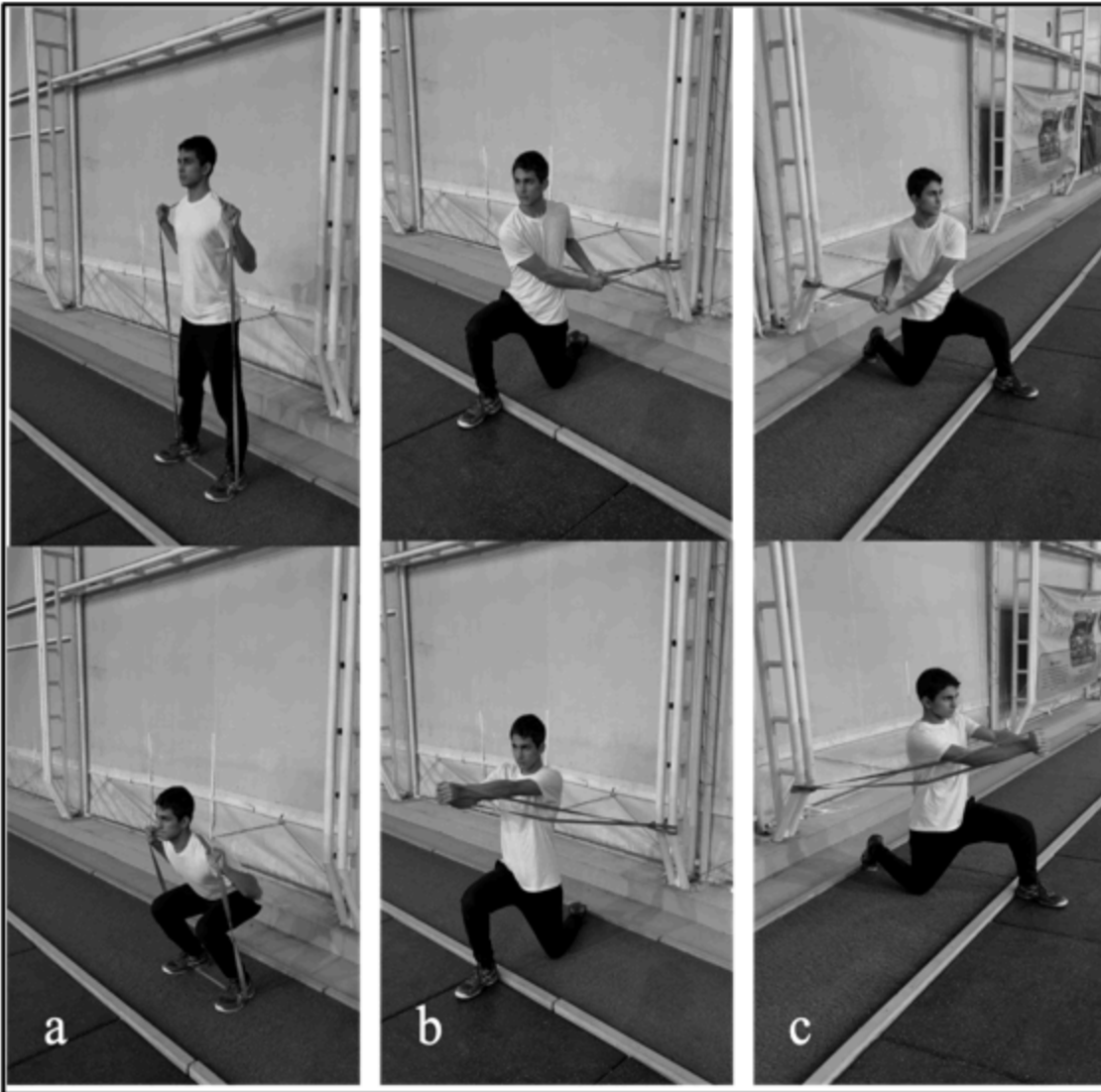


Figure 2

Demonstrations of the elastic band exercises. Back squat (a), elastic band left trunk rotation (b), elastic band right trunk rotation (c)

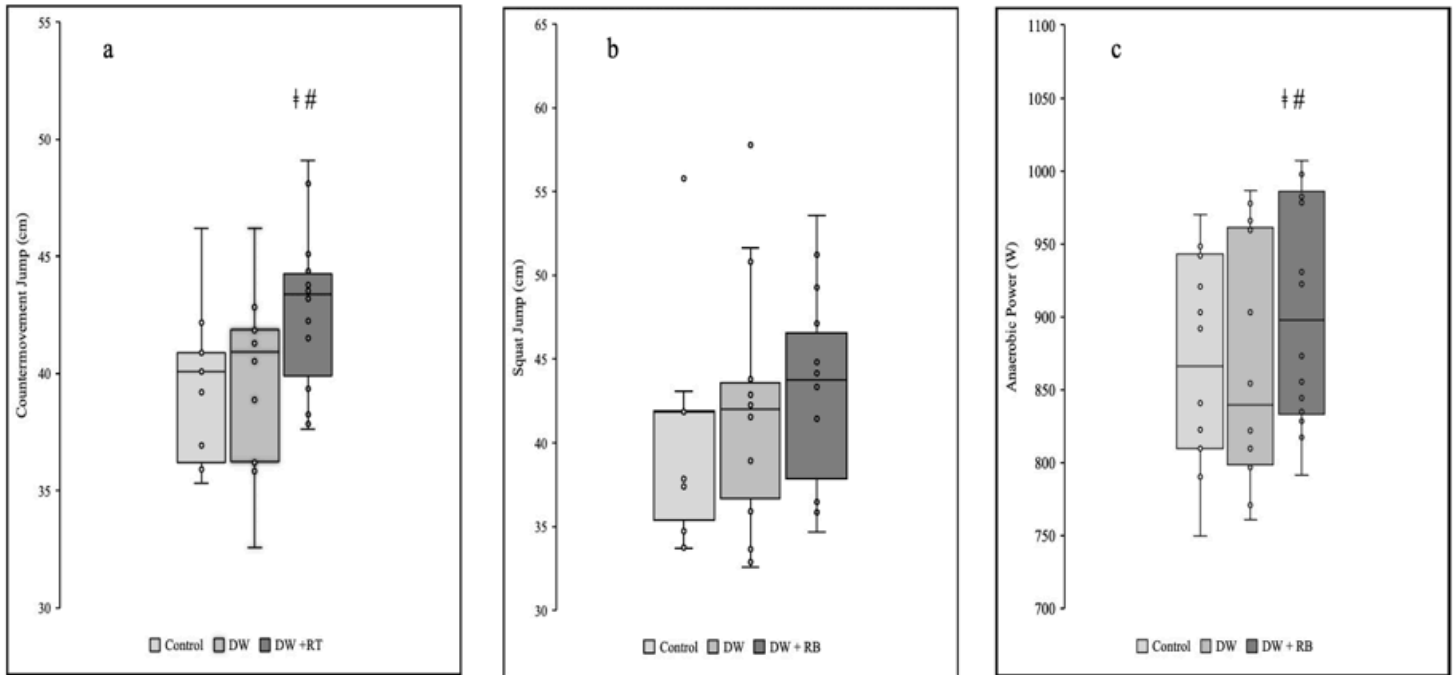


Figure 3

countermovement jump (a), squat jump (b) and anaerobic power (c)

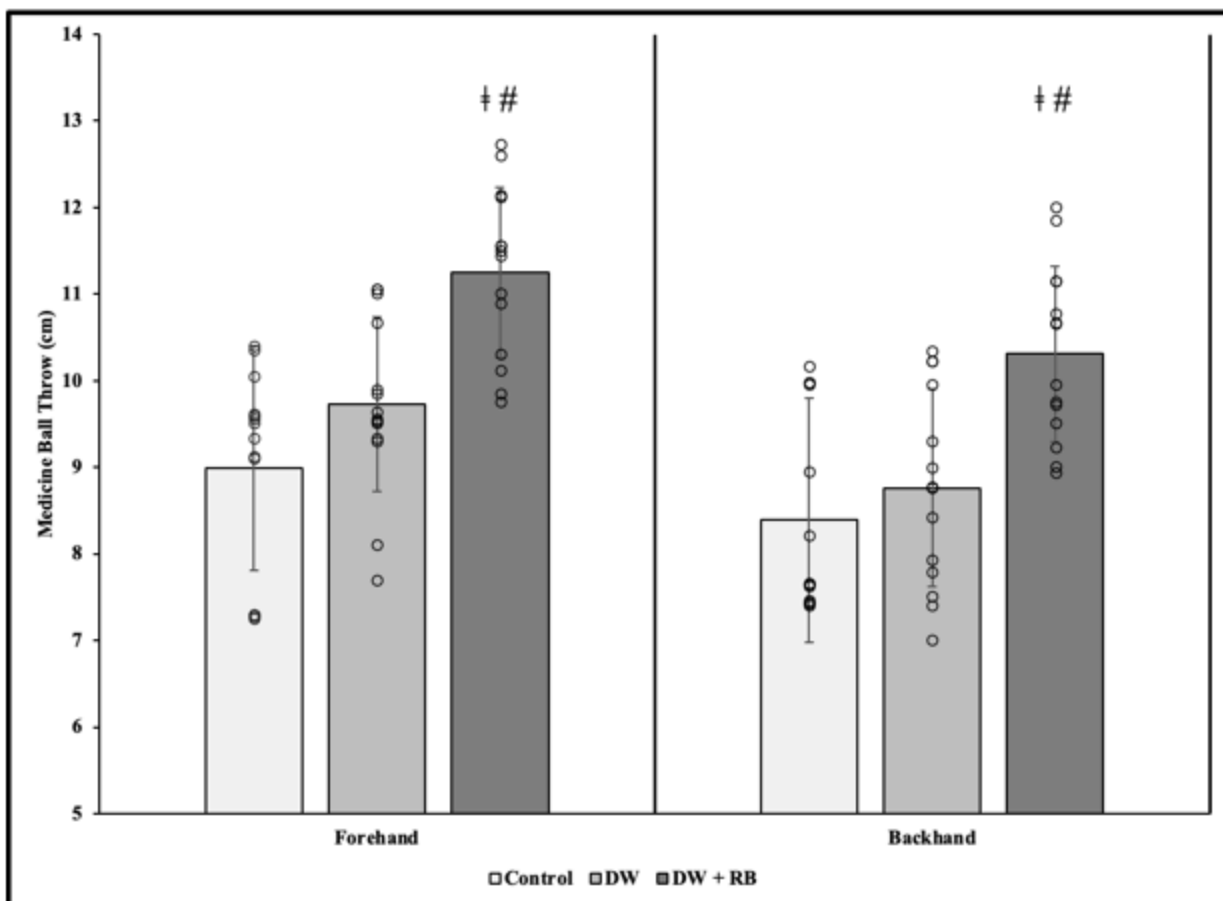


Figure 4

medicine ball throw (Forehand and backhand)