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Effects of 8-Week Thera-Band Training on Spike Speed, Jump Height and Speed of Upper Limb Performance of Young Female Volleyball Players

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ABSTRACT: Introduction and objectives: Elastic resistance has been commonly used in the therapeutic and fitness setting. However, the effects of a strength training program using elastic resistance exercises to the explosive power and spike speed, which are very important elements for successful volleyball practice, has not been clearly demonstrated. Therefore, the aim of this study was to establish the effects of 8-week Thera-Band training protocols on the development of spike speed, counter movement jump (CMJ) height, peak power and speed of upper limb performance of young female volleyball players. **Methods:** The participants consists of 20 competitive female volleyball players who regularly train at the same team and aged 15-17 years (age 16.2 ± 0.7 years). All the players were tested for spike speed, CMJ height, peak power and speed of upper limb performances before and after 8-week training program. The players were divided into Thera-Band Training Group (TTG; *n*=10) and Control Group (CG; *n*=10). Both groups continued technical and tactical volleyball training together 3 days (120 min.d.-1) a week. Additionally, TTG attended Thera-Band training program through 8-week, 2 days per week and 2 sessions (60 min.d.-1). **Results**: The findings of the study showed significant change in CMJ height, peak power and spike speed at the end of 8-week. TTG significantly ($p \leq .001$) improved CMJ height, peak power and spike speed, whereas the CG showed significant changes only CMJ height and peak power ($p \leq .05$) at the end of 8-week. The effect of resistance exercises was significantly higher as compared to the control group ($p < .05$). Results demonstrated that the TTG players showed greater improvements in CMJ height (d = 1.31, moderate effect size), and spiking speed (d = 2.93, large effect size) performance than CG. **Conclusion**: It can be concluded that supervised Thera-Band training contributed development of the performance of spike speed mostly and CMJ height and peak power of lower extremities in young female volleyball players. Due to its effectiveness on muscular performance, the Thera-Band training model can be recommended to the coaches and players in additional to the regular technical training.

KEY WORDS Strength training, Spike, Vertical jump, Peak power, Volleyball

INTRODUCTION

Volleyball is characterized as a ball game that requires biomechanical demands upon the musculoskeletal system as well as great deal of neuromuscular coordination, speed, agility, and power. Passing, setting, spiking, blocking and serving the ball are fundamental movements in a volleyball game, which requires implementation of various vertical or horizontal jumps, and speed actions. It has been suggested that volleyball players competing in better performing teams, have higher vertical jump values [27]. For novice and young players, these values are also considered as important performance indicators [17,18].

Besides the height of jump, the ability to spike the ball with highest possible speed are also important factors for performance of the volleyball players [17,26]. Within this structure, spike is a complex movement pattern requiring flexibility, muscular strength, coordination and neuromuscular efficiency [5]. Therefore, the spike is described as the most explosive movement form among the overhead volleyball skills [5]. It requires a straight approach to the ball with a right angle and jumping with good timing [54]. Volleyball players try to spike the ball at maximal height as this increases the chance to pass the block successfully and to place the ball in the opponent's side due to an optimized release angle [30]. The spike has the highest correlation to the team´s performance in competition [25,44] and it contributes to about 44% of team's success [54]. The spike ability can be enhanced by increasing strength and power of the trunk and the chest/shoulder girdle area using a variety of resistance training and upper body plyometric activities [26]. Because of these demands the lower and upper body strength are very significant factors for performance and injury prevention in volleyball. Especially, shoulder extension strength at high speeds is considered very highly for spiking velocity and is also necessary for the young athletes. Therefore, participation in especially strength and conditioning programs are very important in protection of injuries among women [26] and adolescent female players [56] in volleyball.

Strength training protocols designed to optimize the efficiency and benefits in athletics, have gained popularity [35]. Particularly, to maintain or achieve shoulder-muscle strength and balance, previous research has suggested rotator cuff strengthening programs [38]. In order to increase their muscular strength, individuals prefer to participate in traditional resistance training programs [35]. Those programs are performed using gym equipment such as free weights or machines, resistance bands and their own body weight [7,38]. Current research indicates that supervised resistance training can be a safe, effective and worthwhile activity for children and adolescents [3,15].

Elastic bands, rubber bands and tubing are produced by several manufactures under different product names, such as Thera-band, Elastic Resistance Bands and Tubing. Elastic bands are available in an assortment of grades or thicknesses. Those kind of elastic resistance devices are widely used in the therapeutic and fitness settings [1] and light strength training by a short-term (4-5 weeks) exercise plan [31,32]. Elastic resistance bands never works against the gravity and can be used to train one or more joints at the same time [20]. Therefore, they could potentially be used as a feasible alternative for resistance training [29] and have also gained popularity because of their low cost, simplicity, versatility, accessibility, safety and portability. It has been reported that elastic resistance bands are a relevant tool for increasing muscular strength in young and old populations, both male and female adults with and without musculoskeletal pain [35] and can be used to assist the physical development of volleyball players [26].

It has been well documented that resisted movement training is an effective training mode for increasing muscular performance in various sports such as basketball, taekwondo, and wrestling players [31,32,33], therefore, it should be incorporated into the training program design. Although elastic bands and 3- to 5-pound dumbbells were suggested to be use for the shoulder routine exercises in volleyball [19], it is noteworthy that the effect of its use on young volleyball players in a long-term training is not revealed.

There are limited studies which have investigated the effects of short or long term (4-12 weeks) resistance training programs in young athletes concerning performance variables [12,55]. The results of above-mentioned studies demonstrated that resistance training programs increase throwing velocity muscular strength, power, and endurance youth baseball [12] and tennis players [55], Furthermore, Treiber et al. [55], concluded that resistance training using Thera-Band tubing and lightweight dumbbells might have beneficial effects on strength and functional performance in college-level tennis players. Additionally, transferability of strength gains achieved from general resistance training methods to sport-specific performance remain as a critical issue [31], and it is not clear for volleyball skills such as spike speed.

Although jump height [17,18], and spike speed [25,44] are known to be an important determinants of volleyball performance, to the best of our knowledge, there have been no studies to examine the effect of long-term Thera-Band exercises especially on the spike speed and jump height performance of female volleyball players.

Within this context, this study aims to determine the effects of an 8-week (2 d.wk-1, 60 min.d-1) Thera-Band training protocols targeting the development of spike speed, vertical jump height, peak power, coordination and speed of upper limb on young female volleyball players.

METHODS

Participants

Twenty young (age = 16.2 ± 0.7 years) competitive female volleyball players voluntarily participated in this study. All players were member of a local volleyball club. The participants were selected from a group of volleyball players who were similar in respect to their exercise level (3 d.wk-1/2 h.d-1) and training history (at least 3 years) in the young volleyball leagues. Exclusion criteria included previously engaging in a formal Thera-Band training program, consisting musculoskeletal injury (eg, postoperative conditions, musculotendinous, ligamentous, or bony defects) within 6 months of the start of the study and suffering musculoskeletal pain or any neuromuscular and cardiovascular disorder. Specifically, none of the participants, had injuries that limited range of motion (ROM) at the upper and lower extremities. The study was designed in compliance with the recommendations for clinical research of the World Medical Association Declaration of Helsinki [58]. The protocol was reviewed and approved by the Institutional Ethic Committee of the Marmara University. The club consents were obtained before data collection for the study. Parental consent and assent were obtained for those under age 18. All participants and their parents were informed of the benefits and risks of the investigation, and written informed consent was received from them. All participants completed a questionnaire regarding their personal information (age of training, daily and weekly volleyball trainings) and medical histories.

Study design

This study was undertaken as mixed-model experimental design. According to the preliminary test results, 20 female volleyball players were divided into Thera-Band Training Group (TTG; *n* = 10) and Control Group (CG; *n* = 10). Statistical analysis showed that the groups did not differ before the experiment with regard to any of the variables of training history, height, weight, and body mass index (BMI).

During the 8-week period, TTG and CG players routinely trained together with the same regular volleyball technical and tactical training (total of 24 training sessions) for 3 sessions (Mondays, Wednesday, and Fridays) per week and participated in the one competitive match per in-season week (eight official matches total). The sessions lasted 60 minutes a day and consisted of a dynamic warm-up, jump training, resistance training, speed and agility drills specific for volleyball, and flexibility. Additionally TTG players attended Thera-Band program in 8-week with training (total of 16 training sessions) carried out 2 times per week on nonconsecutive days (Tuesday and Thursday). However, CG completed only regular volleyball technical and tactical training. The effectiveness of the Thera-Band program on spike speed, jump performance of lower extremities and speed of upper limb movement was evaluated with a pretest and posttest. Before and after the 8-week, participants were tested to determine anthropometric features (body weight and height) and physical fitness performances (spiking speed and vertical jump height).

Testing protocols

All participants were assessed before and after an 8-week training program in the same condition. Each participant visited to our laboratory one week prior to pre-season testing for familiarization with equipment and procedures. Post-testing was conducted within a week of the final session of the program. They were carefully instructed with all testing requirements before baseline performance. The players did not undertake any strenuous or unaccustomed exercise in the 24-h before trials, and were restricted from alcohol and caffeine ingestion during this time. They were instructed to be well hydrated and to avoid eating at least 3 hours before measurements. The tests were completed in one day (i.e., 16.00 and 18.00 hours) on an indoor volleyball surface on which the participants were accustomed to training. The participants performed the tests in the following order: anthropometric measurements, plate tapping, counter movement jump (CMJ) and spiking performance tests. One minute of rest was allowed between each test. After completing anthropometric measurement and plate tapping test, each athlete performed a standardized 15-minute warm-up consisting of general movements [walking, jogging at increasing velocities lunging, submaximal contractions of the upper-body muscles (e.g., crunches, pull-ups, push-ups) and both upper- and lower-body dynamic and static stretching] and approximately 5 minutes of light to moderate effort of throwing. The players executed standardized warm-ups directed by one of the researchers and the coach. During all the aforementioned physical tests, the players were verbally encouraged to give their maximal effort.

Anthropometric measurements

Standing height, using a portable Seca stadiometer 208 (Vogel & Halke, Hamburg, Germany) and body weight using a digital scale (Scale Tanita HD-358, Japan) were measured allowing the calculation of the body mass index [(BMI, kg/m2) = height/body mass2]. The participants were in the fasting state, with the dressed in light clothing and barefoot.

Plate tapping test

A plate tapping is a reliable and valid instrument to evaluate the coordination and speed of upper limb movement [2] for dominant arm rate of motion. In the plate tapping test, two yellow discs (20 cm) were placed on a flat surface with their centers 60 cm apart. In between the two discs a white rectangle (30 × 20 cm) was placed. The participants were asked to place the non-preferred hand on the rectangle and move the dominant hand back and forth between the two yellow discs over the rectangle. Two taps were counted as one cycle and the participants were asked to complete 25 cycles as fast as possible. The time taken to complete the test was counted using a stopwatch (Technos, YP2151/8P, BR). Each participant performed the test twice with a 5-min rest interval in a standing position and the best performance was recorded [52]. All players were reported as right-handed. The dominant hand was defined as the one used for spike.

Countermovement jump (CMJ)

Earlier studies have shown that a CMJ is a reliable test to evaluate the explosive strength in the lower extremity extensor muscles in athletes [39]. Jump height (cm) was assessed using a portable jump mat (Newtest 2000 System; Newtest, Oy, Oulu, Finland) which calculated from flight time. Flight time was defined as the period between the instants of take-off and landing that is subsequent ground contact of feet.

The CMJ started from a full erect standing position. Participants were instructed to perform a fast downward movement (to approximately 90º knee flexion) immediately followed by a fast upward movement, and to jump as high as possible. Hands were kept on the hips to minimize any influence of the arm swing. The participants were asked to land on the contact platform in a position similar to that of the take-off. The CMJ test was performed three times with 30 s recovery time between each trial. Three maximal jumps height (cm) were recorded. The best trial was included in further analysis [21].

Peak power (PP)

The CMJ height was then used to determine peak power by the formula given in Lara et al. [36] and this equation was used for national level of female volleyball players. PP = [53.6 x Jump Height (cm) + 67.5 x Body Mass (kg)] – 2624.1

Spike speed performance

Spiking performance was determined as maximum ball speed during hit (spike) by a calibrated radar gun (Sports Radar Gun SR3500; Sports Electronics, Inc., Homosassa, FL, USA). The radar gun was calibrated immediately before testing according to the manufacturer's instructions. The ball characteristics were in accordance with *International Volleyball Federation* approval (Mikasa MVA200). The ball pressure was verified before each testing session (0.30 to 0.325 kg/cm2). Two antennas (1.5 meters apart) delimited the hitting area. A target 2 m long and 2 m wide was placed on a court. Players were instructed to hit (spike) the ball toward the target. The radar gun was placed five meters from the net. The same trained coach tossed the ball for the jump spike in all evaluations to eliminate the difference (to three-four meters in height and a half meter from the net) [56]. After the standardizing warm-up, the subject had to hit spike with the volleyball ball from position 4 to position 5 at the right side of the diagonal. The participants were instructed to spike a ball as hard as possible with the dominant arms. Right arms were dominant by all of the players. The highest ball velocity (km/h) for each player was registered. Three trails were recorded as kilometers per hour, and the best spike speed was taken for further analysis. The participants had approximately one minute of rest between each attempt to avoid any effect of fatigue. The intraclass correlation coefficient for test-retest reliability and typical error of measurement for spiking speed accuracy was 0.92 and 4.1%, respectively.

Training protocols

All training programs were designed to be general volleyball technical-tactical training and supplemental resistance training. The study was implemented during the second-term competitive season (January–March) within the context of the macrocycle for duration of 2 months.

Both groups participated in regular volleyball practice including technical, tactical trainings and games altogether accompanied by the same coach throughout the study. General volleyball training consisted of three volleyball practices on Monday, Wednesday, and Friday and one game on Sunday per week. Volleyball practice typically lasted for 2 hours at the 16.00 – 18.00 pm of the day and under exactly the same conditions for each week. Practices typically focused on technical skills (volleyball specific skills like set, pass, spike, serve, etc.), individual tactical skills (e.g. decision making by one player) and team tactical skills (offensive and defensive schemes).

The average resistance training programme in a meta-analysis on youth resistance training consisted of 2–3 sets of 8–15 repetitions with loads between 60% and 80% of the 1 RM on 6–8 exercises [3]. Further, the clinical trials have shown that elastic resistance programs performed 6 to 12 weeks, 3 times a week for 2 to 3 sets at 8 to 12 repetition maximum resistance significantly improve strength when progressed with increasing volume and intensity of elastic resistance. Typically, two to three sessions a week improve strength, whereas one session per week maintains strength [43]. Therefore, the TTG participated in an 8-week resistance training programs (16 sessions in total), 2 sessions per week (60 min. d-1) on Tuesday and Thursday at the same time (17.00 – 18.00 pm) of day. One of the members of the research team supervised each training session. Resistance training programme had been designed to induce upper extremity speed and lower extremity strength/power.

The training programme was based on the basic concepts emphasized for different resistance training models by using guidelines represented for young athletes [3,14,15]. The Thera-Band training protocol were based on common clinical practice and experience. The types of exercises are selected based on the similarity of their movement patterns to those that constitute the game of volleyball to train muscle groups of the players in the upper and lower extremities. The resistant training program was standardized to include exercises for the eight main muscle groups (knee extension and flexion, abdomen and back muscles, rotation, upper back and arm-shoulder muscles, and press bench for lower extremity muscles). Implemented activities for each weekly exercise program are differentiated to eliminate the monotony. Normally in a periodized training format, major changes in the training sessions are made every 2 to 4 weeks [34]. Therefore, in every two weeks, different exercises were performed and total 32 different exercises were applied to the participants.

The training volume can be dosed by setting a certain period to complete exercise. One set of 10-12 repetition maximum resistance should be performed in approximately 30 s for anaerobic training. The work/rest ratio should be 1:2 to 1:3 for 10-12 repetition maximum [49]. With these basic approaches in mind, during all of the sessions, the Thera-Band exercises program consisted of eight exercises with three sets of 12 repetitions for each one for weeks 1 to 8. Each exercises are completed in approximately 35-40 s and resting intervals between exercises were set to be 1:2 work/rest ratio (70-80 s). There were 2-3 minutes active rest period for each set.

TTG participants performed resistance training using a Thera-Band, and the exercises included total and segmental movements of upper limbs, trunk and lower limbs (Table 1) whereas the control group did not participate in Thera-Band exercises. The TTG had experience in using the Thera band at certain times during previous trainings in warm-up section.

During the first familiarization session, the participants learned the techniques for the exercises. They were also trained to use Thera-Band, instructed in the appropriate technique for every exercise. All participants were instructed to perform each repetition with a concentric-to eccentric phase ratio of 1:2 (in a 3-s repetition; 1 s for the concentric phase and 2 s for the eccentric phase). The tension in the elastic Thera-Band is adjusted according to performance of participants (i.e., by using greater elongation during exercise to increase the resistance, or changing to more resistant bands if necessary) to accommodate their improvements in muscular strength throughout the 8-week duration [12]. Players were encouraged to exert maximal effort during all sets.

The color of the Thera-Band is the indicator of resistance of the Thera-Band. Type (color) of the Thera-Band to be used is determined according to the level of players. Six feet of Thera-Bands were used for TTB training exercises. Training intensity was adjusted by changing the color of the Thera-Bands that means changing the resistance of the band. Participants made progress in weekly resistance program using different color of Thera-Band throughout the training period (Table 1). Thera-Band colors and their relative tension are indicated as low (red), medium (green) and high (blue) [53]. The intensity of the exercises were determined changing the colours of Thera-Band every two or three weeks, assuming the participants completed all repetitions with proper form. The Thera-Band colours were used yellow for 1st and 2nd weeks, green for 3rd, 4th and 5th weeks, and blue for 6th, 7th and 8th weeks. When participants could exceed 12 repetitions, the resistance was increased as keeping 12 repetitions per set.

The training consisted of three parts (total 60 minutes): warm-up (10 minutes), resistant Thera-Band (45 minutes), and cool-down exercises (5 minutes). The standardized warm-up protocol included moderate walking and light jogging (4–5 minutes), and varied callisthenic drills repeated 5 times, with each position held for 2–3 s, before moving on to the next exercise. The warm-up started from the upper extremities (neck clock, shoulder roll, arm hug, windmill) and worked down through the body to the midsection (trunk circle, trunk twist), and lower extremities (body weight squat, lateral lunge).

The resistance of Thera-Band exercises program in the first phase (1-2 weeks) consisted of 8 exercises selected to stress generally the major muscle groups in the following order: Standing Shoulder Press, Chest Fly, Triceps French Press, Biceps Curl, Rhomboid Squeeze, Knee Flexion (Prone), Minisquat, and Ankle Plantarflexion.

In the second phase (3-4 weeks), the resistance of Thera-Band exercises program was altered, and 8 exercises were performed in the following order: Trunk Twist, Reverse Flies, Elbow Kick Back, Concentration Curl Scapular, Retraction, Lunge, Quick Kicks, and Leg Press.

In the third phase (5-6 weeks), the resistance of Thera-Band exercises program was altered, and 8 exercises were performed in the following order: Straight Arm Pulldown, Chest Press, Wrist Flexor, Triceps Kick Back, Rear Deltoid, Dead Lift, Lying Hamstring Curls, and Donkey Kicks .

In the fourth phase (7-8 weeks), the exercises were selected to activate core and lower extremities muscles groups in the following order: Diagonal Chop, Trunk Curl-up, Upright Row, Dynamic Hug, Front Raise, Squat, Knee Extension (Prone), and Calf Raise.

All participants consumed adequate water to ensure proper hydration during training. They were also instructed to eat a light meal and fluids before the training sessions. No participants in the training group missed any training sessions, demonstrating excellent compliance with the training program. No injuries occurred during at the 8-week period. Both group members were not allowed to participate in other physical activities during the study.

Table 1.
Training protocol for resistance Thera Band (TB) training.

Week	TB colors	Set x Repetitions	Drill
1-2	Red	3 x 12	Standing Shoulder Press
			Chest Fly
			Triceps French Press
			Biceps Curl
			Rhomboid Squeeze
			Knee Flexion (Prone)
			Minisquat
			Ankle Plantarflexion
3-4	Green	3 x 12	Trunk Twist
			Reverse Flies
			Elbow Kick Back
			Concentration Curl Scapular
			Retraction
			Lunge
			Quick Kicks
			Leg Press
5-6	Green - Blue	3 x 12	Straight Arm Pulldown
			Chest Press
			Wrist Flexor
			Triceps Kick Back
			Rear Deltoid
			Dead Lift
			Lying Hamstring Curls
			Donkey Kicks
7-8	Blue	3 x 12	Diagonal Chop
			Trunk Curl-up
			Upright Row
			Dynamic Hug
			Front Raise
			Squat
			Knee Extension (Prone)
			Calf Raise

Statistical analyses

The descriptive statistics were expressed as mean ± *SD*, percentage changes, 95% confidence intervals, and effect size. The Mann-Whitney *U*-test was used to compare both the baseline characteristics and changes between groups in the outcomes from pretraining to posttraining. The Wilcoxon's rank-sum test was used to compare the baseline and follow-up in each group.

The test-retest reliability of the dependent variable was determined by calculating intraclass correlation coefficient reliabilities. The reliability analysis (Cronbach's alpha) and intraclass correlation coefficients (ICCs) showed that these tests were highly reliable. The reliability coefficients (Cronbach's alpha) were 0.94, 0.96, 0.94 and 0.92 for dominant arm rate of motion, CMJ height, peak power and spiking speed respectively. In addition, the ICCs for the dominant arm rate of motion (0.94), CMJ height (0.95), peak power (0.94) and spiking speed (0.92) confirm the reliability of the tests. As a rule, an ICC of more than 0.90 is considered as high, between 0.80 and 0.90 as moderate, as and less than 0.80 as insufficient for physiological field tests [50]. Magnitude of treatment effects both within and between groups was estimated with Cohen's effect size. The within-group effect size is defined as the difference between posttest mean and pretest mean divided by pretest SD. The between-group effect size is defined as the difference between experimental group posttest mean and control group posttest mean divided by control group pretest SD [47].

Rhea [47] proposed a new scale for determining measure of effect sizes (Trivial, small, moderate, or large) in strength training research. In this classification Rhea [47] took the training status of the participants into consideration by separating them into 3 groups: untrained (consistent training less than 1 yr.), recreationally trained (consistent training from 1–5 yr.), and highly trained (consistent training of more than 5 yr.). Because the players in this study had prior volleyball experience of 3 years, the scale for ''recreationally trained'' was selected for interpretation: trivial (effect size < 0.35), small (effect size 0.35–0.80), moderate (effect size 0.80 - 1.50), and large (effect size ≥ 1.50). Additionally, the difference of the medians was given with 95% confidence interval (CI). All statistical analyses except Cohen effect size were performed using statistical analysis package (Version 20.0; SPSS, Chicago, IL, USA) with statistical significance set at $p < 0.05$.

STATISTICAL RESULTS

The groups' differences of the anthropometric and training characteristics are summarized in Table 2. Between the two groups, there were no statistically meaningful differences ($p > .05$) among the pretest results related to physical (in age, mass, height, BMI) and performance variables (Table 3). The groups were found to be homogeneous in baseline measurements. Mean (± *SD*) performance variables comparisons between pretest and posttest measurements for the CG and TTG are shown in Table 3.

According to the differences of pretest and posttest, within groups, the Wilcoxon's rank-sum test results revealed significant improvements ($p < .01$) in the CMJ height (+14%, Z = -2.809, $p = .005$, Table 3, Figure 1), peak power (+8.4%, Z = -2.803, $p = .005$, Table 3, Figure 2) and spiking speed (+18%, Z = -2.829, $p = .005$, Table 3, Figure 3), whereas there were no significant differences ($p > 0.05$) in dominant arm rate of motion (Z = -0.780, $p = .435$) (Table 3) for TTG at the end of 8-week. On the other hand, small effect size was found for peak power ($d = 0.48$) when it was compared with the CMJ height ($d = 1.38$) and spiking speed ($d = 0.86$), which had moderate effect size in the TTG.

The CG showed significant ($p > .05$) changes between pretest and posttest in the CMJ height (+3.1%, Z = -2.239, $p = .025$), and peak power (+1.8%; Z = -1.979, $p = .048$) at the end of 8-week (Table 3). Small effect size was found for CMJ height ($d = 0.31$) and peak power ($d = 0.11$) in the CG. There were no significant differences ($p > .05$) in dominant arm rate of motion (Z = -1.355, $p = .176$) and spiking speed (Z = -0.141, $p = .888$) for CG at the end of 8-week.

Table 2. Descriptive data for anthropometric properties of all participants

Variables	Groups	n	Mean ± SD	*p*
Age (year)	TTG	10	16.20 ± 0.63	1.000*
	CG	10	16.20 ± 0.78	
Training age (year)	TTG	10	2.60 ± 0.96	0.628*
	CG	10	2.40 ± 0.84	
Height (cm)	TTG	10	162.12 ± 6.28	0.116*
	CG	10	157.20 ± 7.02	
Body weight (kg)	TTG	10	58.44 ± 9.70	0.615*
	CG	10	56.30 ± 8.99	
Body mass index (kg/m2)	TTG	10	22.15 ± 2.67	0.647*
	CG	10	22.68 ± 2.40	

TTG= Thera-band training group, CG=control group * Not significant ($p > .05$).

Mann-Whitney *U*-test results revealed significant differences ($p < .001$) between the groups in terms of CMJ height ($U = 5.500$, $p = .001$), peak power ($U = 6.000$, $p = .001$) and spiking speed test ($U = 1.000$, $p = .001$) in favor of TTG (Table 3) at the end of 2-month period.

Large effect size (d =2.93) was found for spiking speed. The CMJ height had moderate effect size (*d = 1.31). S*mall effect size ($d = 0.71$) was found for peak power. While significantly higher treatment effects were observed in the TTG compared to the control group, the effect size values ranged from small (peak power), to moderate (CMJ) and finally to large values (spiking speed).

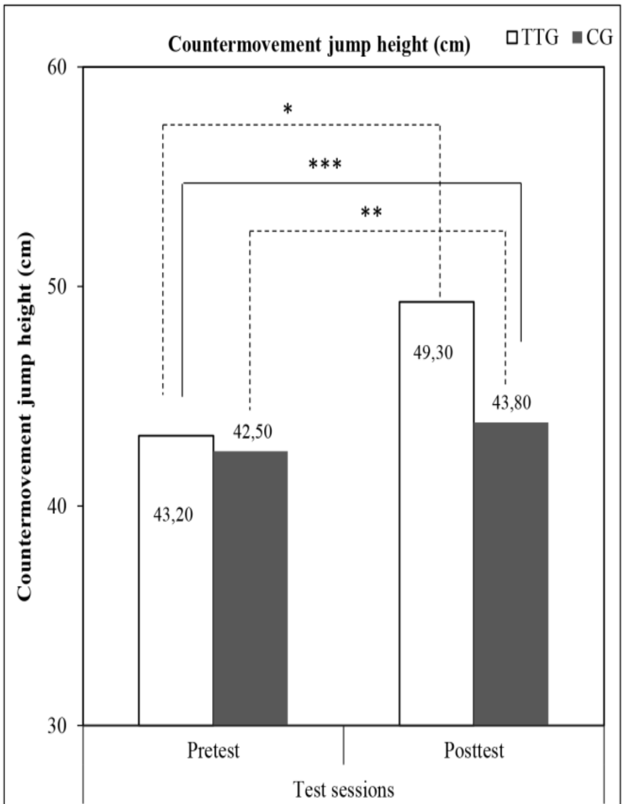

Figure 1. Comparison of countermovment jump height (cm) values for pre and posttest. Within groups, there were significant differences between pre and post tests for TTG (* $p < 0.01$) and CG (**$p < 0.05$). Between groups, the results revealed significant differences (*** $p < 0.01$) between pre and posttest results of groups in terms of countermovment jump height test in favor of TTG. Data are presented as mean (±SD). TTG = thera-band training group; CG = control group

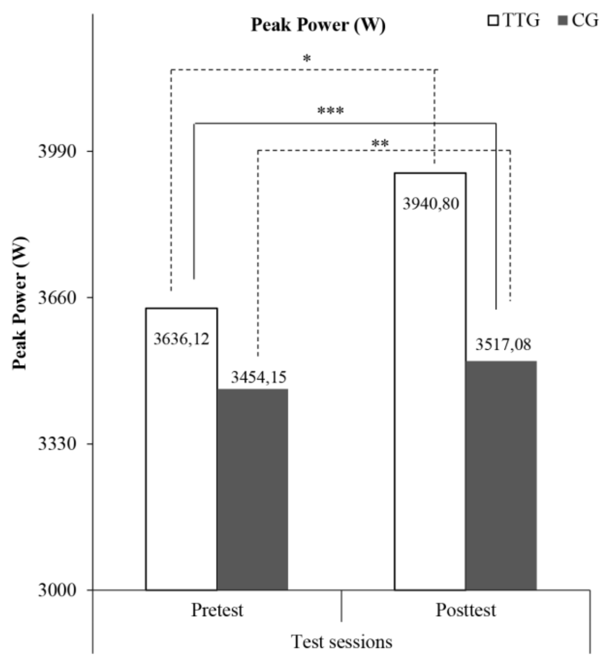

Figure 2. Comparison of peak power (W) values for pre and protest. Within groups, there were significant differences between pre and post tests for TTG (* $p < 0.01$) and CG (** $p < 0.05$). Between groups, the results revealed significant differences (*** $p < 0.01$) between pre and posttest results of groups in terms of spiking speed test in favor of TTG. Data are presented as mean (±SD). TTG = thera-band training group; CG = control group

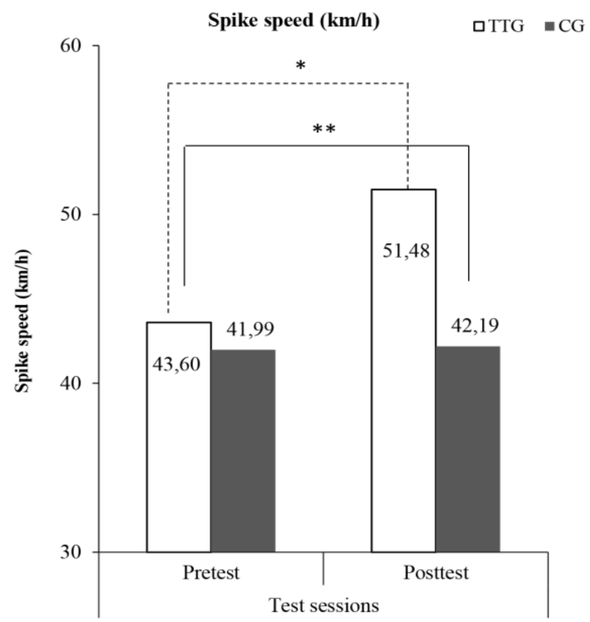

Figure 3. Comparison of spike speed (km/h) values for pre and protest. Within groups, there were only significant differences between pre and post tests for TTG group (* $p < 0.01$). Between groups, the results revealed significant differences (** $p < 0.01$) between pre and posttest results of groups in terms of spiking speed test in favor of TTG. Data are presented as mean (±SD). TTG = thera-band training group; CG = control group

Table 3.

Performance variables of pretest and posttest for TTG (*n* = 10) and CG (*n* = 10)*

Tests	Groups	Pretest Mean (± SD) (95% CI)	Posttest Mean (± SD) (95% CI)	Difference Mean (± SD) (95% CI)	Within group *p*	Between group *p*
Dominant arm rate of motion (s)	TTG	6.16 ± 0.85	6.16 ± 0.84	0.00 ± 0.01	0.435*	
		(5.51-6.78)	(5.55-6.78)	(-0.01-0.01)		0.195*
	CG	6.04 ± 0.52	6.04 ± 0.51	0.00 ± 0.01	0.176 *	
		(5.66-6.42)	(5.67-6.43)	(-0.02-0.01)		
Countermovement jump (cm)	TTG	43.20 ± 4.41	49.30 ± 6.54	6.10 ± 3.51	0.005†	
		(40.04-46.36)	(49.30-44.61)	(3.59-8.61)		0.001†
	CG	42.50 ± 4.19	43.80 ± 4.28	1.30 ± 1.56	0.025‡	
		(39.50-45.50)	(40.73-46.87)	(0.18-2.42)		
Peak power (W)	TTG	3636.12 ± 639.60	3940.80 ± 789.54	304.67 ± 187.91	0.005†	
		(3178.574093.67)	(3375.99-4505.61)	(170.25-439.10)		0.001†
	CG	3454.15 ± 595.37	3517.08 ± 568.04	62.92 ± 83.35	0.048‡	
		(3028.24-3880.06)	(3110.73-3923.43)	(3.30-122.55)		
Spike speed (km/h)	TTG	43.60 ± 9.17	51.48 ± 7.66	7.88 ± 2.67	0.005†	
		(23.01-31.18)	(28.59-35.41)	(3.71-6.09)		0.001†
	CG	41.99 ± 3.17	42.19 ± 2.23	0.19 ± 2.43	0.888*	
		(24.69-27.51)	(24.86-26.94)	(-1.31-0.91)		

*TTG = thera-band training group; CG = control group; CI = confidence interval., *Not significant ($p > .05$)., ‡Significant ($p \leq 0.05$). †Significant ($p \leq .01$).

DISCUSSION

The main finding of this study was that the 8-week (2 d.wk-1, 60 min. d-1) of resistance training by elastic Thera-Band concurrent with the regular volleyball training was led to greater improvement for the spiking speed performances, CMJ height and peak power of lower extremities in young female volleyball players compared with technical volleyball training alone. However, dominant arm rate of motion time was not affected by Thera-Band training. To our knowledge, this is the first study to examine the use of resistance training with elastic bands exercises to investigate spike speed, lower extremity jump height and power performance of young female volleyball players. The traditional volleyball training alone slightly increased CMJ height and peak power of lower extremities but it did not increase spike speed and dominant arm rate of motion time performances. While significantly higher improvement effects were observed in the TTG compared to the control group, the effect size values ranged from small for peak power, to moderate for CMJ and to large values for spiking speed.

In the present study, training containing Thera-Band technique and condition was implemented in addition to regular volleyball training at twice a week. Although present study was the first to examine the effect of Thera-Band training program to athletic performance of female volleyball players, our findings were consistent with previous studies that reported some indirect evidences that seem to confirm our findings. There are limited studies [4,12,55] that have investigated the effects of resistance training program in youth baseball, handball and tennis players on athletic performance variables. It was reported that a significant increase in ball speed of the tennis serve could be after 4-week of Thera-Band and dumbbell strength training to the shoulder in collegiate players [55]. Gorostiaga et al. [22] found that handball throwing velocity in adolescent handball players increased after resistance training. Furthermore, Carter et al. [4] concluded that although both resistance training and plyometric training for upper extremity after 8-week resulted in strength gains, only the plyometric training group improved their throwing velocity by 2.0 mph in collegiate baseball players. These results are supported by data from Escamilla et al. [12], who reported that the baseball players improved their throwing velocity to the 2.2-mph after 4-week (3 d.wk-1, 75 min. d-1) moderate-intensity resistance training with elastic tubing, throwing, and stretching. The findings of present study consistent with results of above mentioned investigations [4,22,55] indicating that handball, baseball and tennis players have increased throwing velocity or speed of the serve after 4-8 weeks of resistance training programs.

In the present study, our experimental group showed significantly greater performance improvement in the spiking speed (+18%) at the end of the 8-week (51.48 km/h in pre-training vs. 87.20 km/h in post-training). In contrast, the controls showed no change in spiking speed ability (0%). In other words, the effects of the Thera-Band training program contributed to the velocity of volleyball spike. These results are supporting the argument of De Renne et al. [11] who reviewed the effects of general, special, and specific resistance training types on throwing velocity can be increased with general resistance training for high school and college players. It has been stated that transferability of strength gains achieved from general resistance training methods to sport-specific performance remain as a critical issue [31]. Therefore, the present study results show that spike speed, which is a sport-specific performance, was increased and transferability of strength gains were achieved by resistance training methods. Because of the spike is a complex and the most explosive movement form among the overhead volleyball skills [5], our results are even more meaningful. Hence, it seems that the use of elastic resistance by Thera-Band is highly recommended for young volleyball players in order to improve their spiking speed performance levels.

During the volleyball spike, power of the trunk and upper limbs are integral parts of the energy transferred by the kinetic chain from the lower to upper extremities. Therefore, the exercises program was also designed to provide an improvement in the kinetic chain. Although the relationship of strength and spiking ability were not investigated in our study, it can be concluded that inclusion of exercises that are designed to increase the strength of upper and lower limbs may enhance a player's spiking ability. It has been reported that shoulder extension strength is the dominant physiological variables related to achieving higher spiking speed for collegiate female volleyball player [16]. On the other hand, a study conducted by Pugh et al. [46] stated that there was a moderate relationship between strength and ball speed in the volleyball spike. It has been suggested that an absolute level of strength would have been necessary but not sufficient for ultimate ball speed. Ball speed may be a combination of several factors such as technique, coordination, flexibility, and strength [46]. This relationship should be examined in further researches.

Explosive leg muscle power is an important part of increasing vertical jump performance [51], and hence it is beneficial to include exercises that develop leg muscle power in the overall conditioning program of volleyball players [59]. Achievement of a greater jump height in volleyball provides advantages for attack and block, which means that jump height is directly related to performance in volleyball. Increased eccentric loading also occurs with the use of elastic bands [9] which has been reported to be associated with higher force values than concentric loading [57]. In the present study, the eccentric and concentric loads condition with Thera-Band training promoted significantly better jump height performance and lower-body peak power after 8-week of training. Thera-Band resistance training combined with volleyball training had effects the peak power, evaluated with the average height of vertical jumps according to Lara et al. [36]. There were significant differences between groups for CMJ performance, that is, the TTG group showed higher CMJ performance than the CG. CMJ performance increased 6.1 cm (+14%) for the TTG and 1.3 cm (+3.1%) for the CG. Another result is that PP values significantly increased in TTG (+8.4%) whereas these values increased slightly in CG (+1.8%). It might be concluded that CG in present study showed a few enhancing their CMJ performance since they train volleyball in their regular training sessions.

The positive improvements resulting from Thera-Band resistance training supports some of the literature's arguments. The results of present study are supporting the evidence [3,15] that reviewed the effects of supervised resistance training can be safe, effective and worthwhile activity for young population in strength training sessions. Our results are consistent also with study of Imachi et al. [28] that implementation of rubber bands for CMJ in volleyball players increased jump height about 8-10 cm, while improvement in traditional CMJ was only 3.5 cm. They conducted a study on the effects of ‘‘suspension’’ training on vertical jumping ability over a period of 10 weeks. A direct comparison of findings of the study and of previous investigations is not possible due to differences in training models. But still, our results related to the increase of vertical jump performance confirm previous studies with different training models [23,39,45]. The results in the present study are parallel to those observed by Marques et al. [40] who also found an increase of unloaded and loaded CMJ heights by varying percentages between 3.8 and 11.2% after 12-week of plyometric training in elite female volleyball players. Häkkinen [23] reported significant increases in CMJs (32.8 ± 1.6 to 34.3 ± 1.3 cm; $p < 0.05$) in 9 competitive female volleyball players after 10-week of after 4-8 weeks resistance training program, during the competitive season, similar to those observed in the present study. In addition, our study was in line with the findings of Pereira et al. [45]who used 8-week combined plyometric and ball throwing program on the upper and lower body performance in young female volleyball players, and found a meaningful increase at jumping ability (+20.1%).

Several factors may contribute to changes in muscle performance during CMJ, such as training aiming at increasing muscle capacity for developing higher tension, adding or storing more contractile elements, and rejuvenating elastic energy [6]. The recent studies [40,59] reported that 8-week training is needed specifically for motor capacity and strength development, especially when participants are young. This approach is consistent with the results of our study since considerable amount of positive effect on strength development was observed after young female volleyball players performed exercise training of 8-week. It can be suggested that Thera-Band training results in strengthening leg muscles and increasing the speed of the motor reflexes of the legs. The Thera-Band training including multidirectional lower body exercises offers a unique and novel training stimulus that brings about important results.

Because there was a significant difference between PP values of the TTG and the CG, one might also consider that the training model contributes to greater storage of elastic energy in TTG players. The mechanisms behind the superiority of the TTG in terms of power, and jump height values are likely a combination of neurogenic and myogenic factors [47]. In the present study, these mechanisms were not directly examined and this topic needs more studies. However, with extra loads, these mechanisms produce greater stretch of the intrafusal muscle fibers which would promote greater stimulation of the associated motor neurons. Furthermore, this situation might evoke the transmission of greater than normal afferent nerve impulses to central nervous system and the creation of positive impacts on muscular performance [48]. The higher PP values for performance of legs of TTG as compared with the CG can be explained by neuromuscular adaptation. Some studies suggest that the optimum external loads to maximize power output could be as high as 70% of body weight [24], while others point out the sufficiency of bodyweight indicating that external load is not required [42]. Based on the results of this study, it is figured out that even lower external loads created by Thera-Bands affects the CMJ performance and the power output in jump positively. The recorded values of the increase in the jump height shares similarities with former studies that interpreted the impacts of training with 'negative' loads [49], training without additional load [8], and training with added weights [41]. The results from both the plyometric training [37] are consistent with the results that are obtained from recent study.

The plate tapping test was intended to measure the movement speed of the upper extremities of the players. This test is a reaction test using an alternating tapping action, which measures upper body reaction time, hand-eye quickness and coordination. In previous studies, it is found out that yoga practice improves repetitive tapping performance in adults and children of both sexes [10] and also in volunteers who used a computer keyboard for more than 5 hours a day [52]. Thera-Band resistance training combined with volleyball training or volleyball training alone had no effects on dominant arm rate of motion, which was evaluated with plate tapping test [2]. According to the results of the test, there was no significant difference between TTG and CG in terms of the movement speed of the upper extremities. A lack of movement specificity might have contributed to the fall of the resistance training at increasing mean dominant arm rate of motion in the present study. Another reason for that might be velocity differences of the training modal related to the tested movement. Methodological, proprioception, and dose-response issues might be interpreted as expounding for this lack of sufficiency of resistance training. Finally, the number of training sessions might not have been sufficient to improve proprioception. This would be in concordance with the current position statement of the National Strength and Conditioning Association [13], indicating the need for specificity of training.

There are some limitations to be considered when interpreting results of this study. The main methodological limitation of this study was the small sample size, although medium- to large-effect sizes were obtained for most of the variables. Another limitation of the present study was that functional strength ratios and ROM of the shoulder rotators were not investigated which could have provided more specific information about the effectiveness of the present training program. Our findings were limited to one particular category of volleyball players—young female. Thus, the results of the present study should be considered exploratory and should serve to suggest methods for future investigation. Future studies should extend these observations to the different age and gender groups at the other levels of competitors with larger sample size.

Despite these limitations, we can conclude that well planned 2 days per week Thera-Band training with duration of 8-week, in addition to technical volleyball training, led to improved CMJ height, lower limb power, and speed of spike performance, however, it had no significant impact on the movement speed of the upper extremities.

It must be noted that there is a lack of information concerning the effects of Thera-Band training program in the muscle performance especially on female players. Furthermore, this is the first study to examine how improvements of muscular strength, power and spiking speed performance of young female volleyball players are influenced by Thera-Band training.

Based on the results, we can conclude that supervised Thera-Band training with duration of 8-week (2 d.wk-1, 60 min. d-1) increased mostly spike speed performance, compared with volleyball training alone. In addition, the Thera-Band training also provided improvement in CMJ height and peak power of lower limb performance more than volleyball training alone.

The results indicated that safe, effective and alternative resistance training could be useful for strength and conditioning coaches, especially in competition season. Moreover, it seems appropriate for especially young female volleyball players who had a beginner level of resistance training by Thera-Band. The results of the present study are also significant because transferability of strength gains were achieved by resistance training methods for the sport-specific performances like spiking speed.

Competitive players should use Thera-Band exercises program that is implemented in our study. Further studies should also focus on the long-term effectiveness of Thera-Band training and its relationship to strength, power, flexibility and spike speed exercises for different ages and genders.

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