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Original Investigation

# Acute effects of a dynamic stretching and core stability exercise protocol on physical performance in U-16 volleyball players

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***Purpose:*** Stretching and core exercises are is often used in different sports to develop higher sport performance and reduce injury risks. In acute, dynamic stretching (DS) seems to produce more benefits than static for improving physical performance. Moreover, sports tasks characterized by explosive and multi joints movement, such as wall jumping or dunking and serving in volleyball, also require core stabilization. Therefore, the aim of present study was to evaluate a potential post-activation potentiation enhancement (PAPE) effect induced by a functional exercise protocol including dynamic stretching and stimulation of core stability (StretCor) on physical performance in a group of U-16 volleyball players.
***Methods:*** Eighteen young volleyball players (9 boys and 9 girls; age: 15.33± .68 y; BMI: 22.12±2.25 $kg \cdot m^{-2}$) participating in the regional championship were recruited by Italian Volleyball Federation (FIPAV) – Campania Committee. The StretCor protocol consisted in eight exercises, performed with ball, combining both DS and Core Stability (CS) exercises that stimulates the main muscles group. Before and after exercise protocol, Countermovement Jump (CMJ), modified Stars Excursion Balance Test (mSEBT) and agility T-test performances were assessed in all participants.
***Results:*** After StretCor protocol, there were improvements ($P< .05$) in agility T-test (10.48±1.01 vs 10.70±1.09 s), jump height (31.81±5.36 vs 29.75±5.73 cm) and relative peak power (51.53±9.77 vs 46.04±6.21 W/kg). Moreover, in mSEBT, left normalized Anterior (left ANT) (71.29±7.59 vs 66.84±7.19 %), Posteromedial direction (left PM) (105.63±8.80 vs 98.28±12.82 %), Posterolateral (left PL) directions (106.15±9.95 vs 98.47±13.06 %) and in right normalized Posterolateral direction (right PL) (103.90±10.65 vs 98.14±12.95 %) were improved after StretCor protocol; in addition, improvement were also observed in left (94.36±6.61 vs 87.87±9.88 %) and right (92.85±7.03 vs 88.47±10.22 %) composite (COMP) score.
***Conclusions:*** The present study suggests that an acute session of StretCor protocol, improved lower limb muscle power, dynamic balance and agility in U-16 volleyball players. We suggest including these types of exercises as a CA to produce a PAPE effect in the warm-up phase of volleyball training for improve the physical performance.

***Keywords:*** Sport performance, warm-up, jump performance, conditioning activities, functional exercises.

## Introduction

The performance in sport characterized by explosive actions involving the upper or lower limbs, such as wall jumping or dunking and serving in volleyball, depend not only on techniques, but also by the combination of different factors such as explosiveness, flexibility, and muscle strength[1-4]. Moreover, during a volleyball match, players do numerous short sprints with quick, sudden change of directions and fast reactions during attacking and defensive phases that require a good core stability (CS)[5].
Stretching and core exercises are some of the conditioning activities (CA) mostly used by athletes of different sport during the training session or in the warm-up phase. Static stretching exercises are used to improve joint flexibility and the range of motion (ROM) and reduce some types the injuries in athletes (e.g. musculotendinous injuries especially with explosive and change of direction activities)[6]. Among the different techniques used, an acute bout of dynamic stretching (DS) appears to be more effective than static (SS) in improving physical performance in acute[6-10]. It has been demonstrated that DS, performed in controlled movement through the active range of motion, either does not impair or can improve power, sprint, and jump performance[6,7].
The *core* located in the central part of the body is composed of tendon-ligament structures and muscle groups including: the abdominals at the front, the paraspinals and glutei at the back, the diaphragm at the top as well as the hip and pelvic floor muscles at the bottom. Reinforcing the *core* muscles leads to an improvement of trunk and hip stability that in turn reduce the risk of injuries and improve specific sport actions i.e. explosive actions involving upper and lower limb muscles[11].
In many studies[11-13] in which core stability exercise (CS) protocols, lasting an average of at least eight weeks, have been carried out, only limited evidence has been provided on the effects in athletic performance. However, in these studies[12-14], CS protocols were administrated not combined with functional exercises aimed to induce the correct coordination of the segments involved in the

kinetic chain in specific sport. Furthermore, core strengthening exercises require good joint range of motion (ROM) of the spine in the movements of flexion, extension, lateral flexion, rotation, and a combination of these joint actions[1].

Several methods are known to potentiate muscle force production and high muscle power in sports. Post-activation potentiation enhancement (PAPE) has been previously described as a physiological phenomenon induced by a CA during warm-up to improve performance in a competition or match. The theories proposed to explain the performance induced by PAPE include the increased muscle temperature, muscle fiber water content, and other mechanism[15].

Until now, in volleyball field, accommodating and free weight resistance exercises with different intensity (from 40% to 100% of a maximum repetition, 1RM), elastic band, plyometric activities have been used as CA to evoke PAPE and to enhance subsequent explosive strength performance[15]. However, a meta-analysis reported that in sports-related settings the magnitude of the PAPE effect depends not only by one but to a multitude factor such as gender, muscle fiber type, training status, training experience, type of exercise, intensity, volume, and rest periods. Moreover, the similarity between of the motor pattern of sport activities following the CA seems to influence the expression of the PAPE phenomenon[16].

Generally, stretching and CS protocols are performed separately in the training session or on different days. To best of our knowledge, no studies to date have evaluated the PAPE response in acute of functional DS and CS exercises, which also activate the muscles of the upper and lower limbs, on performance in volleyball players. Thus, the aim of present pilot study was to evaluate the PAPE effect of a combined functional DS and CS exercises protocol (StretCore) on explosive lower-body power, agility and dynamic balance performance in a group of U-16 volleyball players.

## Methods

***Participants***

Eighteen young (9 boys and 9 girls; age: 15.33±0.68 years; body mass: 69.12±8.34 kg; Height: 1.76±0.06 m; BMI: 22.12±2.25 $kg \cdot m^{-2}$) participating in the regional championship were recruited by Italian Volleyball Federation (FIPAV) – Campania Committee. Inclusion criteria: (i) age between 14 to 17 years; (ii) no injuries during the last three months prior to performance assessment; (iii) at least five years of experience in competitive sport; exclusion criteria: (i) less than five years' experience in competitive sports; (ii) any injuries in the three months prior to performance assessment. Parents or legal representatives of the young participants signed the informed consent, stating also that each child could be withdrawn from the study at any time or decide to not perform a specific item included in the protocol.

***Experimental design***

The study was conducted at Regional FiPAV volleyball center of Campania Committee on three days over 1-week period during which the young players did not participate in any training or matches. On first day, the inclusion/exclusion criteria were collected for each participant by an interview. On second day, weight, height and length measure of lower limbs were also collected. On third day, recruited volunteers after a standardized warm-up routine (5 min of jogging at a comfortable pace), underwent to different test protocols before and immediately after StretCore protocol to evaluate specific physical performance components. The tests were: Countermovement Jump (CMJ), modified Stars Excursion Balance test (mSEBT) and T-test. Two weeks prior to the study, young players completed two testing sessions to familiarize with procedures. Each test was fully explained to all participants beforehand and supervised by skilled specialists in sport sciences to minimize the potential intra- and inter-rater variability. All sessions were administered in the same gym facility, at the same time (15:00–18:00 h), ambient temperature (21.7±0.5°C) and relative humidity (60±2%) during the preparation period at beginning of the competitive season.

***Anthropometric measures***

Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with players in bare feet and light clothing using a stadiometer (SECA 213, Birmingham, UK) and an electronic weighing scale (SECA 813, Birmingham, UK). standardized equipment. The length of the lower limbs was measured in supine position from the anterosuperior iliac crest to the median ankle[17].

***Countermovement Jump (CMJ)***

CMJ was performed according to the protocols previously described[18] using a ForceDecks Dual Force Plate System (Vald Performance, Brisbane, Queensland, Australia).

The participants started from the upright standing position with their hands on hips; they were asked to flex their knees (~90°) as quickly as possible and, immediately, jump as high as possible. Three trials were performed separated by 1 min of passive recovery and the best results are used for the analysis. Jump height and relative peak power values were provided by the manufacturer's software (Vald Performance, Brisbane, Queensland, Australia). In particular, jump height (cm) was calculated using the impulse-momentum equation while relative peak power the maximal force produced throughout the entire movement divided by the individual's body mass. A detailed description of CVJ force-time metrics can be found in the Vald user manual (https://valdperformance.com/forcedecks/) and previous research reports[19,20].

***Stars Excursion Balance test (mSEBT)***

We used mSEBT with anterior (ANT), posteromedial (PM), and posterolateral (PL) reach directions to evaluate the dynamic balance of the young players. The arrangement of the three directions on the floor and test procedures was carried out as described elsewhere[21].

Briefly, participants standing with the most distal part of the big toe at the cross of the Y at the beginning of the anterior tape measure, were instructed to reach as far as possible along each of the three reach lines, make a light touch on the line with the most distal part of the big toe and return the reaching leg back to the center while maintaining a single-leg stance with the other leg. Participants performed three trials in each direction on each leg. The test began with the right leg as stance leg followed by the left leg in the ANT, PM and PL reach directions in succession. Ten seconds of rest were provided between the different trials of one reach direction. Six trials per reach direction were allowed to obtain three valid scores; the mean value was used to calculate normalized mSEBT scores according to the participant's lower limbs length measured as described above. The mean of the three normalized reach direction scores was used to calculate the composite score (COMP)[22].

***T-test***

The procedure was performed as described by Semenick[23]. The participants, at own discretion sprint quickly to cones, positioned to form a letter T, and touch them in an established sequence. The first positioned cone at start and second one placed at 9.14 meters from the first while third and fourth spaced 4.57 meters apart from the second. The participants stand 50 cm

behind a photocell (which indicated the start and finish lines, respectively); when they started the photocell sensor system (Microgate, Bolzano, Italy) sent the signal to a stopwatch connected that started the time. They had sprint forward 9.14 m to second cone, touch it with the right hand, then shuffled to the left 4.57 m and touch the third cone with the left hand then shuffled to the right 9.14 m and touch the fourth cone with right hand, then shuffled to the left 4.57 m back toward and touched with left hand the second cone and finally ran backward, passing the finishing line marked by photocell sensor which sent the signal to a stopwatch that stopped the time. Three test trials, with 30 seconds rest, were performed and times were recorded to the nearest one-hundredth. The fastest trial was used for the statistical analyses.

***StretCor protocol***

The StretCor protocol consisted of 8 exercises, separated by 15 seconds of recovery, combining both dynamic stretching and activities to stimulate CS lasted about 10-minute. The exercises focused on main muscles groups involved in the typical team game actions such as the ischio-crural, hip flexors, shoulder muscles as well as the core muscles. The order, illustration and the description of exercises included in the StretCor protocol are reported in Figure 1.


1. Single leg sumo and upper limbs stretch: sumo squat position, shift the weight of the body to the left lower limb, catch a ball thrown by a partner with the upper limbs extended, release the ball and return to the squat sumo position and repeat with the other limb. Repeat the exercise 20 times, 10 times for each limb.

2. Quad stretch + walking reverse lunge with torso twist and upper limbs stretch: standing position hands at hips, move with the same limb in a consecutive manner, without placing the foot on the ground, first with the knee up towards the chest, then with a sideways rotation and then perform a rear lunge touching the ground with the knee. From this position take the ball thrown by a partner by extending the lower limbs high above the head, then release the ball and from the rear lunge position, repeat the same with the left limb. Repeat the exercise covering the 9-metre lateral distance of the volleyball court twice.

3. Lateral lunge, leg raise, and upper limbs stretch: Starting position with lower limbs spread wider than shoulder width upper limbs extended forward: perform two lateral lunges, first to the right and then to the left, until the knees are bent at 90 degrees. During the first lunge to the side, before moving on to the other lunge to the opposite side, a partner throws a ball, which must be caught with the upper limbs extended high above the head, then with the ball in hand perform the lunge to the opposite side and release the ball. Then turn with your body 180 degrees and perform two hops moving sideways and then resume the starting position and repeat the exercise again. Repeat the exercise covering the 9-metre lateral distance of the volleyball court twice.

4. Standing superman position with torso twist and upper limbs stretch: standing position, with a ball in the hands: extend right lower limb posteriorly and simultaneously bring your upper limbs forward with the ball in the hand, leaning your torso forward. Maintaining this position, first rotate your upper body to the right and then to the left, then return to the starting position. Rotate your body 180 degrees and repeat the exercise by extending your left lower limb. Repeat the exercise 20 times, 10 times for each limb.

5. Spiderman exercise with torso twist and upper limbs stretch: quadruped position with forefeet and hands on the ground: move forward with the right foot then holding on with the right and left foot extend the upper limbs up and catch a ball thrown by a partner and then release it and return with hands on the ground. Then pivoting with your right foot move forward with your hands on the ground (as spiderman style) and bring your left foot forward then holding onto your left and right foot extend your upper limbs up and catch a ball thrown by a partner and then release it and return with your hands on the ground. Repeat the exercise covering the 9-metre lateral distance of the volleyball court twice.

6. Quad stretch + walking lunges with torso twist and upper limbs stretch: standing position, bring the right knee with the hands until the chest, then release it and with the same leg lunge forward, then make a torso rotation to the left, bringing your upper limbs up, extending them and catching a ball thrown by a partner, then release it. On standing back up, bring the left knee with the hands until the chest, then release it and with the same leg lunge forward, then rotate your torso to the right, bringing your upper limbs up, extending them and catching a ball thrown by a partner, then release it. Repeat the exercise covering the 9-metre lateral distance of the volleyball court twice.

7. Speed skater exercise: standing position, in support with only the right lower limb, left lower limb with flexed knee, right upper limb with flexed elbow and opposite the right knee and left upper limb extended behind. With the push on the right lower limb, perform a lateral and forward leap and move into the same starting position as the "speed skater". Repeat the sequence covering the 9-metre lateral distance of the volleyball court twice.

8. Squat and quad stretch: squat position, lower the upper body and bring your right lower limb by bending the knee and slowly bring it to your chest, hold the position for two seconds and return to the starting position. Repeat the exercise 20 times, 10 times for each limb.

**Figure 1.** Illustration and detailed description of eight exercises included in StretCor protocol.

***Statistical analysis***

Data are presented as means and standard deviations (mean ± SD). Shapiro-Wilk test was used to verify the assumption of normality of the distributions for each raw data. The ICC (Intraclass Coefficient Correlation) and CV (Coefficient of Variation) were used to determine the reliability and the repeatability of the measures[24]. An unpaired *t*-test or non-parametric test (Wilcoxon-Mann-Whitney test) were used to compare differences in anthropometric characteristics in boys and girls. Moore equations[25] were used to estimate the distance in years which boys and girls were from the peak height velocity (PHV). A paired T-test or non-parametric test (Wilcoxon-Mann-Whitney test) were used to compare differences for the performance variable analyzed before and after the StretCor protocol. Effect size (ES) was calculated by Cohen's (*d*)[26] for all variables between pre- and post-testing. The magnitude of the difference was considered small ( .2), moderate ( .5), or large ( .8). Jamovi software (version 2.3.28) was used for the analyses[27]. The significance level was set at $P \leq .05$.

## Results

The characteristic of volley players participant to the study were summarized in Table 1. No significant differences ($P > .05$) in anthropometric measurements were found among the participants except for age which was significant higher ($P \leq .05$) in boys compared to girls. However, both boys and girls were in post PHV phase (+2.80 ± .61 and +2.22 ± .44, respectively).

Table 2 shows the parameters of reliability for the tests. ICC values ranged from .754 to .951 for jump height, from .864 to .975 for peak power/BM and from .681 to .973 for T-test scores. ICC values for mSEBT in right and left lower limb for each reach directions, and COMP score ranged from .757 - .980. CVs for all parameters ranged from 2.07 to 9.01%.

The results of test performances pre- and post-StretCore protocol are reported in Table 3. At baseline no significant differences were observed for normalized mSEBT test in all directions and for COMP score percentage on right and left limb respectively ($P > .05$); no significant differences were also observed for CMJ and T-test performances. After StretCor protocol the normPL

**Table 1.** Characteristics of participants (*n*=18).

| Variables | Boys (*n*=9) | Girls (*n*=9) | *P-value* |
|---|---|---|---|
| Age (years) | 15.88± .33 | 14.77± .44 | <.001 |
| Stature (m) | 1.79± .05 | 1.74± .06 | .080 |
| Body mass (kg) | 69.57±.5.25 | 68.66±10.94 | .825 |
| Body mass index (kg·m$^{-2}$) | 21.77±1.95 | 22.65±2.49 | .418 |
| Lower limb length (cm) right | 96.22±3.93 | 94.66±4.75 | .250 |
| Lower limb length sx (cm) left | 96.38±4.09 | 95.11±4.40 | .532 |

**Table 2.** Test-retest data for each variable assessed.

| Variable (Units) | | ICC | 95% CI | CV | 95% CI |
|---|---|---|---|---|---|
| **mSEBT** | Right lower limb | | | | |
| normANT (%) | | .941 | .874 - .975 | 5.02 | 3.58 - 6.46 |
| normPM (%) | | .891 | .761 - .955 | 7.04 | 4.99 - 9.01 |
| normPL (%) | | .926 | .841 - .969 | 6.13 | 4.35 - 7.85 |
| COMP (%) | | .934 | .854 - .973 | 4.90 | 3.49 - 6.31 |
| **mSEBT** | Left Lower limb | | | | |
| normANT (%) | | .951 | .895 - .980 | 4.13 | 2.95 - 5.33 |
| normPM (%) | | .927 | .838 - .970 | 5.69 | 3.96 - 7.16 |
| normPL (%) | | .902 | .757 - .962 | 6.37 | 4.55 - 8.21 |
| COMP (%) | | .941 | .852 - .977 | 4.02 | 2.86 - 5.16 |
| **CMJ** | | | | | |
| Jump height (cm) | | .880 | .754 - .951 | 6.40 | 4.55 - 8.25 |
| Peak power/BM (W/kg) | | .937 | .864 - .975 | 3.76 | 2.62 - 4.78 |
| **T-test** (s) | | .918 | .681 - .973 | 2.95 | 2.07 - 3.72 |

Note: mSEBT, modified Stars Excursion Balance Test; normANT, normalized Anterior direction; normPM, normalized Posteromedial direction; normPL, normalized Posterolateral direction; COM, Composite score; CMJ, Counter Movement Jump; BM, Body Mass. ICC, Intraclass Coefficient Correlation; CV, Coefficient of Variation; CI, Confidence Interval.

**Table 3.** Performance values pre- and post StretCor protocol.

| Variable (Units) | | Pre | Post | *P* value | ES | 95% CI |
|---|---|---|---|---|---|---|
| **mSEBT** | Right lower limb | | | | | |
| NormANT (%) | | 67.98±7.90 | 70.26±5.86 | .094 | .405 | .068 - .868 |
| NormPM (%) | | 99.28±12.74 | 104.38±8.56 | .080 | .426 | .049 - .891 |
| NormPL (%) | | 98.14±12.95 | 103.90±10.65* | .014 | .624 | .124 - 1.110 |
| COMP (%) | | 88.47±10.22 | 92.85±7.03* | .015 | .617 | .117 - 1.102 |
| **mSEBT** | Left Lower limb | | | | | |
| NormANT (%) | | 66.84±7.19 | 71.29±7.59* | .019 | .592 | .096 - 1.074 |
| NormPM (%) | | 98.28±12.82 | 105.63±8.80* | .013 | .633 | .131 - 1.119 |
| NormPL (%) | | 98.47±13.06 | 106.15±9.95* | <.001 | .905 | .359 - 1.433 |
| COMP (%) | | 87.87±9.88 | 94.36±6.61* | .002 | .844 | .309 - 1.361 |
| **CMJ** | | | | | | |
| Jump height (cm) | | 29.75±5.73 | 31.81±5.36* | .005 | .753 | .219 - 1.271 |
| Peak power/BM (W/kg) | | 46.04±6.21 | 51.53±9.77* | .004 | .786 | .246 - 1.309 |
| **T-test** (s) | | 10.70±1.09 | 10.48±1.00* | .021 | .619 | .090 - 1.132 |

Note: mSEBT, modified Star Excursion Balance Test; NormANT, normalized Anterior direction; NormPM, Normalized Posteromedial direction; NormPL, Normalized Posterolateral direction; COM, Composite score; CMJ, Countermovement Jump; BM, Body Mass. CI, Confidence Interval; ES, Effect Size. *Significant difference ($P \leq .05$) compared to Precondition.

and COMP score percentage values of mSEBT in both right and left lower limbs results increased ($P \leq .05$) compared to baseline; differently, normANT and normPM results increased only in left lower limb ($P \leq .05$) after StretCore protocol compared to baseline; Height jump, relative peak power as well as T-test performances results significantly improved ($P \leq .05$) after StretCore protocol compared to baseline (Table 3 and Figure 2).

## Discussion

The aim of the present study was to analyze the PAPE effect induced by a combined training protocol including DS and CS functional exercises (StretCor) on some physical variables associated to performance in a group of U-16 volleyball players. Our results evidenced that in acute StretCor protocol training

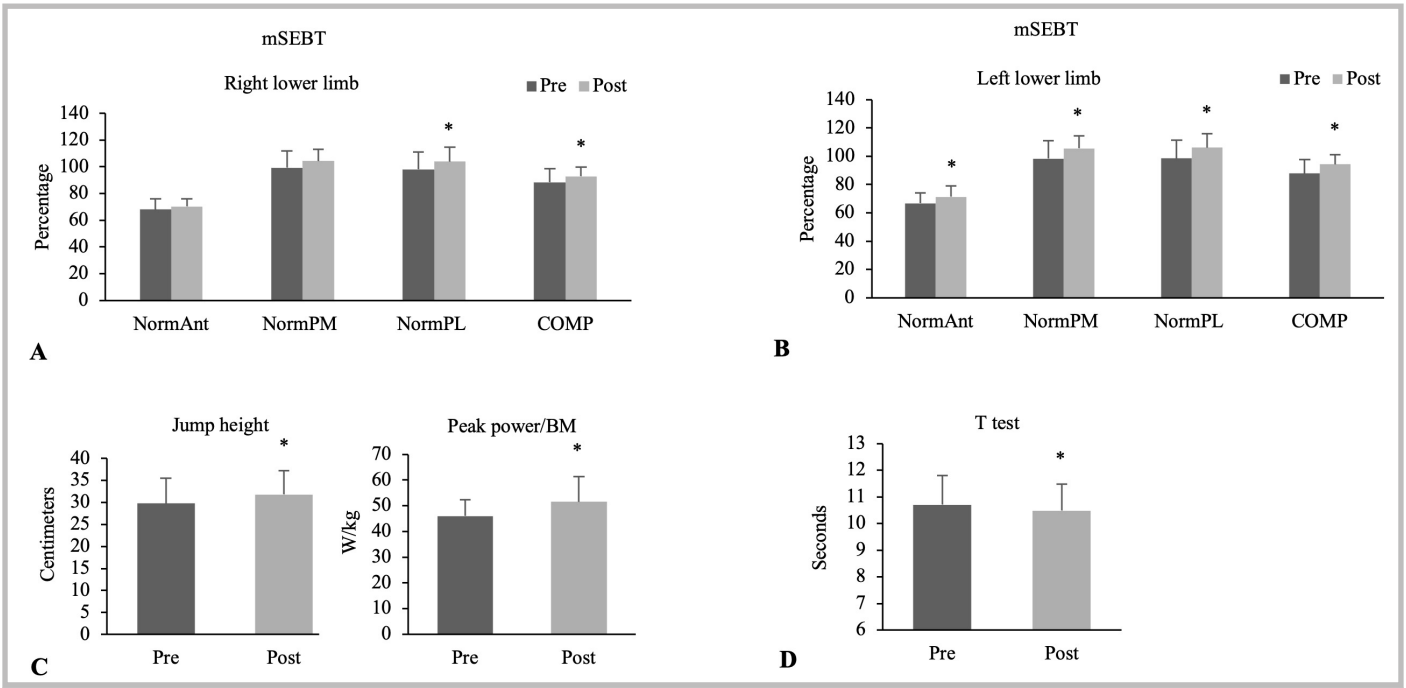


**Figure 2.** Pre and Post StretCor protocol results of modified Star Excursion Balance Test (mSEBT), Normalized Anterior (NormAnt), Normalized Posteromedial (NormPM), Normalized Posterolateral (NormPL) reached distances and Composite score (COMP) in right lower limb (2A) and left lower limb (2B); Jump height and Peak power/Body Mass (BM) (2C) and T-test results (2D). Significative differences as showed with "*" - $P \leq .05$ comparing to Pre condition.

improve the parameters linked to volleyball performance such as dynamic balance, jump height, relative peak power, and agility in the participant.

Previous studies[2-4,6-9,11] analyzed separately the in acute effects of stretching or core stability exercises on different parameters associated to volleyball performance. Although SS is widely used in warm up routine, many studies reported that DS seems to have more positive effects on agility, power generation and jump performance[6,8,28-30]. Kruse et al.[27] found significantly higher jump height values (~6%) in CMJ test after DS compared to SS in a group of collegial female volleyball players. Hough et al.[29] report an improvement of about 5% in vertical jump performance after DS compared with no stretching in a group of competitive university athletes (football, hockey, athletics, squash, and cricket). Moreover, a recent metanalysis[30] evidenced that DS or SS combined with DS improve explosive sport performance differently from SS that reduces it.

Our results are in line with above reported with an increased capacity of jump performance in CMJ task. Such improvements may be ascribed to higher values (+12%) of relative peak power detected after StretCor protocol compared to baseline. Further, previous studies evidenced a strong correlation between jump height and peak power in athletes[31].

PAPE is a physiological/neuromuscular phenomenon associated with acute improvement in muscular performance[15]. However, the magnitude effect of PAPE depends on several factors including performance levels of athletes, type of the activity following the CA, the joints excursion of the joints involved in the movements performed as a CA and rest period[31-34]. For instance, it has been reported that a CA such as the back squat has a better PAPE effect when assessed with the CMJ as a target exercise[32]. CA with movements involving the joint excursion close to that required in the subsequent performance evoke a greater PAPE effect[33-35]. In addition, the PAPE effect is also promoted by ACs that increase the lengthening-shortening cycle as such as DS that activate the neuromuscular system, improving the recruitment of motor units and optimizing force generation[36]. The StreCor protocol was designed not only to combine DS and CS exercises and promote joint excursion, but also to stimulate the strength and power of main muscle groups involved in typical volleyball team game actions. Thus, we can speculate that the lightly greater percentage in jump performance (~7%) after StretCor protocol reported in this study compared to previous[28-29]may be due to the better force of transmission due to activation of core muscles[37-40] induced by the combination of DS and CS exercises. In fact, it has been described that the activation of core musculature, by stabilizing the spine and pelvis, allows, in patterns with those of extremities, a better transfer of force thereby facilitating the production of force in activities as jumping[41,42].

Despite the acute effects of different type of stretching on dynamic balance remain controversial, DS seems to be more effective than SS[43-45]. Furthermore, no previous studies have been analyzed the acute effects of CS exercises on dynamic balance. As Kibler et al.[41] described the activation of *core* musculature in patterns with extremity movements helps to improve postural control. It has been hypotized that in an unstable position, such as standing on one leg, the pre-activation of the *rectus abdominus* muscle and obliques allow to maintain dynamic balance during movement of opposite limb[46,47]. Moreover, it has been reported a greater PAPE effect in CA that provided multiarticular exercises involving large muscle masses (e.g. squats, bench press)[15]. Our results showed better mSEBT score after StretCor protocol, thus

one could speculate that DS in combination with core stimulation muscle, obtained by multiplanar and multi-joint movements, may have produced a greater recruitment of trunk musculature inducing a better dynamic balance.

In addition to jumping and power performances, the key elements for success for volleyball task also require agility to react quickly to numerous sprints and changes of direction with continue acceleration or deceleration through space in a very short time[48,49]. Studies involving team handball and basketball players[50,51] demonstrated that during a match the ability to maintain and regulate correct positions of the body while rapidly they change of direction is linked to dynamic balance. Thus, the improvement in agility performance in present study could be probably ascribed to better dynamic control of body induced by activation of core muscles which allowed quicker movements of lower and upper limbs favoring T-test tasks execution. Moreover, some exercises used in the StretCor protocol provided quickly action by stimulating consecutively the eccentric and the concentric phase during a stretch-shortening cycle of muscle action[15]. Thus, better reactive strength may have contributed to higher PAPE effect and consequently the ability to perform sudden stops and accelerate thus improving change of directions speed[52].

The main limits of this study were: i) the absence of a control group which limits it to a pilot study and makes it difficult to understand whether the change observed has arisen from the treatment; ii) the low number of participants. Thus, the results should be confirmed in enlarge simple size including older and more experienced athletes and also consider two separate groups of males and females to assess the potential effect of sex on physical performance; iii) the lack of assessment of specific volleyball skills, i.e. service accuracy and service speed; iiii) the assessment of performance immediately after StretCor protocol did not allow to us to monitor the duration of benefits over time.

## Practical Applications

Based on the results obtained, we suggest to volleyball coaches to: i) include StretCor protocol in each training sessions and before competition during warm-up phase to improve the performance of some important volleyball task such as jumping, dynamic balance and agility; ii) use StretCor protocol during game competition in the warm-up of reserve athletes preparing to enter the game to be ready and optimize their performance.

## Conclusions

To the best of our knowledge, this study was the first to explore the PAPE effect in acute of a combination of DS and CS functional exercises on the coordination of the body segments involved in the volleyball performance. We demonstrate that the combination of DS and CS exercises have positive effects on explosive lower-body power, agility, and dynamic balance performance in U-16 volleyball players. In conclusion, the results of present study suggest that StretCor protocol can be considered as a specific CA with a PAPE effect for volleyball in young people. However, further studies are needed to confirm the potential practical application for improving performance during matches and evaluate how long the effects could be prolonged or persist.


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## Ethical Committee approval

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## Topic

Sport Science

## Conflicts of interest

The authors have no conflicts of interest to declare.


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## Author-s contribution

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