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ACUTE EFFECT OF ISOMETRIC MID-THIGH PULLS ON POSTACTIVATION POTENTIATION DURING STRETCH-SHORTENING CYCLE AND NON-STRETCH-SHORTENING CYCLE VERTICAL JUMPS

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Abstract

Introduction: There is research to support the contention that isometric exercise can lead to an acute augmentation in subsequent explosive exercise performance, in a phenomenon termed postactivation potentiation (PAP).

Objective: To investigate the impact of the isometric mid-thigh pull (IMTP) exercise on peak power (PP) and jump height (JH) during stretch-shortening cycle (SSC) and non-SSC vertical jumps.

Methods: Following informed consent, eighteen resistance trained males (age 21.1 ± 3.8 years, height 180.4 ± 6.2 cm, and body mass 86.8 ± 13.3 kg) performed three testing conditions on separate days. *Baseline*: Countermovement jump (CMJ) and squat jump (SJ) JH and PP were assessed using a Myotest Pro accelerometer device. *IMTP+4:* CMJ and SJ JH and PP were measured 4 minutes after the IMTP. *IMTP+8*: CMJ and SJ JH and PP were measured 8 minutes after the IMTP.

Results: There was a significant increase in SJ PP in both IMTP+4 and IMTP+8 conditions compared to baseline (both $P < 0.05$). SJ JH was not significantly different in IMTP+4 and IMTP+8 compared to baseline (both $P > 0.05$). CMJ PP and JH were not significantly different between conditions (all $P > 0.05$).

Conclusions: These results suggest than an IMTP resulted in an acute augmentation in SJ PP after both 4 and 8 minutes, while CMJ performance was not significantly affected by the same protocol. Thus, an IMTP PAP protocol may acutely enhance short-term power output in non-SSC vertical jumps, but not in SSC vertical jumps.

***Key words:** countermovement jump, squat jump, peak power, myotest accelerometer*

Introduction

Muscular performance is affected by previous contractile history, while force and power generation depends on the balance between co-existing fatigue and potentiation [1-4]. It has been suggested that it is the net balance of each that determines whether subsequent performance is impaired or enhanced [3,5]. Postactivation potentiation (PAP) may therefore be defined as a phenomenon whereby the net balance of potentiation outweighs that of fatigue, subsequently augmenting acute muscular force and power generation. To date, two primary mechanisms have been proposed. The first related to an acute increase in regulatory light chain (RLC) phosphorylation, altering the actin-myosin sensitivity to Ca^2+ [3,6,7], and the second being related to an increase in type 1a afferent fibre and α-motoneuron excitability as measured by changes in Hoffman-reflex (H-reflex) [6,8]. Due to methodological limitations, very little conclusive evidence is available to identify which of these mechanisms, if any, are responsible for short term increases in exercise performance.

A number of studies have examined the effect of different preconditioning intensities on subsequent explosive muscular activity, using either 'complex' or 'contrast' training modalities [9-13]. Complex training will typically involve the exposure to multiple sets of dynamic preconditioning exercise, prior to performing multiple sets of an explosive exercise. Alternatively, contrast training entails multiple sets of contrasting a dynamic heavy load to a lighter more explosive load in a single-set alternating manner. The aim of both of these dynamic methods of potentiation is to increase and maximise power generation during the explosive activity. Typically, these studies have reported either an increase or no change in performance during varying low body stretch-shortening cycle (SSC) activities. However, a number of other methods have also been explored [14-17]. One of which is where researchers have attempted to exploit the unique nature of isometric contractions in acutely augmenting a PAP effect [18-21]. Isometric exercise is of particular interest within the field of PAP research, as theoretically different contraction types could provide varying effects on both fatigue and potentiation [3]. For example, while the mechanisms of fatigue predominantly induced by dynamic exercise may be peripheral, the fatigue produced during isometric preconditioning activities may be more central in nature, or limited as a result of a reduced neural drive to the muscle [22]. Furthermore, potentiation as a result of dynamic exercise could be the result of more centralised mechanisms, while isometric exercise may better activate the peripheral mechanisms associated with PAP [3].

Isometric PAP studies have demonstrated equivocal results; while some have shown up to a ~10% increase in various kinetic and kinematic parameters [19,20], others have shown no change, or a reduction in performance [18,21]. It is interesting to note that those studies that found a reduction in performance only did so when examining higher volume isometric preconditioning protocols (typically ~20-30 seconds over multiple sets), while those showing more favourable results utilised lower volume isometric protocols (typically <10 seconds over single or multiple sets).

Studies utilising isometric exercise have typically examined rest periods spanning from immediately post [7], up to 15 minutes post [18]. Esformes et al. [23] demonstrated an increase in upper body peak power at 12 minutes post, while Rixon et al. [20] found lower body peak power to be enhanced at 3 minutes while no effects on jump height were observed. Berning et al. [14] found an increase in jump height both 3 and 4 minutes post in resistance trained subjects, however in untrained subjects jump height remained unchanged. Using an isometric open kinetic chain exercise, French et al. [19] demonstrated an increase in depth jump height at 0-5 second's post, while countermovement jump height remained unchanged. It appears that of the current data available, the establishment of an optimal rest interval in order to elicit a PAP effect using isometric exercise remains elusive. A number of factors come in to play when determining the effects of time recovery on PAP, and these have yet to be fully determined.

There is little conclusive evidence to demonstrate the superiority of one contraction type over another in yielding a PAP effect. However, it may be noted that a recent study that compared isometric to dynamic preconditioning activities, found a significant increase in upper body power after isometric preloading, while no effects were observed after dynamic preconditioning [23]. Isometric exercise could also offer a more practical solution for the strength and conditioning practitioner, particularly those involved within team sports, as the issue of determining an optimal load for each athlete in order to initiate a potentiating response would in theory not exist. It may even be possible to instruct the athlete to push or pull against any secure and immovable object that is at their disposal for a very short period of time, in order to initiate some form potentiating effect.

The effectiveness of an isometric PAP protocol therefore warrants further exploration, since they may provide a more practical solution to the strength and conditioning practitioner over dynamic methods of potentiation. Furthermore, the influence these protocols have yet to be examined for their impact on the SSC during biomechanically similar tasks. Therefore, the purpose of this research was to examine whether the Isometric Mid-Thigh Pull (IMTP) exercise could acutely augment peak power (PP) and jump height (JH) during subsequent SSC and non-SSC vertical jumps.

Methods

Study Design

Eighteen resistance trained males completed the following testing conditions using a within-subject, repeated measures crossover design. *Baseline*: Countermovement jump (CMJ) and squat jump (SJ) performance was measured to obtain baseline values. *IMTP+4:* CMJ and SJ performance was measured beginning 4 minutes post IMTP. *IMTP+8:* was identical in design to *IMTP+4*; however an assessment of CMJ and SJ performance began after 8 minutes post IMTP.

Participants

Following approval, eighteen resistance trained males (mean ± SD: age 21.1 ± 3.8 years, height 180.4 ± 6.2 cm, body mass 86.8 ± 13.3 kg, resistance training experience 5.9 ± 4.5 years) agreed to participate in the study. All participants were free of musculoskeletal pain and injury, and had experience in a variety of competitive sports (rugby union, athletics, soccer), as well as familiarity with the Weightlifting movements. Participants were required to abstain from any lower body resistance exercise within the 48 hour period prior to data collection. They were also asked to refrain from all solid foods and caloric beverages within 2 hours prior to exercise.

Procedures

Participants initially visited the laboratory for familiarisation with the testing procedures. Following this, participants were required to visit the performance lab on 3 separate occasions, each separated by at least 48 hours. The following describes each testing condition completed in a randomised order:

Baseline: Participants completed a standardised full-body warm-up consisting of a series of dynamic stretches, followed by 4 minutes of passive rest. Baseline measures for the CMJ and SJ were then established, where PP and JH were analysed using a Myotest Pro accelerometer device (Myotest, SA). A single CMJ repetition was performed followed 30 seconds later by a SJ repetition. Two minutes of passive rest was provided between each vertical jump sequence, repeating for a total of 3 CMJ's and 3 SJ's. *IMTP+4*: Participants completed a standardised full-body warm-up consisting of upper and lower body dynamic stretches, which was then followed by 4 minutes of passive rest. Participants were then asked to perform the IMTP exercise, followed by 4 minutes of passive rest. PP and JH were then analysed using the Myotest Pro accelerometer. A single CMJ repetition was performed followed 30 seconds later by a SJ repetition. Two minutes of passive rest was provided between each vertical jump sequence, repeating for a total of 3 CMJ's and 3 SJ's. The jump sequences were therefore executed at 4, 6 and 8 minutes post IMTP. *IMTP+8*: Participants completed the same procedures as in *IMTP+4*, however 8 minutes of passive rest was provided after the IMTP prior to analysis of PP and JH. Therefore jump sequences were performed at 8, 10 and 12 minutes post IMTP.

In order to perform the IMTP participants were required to pull on an immovable Olympic bar (performed in a power rack with pins) as quickly as possible, and maintain a maximal effort for 5 seconds. The IMTP was specifically chosen due to the biomechanically similar positions achieved to vertical jumping tasks and its role in activating the hip, knee and ankle plantar flexor musculature. Measurements of force and rate of force production during the IMTP have been shown to correlate well with a number of performance variables during dynamic explosive activities [24-26], and Kawamori et al. [27] have shown isometric peak force obtained during the IMTP to correlate well with vertical displacement achieved during the CMJ and SJ. In addition, the 5 second isometric contraction commonly used for the IMTP closely resembles that of the time periods used by prior isometric PAP research [14,23]. A maximal intensity effort was performed in order to stimulate as many type II muscle fibres as possible during the IMTP, ultimately conferring to a greater PAP response [28]. For each participant the height of the Olympic bar was set-up horizontally at mid-thigh level, allowing an external knee angle of approximately 130° (fully extended knee = 180°). Knee angle was established using a Goniometer (Gaimpro, UK) and participants were required to maintain this position throughout the duration of each IMTP. Upon command from the tester, participants were instructed to pull on the immovable bar "hard and fast" using a technique that has previously been employed elsewhere [24,29,30]. Participants were required to perform only one repetition at maximal effort for each of the IMTP+4 and IMTP+8 conditions respectively.

Participants performed un-weighted CMJ and SJ without the aid of an arm swing; this was standardised by maintaining the hands on the hips throughout jump attempts. The CMJ involved participants squatting down to an approximate 90° knee angle, immediately utilizing a SSC action through a powerful extension of the legs. The SJ was performed under the same conditions, however a static squat position was held for 3 seconds prior to jumping, in order to test concentric-only vertical jumping ability. Participants were given strict instructions and provided with visual feedback to ensure that the contribution of the SSC to SJ performance was minimised. In all conditions vertical jumps were performed according to the Myotest Pro CMJ and SJ test protocols. Previous research has demonstrated the Myotest device to be a reliable tool for assessing repeated measures of vertical jump performance [31,32], and was chosen due to its practicality and ease of use for practitioners and athletes. The device was attached to a large Velcro belt on the lateral side of the body at hip level according to the manufacturer instruction. The average of 3 jump attempts for each condition were used for statistical analysis, where data obtained by the Myotest Pro accelerometer allowed for the calculation of PP and JH at a sampling frequency of 500 Hz.

Statistical analysis

Any changes in PP and JH between conditions for both the SJ and CMJ were analysed using a 3 way repeated-measures Analysis Of Variance (ANOVA) with time as the within subjects variable. Post-hoc analysis using Bonferroni adjustments were performed where any significant differences were found and partial η^2 was used as a measure of effect size. Acknowledging that any effect of PAP may have been time dependant further analysis was conducted using a series of 3(time) X 3 (jump order) was repeated measures ANOVAs as a means to examine whether there was variation within the series of jumps undertaken post PAP at each time point. Statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS v.19.0). The criterion for statistical significance was set *a priori* at $P = 0.05$.

Results

There were no significant differences in CMJ PP and JH across conditions, nor were there significant differences in SJ JH across conditions (all $P > 0.05$). However, results indicated there was a significant main effect for SJ PP (F 2, 34 = 7.254, $P = 0.002$, partial η^2 = 0.299). Bonferroni post-hoc pairwise comparisons revealed that PP was significantly greater at IMTP+4 compared to baseline (Mean Diff = -3.445, $P = 0.047$) and at IMTP+8 compared to baseline (Mean Diff = -5.239, $P = 0.002$) but not significantly different between IMTP+4 and IMTP+8 ($P = 0.847$, See Fig. 2). Mean ± S.D. of CMJ and SJ, PP and JH are presented in Table 1. Subsequent analysis using a series of 3 (time) X 3 (jump order) was repeated measures ANOVAs for PF and JH for both CMJ and SJ indicated no significant interactions or main effects for CMJ or SJ for JH or PP ($P > 0.005$).

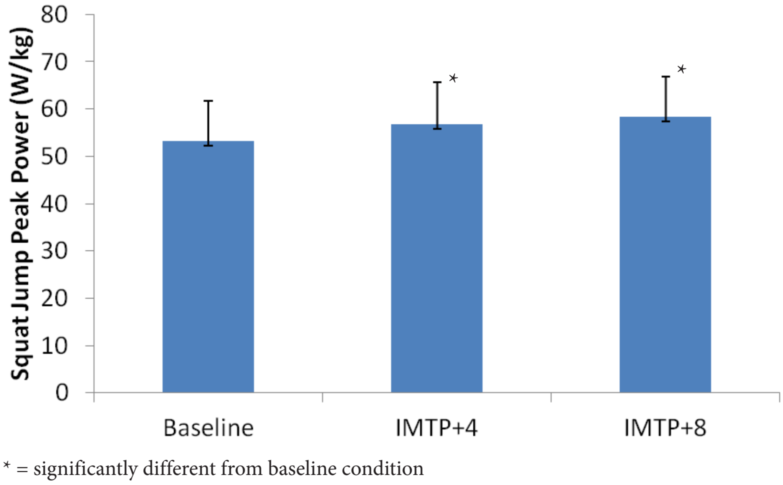

Fig. 2. *Mean ± S.D. of squat jump peak power across conditions*

Table 1. *Mean ± S.D. of peak power and jump height during squat jump and counter movement jump across conditions*

	Baseline		IMTP+4		IMTP+8	
	M	S.D.	M	S.D.	M	S.D.
SJ-PP (W/kg)	53.2	8.6	56.8*	8.8	58.4*	8.5
SJ-JH (cm)	30.0	5.5	30.3	5.6	31.3	6.9
CMJ-PP (W/kg)	51.3	8.9	52.4	7.9	54.9	8.1
CMJ-JH (cm)	36.3	7.4	36.9	7.7	37.3	8.1

* = significantly different from baseline condition

Discussion

This is the first study to examine use of the IMTP as part of a PAP protocol to enhance jump performance, and further to explore the effects of isometric preconditioning on SSC and non-SSC activities. Our results show that a 5 second IMTP results in an acute augmentation in PP during the SJ beginning after both 4 and 8 minutes, while any improvements in JH did not reach statistical significance. Furthermore, these findings suggest that a non-SSC vertical jump is more sensitive to an isometric PAP protocol than a biomechanically similar SSC activity. The current research was exploratory; therefore limited studies are available from which to compare these findings. Rixon et al. [24] demonstrated a significant increase in CMJ PP after an isometric back squat, however SJ performance was not assessed, nor was the duration of isometric preconditioning contraction or post potentiating rest interval comparable to the present study. To the author's knowledge, only one PAP study has attempted to augment both CMJ and SJ performance, but this study used a dynamic pre-stimulus and did not report power output [11]. It was found that both CMJ and SJ height may be enhanced, but it appeared that these results were both exercise and load dependent; while CMJ's responded to loaded jump squats and half squats with low and moderate loads, SJ performance was only significantly enhanced following half squatting with a moderate load [11]. Like the present study, these results suggest that SSC and non-SSC vertical jumps respond to methods of PAP in an independent manner, depending on the mode and intensity of preconditioning exercise. Despite the findings of these studies, it would be erroneous to draw direct comparisons to our study due to differences in its exploratory design.

Prior research has found a strong positive correlation between vertical jump height and relative peak power, in both CMJ and SJ in athletically trained males ($r = 0.83$-0.94) [33]. The lack of concomitant increases in SJ JH along with SJ PP cannot be fully explained, however, although it never reached statistical significance there was a general trend for SJ JH to increase as time increased towards the IMTP+8 condition. Rixon et al. [20] found a significant increase PP but no increase in JH when using a CMJ. Robbins and Docherty [21] also found no increase in CMJ JH, although PP was not assessed. Berning et al. [14] only found an increase in JH when using a resistance trained group of subjects, while a non-resistance trained group showed no such performance improvements. They also observed a slightly greater increase in JH 5 minutes post compared to 4 minutes post potentiating exercise. Using an upper body isometric PAP exercise, Esformes et al. [23] demonstrated an increase in upper body PP, but no significant augmentation in either peak force, peak rate of force development or peak barbell displacement. One possible suggestion for the observed results of this study may be that PP is more sensitive to change as a variable than JH, although this remains unclear.

Similarly, the reasons for the increased PP shown in the SJ are unclear. However, there may be some suggestions for this finding. It is possible that an augmentation in peak power output was achieved through an acute increase in RLC phosphorylation, as suggested to be the most likely PAP mechanism as a result of isometric exercise [3]. Although somewhat hypothetical, is has been suggested that isometric PAP exercise induces greater levels of central fatigue, while activating peripheral mechanisms of potentiation [3]. Therefore according to these suggestions, some of the central mechanisms that govern the SSC (see for example Wilson and Flanagan [4]) may have caused the CMJ to been more subject to the effects of central fatigue, than compared to the SJ. Hence the net balance of fatigue and potentiation were more favourable to an increase in vertical jumping ability during the SJ. These suggestions are however speculative and further research is warranted in order to confirm the potential contribution of these or any other mechanisms that may be involved.

Future research may wish to take a more exhaustive approach in the use of temporal phase analysis of the potential changes in CMJ and SJ. The equipment used in the present study may serve as a limitation to further research in the area, and it is suggested that alternative methods of power assessment be considered. By doing so, this could enable measures of performance during isolated force-time intervals, and at differing phases of motion during vertical jumping tasks. Furthermore, the results obtained during this study may be limited to the fairly homogenous population used, and should therefore be considered in both an applied sense and for future research to examine. It is also suggested that further research in this area should consider the type of explosive activity chosen for measuring PAP response. The magnitude of PAP effect from any preconditioning exercise may differ depending on the subsequent exercise type and relative contribution of the SSC.

In this study it was demonstrated that resistance trained males achieved a significant augmentation in power output during the SJ, following an IMTP preconditioning stimulus beginning at both 4 and 8 minutes prior. Practically, isometric PAP exercise reduces the need to individually calculate optimal loads, in contrast to alternative dynamic methods of PAP. Furthermore, coaching and sports science practitioners should consider the performance needs analysis of their sport, as the results of this study demonstrate differing PAP effects on biomechanically similar vertical jumping tasks, with and without use of the SSC. However, the results of this study do confirm that those wishing to potentiate muscle can do so using an IMTP with resulting improvements in squat jump peak power.

Conflict of interest

None

Disclosure Statement

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References

1. Chiu LZ, Fry AC, Schilling BK, et al. Neuromuscular fatigue and potentiation following two successive high intensity resistance exercise sessions. *Eur J Appl Physiol* 2004; 92: 385-92.
2. Kilduff LP, Bevan HR, Kingsley MLC, et al. Post-activation potentiation in professional rugby players: optimal recovery. *J Strength Cond Res* 2008; 2: 1134-8.
3. Tillin NE, Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Med* 2009; 39: 147-66.
4. Wilson JM, Flanagan EP. The role of elastic energy in activities with high force and power requirements: A brief review. *J Strength Cond Res* 2008; 22: 1705-15.
5. Docherty D, Hodgson MJ. The application of postactivation potentiation to elite sport. *Int J Sports Physiol Perform* 2007; 2: 439-44.
6. Smith JC, Fry AC. Effects of a ten-second maximum voluntary contraction on regulatory myosin light-chain phosphorylation and dynamic measures. *J Strength Cond Res* 2007; 21: 73-6.
7. Szczesna D, Zhao J, Jones M, et al. Phosphorylation of the regulatory light chains of myosin affects Ca2+ sensitivity of skeletal muscle contraction. *J Appl Physiol* 2002; 92: 1661-70.
8. Iglesias-Soler E, Paredes X, Carballeira E, et al. Effect of intensity and duration of conditioning protocol on post--activation potentiation and changes in H-reflex. *Eur J Sport Sci* 2011; 11: 33-8.
9. Baker D. Acute effects of alternating heavy and light resistance on power output during upper-body complex power training. *J Strength Cond Res* 2003; 17: 493-7.
10. Clark RA, Bryant AL, Reaburn P. The acute effects of a single set of contrast preloading on a loaded countermovement jump training session. *J Strength Cond Res* 2006; 20:162-6.
11. Smilios I, Pilianidis T, Sotiropoulos K, et al. Short-term effects of selected exercise and load in contrast training on vertical jump performance. *J Strength Cond Res* 2005; 19: 135-9.
12. Weber K, Brown L, Coburn J, Zinder S. Acute effects of heavy-load squats on consecutive squat jump performance. *J Strength Cond Res* 2008; 22: 726-30.
13. Young WB, Jenner A, Griffiths K. Acute enhancement of power performance from heavy load squats. *J Strength Cond Res* 1998; 12: 82-4.
14. Berning JM, Adams KJ, DeBeliso M, et al. Effect of functional isometric squats on vertical jump in trained and untrained men. *J Strength Cond Res* 2010; 24: 2285-9.
15. Matthews MJ, Comfort P, Crebin R. Complex training in ice hockey: the effects of a heavy resisted sprint on subsequent ice-hockey sprint performance. *J Strength Cond Res* 2010; 24: 2883-7.
16. Ojasto T, Hakkinen K. Effects of different accentuated eccentric load levels in eccentric-concentric actions on acute neuromuscular, maximal force, and power responses. *J Strength Cond Res* 2009; 23: 996-1004.
17. Sheppard J, Newton R, McGuigan M. The effect of accentuated eccentric load on jump kinetics in high-performance volleyball players. *Int J Sports Sci Coach* 2007; 2: 267-73.
18. Behm DG, Button DC, Barbour G, et al. Conflicting effects of fatigue and potentiation on voluntary force. *J Strength Cond Res* 2004; 18: 365-72.

19. French DN, Kraemer WJ, Cooke CB. Changes in dynamic exercise performance following a sequence of preconditioning isometric muscle actions. *J Strength Cond Res* 2003; 17: 678-85.
20. Rixon KP, Lamont HS, Bemben MG. Influence of type of muscle contraction, gender, and lifting experience on postactivation potentiation performance. *J Strength Cond Res* 2007; 21: 500-5.
21. Robbins DW, Docherty D. Effect of loading enhancement of power performance over three consecutive trials. *J Strength Cond Res* 2005; 19: 898-902.
22. Babault N, Desbrosses K, Fabre M, et al. Neuromuscular fatigue development during maximal concentric and isometric knee extensions. *J Appl Physiol* 2006; 100: 780-5.
23. Esformes JI, Keenan M, Moody, J Bampouras TM. Effect of different types of conditioning contraction on upper body postactivation potentiation. *J Strength Cond Res* 2011; 25: 143-8.
24. Haff GG, Stone MH, O'Bryant H, et al. Force-time dependent characteristics of dynamic and isometric muscle actions. *J Strength Cond Res* 1997; 11: 269-72.
25. Nuzzo JL, McBride JM, Cormie P, McCaulley GO. Jump performance and multijoint isometric and dynamic tests of strength. *J Strength Cond Res* 2008; 22: 699-707.
26. West DJ, Owen NJ, Jones MR, et al. Relationship between force-time characteristics of the isometric midthigh pull and dynamic performance in professional rugby league players. *J Strength Cond Res* 2011; 25: 3070-5.
27. Kawamori N, Rossi SJ, Justice BD, et al. Peak force and rate of force development during isometric and dynamic mid-thigh clean pulls performed at various intensities. *J Strength Cond Res* 2006; 20: 483-91.
28. Hamada T, Sale DG, MacDougall JD, Tarnpolsky MA. Postactivation potentiation, fiber type, and twitch contraction time in human knee extensor muscles. *J Appl Physiol* 2000; 88: 2131-7.
29. McGuigan MR, Winchester JB, Erickson T. The importance of isometric maximum strength in college wrestlers. *J Sports Sci Med* 2006; CSSI: 108-13.
30. McGuigan MR, Winchester JB. The relationship between isometric and dynamic strength in college football Players. *J Sports Sci Med* 2008; 7: 101-5.
31. Bubanj S, Stankovic R, Bubanj R, et al. Reliability of Myotest tested by a countermovement jump. *Acta Kinesiologica* 2011; 4: 46-8.
32. Nuzzo JL, Anning JH, Scharfenberb JM. The reliability of three devices used for measuring vertical jump height. *J Strength Cond Res* 2011; 25: 2580-90.
33. Riggs MP, Sheppard JM. The relative importance of strength and power qualities to vertical jump height of elite beach volleyball players during the counter-movement and squat jump. *J Hum Sport Exerc* 2009; 4: 221-36.

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