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Research Paper: Immediate Effects of Plyometric Exercises on Speed, Balance and Jump Ability of Amateur Futsal Players: A Randomized Control Trial

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ABSTRACT

Introduction: The rate of football-related traumas is high. However, greater levels of fitness may decrease the probability of these injuries. Researchers believe that plyometric training can have significant short-term results. This study aimed to investigate the effects of plyometric exercises on athletic performance (speed, balance, and vertical jump ability) of male amateur futsal players.

Materials and Methods: Thirty male amateur futsal players were randomly divided into control and plyometric groups. All participants went through 15 minutes of standard warm-up activity, and then they were asked to perform the tests. The athletes of the plyometric group also completed three rounds of plyometric jumps and then were assessed 3, 10, 15 and 20 minutes after the warm up. The athletes of the control group were evaluated 3, 10, and 15 minutes immediately after the standard warm-up activity.

Results: The study findings indicated an overall improvement in balance and vertical jump scores of amateur futsal players following plyometric exercises ($P<0.05$). However, there was no significant effect on athletes' speed. Speed, vertical jump, and balance did not significantly change in the control group.

Conclusion: Vertical jump and balance ability may improve immediately after plyometric exercises. Further studies are necessary to reassess speed test results.

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1. Introduction

Football is the world's most popular sport, with nearly 200000 professional players and around 240 million amateur players in different levels of competition [1]. Futsal is a type of football played indoors and on a smaller field. This sport has also attracted a lot of fans all over the world [2]. Nevertheless, the rate of futsal-related traumas is among the 10 top-rated risky sports with the highest injuries [2]. For instance, one study reported 55.2 injuries per 1000 hours of futsal playing [3]. Furthermore, these futsal-inflicted traumas result in undesirable outcomes, including accelerated osteoarthritis [4], different types of injuries in the muscle-tendon area [5], ligament injuries [6], cartilage injuries [7], loss of physical activity [8], and higher recurrent injuries [9]. However, activities resulting in a higher level of fitness can considerably reduce the probability of injuries and serve as a beneficial tool for the professional career and post-career period of the athletes.

Several training exercises could generate Acute Short-Term (AST) effects [10]. In this respect, if AST increases the strength performance, as a form of response to the voluntary muscular activity, it can be regarded as Post-activation Potentiation (PAP) [11]. Usually, PAP occurs due to the excitation in the central nervous system. It can vastly enhance the contractile function due to a heavy conditioning stimulus [12]. Furthermore, the practical strategy used to investigate PAP mainly involves performing a maximum or sub-maximum and dynamic or static strength exercises [13, 14]. In this regard, plyometric muscular movements might be able to initiate rapid muscular strength potentiation [15, 16]. A group of researchers strongly believe that plyometric training improves the power and dynamic performance of athletes; in particular, it may result in stretch-shortening cycles and enhanced movement speed [15].

Moreover, the implementation of this training highly refines the coordination and synchronization of muscle movements, especially at the time of performing simple motor execution tasks in a match [15, 17]. Several studies have pointed out that fatigue and PAP coincide after exposure to a conditioning stimulus, which provides a balance between PAP and fatigue. This status essentially determines the effects of performing an explosive activity [18]. Prolonged exercises such as running may weaken balance (muscle fatigue effect) [19], but it is still unclear how a short and intense exercise such as plyometric one may affect balance.

The volume, variety, and intensity of the conditioning stimulus may substantially affect the relationship between potentiation and fatigue [20]. Therefore, athletes must take full advantage of the PAP phenomenon in their training practices [20]. In some sports such as futsal or football, sprints, and high jumps are required many times both in training and during a game to acquire the possession of the ball. Athletes are often expected to perform these tasks repeatedly and at a relatively high level. These abilities are significantly more troublesome for non-professional athletes due to their poor physical fitness. A condition that potentially increases the risk of trauma during practices or games. Therefore, specific exercises, which could immediately enhance the balance and agility of the athletes before a competition, may result in a considerable decrease in the rate of trauma.

It should also be noted that amateur athletes with no regular exercises cannot possibly improve their performance. Thus, PAP can provide them with an alternative way to enhance their balance, agility, and, ultimately, their associated overall performance. Since the number of substitutions a team can make in a futsal game is limitless, it is feasible to use several safe, effective, and practical exercises during the short replacement time. This strategy might even alter the course of the game.

The primary purpose of this study was to investigate the effects of plyometric exercises on the speed, balance, and vertical jump in male amateur futsal players.

2. Methods

This study was designed as a single-blinded randomized control trial to evaluate speed, vertical jump, and balance ability in amateur male futsal players. Participants were randomly assigned to an experimental (plyometric) and a control group. The volunteers in the control group completed a regular warm-up, whereas the volunteers in the experimental group completed a set of plyometric exercises after the warm-up. The effectiveness of the plyometric exercises on volunteers' speed, vertical jump, and balance was evaluated before the warm-up and then 3, 8, and 11 minutes after the warm-up (for the control group) and exercises (for the experimental group).

Thirty male amateur futsal players were voluntarily recruited for this study. The Mean±SD age of the participants was 25.66±2.89 years in the plyometric group and 25.73±2.78 years in the control group. The participants were fully informed about the study and were screened for any significant medical history, specifically lower

limb injury in the past six months. Besides, they signed an informed consent form before the study.

The inclusion criteria were one session futsal practice per week for at least one year. Their age must be between 20 and 30 years old, and only male futsal players were accepted. The volunteers would be excluded from the study if they suffered from lower limb injury, heart disease, or personal problems.

Volunteers were randomly assigned to 2 groups after ensuring that the entry criteria were met. Thirty futsal players referred to the Heidarian Qom stadium in summer and fall 2018, were asked to choose a paper out of the papers that contained numbers 1 and 2. Then, the individuals who chose paper No. 1 were assigned to the control group (n=15), and the rest were put together in the plyometric group (n=15).

Two days before the initiation of the study, the participants took part in a practice session to be acquainted with the procedure and the evaluation method. The researcher provided detailed instructions to each volunteer. On the evaluation day, the tests were repeated, where the candidates were allowed to complete the original test by yet another reminder as to how they should be carried out.

At the beginning, the participants underwent a 15-minute standardized warm-up activity (10 squats using two legs, 10 squats using right and left legs, 10 forward lunges using right and left legs, 10 side lunges using right and left legs, three stretches holding for 15 seconds and resting for 5 seconds for hamstrings, quadriceps, calves, abductors and adductors muscles) [21]. After three minutes of rest, all outcome measures were determined before the exercises, and the data were subsequently collected. The jump test and running time were recorded on a 10-m walkway, and the Star Excursion Balance Test (SEBT) was then performed and recorded for the dominant leg (Figure 1).

The vertical jump and SEBT were repeated three times, and the obtained data were recorded. Next, each volunteer in the experimental group conducted the plyometric exercises under the supervision of a therapist supervised. The plyometric exercises included two sets of 10 ankle hop (Figure 2), three sets of 5 hurdle hops (Figure 3), and two sets of 5 drop jumps (Figure 4)

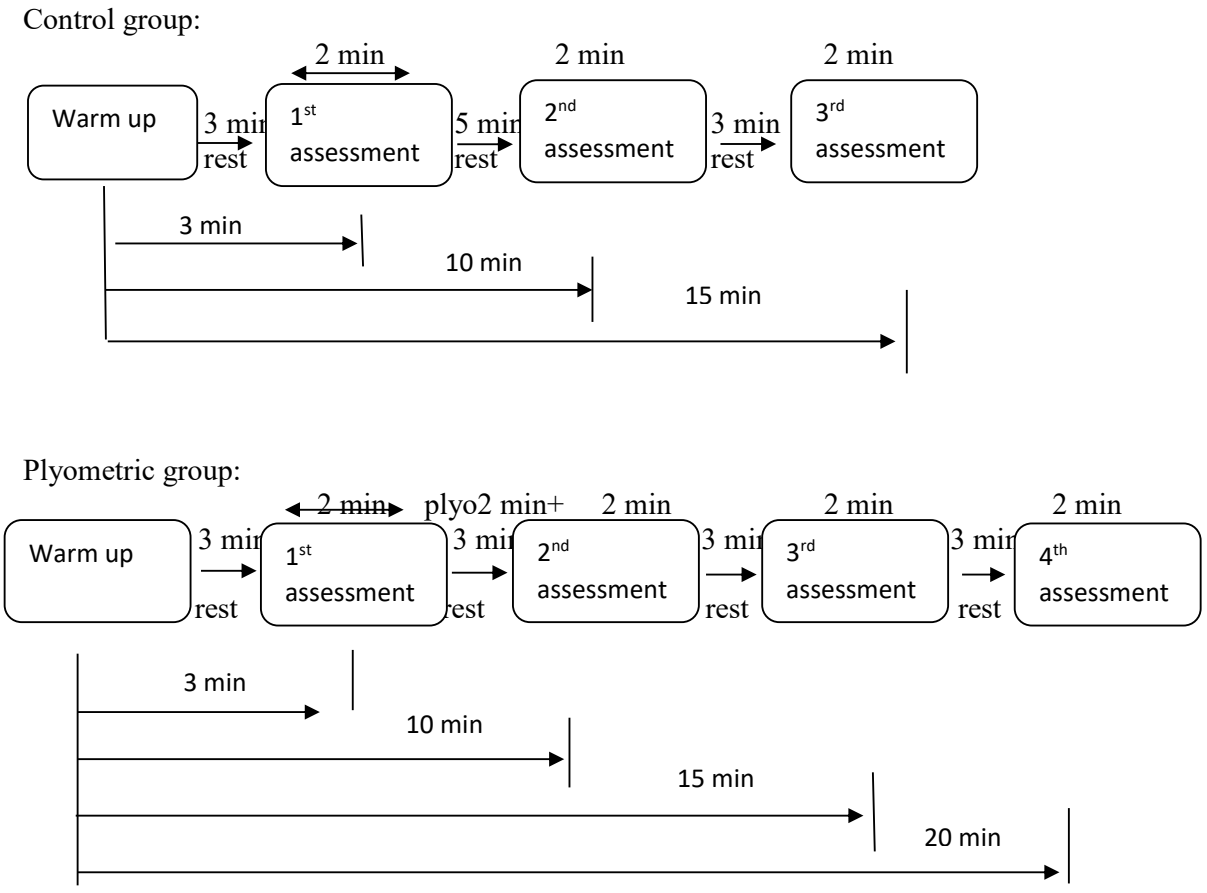

Figure 1. Research framework

Table 1. Mean±SD test values obtained after 3, 8, 11 minutes of plyometric exercises in the plyometric group

Time / Direction F Score (Pv)	Mean±SD			
	Before Exercise	Three Minutes After the Exercise	Eight Minutes After the Exercise	Eleven Minutes After the Exercise
Anterior 2.60 (0.06)	92.26±9.30	97±9.35*	96.66±10.82	96.20±13.22
Anteromedial 3.42 (0.04)	92.40±9.25	96.33±8.41*	96.73±7.87	96.53±9.61
Medial 7.96 (0.00)	86.26±9.17*	91.26±11.37*	93±11.77*	93.73±12.40*
Posteromedial 5.41 (0.003)	82.46±12.47	88.53±11.66*	88.53±12.63	88.73±13.15
Posterior 9.87 (0.00)	74.53±14.29	80.60±14.12*	83±13.75*	83.40±15.07*
Posterolateral 4.47 (0.008)	72.86±12.63	76.53±13.97	77.40±13.55	80.33±16.38*
Lateral 9.51 (0.00)	63±16.02	68.93±17.39*	72.40±17.32*	71.13±16.41
Anterolateral 2.004 (0.015)	76.93±6.92	79.33±9.34	79.86±10.58	79.60±9.76

* P≤0.05

JMR

with 15 seconds rest between each set. Also, there was a 15-second rest between each type of jump. Three, 8, and 11 minutes after the last jump, the outcome measures were re-evaluated, and data were recorded. These time records were obtained from other conducted studies (22, 6, 11, and 23). The warm-up procedure was performed in a similar way for the control group, and the outcome measures were evaluated 3, 10, and 15 minutes after the rest. In the vertical jump record, the participants should jump three times, and the highest jump was recorded as their approved jump score (the distance between jumps and standing reach). In the SEBT record, the participants were marked in all eight directions, repeating the procedure three times, while a laser meter was used to

Table 2. Mean±SD values of the tests at 3, 10, 15 minutes after warm-up in the control group

Time / Direction F Score (Pv)	Mean±SD		
	Three Minutes After the Warm-Up	Ten Minutes After the Warm-Up	Fifteen Minutes After the Warm-Up
Anterior 0.22 (0.74)	98.86±6.20	98.06±6.38	98.33±8.09
Anteromedial 0.60 (0.55)	95.66±2.08	94.93±1.84	96.06±2.25
Medial 0.29 (0.74)	85±14.27	85.20±16.58	86±15.79
Posteromedial 4.23 (0.03)	81.06±12.87	80.53±15.84	84.20±13.89*
Posterior 0.84 (0.4)	79.80±9.88	77.73±13.53	78.40±12.81
Posterolateral 0.31 (0.7)	75.80±9.97	76.60±12.35	77.33±14.94
Lateral 4.42 (0.02)	72.60±13.55	76.20±13.52*	74.33±15.17
Anterolateral 5.02 (0.01)	82.66±7.43	84.20±8.44	86.20±7.63*

* P≤0.05

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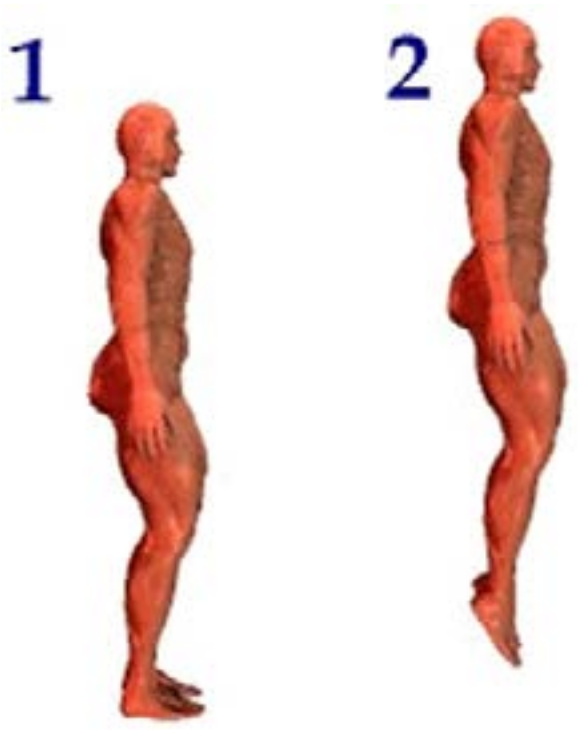

Figure 2. Ankle hop exercise JMR

measure the distance between the marked point and the center of the star.

Statistical analyses are presented as Mean±SD. Analysis of Variance (ANOVA) in repeated measure design was conducted to compare the jump height, speed, and balance separately to evaluate the intergroup differences between pre- and post-exercise time points. The level of substantial significance was determined at $P<0.05$. The Bonferroni correction can be used when a significant main effect was observed. The independent t test was performed to compare the variables between the control and plyometric groups.

3. Results

The Mean±SD Body Mass Index (BMI) of the participants was 23.34±3.18 kg/m^2 in the plyometric group, and 25.4±3.21 kg/m^2 in the control group and the Mean±SD length of the lower limb was 92.4±6.94 cm in the plyometric group and 93.65±3.9 cm in the control group.

Speed. There were no significant differences between pre- and post-plyometric exercises ($F_{2,42}=1.37$, $P\geq0.05$) and at 3, 10, and 15 minutes after warm-up in the control group. In comparison, there were no significant differences between the first ($P\leq0.05$, $t=0.283$), second ($t=0.240$, $P\geq0.05$) and third ($t=0.329$, $P\geq0.05$) times of assessments for speed parameter.

Figure 3. Hurdle hop exercise JMR

Vertical jump. Using the Bonferroni correction, we could establish significant differences between pre- and post-plyometric assessments at 3, 8, and 11 minutes after the exercises in the experimental group ($F_{3,42}=3.39$, $P\leq0.05$). Moreover, adjusted pairwise comparison indicated that jump height before plyometric exercises was significantly lower than those in all other time points. The mean difference between jump height before the plyometric exercise and the values at 3, 8, and 11 minutes after plyometric exercises were 2.84 cm, 1.8 cm, and 1.97 cm, respectively.

There was no significant difference between the jump height achieved at 3, 10, and 15 minutes after the

Figure 4. Drop jump exercise

warm-up in the control group (P≥0.05). In comparison, there were no significant differences between the first (P≤0.05, t=0.786), second (P≤0.05, t=0.679), and the third (P≤0.05, t=0.306) times of assessments for vertical jump tests in the groups.

Balance. After examining the Bonferroni's correction in 7 out of the 8 directions with the SEBT (anterior, anteromedial, medial, posteromedial, posterior, posterolateral and lateral), we found a significant difference between the recorded data of pre- and post-exercise. It was observed that the Mean±SD values changed from 63 (6.92) to 97 (17.39), respectively, the highest and lowest values recorded. Table 1 presents the Mean±SD values.

Three out of 8 directions of SEBT (posteromedial, lateral and anterolateral) had a significant difference between the recorded numbers in 3 times points in the control group. Table 2 presents the Mean±SD values. Moreover, in comparison to the first, second, and third balance tests, significant differences were observed in 2 out of 8 directions, i.e., anterior (P≥0.05, t(2) = 0.286) and anterolateral (P≥0.05,t(2)=0.186) in the first assessment while the rest of the tests and directions did not reveal any significant changes.

4. Discussion

This study was carried out to explore the effects of plyometric exercises on speed, vertical jump, and balance of male amateur futsal players. Our obtained results indicated an overall improvement in the balance and vertical jump scores of amateur futsal players after completing plyometric exercises.

The key reason responsible for these alterations might be the physiological reactions in the muscles following plyometric exercises, where these exercises can alter the level of performance with respect to the jump height and balance of an athlete. Moreover, these variations can also be attributed to the nature of plyometric movements. The plyometric movements mainly provide the muscle-ten-

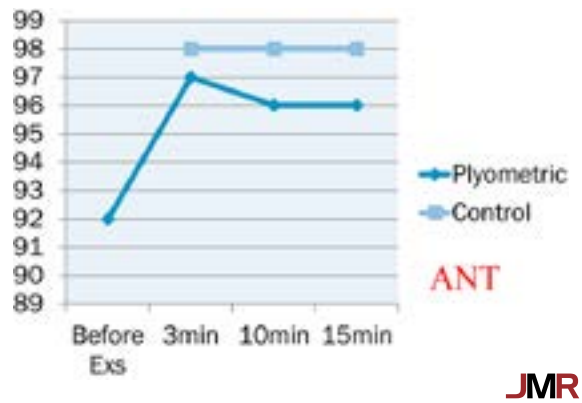

Figure 5. Balance anterior direction results in groups

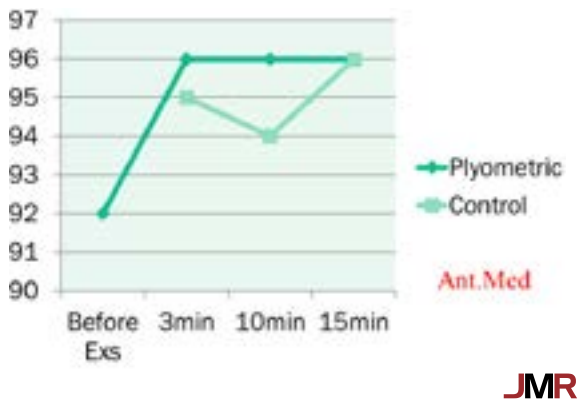

Figure 6. Balance Anteromedial direction results in groups

don unit with a pre-stretch and a physiological length-tension curve to improve the ability of the muscle fibers and thereby generating more tension and force.

Furthermore, plyometric exercises increase neuro-muscular coordination by training the nervous system and adopting more automatic movements during balance improvement activities [26]. As previously mentioned, the PAP serves basically as a response to a conditioning stimulus, which then elevates the level of motor performance in athletes [18, 27]. It is widely believed that an increase in the phosphorylation of myosin regulatory light chains is the main reason for this motor performance elevation. This phenomenon, in turn, makes them more sensitive to myoplasmic calcium alterations and an increased level of alpha motor neuron excitability [28]. Moreover, a plyometric stimulus can induce equivalent levels of potentiation after a significant resistance stimulus [29].

The findings of this research for the height of jump were in favor of all identified previous research studies [20, 30, 31]. On the contrary, the findings of the speed test in the present study were inconsistent with the results of the previous studies [32, 33].

No significant improvement was observed with respect to their speed after performing these exercises. The reason for these little changes in speed test results might be attributed to the type of plyometric training used in the present study. We applied exercises with many vertical jumps, which were more frequent compared with the exercises with horizontal jumps. It seems that using professional athletes with previous plyometric training can alter the results of the study.

The former researchers considered longer distances for their speed test (20 m). This difference might be the reason for different results since longer distance might physiologically add speed deceleration control for the volunteers, which lead to shortening speed period for them. However, in this study, shorter distances were used to match with explosive running times during the game [31, 34]. In previous studies, the speed test was repeated on different and close days. This repetition may alter the results.

Our main limitation for this study was the lack of Space For Star Excursion Balance Test (SEBT). Our experience revealed that the existence of several star tests reduces the psychological ability of an athlete to break his previous record. Furthermore, different types of floors in a futsal hall can alter the speed test results in other conducted studies.

5. Conclusion

Based on the present findings, it may be beneficial for the amateur futsal players to perform these plyometric exercises before a competition and or during the substitutions rest period to enhance the ability of jump heights and dynamic balance in a defined short period. The results of this study do not show any changes in the athlete's speed after performing the plyometric exercises.

Ethical Considerations

Compliance with ethical guidelines

The method of the study was approved by the Deputy of Research, School of Rehabilitation, Tehran University of Medical Sciences (TUMS). The ethical approval was registered under (Code "IR.TUMS.FNM.REC.1397.002") at the Ethics Committee of the TUMS before any practice sessions.

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Authors contributions

Nafiseh Zekri: carried out the literature search and review, recruit the players, data extraction, performed the statistical analysis, prepared the initial draft, coordinated revisions, submitted the manuscript, and prepared the written draft. Siamak Bashardoust Tajali: contributed to the literature search and review, developed the research strategy, developed the critical appraisal, coordinated the project, contributed to synthesize the results and manuscript revisions. Nastaran Ghotbi: contributed to the search strategy, coordinated the project and manuscript revisions. All authors read and approved the final article.

Conflict of interest

The authors declared no conflict of interests.

References

[1] Junge A, Dvorak J. Soccer injuries. Sports Medicine. 2004; 34(13):929-38. [DOI:10.2165/00007256-200434130-00004] [PMID]

[2] Ebrahimi Varkiani M, Alizadeh MH, Pourkazemi L. The epidemiology of futsal injuries via sport medicine federation

injury surveillance system of Iran in 2010. Procedia - Social and Behavioral Sciences. 2013; 82:946-51. [DOI:10.1016/j.sbspro.2013.08.001]

[3] Schmikli SL, Backx FJG, Kemler HJ, Mechelen, W. National survey on sports injuries in the netherlands: Target populations for sports injury prevention programs. Clinical Journal of Sport Medicine. 2009; 19(2):101-10. [DOI:10.1097/JSM.0b013e31819b9ca3] [PMID]

[4] Wright RW, Dunn WR, Amendola A, Andrish JT, Bergfeld J, Kaeding CC, et al. Risk of tearing the intact anterior cruciate ligament in the contralateral knee and rupturing the anterior cruciate ligament graft during the first 2 years after anterior cruciate ligament reconstruction: A prospective Moon Cohort study. The American Journal of Sports Medicine. 2007; 35(7):1131-4. [DOI:10.1177/0363546507301318] [PMID]

[5] Gribble Ph, Hertel J, Plisky Ph. Using star excursion balance test to asses dynamic postural-control deficits and outcomes in lower extremity injury: A literature and systematic review. Journal of Athletic Training. 2012; 47(3):339-57. [DOI:10.4085/1062-6050-47.3.08] [PMID] [PMCID]

[6] Lioyd DG. Rationale for training programs to reduce anterior cruciate ligament injuries in Australian football. Journal of Orthopaedic & Sports Physical Therapy. 2001; 31(11):645-54. [DOI:10.2519/jospt.2001.31.11.645] [PMID]

[7] Riyami M, Rolf C. Evaluation of microfracture of traumatic chondral injuries to the knee in professional football and rugby players. Journal of Orthopaedic Surgery and Research. 2009; 4:13. [DOI:10.1186/1749-799X-4-13] [PMID] [PMCID]

[8] Ardern CL, Webster KE, Taylor NF, Feller JA. Return to sport following anterior cruciate ligament reconstruction surgery: A systematic review and meta-analysis of the state of play. British Journal of Sports Medicine. 2011; 45(7):763-4. [DOI:10.1136/bjsm.2010.076364]

[9] Rauh MJ, Macera CA, Ji M, Wiksten DL. Subsequent injury patterns in girls' high school sports. Journal of Athletic Training. 2007; 42(4):486-94. [PMID] [PMCID]

[10] Miarka B, Del Vecchio FB, Franchini E. Acute effects and postactivation potentiation the special judo fitness test. Journal of Strength and Conditioning Research. 2011; 25(2):427-31. [DOI:10.1519/JSC.0b013e3181bf43ff] [PMID]

[11] Sale DG. Postactivation potentiation: Role in human performance. Exercise and Sport Sciences Reviews. 2002; 30(3):138-43. [DOI:10.1097/00003677-200207000-00008] [PMID]

[12] Rixon KP, Lamont HS, Bemben MG. Influence of type of muscle contraction, gender and lifting experience on postactivation potentiation performance. Journal of Strength and Conditioning Research. 2007; 21(2):500-5. [DOI:10.1519/R-18855.1] [PMID]

[13] Krstulović S, Zuvela F, Katić R. Biomotor systems in elite junior judoists. Collegium Antropologicum. 2006; 30(4):845-51. [PMID]

[14] Rimmer E, Sleivert G. Effects of a plyometrics intervention program on sprint performance. Journal of Strength and Conditioning Research. 2000; 14(3):295-301. [DOI:10.1519/00124278-200008000-00009]

[15] Fatouros IG, Jamurtas AZ, Leontsini D, Taxildaris K, Aggelousis N, Kostopoulus N, et al. Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. Journal of Strength and Conditioning Research. 2000; 14(4):470-6. [DOI:10.1519/00124278-200011000-00016]

[16] Hunter JP, Marshall RN. Effects of power and flexibility training on vertical jump technique. Medicine & Science in Sports & Exercise. 2002; 34(3):478-86. [DOI:10.1097/00005768-200203000-00015] [PMID]

[17] Myer GD, Ford KR, McLean SG, and Hewett TE. The effects of plyometric versus dynamic stabilization and balance training on lower extremity biomechanics. The American Journal of Sports Medicine. 2006; 34(3):445-55. [DOI:10.1177/0363546505281241] [PMID]

[18] Tillin NA, Bishop D. Factors modulating post-activation potentiation and its effect on the performance of subsequent explosive activities. Sports Medicine. 2009; 39:147-66. [DOI:10.2165/00007256-200939020-00004] [PMID]

[19] Mello RG, Oliveira LF, Nadal J. Effects of maximal oxygen uptake test and prolonged cycle ergometer exercise on sway density plot of postural control. Paper presented at: Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 3-6 September 2009; Minneapolis, MN, USA. [DOI:10.1109/IEMBS.2009.5334148] [PMID]

[20] Tobin DP, Delahunt E. The acute effect of a plyometric stimulus on jump performance in professional rugby players. Journal of Strength and Conditioning Research. 2014; 28(2):367-72. [DOI:10.1519/JSC.0b013e318299a214] [PMID]

[21] Romero-Franco N, Jimenez-Reyes P. Unipedal postural balance and countermovement jump after a warm-up and plyometric training session: A randomized controlled trial. The Journal of Strength & Conditioning Research. 2015; 29(11):3216-22. [DOI:10.1519/JSC.0000000000000990] [PMID]

[22] Lohmander LS, Östenberg A, Englund M, Roos H. High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. Arthritis & Rheumatology. 2004; 50(10):3145-52. [DOI:10.1002/art.20589] [PMID]

[23] Lockie RG, Murphy AJ, Callaghan SJ, Jeffriess MD. Effects of sprint and plyometrics training on field sport acceleration technique. Journal of Strength and Conditioning Research. 2014; 28(7):1790-801. [DOI:10.1519/JSC.0000000000000297] [PMID]

[24] Davies GJ, Ellenbecker TS. Eccentric Isokinetics. Orthop Phys Ther Clin N Am. 1992;1(2):297-336.

[25] Davies GJ, Matheson JW. Shoulder plyometrics. Sports Med Arthrosc. 2001;9(1):1-18. [DOI:10.1097/00132585-200101000-00001]

[26] Davies G, Riemann BL, Manske R. Current concepts of plyometric exercise. International Journal of Sports Physical Therapy. 2015; 10(6):760-86. [PMID] [PMCID]

[27] Hodgson M, Docherty D, Robbins D. Post-activation potentiation: Underlying physiology and implications for motor performance. Sports Medicine. 2005; 35:585-95. [DOI:10.2165/00007256-200535070-00004] [PMID]

[28] Trimble MH, Harp SS. Postexercise potentiation of the H-reflex in humans. Medicine & Science in Sports & Exercise. 1998; 30(6):933-41. [DOI:10.1249/00005768-199806000-00024] [PMID]

[29] de Villareal ESS, Gonzalez-Badillo JJ, Izquierdo M. Optimal warm-up stimuli of muscle activation to enhance short and long term acute jumping performance. European Journal of Applied Physiology. 2007; 100:393-401. [DOI:10.1007/s00421-007-0440-9] [PMID]

[30] Loturco I, Kobal R, Maldonado T, Piazzi AF, Bottino A, Kitamura K, et al. Jump squat is more related to sprinting and jumping abilities than Olympic push press. International Journal of Sports Medicine. 2017; 38(8):604-12. [DOI:10.1055/s-0035-1565201] [PMID]

[31] Hammami R, Granacher U, Makhlouf I, Behm DG, Chaouchi A. Sequencing effects of balance and plyometric training on physical performance in youth soccer athletes. The Journal of Strength & Conditioning Research. 2016; 30(12):3278-89. [DOI:10.1519/JSC.0000000000001425] [PMID]

[32] Dello Iacono A, Martone D, Padulo J. Acute effects of drop-jump protocols on explosive performances of elite handball playeres. The Journal of Strength & Conditioning Research. 2016; 30(11):3122-33. [DOI:10.1519/JSC.0000000000001393] [PMID]

[33] Turner AP, Bellhouse S, Kilduff LP, Russel M. Postactivation potentiation of sprint acceleration performance using plyometric exercise. The Journal of Strength & Conditioning Research. 2015; 29(2):343-50. [DOI:10.1519/JSC.0000000000000647] [PMID]

[34] Asadi A, Saez de Villarreal E, Arazi H. The effects of plyometric type neuromuscular training on postural control performance of male team basketball players. The Journal of Strength & Conditioning Research. 2015; 29(7):1870-5. [DOI:10.1519/JSC.0000000000000832] [PMID]

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