Muscular adaptations to depth jump plyometric training: Comparison of sand vs. land surface

HAMID ARAZI[1], MAHDI MOHAMMADI[1], ABBAS ASADI[2,*]

[1]Department of Exercise Physiology, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran
[2]Roudbar Branch, Islamic Azad University, Roudbar, Iran
*Corresponding author: Abbas Asadi; Roudbar Branch, Islamic Azad University, Roudbar, Iran;
E-mail: abbas_asadi1175@yahoo.com

(Received: April 30, 2014; Revised manuscript received: June 7, 2014; Accepted: June 9, 2014)

Abstract: The purpose of this study was to compare the effects of plyometric training on sand vs. land surface on muscular performance adaptations in men. Fourteen healthy men were randomly assigned to two training groups: a) Sand Depth Jump (SDJ; $N = 7$) and b) Land Depth Jump (LDJ; $N = 7$). Training was performed for 6 weeks and consisted of 5 × 20 repetitions of DJ training on 20-cm dry sand or 3-cm hard court surface twice weekly. Vertical Jump Test (VJT), Standing Long Jump Test (SLJT), 20-m and 40-m sprint, T-test (TT) and one repetition maximum leg press ($1RM_{LP}$) were performed before and after training. Significant improvements in VJT [4 (ES = 0.63) vs. 5.4 (ES = 0.85) cm], SLJT [8.3 (ES = 0.3) vs. 12.7 (ES = 0.57) cm], and $1RM_{LP}$ [23.5 (ES = 0.56) vs. 15.3 (ES = 0.49) kg] were seen for both the groups. Likewise, significant decreases were observed for both SDJ and LDJ groups in 20-m [0.3 (ES = 0.72) vs. 0.4 (ES = 1.98) s] and 40-m sprint times [0.2 (ES = 0.4) vs. 0.5 (ES = 0.71) s], and TT [0.5 (ES = 0.62) vs. 0.9 (ES = 0.57) s]. With regard to ES, it can be recommended that athletes used LDJ training for enhancing sprint and jump and SDJ training for improving agility and strength.

Keywords: stretch-shortening cycle, sand, jumping ability, performance

Introduction

Plyometric exercises involve the training of the stretch-shortening cycle (SSC) phenomena and have been shown to be an effective way to achieve the highest velocities [1, 2]. Plyometrics are used to improve lower body power and increase explosiveness by training the muscle to do more work in a shorter time [3]. Plyometric training has been shown to an effective method for the improvement of sprinting and jumping ability [1, 3, 4], strength [4], and it has also been reported to improve running economy [5] and agility [1, 6].

However plyometric exercises include variations of jumping, bounding and hopping drills, true plyometric training requires the rapid eccentric muscle action and maximal effort of the athletes during the concentric muscle action. This type of plyometric training can be form of depth jump [2, 7]. Drop or depth jump (DJ) is a plyometric or SSC exercise and has been shown to be effective for the improvement of jumping ability and muscular performance [1, 4, 6, 8, 9]. Commonly plyometric training such as DJ is performed on firm surface. Although performing DJs on firm surface can stimulate SSC greater than other surfaces, this type of surface induces muscle soreness and damage greater than other surfaces (i.e., sand, grass and mat) [10, 11]. Impellizzeri et al. [10] compared the effects of 4-week plyometric training on sand vs. grass surface coupled with soccer training, aerobic interval training and technical-tactical training on muscle soreness and physical performance in soccer players, and reported plyometric training on sand improved jumping and sprinting ability and induced less muscle soreness.

However, less muscle soreness and muscle damage were seen by plyometrics on sand [10, 11], there were differences between sand and firm surfaces. Performing plyometrics on sand causes a lower reuse of elastic energy and energy loss due to feet slipping during the concentric action [11, 12]. Also, it is likely that much of the energy produced by the muscles will not be returned (i.e., energy will be absorbed), resulting decrease in muscular performance on the sand, when compared to hard surface [10–12].

Although a few studies have explored the influence of sand surface on muscular performance [10, 11], no study has directly compared sand and firm conditions in relation to muscular performance following 6 weeks DJ training. It is important to understand the differences in response to plyometric training between sand and firm surfaces, since many assumptions have been made from studies using different surfaces. Therefore, the purpose of this study was to compare the effects of 6-week DJ plyometric training on sand and land surfaces on muscular performance in healthy men.

In this study we had two purposes: 1) examine the effects of 6 weeks DJ plyometric training on sand on sprinting and jumping ability, agility and strength; 2) to compare possible changes in muscular performance induced by DJ plyometric training between sand and land surfaces.

Materials and Methods

The subjects were 14 healthy men who were familiar with plyometric exercise and training volunteered to participate in this study. Subjects were randomly assigned to one of two training groups: a) Sand Depth Jump training (SDJ; $N = 7$, age 20.7 ± 0.5 y, height 175.5 ± 3.2 cm, body mass 72.3 ± 6.1 kg) or b) Land Depth Jump training (LDJ; $N = 7$, age 20.5 ± 0.3 y, height 176.3 ± 2.1 cm, body mass 71.2 ± 5.3 kg). A priori calculations of statistical power indicated that this sample size was appropriate to satisfy power at or above 80% [13]. Subjects did not have medical or orthopedic problems that compromised their participation in this study. Each subject was informed of the risks and benefits of the study and subsequently signed an informed consent form in accordance with the guidelines of the university's Institutional Review Board.

This study was designed to examine the effects of depth jump training on sand vs. land surface in healthy men. Subjects performed depth jump training either sand or land surface for 6 weeks. Subjects in both groups were instructed on proper technique of training and testing equipment one week prior to data collection. Participants subsequently underwent 6 weeks of training and were tested pre- and post-training for changes in muscle strength, agility, jumping ability and sprinting ability. This design enabled us to examine the effects of plyometric training on sand vs. land surface on muscular performance.

The participant underwent two days of testing, namely one pre- and one post-test day, respectively. A week before the official testing week, each subject was familiarized with the testing procedures and plyometric training programs, and the demographic data were gathered and anthropometric measurements (body mass and stature) taken. The baseline testing of agility (T-test), jumping ability (Vertical Jump Test and Standing Long Jump Test), 20-m and 40-m sprint and one repetition maximum leg press ($1RM_{LP}$) were completed one week before the beginning of the different plyometric training protocols. Post-testing was performed a week after the training period. The subjects were tested at the exact same time of day (post-test day) and same day of the week as the pre-test day to minimize the effect of circadian variations in the test results. All subjects had to continue with the normal daily life activity. Subjects had not had experience in any type of plyometric training programs for at least six months prior to the start of the study and were not permitted to participate in any resistance training programs during the time period of the study. Test–retest intraclass reliabilities were $R \geq 0.95$ for all tests.

The following laboratory tests were conducted: The Vertical Jump Test (VJT) was performed according to the method of Holcomb et al. [5]. The VJT was performed using the Vertec device (Power Systems, Knoxville, Tennessee, TN 22550, USA). Before commencement of the testing procedure, the height of vertical column was adjusted so that the subject could touch the movable vanes to register a standing touch height. Each subject stood with the dominant arm's shoulder and the dominant leg's foot under the colored movable vanes. Keeping the heels on the floor, the subject then reached upwards as high as possible. The distance was recorded as the standing touch height to the nearest 1 cm. An arm swing and counter movement were not used to jump as high as possible and to tap the highest possible vane. This distance was recorded and noted as the jumping distance. The differences between the standing touch height and jumping distance was calculated and recorded to the nearest 1 cm. The subjects performed a minimum of three trials with a 30 s rest period between each trial. The better of the three trials was then recorded.

The Standing Long Jump Test (SLJT) was executed according to the method of Arazi et al. [2]. The SLJT was measured via a tape measure. Subjects were required to stand with their toes behind the zero point of the tape measure prior to jumping. Subjects were not allowed a preparatory step of any kind but arm swings were allowed at the discretion of the subject. Distance was determined measuring the point at which the heel of the trial leg touched the ground. Each subject performed three trials with a 30-s rest in between each trial. The best jump of the three was used for analysis.

The 20-m and 40-m sprint was measured according to the method of Rimmer and Sleveret [14]. Sprints were performed on an indoor track for 40 m, with the timing devise situated in 2 locations to determine 20-m and 40-m sprint times (JBL Systems, Oslo, Norway). Each subject was given 2 maximal trials. Three minutes of rest was permitted between trials and the fastest time was recorded for analysis.

Subjects' agility was evaluated by using the T-test (TT) according to the method of Miller et al. [8]. The subjects were instructed to sprint from a standing starting position to a cone 10 m away, followed by a side-shuffle left to a cone 5 m away. After touching the cone the subjects side-shuffled to the cone 10 m away and then side-shuffled back to the middle cone. The test was concluded by back-pedaling to the starting line. The test score was recorded as the best time of three trials. A 3-minute rest period was allowed between each trial. Subjects were disqualified if they failed to touch the base of any cone, crossed the one foot in front of the other or failed to face forward for the entire test.

A bilateral leg press (Body Solid, GLPH 1100, USA) test was selected to provide data on maximal dynamic strength through the full range of motion of the muscles involved. The procedure used for assessing 1RM was described by Kraemer and Fry [15]. The participant was in a seated position so that the knee angle was 90° and the weight sliding obliquely at 45°. On command, the participants performed a concentric leg extension (as fast as possible) starting from the flexed position to reach the full extension against the resistance determined by the weight. The participants performed a warm-up set of 8–10 repetitions at a light weight (approximately 50% of 1RM). A second warm-up consisting of a set 3–5 repetitions with moderate weight (approximately 75% of 1RM), and third warm-up including 1–3 repetitions with a heavy weight (approximately 90% of 1RM) followed. After the warm-up, the participants performed 1RM strength exercises by enhancing the load during consecutive trials until the participants were unable to properly perform a proper lift, complete range of motion and correct technique. Three five-minute rests were provided between the attempts for each participant. The $1RM_{LP}$ were obtained within 3–5 sets to avoid excessive fatigue.

The plyometric training programs included twice weekly (on Sunday and Wednesday) for 6 weeks. The 6-week training duration was chosen because it is well known that neural and muscular adaptation can occur within this time frame following power training [2, 6, 16]. Each training session lasted 35-min, including 10-min warm-up (e.g., jogging, stretching and ballistic exercises), 20-min training (DJ training on sand or land surface), and 5-min cool-down (e.g., jogging and stretching exercises). Subjects performed 5 sets of 20 repetitions [6, 11] of DJ with a 5-second interval between jumps. A 2-min and 72-hour rest period was given between sets and training sessions, respectively. Subjects performed DJ onto a 0.2-m-deep dry sand surface and or 3-cm hard court surface [10, 11]. The SDJ and LDJ subjects began by standing on a 45-cm plyometric box and were instructed to lead with 1 foot as they stepped down from the box and land with 2 feet on the ground. Instantly upon ground contact, subjects were instructed to "explode" off the ground by jumping as quickly and as high as possible. All training was supervised by certified instructors. Adherence to training was 100%, as each subject completed 12 workouts. Missed workouts were made up during a scheduled rest day.

All data are presented as mean ± *SD*. A two-way analysis of variance with repeated measures was used to determine significant differences among groups. A criterion α level of $p \leq 0.05$ was used to determine statistical significance. All statistical analyses were performed through the use of a statistical software package (SPSS®, Version 16.0, SPSS., Chicago, IL). The calculation of effect size (the difference between pretest and post-test scores divided by the pretest standard deviation) was used to examine the magnitude of any treatment effect.

Results

Changes in VJT and SLJT are presented in *Fig. 1A* and *B*. VJT increased significantly in SDJ (8%, $p = 0.01$, ES = 0.63) and LDJ (12%, $p = 0.001$, ES = 0.85), without differences between groups. Moreover, SLJT increased significantly in SDJ (4%, $p = 0.05$, ES = 0.3) and LDJ (6%, $p = 0.009$, ES = 0.57), with no differences between them.

Sprinting performance results are presented in *Fig. 1C* and *D*. Significant decreases in 20-m and 40-m sprint times were observed in SDJ (9, $p = 0.05$, ES = 0.72 and 4%, $p = 0.05$, ES = 0.4) and LDJ (8, $p = 0.008$, ES = 1.95 and 12%, $p = 0.01$, ES = 0.71) post-training, respectively. However, no significant differences were seen between groups at post-training.

Agility TT performance data are presented in *Fig. 1E*. Both groups demonstrated significant improvements in TT post-training (SDJ; 5%, $p = 0.009$, ES = 0.62 and LDJ; 8%, $p = 0.05$, ES = 0.57), with no difference observed between groups. In addition, $1RM_{LP}$ (13, $p = 0.001$, ES = 0.56 and 10%, $p = 0.002$, ES = 0.49 in SDJ and LDJ, respectively) increased significantly for both the groups, without differences between groups *(Fig. 1F)*.

Discussion

This study succeeded in showing that sand and land based DJ training programs of a six-week duration had a significant training effect with regard to all the measured jumping ability, agility, strength and speed values from pre- to post-training. In spite of the favorable results with regard to the training affect that each of the experimental groups (SDJ and LDJ) experienced, the SDJ was the group that had achieved better pre- and post-test training differences in $1RM_{LP}$. Also, the LDJ increased better pre- and post-training differences in other variables.

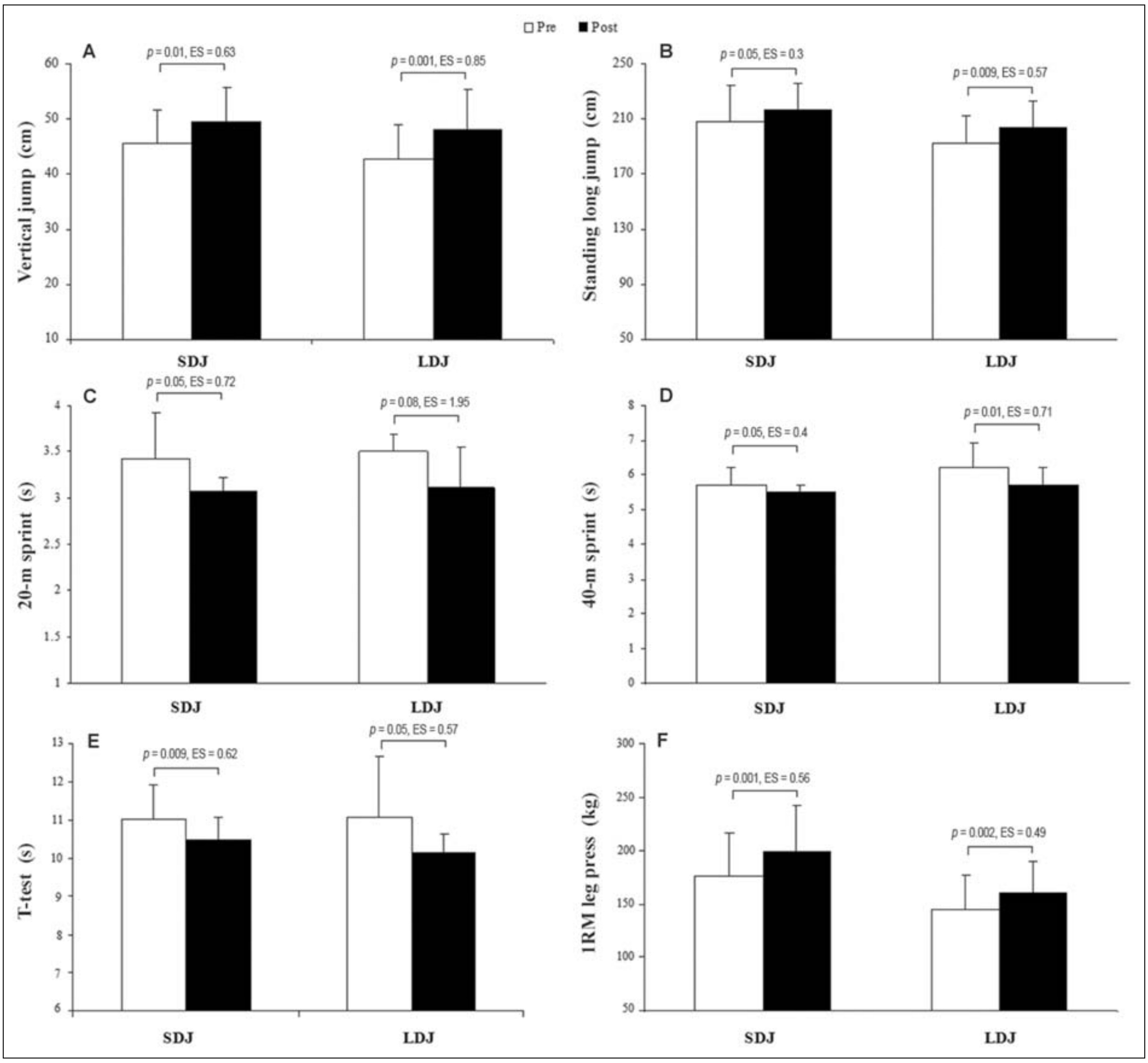

Fig. 1. Significant changes in vertical jump and standing long jump, 20-m and 40-m sprint time, agility T-test and $1RM_{LP}$ at post-training compared with pre-training values. Values are mean ± *SD*. SDJ: Sand Depth Jump; LDJ: Land Depth Jump

To the best of our knowledge, no other studies have been conducted to compare the effects of sand and land based plyometric training program on jumping ability, agility, strength and speed, which made it difficult to compare the results of this study to other studies. However, one study has compared the benefits of sand based plyometric programs to those of grass based plyometric training programs in soccer players [10]. Overall, those study seem to suggest that sand and grass based plyometric training programs of 4-week have similar effects with regard to changes in jumping and sprint performance, which is consistent with the findings of this study.

Similar to the results of the current study, a large number of studies reported a significant training effect for muscular performance from pre- to post-training in land plyometric training programs [3, 4, 6, 8–10, 14, 17]. In this study we found significant main effect of plyometric training on sand and land surface in VJT and SLJT, whereas no significant differences were seen between groups. The results of this study are supported with previous studies in the literature.

Although several authors have reported significant improvements in VJT and SLJT using plyometric training in male [1, 4, 18, 19], there are a few studies about the sand vs. land plyoemtric training and there is still a discrepancy about the factors influencing these improvements. Many researchers suggested that VJT and SLJT gains after plyometric training are attributed to a neural adaptation located in the nervous system rather than to morphologic changes [20–23]. According to these authors, neuromuscular factors such as increasing the degree of muscular coordination and maximizing the ability to use the muscle's SSC appear to be more important than changes in fiber size. In addition, previous studies have indicated that neuromuscular adaptations such as increased motor unit functioning, increased inhibition of antagonist muscles as well as activation and co-contraction of synergistic muscles may account for the improvement of VJT and SLJT [22, 23].

In this study, we found significant improvements in 20-m and 40-m sprint times, with no significant differences between the SDJ and LDJ training groups. These findings are in line with previous authors who reported significant decreases in sprint time following plyometric training [3, 6, 14, 18].

Compared to the results of Markovic et al. [18] and Thomas et al. [16], the rates of improvements in sprint were greater. Markovic et al. [18] examined the effects of 10 weeks land based plyometric training (e.g., DJ and hurdle jumps) on 20-m sprint time and did not find significant changes. Also, Thomas et al. [16] examined the effects of LDJ training on 20 m sprint, and did not find significant improvements. It seems that, the differences in intensity of training, training volume and sample size could be a reason of the discrepancy in results.

In relation to the transfer of plyometric training to sprinting, Young [24] suggested that jumping may be considered a specific exercise for the development of acceleration because of the similar contact times of jumping and sprinting during the initial acceleration phase. Other mechanism(s) that improved sprint performance could be changes in stride length and stride frequency via plyometric training [14]. However, we did not evaluate these variables, previous authors reported high relationship between stride length and frequency with sprint performance [14].

Although no studies could be found that have simultaneously investigated the possible effects of sand based plyometric training on the agility of participants, this study found positive effects of SDJ and LDJ training on agility TT performance. These findings are in line with previous studies that reported positive effects of plyometric training (land based) on agility performance [2, 4, 8, 16]. Agility improvement requires rapid force development and high power output, and it seems that DJ training can improve these requirements [8]. In addition, the DJ training may have improved the eccentric strength of the thigh muscles, a prevalent component in change of direction during the deceleration phase [25]. Neural adaptations and enhancement of motor unit recruitment are other mechanisms can lead to increase for the agility tests [2, 4, 8, 16]. Moreover, agility tasks require a rapid switch from eccentric to concentric muscle action in the leg extensor muscles (the SSC muscle function). Thus, it has been suggested that SSC training (DJ) can decrease ground reaction test times through the increase in muscular force output and movement efficiency, therefore positively affecting agility performance [26, 27].

In this study, both groups increased $1RM_{LP}$ significantly, whereas no significant differences were observed between groups. However, the SDJ group improved $1RM_{LP}$ greater than LDJ group; this increase was not statistically significant. Numerous studies have demonstrated improvements in strength via plyometric training [3, 6, 28]. In contrast, a number of authors failed to report significant positive effects of plyometric training on strength [18]. Several studies have reported significant correlations between muscular strength and sprinting speed [21, 27]. Young et al. [27] reported significant correlations between strength per body mass measures and starting ability (r = 0.86), acceleration out of the block (r = 0.64), and maximum sprinting speed (r = 0.80). Canavan et al. [21] reported significant kinetic relationship between Olympic lifts and vertical jump performance. In the present study, $1RM_{LP}$ increased significantly in both groups. It is likely that the improvements observed in lower-body strength contributed to the improvements in both jumping and sprinting performance observed in the present study. Several studies have indicated the importance of plyometric training for improving vertical jump and sprint performance [2, 3, 6, 28]. The strength increases support previous studies, which have shown the effectiveness of plyometric training for increasing muscular strength [3, 6, 18, 28]. Moreover, it is likely that mechanism(s) such as enhanced motor neuron excitability, increased motor unit recruitment, or increased activation of synergists or all; resulting from the DJ may have contributed to increase in $1RM_{LP}$ performance in our investigation [3, 6, 28].

Overall, in this study we found greater increases for LDJ group in VJT, SLJT, sprint and TT, whereas SDJ group increased greater than LDJ group in $1RM_{LP}$. According to previous authors suggestions the longer contact time can induce the less effective the SSC [9]. During performing plyometrics on sand, compliance and friction can plays negative effects on SSC, decreases of myotatic reflex, degration of elastic energy potentiating and increase amortization phase resulting worsens in performance [10–12]. These mechanisms can be key factors for greater increases in VJT, SLJT, sprint and TT for LDJ group. Also, greater increases in strength performance by SDJ group can be greater work by muscle during jumping on sand. The absorptive qualities of sand are likely to increase contraction time allow the leg extensor muscles to build up active state and force prior to shortening. This would enable subjects to produce more work on the sand than on the land resulting greater increases in strength performance [10, 11].

Improving muscle function and muscular performance is of the utmost importance for strength and conditioning professionals. To enhance explosive muscle power, sprint, agility and strength performance via plyometric training, several training surface can be used, such as aquatic, grass, sand and land. The findings of this study indicate that DJ training on sand and land can be used effectively as a training surface for improving explosive leg power and muscular performance. Therefore, in addition to the well-known training surface such as sand, land and aquatic, strength and conditioning professionals may well incorporate sand based plyometric training into an overall conditioning program of athletes striving to achieve a high level of explosive leg power and muscular performance.

* * *

Funding sources: None.

Authors' contribution: HA designed the study, wrote the manuscript and made revisions; MM assisted the study design, contributed to take the data, wrote the manuscript; AA assisted the study design, performed the statistical analysis, wrote the manuscript and made revisions to make revisions and to elaborate the graphics.

Conflict of interest: None.

References

1. Chu DA (1998): Jumping Into Plyometrics. Human Kinetics, Champaign, IL
2. Arazi H, Coetzee B, Asadi A: Comparative effect of land and aquatic based plyometric training on the jumping ability and agility of young basketball players. South African J Res Sport Phys Edu Rec 34, 1–14 (2012)
3. Arazi H, Asadi A: The effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. J Hum Sport Exerc 6, 101–111 (2011)
4. Asadi A: Effects of six weeks depth jump and countermovement jump training on agility performance. J Sport Sci 5, 67–70 (2012)
5. Holcomb WR, Lander JF, Rutland RM, Wilson G: The effectiveness of a modified plyometric program on power and the vertical jump. J Strength Cond Res 10, 89–92 (1996)
6. Sáez-Sáez De Villarreal E, González-Badillo JJ, Izquierdo M: Low and moderate plyometric training frequency produce greater jumping and sprinting gains compared with high frequency. J Strength Cond Res 22, 715–725 (2008)
7. Turner AM, Owings M, Schwane JA: Improvement in running economy after 6 weeks of plyometric training. J Strength Cond Res 17, 60–67 (2003)
8. Miller MG, Herniman TJ, Ricard MD, Cheatham CC, Michael TJ: The effects of a 6-week plyometric training program on agility. J Sports Sci Med 5, 459–465 (2006)
9. Sáez-Sáez De Villarreal E, Kellis E, Kraemer WJ, Izquierdo M: Determining variables of plyometric training for improving vertical jump height performance: A meta-analysis. J Strength Cond Res 23, 495–506 (2009)
10. Impellizzeri FM, Rampinini E, Castagna C, Martino F, Fiorini S, Wisloff U: Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. Br J Sports Med 42, 42–46 (2008)
11. Miyama M, Nosaka K: Influence of surface on muscle damage and soreness induced by consecutive drop jumps. J Strength Cond Res 18, 206–211 (2004)
12. Giatsis G, Kollias I, Panoutsakopoulos V, Papaiakovou G: Biomechanical differences in elite beach volleyball players in vertical squat jump on rigid and sand surface. Sports Biomech 3, 145–158 (2004)
13. Faul F, Erdfelder E, Lang AG, Buchner A: G*Power 3: A flexible statistical power analysis program for the social, behavioural and biomedical sciences. Behav Res Methods 39, 175–191 (2007)
14. Rimmer E, Sleveret G: Effects of a plyometric intervention program on sprint performance. J Strength Cond Res 14, 295–301 (2000)
15. Kraemer WJ, Fry AC (1995): Strength testing: development and evaluation of methodology. In: Physiological Assessment of Humane Fitness, eds Maud P and Foster C, Human Kinetics, Champaign, IL
16. Thomas K, French D, Philip PR: The effect of two plyometric training techniques on muscular power and agility in youth soccer players. J Strength Cond Res 23, 332–335 (2009)
17. Toumi H, Best TM, Martin A, F'Guyer S, Poumarat G: Effects of eccentric phase velocity of plyometric training on the vertical jump. Int J Sports Med 25, 391–398 (2004)
18. Markovic G, Jukic I, Milanovic D, Metikos D: Effects of sprint and plyometric training on muscle function and athletic performance. J Strength Cond Res 21, 543–549 (2007)
19. Young WB, Bilby, GE: The effect of voluntary effort to influence speed contraction on strength, muscular power and hypertrophy development. J Strength Cond Res 7, 172–178 (1993)
20. Maffiuletti NA, Dugnani S, Folz M, Di Pierno E, Mauro F: Effect of combined electrostimulation and plyometric training on vertical jump height. Med Sci Sports Exerc 34, 1638–1644 (2002)
21. Canavan PK, Garrett GE, Armstrong LE: Kinematic and kinetic relationships between an Olympic-lift and the vertical jump. J Strength Cond Res 10, 127–130 (1996)
22. Markovic G, Mikulic P: Neuro-musculoskeletal and performance adaptations to lower-extremity plyometric training. Sports Med 40, 859–895 (2010)
23. Potteiger JA, Lockwood RH, Haub MD, Dolezal BA, Alumzaini KS, Schroeder JM, Zebas CJ: Muscle power and fiber characteristic following 8 weeks of plyometric training. J Strength Cond Res 13, 275–279 (1999)
24. Young WB: Sprint bounding and the sprint bound index. Nat Strength Cond Asso J 14, 18–21 (1992)
25. Sheffard JM, Young WB: Agility literature review: Classification, training and testing. J Sports Sci 24, 919–932 (2006)
26. Alexander MJ: The relationship between muscle strength and sprint kinematics in elite sprinters. Can J Sport Sci 14, 148–157 (1989)
27. Young W, McLean B, Ardagna J: Relationship between strength qualities and sprinting performance. J Sports Med Phys Fitness 35, 13–19 (1995)
28. Sáez-Sáez De Villarreal E, Requena B, Newton RU: Does plyometric training improve strength performance? A meta-analysis. J Sci Med Sport 13, 513–522 (2010)
29. Cronin JB, Mcnair PJ, Marshall RN: Is velocity specific strength training important in improving functional performance? J Sports Med Phys Fitness 42, 267–273 (2002)