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Muscular performance adaptations to short-term plyometric training on sand: influence of interday rest

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ABSTRACT

Asadi, A. (2015). Muscular performance adaptations to short-term plyometric training on sand: influence of interday rest. *J. Hum. Sport Exerc., 10*(3), pp.775-784. The aim of the current investigation was to determine the effects of short-term plyometric depth jump training on sand interposed with 48 hours or 72 hours of rest between training sessions on power type muscular adaptations in recreationally physical active men. Fifteen collegiate physical active men, who were familiar with plyometric exercise, participated in this study and were randomly divided into 2 groups: plyometric training with 48 h (PT48, N=7) and 72 h (PT72, N=8) of rest between training sessions. Pre and post training on sand, participants were measured in vertical jump (VJ), standing long jump (SLJ), agility t Test (TT), 20 and 40 m sprints, and one repetition maximum leg press ($1RM_{LP}$). The plyometric training program on sand was applied during 6 weeks, 2 sessions per week, with 5 sets of 20 repetitions depth jump exercise from 45 cm box height. After completing 6 weeks training period, the PT48 and PT72 groups showed significant improvement in all performance tests ($p<0.05$), with statistically significant differences between treatments in TT and 40 m sprint time. With regard to significant differences in TT and 40 m sprint for PT72 compared with PT48 and greater improvements for PT72 in all tests, it can be recommend that coaches, strength and conditioning professionals apply 72 h rest between plyometric training sessions when sand surface was used. **Key words:** SAND, STRETCH SHORTENING CYCLE, POWER EXPLOSIVE.

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INTRODUCTION

Plyometric training gained popularity in the early 1970s as athletes from the Eastern European countries (Arazi, Coetzee & Asadi, 2012; Chu 1998). Plyometrics consists of a rapid stretching of a muscle (eccentric phase) immediately followed by a concentric or shortening action of the same muscle and connective tissue (Arazi et al., 2012; Chu 1998). The stored elastic energy within the muscle is used to produce more force than can be provided by a concentric action alone. These rapid eccentric to concentric phase called stretch shortening cycle (SSC) (Chu 1998; Baechle & Earle, 2000). It has been well documented that this type of training is an effective training mode for improving muscular power (Arazi et al., 2012; Arazi & Asadi, 2011; Asadi & Arazi, 2012; Saez Saez de Villarreal, Gonzalez-Badillo & Izquierdo, 2008; Saez Saez de Villarreal, Kells, Kraemer & Izquierdo, 2009), speed (Arazi & Asadi, 2011; Asadi & Arazi, 2012; Saez Saez de Villarreal, Requena & Newton, 2010; Rimmer & Sleveret, 2000), agility (Arazi et al., 2012; Asadi & Arazi, 2012; Miller, Herniman, Ricard, Cheatham & Michael, 2006) and strength (Arazi & Asadi, 2011; Saez Saez de Villarreal et al., 2008; 2010). The possible mechanisms for enhancing muscular performance following plyometric training are related to stimulation of SSC (Saez Saez de Villarreal et al., 2009; Markovic & Mikulic, 2010). It appears that when plyometric exercise induced greater effects on SSC, the rate of improvements were greater (Saez Saez de Villarreal et al., 2009; Markovic & Mikulic, 2010), thus proper SSC stimulating is a key note for the augment of performance.

Similar to resistance training, plyometric training design is related to several variables such as intensity, volume, progression, type of exercise, training surface, rest interval and recovery (Chu 1998; Baechle & Earle, 2000) that manipulation of these variables can influence on SSC and resulting different muscular responses. There were several studies about the effects of intensity, volume, exercise type of plyometric training on performance (Arazi et al., 2012; Arazi & Asadi, 2011; Asadi & Arazi, 2012; Saez Saez de Villarreal et al., 2008), but little is known about the influence of rest between training sessions on muscular performance. Recently, Ramírez-Campillo et al. (2013) examined the effects of plyometric training with 24 and 48 hours of rest between training sessions on muscular adaptations and did not find statistically significant differences between them, whereas both the groups showed improvements in comparison to pre training.

Since, plyometric training surface is one of the important variables for designing plyometric training and a large number of authors examined the influence of sand surface on muscular performance (Ramírez-Campillo et al., 2013; Impellizzeri et al., 2008; Miyama & Nosaka, 2004) and newly strength and conditioning professionals focused on sand surface thus examining rest between sand plyometric training sessions is vital and necessary. With regard to literature about the nature of sand surface such as friction and instability that induce negative effects on SSC, decreases of myotatic reflex, degradation of elastic energy potentiating, it seems that more rest between training sessions are need to "adequate recovery" and resulting regeneration of SSC benefits (Ramírez-Campillo et al., 2013; Impellizzeri et al., 2008; Miyama & Nosaka, 2004; Bishop, 2003; Giatsis, Kollias, Panoutsakopoulos & Papaiakovou, 2004). Moreover, it is important to understand the sand mechanisms to improvement of muscular performance, since many assumptions have been made from studies using this surface and appropriate rest between sand plyometric training sessions to allow for "adequate recovery" (Impellizzeri et al., 2008; Miyama & Nosaka, 2004; Bishop, 2003; Giatsis et al., 2004).. Therefore, the purpose of this investigation was to examine the influence of 6 weeks depth jump plyometric training with 48 and 72 hours of rest between training sessions on power type muscular adaptations. It was hypothesized that 72 hours would predominate over 48 hours in training-induced sprint and agility with regard to controlling training intensity (height of jump).

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MATERIAL AND METHODS

Study design

This study examined the ability of two times a week, short-term sand plyometric training intervention with either 48 or 72 hours of rest between training sessions in collegiate physically active men. Two groups were formed from college students; one group performed twice weekly sand depth jump plyometric training with 48 hours of rest between training sessions (PT48), and second group performed twice weekly sand depth jump plyometric training with 72 hours of rest between training sessions (PT72). Pre and post 6 weeks training period, all participants were measured in five power type muscular performance tests. This was a randomized controlled trial.

Subjects

The subjects were 14 collegiate physically active men, who were familiar with plyometric exercise but did not train at least six months before their inclusion in this study. All subjects were asked to complete a personal health and medical history questionnaire, which served as a screening tool. All subjects had no history of any kind of medical condition that would prevent them from participating in the training intervention. The University's ethics committee approved the experimental procedures and study protocols, which were fully explained to all subjects. Each subject signed a written consent form after having read and understood the details of the experiments. A prior estimated sample size for β = 0.80 with α = 0.05 was calculated based on tabled data from previous research (Faul, Erdfelder, Lang & Buchner, 2007). Inclusion criteria included the ability to lift a weight more than 2.5 times the body weight in a leg press exercise. Exclusion criteria included subjects with potential medical problems or a history of ankle, knee, or back pathology in the 3 months preceding the study; subjects with medical or orthopedic problems that compromised their participation or performance in this study or any lower extremity reconstructive surgery in the past 2 years or unresolved musculoskeletal disorders; and subjects who were taking and had previously taken anabolic steroids, growth hormone, or related performance- enhancement drugs of any kind. Mean ± SD for each group's characteristics are presented in Table 1.

Table 1. Subjects characteristics. (mean±SD).

Group	N	Age (y)	Height (cm)	Body mass (kg)
PT48	7	20.2 ± 1.1	180.5 ± 4.2	73.3 ± 7.1
PT72	7	20.7 ± 1.5	180.1 ± 5.5	71.7 ± 9.6

Testing Procedures

Subjects were familiarized with training and testing a week before beginning either measurements or formal training. Standardized tests of explosive actions were performed before and after training under the same weather and field conditions. Testing sessions were scheduled 48 hours before and after training period to minimize the influence of fatigue. Prior to testing, each subject underwent a 15-minute progressive standard warm up on the field and then specific warm up conducted to perform 2 or 3 sub maximal trials for each test. All tests were performed on the same day and supervised and recorded by the certified instructors. Test order was the same on both testing occasions (pre and post) and the better score of 2 trials was recorded for further analysis. Three minutes of rest was accorded between each trial to reduce fatigue effects. All the subjects visited in laboratory on 3 different days separated by 48 hours of rest:

On the first day, anthropometric measurements were taken: height and body mass were measured for each participant using Seca standard stadiometer (95-195 cm, accurate to 0.1 cm) and a Seca Electronic balance (0-150 kg, accurate to 0.1 kg). During this session, the subjects were randomly assigned in each group.

On the second day, vertical jump, standing long jump and agility t Test were measured. The vertical jump (VJ) height was measured according to method previously described by Asadi and Arazi (2012) and a standard jump-and-reach technique and an adjustable measuring device (VERTEC, Power Systems, Knoxville, Tennessee, TN 22550, USA). Participants were given a specific warm up of 3 jumps at sub-maximal effort. A countermovement without the arms swing was allowed for each jump. The test-retest reliability for vertical jump was 0.95. The standing long jump (SLJ) was used as a test of bilateral leg power and performed with both legs together. Arm movements were permitted for support during the take-off movements. Trials were only evaluated when the subjects landed properly on their feet while not falling back. The distance between the toes at start and the heels at landing was used as a testing criterion (Arazi et al., 2012). The test-retest reliability for standing long jump was 0.99. The agility t Test (TT) (Figure 1) was used to determine speed with directional changes such as forward sprinting, left and right shuffling, and backpedalling. Based on the protocol outlined by Miller et al. (2006), participants began with both feet behind the starting line A. At his own discretion, each subject sprinted forward to cone B and touch the base of it with the right hand. Facing forward and without crossing feet, they shuffled to the left to cone C and touch its base with the left hand. Participants then shuffled to the right to cone D and touch its base with the right hand. They shuffled back to the left to cone B and touch its base. Finally, subjects ran backward as quickly as possible and return to line A. Any subject who crossed one foot in front of the other, failed to touch the base of the cone, and/or failed to face forward throughout had to repeat the test. The test-retest reliability for standing long jump was 0.98. There were 5 min of rest between tests to ensure recovery and reduce fatigue effects.

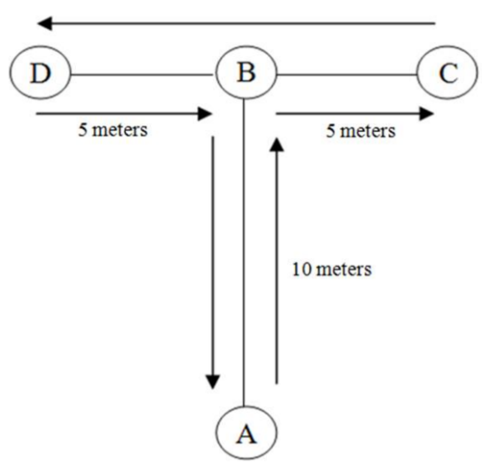

Figure 1. Agility t Test procedure.

On the third day, 20 and 40 m sprints and one repetition maximum leg press ($1RM_{LP}$) were measured. The subjects in the intervention group performed their presprints and postsprints on a hard even surface in an indoor facility. Participants commenced each sprint from a standing (static) position in which they positioned their front foot 50 cm behind the start line. Subjects decided themselves when to start each run with the time being recorded when the subject intercepted the photocell beam. Subjects were instructed to sprint as fast as possible through the distance. Times were recorded by photocells (JBL Systems, Oslo, Norway) placed at the start line and after 20 m, and 40 m (Asadi & Arazi, 2012; Rimmer & Sleveret, 2000). The test-retest reliability for 20 and 40 m sprints were 0.94 and 0.97, respectively.

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Maximal muscular strength was assessed as a voluntary one repetition maximum (1RM) using the bilateral inclined leg press (LP) exercise (Body Solid, GLPH 1100, USA). The subjects performed a light set of 8 to 10 repetitions. This was followed by a second set of six to eight repetitions with a heavier weight (50 to 60% 1RM). The subjects then completed a subsequent two repetition sets of increasing load until only one repetition could be performed despite attempting a second repetition. This testing protocol usually required a total of five to seven sets. The LP exercise was standardized so that all subjects lowered the weight to a knee joint angle of 90° before initiating the concentric phase of the lift and the weight sliding obliquely at 45º. Three to five minutes of rest was allowed between sets, and verbal encouragement was consistently provided (Arazi & Asadi, 2011; Saez Saez de Villarreal et al., 2008). The test-retest reliability for the $1RM_{LP}$ was 0.93.

All testing sessions were supervised by certificated instructors (NSCF). To determine the reliability of the measurements, two measurements of variables were made in 10 subjects. The reliability of the measurements was tested in two sessions, 48 h apart from each other, in the same 10 subjects.

Plyometric Training

The plyometric training groups performed depth jump exercise on sand twice per week for six 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 (Asadi & Arazi, 2012; Miller et al., 2006; Adams, O'shea, O'shea & Climstein, 1992; Mirzaei, Norasteh & Asadi, 2013; Thomas, French & Philip, 2009). Each training session lasted 35-min, including 10-min warm-up (e.g., jogging, stretching and ballistic exercises), 20-min training, and 5-min cool-down (e.g., jogging and stretching exercises). Plyometric training sessions separated with 48 h for PT48 and with 72 h for PT72. The PT48 and PT72 completed the same amount of total jumps during intervention (5 sets of 20 repetitions in each training session), used the same surface (20 cm dry sand) and time of day (afternoon) for training, with the same rest intervals between jumps (8 sec) and series (2 min). Participants performed plyometric training barefoot, because most sports activities on sand surface are performed without shoes (Miyama & Nosaka, 2004; Bishop 2003). The DJ training was began by standing on a 45-cm plyometric box and were instructed to lead with 1 foot as the subjects stepped down from the box and land with 2 feet on the sand. Instantly upon sand contact, subjects were instructed to "explode" off the sand by jumping as quickly and as high as possible. Subjects were instructed to perform exercises in each training session with maximal effort (Thomas et al., 2009; Gehri, Ricard, Kleiner & Kirkendall, 1998). A Certified Strength and Conditioning Specialist (NSCF) checked for correct technique of DJ training at all training sessions. Adherence to training was 100%, as each subject completed 12 workouts. Missed workouts were made up during a scheduled rest day. During the familiarization week, a pilot was performed and found that all subjects could not perform jump more than 45 cm box. According to this note, this box height and the level of jump height were equated and therefore the intensity of exercise and eccentric stress was similar.

Statistical Analyses

All values are presented as mean ± SD. The magnitude of changes was assessed by effect size (the difference between pretest and posttest scores divided by the pretest standard deviation). Data normality was checked with Shapiro-Wilk test. To determine the effects of intervention on performance adaptations, a two-way repeated measure was applied. When a significant F value was achieved, Bonfferoni post hoc test was performed to locate the pairwise differences between the means. The level of significant was set at $p \leq 0.05$. The statistical tests were performed using the SPSS statistical package version 16 (Chicago, IL, USA).

RESULTS

The data analysis showed that after training both plyometrically trained groups demonstrated a statistically significant increase in VJ, SLJ, TT, 20 and 40 m sprints, and $1RM_{LP}$ performance, with differences between groups in 40 m sprint and TT ($p \leq 0.05$). Also, the magnitude of change was compared and revealed that the changes in all tests were greater for PT72. More details about the performance adaptations following plyometric training are presented in figure 2.

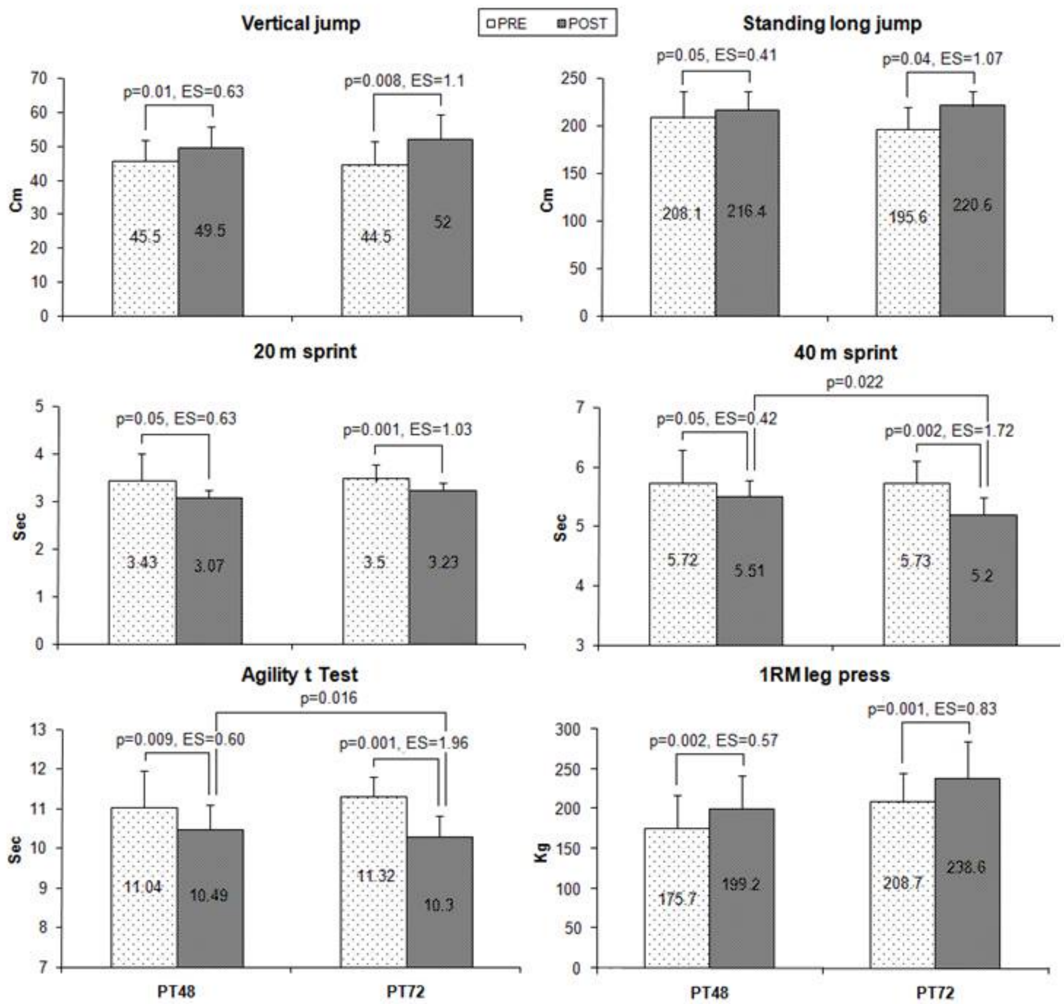

Figure 2. Pre to post changes in muscular performance adaptation tests for the PT48 and PT72. Values are mean ± SD.

DISCUSSION

This study was the first study that compared sand plyometric training with 48 and 72 h of rest between training sessions on muscular adaptations. The present investigation suggests that six weeks of plyometric training on sand, with either 48 or 72 h of rest between sessions, induced significant improvements in VJ, SLJ, 20 and 40 m sprint times, agility TT and $1RM_{LP}$ performances in collegiate physically active students. Also, the findings of the current study show that the PT72 group gained greater than PT48 in sprint and agility. In addition, with regard to ES, the magnitudes of improvements were greater for PT72 in all

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performance tests. It has been well recommended that plyometric training sessions should not be performed on consecutive days (Diallo, Dore, Duche & Van Praagh, 2001; Wathen 1993) and some interventions used > 48 h of rest between plyomtric training sessions to allow for adequate recovery, suggesting that these time of rest would be necessary to induce adequate training stimulation and recovery (Chu 1998; Diallo et al., 2001; Wathen 1993). In this study, both the PT48 and PT72 showed significant improvements in performance tests, there were also significant differences between groups in 40 m sprint and agility which revealed that 72 h of rest between sand plyometric training sessions is appropriate time to adequate and resulting greater muscular performance adaptations.

Therefore, several possible mechanisms can be postulated to understand how this relatively 72 h rest period between plyometric training sessions allow significant power and strength performance adaptations in short-term (6-week) when plyometric training was applied two times a week on sand surface. Some of these are: changes in the contractile apparatus of the muscle fibers, better neural adaptations such as leg muscle activation strategies, inter-muscular coordination, stretch reflex excitability, greater changes in muscle architecture (i.e. a decrease in fascicle angle and an increase in fascicle length of knee extensors), and better changes in stiffness of various elastic components of the muscle-tendon complex (Saez Saez de Villarreal et al., 2009; Markovic & Mikulic, 2010; Adams et al., 1992; Thomas et al., 2009; Gehri et al., 1998; McClenton, Brown, Coburn & Kersey, 2008). It was once study that examined the influence of different rest between training sessions on sand on muscular performance. Further studies are necessary to elucidate the underling mechanisms that allow physically active men to obtain significant muscular performance adaptations of sand plyometric training. Moreover, more knowledge is vital for athletes of different sport disciplines responses to plyometric training on sand.

The both treatment groups significantly increased jumping ability such as VJ and SLJ, with no statistically significant difference between groups. The significant enhance in jump performance in VJ and SLJ tests confirms the effectiveness of the application of sand depth jump phyometric training stimulus in achieving explosive straining adaptations. These findings are in line with previous studies that found significant improvements in jumping performance following depth jump plyometric training (Saez Saez de Villarreal et al., 2009; Markovic, Jukic, Milanovic & Metikos, 2007; Adams et al., 1992; Thomas et al., 2008; Gehri et al., 1998; McClenton et al., 2008) and or sand plyometric training (Impellizzeri et al., 2008). In contrast, Herrero, Izquierdo, Maffiuletti, and Garcia-Lopez (2005) did not find significant increases in jump via horizontal and depth jump training. The improvement observed could have been induced by various neuromuscular adaptations such as: increasing the degree of muscular coordination, increasing inhabitation of antagonist muscles as well as activation and co-contraction of synergistic muscles and “motor unit functioning” (Markovic & Mikulic, 2010; Mirzaei et al., 2013; Thomas et al., 2009; Gehri et al., 1998; McClenton et al., 2008) but because no physiological measurements were made, only speculations are possible.

Significant decreases in 20 and 40 m sprint times and agility t Test in PT48 and PT72 suggested that plyometric training on sand may be a meaningful stimulus for the acceleration ability. Moreover, there were significant differences between PT48 and PT72 in 40 m sprint and agility performance. These results agree with those previously reported significant increases in agility and sprint performance (Arazi et al., 2012; Arazi & Asadi, 2011; Asadi & Arazi, 2012; Saez Saez de Villarreal et al., 2008; 2009; 2010; Saez Saez de Villarreal, Requena & Cronin, 2012; Rimmer & Sleveret, 2000; Miller et al., 2006), but on sand plyometric training, only Impellizzeri et al. (2008) reported significant benefits of sand plyometric training on sprint performance. The nature of the plyometric training (interaction in foot contact time between depth jump training and sprint and agility movements) stimulus in these studies studies may help explain the increased acceleration sprint and agility performance (Rimmer & Sleveret, 2000; Thomas et al., 2009). In addition, the sufficient of rest between training sessions (72 hours) induced greater increases in agility and sprinting ability. Sprint and agility tasks require a rapid switch from eccentric to concentric muscle action in the leg extensor muscles (i.e. the SSC muscle function). Thus, it seems that plyometric training can decease ground reaction test times through the increase in muscle force output and movement efficiency, therefore positively affecting sprint and agility performance (Markovic & Mikulic, 2010; Thomas et al., 2009).

Both the training groups increased $1RM_{LP}$ significantly, whereas no significant differences were observed between groups. Several studies have demonstrated improvements in strength via plyometric training (Arazi & Asadi, 2011; Saez Saez de Villarreal et al., 2008; 2010; Markovic & Mikulic, 2010). In contrast, a number of authors failed to report significant positive effect of plyometric training on strength (Markovic et al., 2007). 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 shown the importance of plyometric training for improving vertical jump and sprint performance (Arazi et al., 2010; Arazi & Asadi, 2011; Gehri et al., 1998). The strength increases are supported by previous studies, which have shown the effectiveness of plyometric training for developing power resulting muscular strength enhances (Arazi & Asadi, 2011; Saez Saez de Villarreal et al., 2008). 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 training on sand may have contributed to an increase in $1RM_{LP}$ performance in our investigation (Arazi & Asadi, 2011; Saez Saez de Villarreal et al., 2008; 2010; Markovic and Mikulic, 2010). Performing plyometrics on sand develops larger and stronger leg musculature and causes more energy to be spent per unit of time than hard ground. Sand acts as a resistance that provides longer time under tension to the muscles and involves more muscle fibers in order to jump, which is a precursor to muscle strength increase (Impellizzeri et al., 2008; Giatsis et al., 2004; Bishop 2003).

In conclusion, PT48 and PT72 groups achieved significant improvements in power type muscular performance after training and these improvements were greater for PT72. Therefore, when two plyometrci training sessions are performed on sand each week, 72 h of rest between these is adequate to induce significant explosive power adaptations and allow to adequate recovery in physically active men. Improving muscular performance is of the utmost importance to strength and conditioning professionals. Speed and jumping ability, agility and strength are vital to success in most sports. The results of the present study suggest that the depth jump training on sand is viable training accessory that can be used to enhance muscular performance over a 6-week training period. The results of this study highlight the potential of using sand plyometric training to improve jumping and sprinting ability, agility and strength and also rest between training session in important and it appear that 72 h of rest between training sessions is appropriate time to allow for "adequate recovery" and resulting greater muscular adaptations than PT48. Thus, it can be recommended that, coaches and strength and conditioning professional design plyometrics on sand with > 48 hours of rest between training sessions.

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