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The influence of varied rest intervals after plyometric exercise on maximum squat performance

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Abstract. The purpose of this study was to compare the effects of a plyometric exercise on 1 repetition maximum (1RM) squat performance after short (15, 30 second) and long (60-second) rest interval following plyometric training in trained male athletes. The subjects were fifteen trained men [age= 22±1.4 years, Mass=80.61±3.20 kg] who had previous experience in strength training and experience performing plyometric exercises. All subjects performed 4 testing sessions and separated by at least 1 day of rest. Before all testing sessions subjects participated in a warming-up program and it kept constant through all testing sessions. During the first testing sessions, 1RM was assessed in back squat and during the depth jump sessions subjects performed in counterbalanced order a set of 2 depth jump (DJ) 15, 30, or 60-second before each 1RM attempts. One-way repeated analyses of variance with Bonferroni post hocs demonstrate significant differences between 1RM in baseline measurement and DJ sessions ($P<0.05$). Also, 1RM in back squat significant improved ($P<0.05$) after 15-second (2.74 %) and 30-second (2.43%) post a set of 2 depth jump. Therefore, these data provides support for the use of plyometric exercise 15 to 30-second before 1RM test to improve maximum strength performance.

Keywords: Plyometric exercise, Rest interval length, One-repetition maximum

Introduction

Muscular strength is defined as the maximal force exerted by a muscular or muscle group at a specific velocity. Measurement of strength applies to the monitoring of improvement during a resistance-training program giving such resistance-training program are used by individuals of all ages and health status, correct evaluation of strength is a necessity. Muscular strength test is a common assessment which is used to evaluate the strength of athletes.

Athletes are often instructed to engage in some type of physical activities or warm-up before any type of strength testing (Masamoto, et. al., 2003). The benefits of warm-up relates to the increasing of the muscle temperature and energy metabolism, tissue elasticity, cardiac output, peripheral blood flow, and finally improving the functions of the central nervous system and neuromuscular recruitment of motor units (Robergs et. al., 2000).

There are two types of warm-up: non-specific and specific. Non-specific techniques involve movements are not directly related which must the actual activity to be performed, while specific warm-up includes practice of the activity or exercise to be performed (Chu, 1996). Another form of warm-up includes the use of a maximal or near-maximal activity to enhance the strength and power performance which has been termed "muscle postactivation potentiation , and appears to be more common in the experienced resistance-trained athletes than in the recreationally-trained population (Chiu et. al., 2003). It is believed that postactivation potentiation (PAP) can enhance the muscle performance by increasing the neural signal that activates the muscle (Hamada et. al., 2000).

The methods used to induce PAP in humans vary; however, they are mainly comprised of either an isometric maximum voluntary contraction (MVC) (Gullich, 1996) or a dynamic movement that involved either high force, low velocity movements such as a squat or bench press (Hkysomallis and Kid-gell, 2001) or low force, high velocity movements such as hopping or jumping (Masamoto, et. al., 2003).

Although, vertical jump performance is a common method to assess the PAP level; however, other protocols jumping such as 1RM squat (Masamoto et. al., 2003), explosive push-ups (Hkysomallis and Kid-gell, 2001) and loaded countermovement jump (Mcbride et. al., 2005) have also been used.

Depth jumps are an exercise of short duration and high intensity, therefore, the primary energy system is the phosphagen. Depth jumps have been demonstrated that to be more effective way to increase power output, force production, and jumping performance than other vertical plyometric exercise such as countermovement jumps (Read and Cisar, 2001).

Read and Cisar (2001) studied the effects of 15, 30, and 60-second rest on depth jump performance over 3 sets of 10-depth jumps; results showed that a 15-second rest interval is sufficient for recovery during the performance of depth jumps.

Masamoto, et. al., (2003) examined the acute effects of plyometric exercise on 1-reptition maximum squat performance in trained male athlete, that subjects participated in 3 testing sessions that in first testing session 1RM in back squat was assessed and during second and third session performed 3-double-leg tuck jumps or 2 depth jumps 30-seconds before each 1RM attempt. Results indicated that the performance of depth jump before 1RM squat testing resulted in a significantly greater 1RM lift than did the first testing session [none-plyometric session]. Whether this postactivation muscle potentiation occurs immediately after 1-RM squat testing or how long it is sustained following maximal squat testing is not clear through this examination.

In addition, the influence of different stretching programs and plyometric exercise on jumping ability and maximal strength continues to be researched (Young et. al., 2001), and many study have addressed the influence of different rest interval length on metabolic (Kraemer et. al., 1987), hormonal (Kraemer et. al., 1993), cardiovascular (Fleck, 1988) and training volume (Rahimi, 2005), but to our knowledge, no studies have addressed the effect of different recovery periods (15, 30, and 60-second) between the end of the plyometric exercise and the beginning of the 1RM strength test. From a training perspective, more specific information related to the effect of plyometric exercise on 1RM strength would be useful to coaches, trainers and athletes that designed strength training program and as well as has application to the monitoring of improvement during a resistance-training protocol and to optimizing 1RM tests. Therefore, the purpose of this study was to examine the influence of varied rest interval length after plyometric exercise on 1RM squat performance.

Material and Methods

Subjects : A group of 15-male athletes volunteered for this study [age=22±1.4 years, body mass=80.61±3.20 kg]. All subjects were members of the basketball teams and participated regularly in basketball practice. They also had experience in strength training along with plyometric exercise at least 3 years. The subjects signed a human subject's informed consent form before participating in this study and received all the necessary information about the study procedures in oral and written form. The subjects did not perform strength-training or plyometric exercise for the lower body during the study period.

Testing Procedures: Data collection occurred over a period of 4 sessions with 1 testing session each day and separated by at least 1-day of rest. In the first session 1RM in the back squat exercise was determined via preliminary testing. The squat was performed in a power cage. The pins in the power cage were adjusted to allow the subject to descend to the point where the tops of the thighs were parallel to the floor. A successful parallel squat required descending by flexing the knees and hips until the proximal head of the femur reached the same horizontal plane as the superior border of the patella. An attempt was considered successful when the movement was completed through a full range of motion without deviating from proper technique and form. Spotters were present to provide verbal encouragement and safety for the subjects.

Warm-up consisted of performing low-intensity aerobic exercise [5-minute of stationary cycling at a "comfortable pace] followed by 6 lower-body static stretching (Masamoto, et. al., 2003), and it kept constant throughout all testing sessions. During the next 3 testing sessions, subjects performed 2 depth jumps with 15, 30 and 60-second rest interval before each 1RM attempt. A counterbalanced procedure was used to determine the order of the rest interval length after plyometric exercise for each testing session. The depth jump is a high-intensity plyometric exercise performed by stepping from a box to the floor with both feet and then immediately jumping as high as possible, for the purpose of this study a 45-cm box was used (Masamoto, et. al., 2003). All subjects had previous experience on performing the depth jump as used in this study. The plyometric exercise that used in this study had the same posture with the squat exercise and is biomechanically comparable to the squat exercise (Chu, 1996).

Statistical Analyses: The results were analyzed with SPSS11.5 statistical software. The 1RM in squat exercise from the different sessions were compared using a one-way analysis of variance [ANOVA] with repeated measures. The alpha level was set at 0.05 in order for a difference to be considered significantly. Interclass reliability was assessed among the last 4 testing sessions. When a significant effect was detected, a pairwise comparison of the sessions was done using Bonferroni's post hoc test to identify the important significant differences among sessions

Results

The results for the 1RM squat in the first testing session and the sessions in which subjects performed depth jump with different recoveries before1RM squat test are listed in table 1. Performance of a 2 DJ resulted in significant differences in maximal squat

Table 1. Mean (±SD) values for 1RM in back squat

Sessions			
Non-plyometric	*Plyometric*		
1RM	1RM, 15-Sec Post-Plyometric	1RM, 30-Sec Post-Plyometric	1RM, 60-Sec Post-Plyometric
153.2 ± 2.8 Kg†¶	157.4 ± 1.59 Kg*†	156.3 ± 2.43 Kg£¶	153.13 ± 2.89 Kg*£

* Significant difference between 1RM squats in 15- and 60-second rest conditions ($p < 0.05$).
£ Significant difference between 1RM squats in 30- and 60-second rest conditions ($p < 0.05$).
† Significant difference between 1RM squats in 15- second rest conditions and first session ($p < 0.05$).
¶ Significant difference between 1RM squats in 30- second rest conditions and first session ($p < 0.05$).

performance. Improvements in maximal squat performance appear to occur within 15 (2.74%) to 30 (2.43%) second of plyometric exercise. Significant differences were also observed between maximal squat performance in 15 and 60 second (P=0.001), 30 and 60 (P= 0.006), but there was no significant differences between 15 and 30 second (P>0.05), 60 second and first session (P>0.05).

Discussion

The results demonstrated that, if plyometric exercise was performed 15 to 30- second before 1RM testing, it could significantly enhance maximum squat performance in athletes. In this study plyometric exercise was performed before a maximum squat performance with 15, 30 and 60-second rest between plyometric exercise and 1RM squat performance. Masamoto, et. al., (2003) reported that plyometric exercise significantly increased the maximaum strength performance (1RM Squat), as well as results of our study supported this report. In addition, our findings showed that in order to optimize this effect plyometric exercise should be performed 15 to 30-second before 1RM testing.

The exact mechanism responsible to increase the 1RM squat performance 15-30 second post plyometric protocol is not clear. However, the mechanism which enhanced the contractile properties of the muscle is more likely to be related, either the theory of phosphorylation of light chain myosin, as suggested by Sale (2002) or by an increased level of excitation of active motor unites (Gulljch, et. al., 1996).

Young et. al. (1998) used a 5RM squat load for 1 set prior to a LCMJ and found that there was a 2.8% augmentation in jump height. Gullich et. al., (1996) found that average jump height was increased by 2.6% to 4.7%, depending on the nature of the MVC done prior to testing. Gourgoulis et. al. (2003) administered several sets of increasing-intensity half-squats and found that CMJ was improved by 2.39%. These researches have been shown that PAP response may be an effective way to temporarily increase athletics performance. Our findings are consistent with this fact and showed that plyometric exercise elicited PAP response to promote maximal strength performance.

Based on previous research (Gulljch et. al., 1996; Hamada, et. al., 2000), it was speculated that initiate PAP may be related to training mood, intensity, volume, and recovery period between the end of the conditioning activity and the beginning of the performance (Bishop 2003, Sale 2002). Our results showed recovery period between the end of the conditioning activity and the beginning of the performance as a strategy to optimize PAP and subsequent maximal strength performance enhancement.

Read and Cisar, (2001) reported that 15-second rest interval would be enough for recovery between depth jumps as well as our study showed low-rest interval length [15 to 30-second rest] may be enough for recovery between depth jumps and 1RM attempt. Our findings showed that in situations that 15-seconed or 30-second rest interval was used between a set of 2 depth jump and a 1RM squat performance resulted significant increaseing in 1RM squat performance by 4.2 kg [2.74%] and 3.7 kg [2.43%] respectively than the first testing session that performed without plyometric exercise. In addition when rest interval length between plyometric exercise and 1RM attempt was longer [60-second rest], positive significant effect of plyometric exercise on maximal strength performance was not observed.

Masamoto, et. al., (2003) concluded that only high intensity plyometric exercises could enhance neural stimulation to a level that would significantly increase maximal muscle strength and Deschenes (1989) reported that higher-threshold motor units [fast-twitch muscle fibers] were recruited only when higher-power outputs were demanded. The volume of the plyometric exercise used in our study was consisting same as which Masamoto, et. al., (2003) used, therefore, the volume kept to guard against exercise-induced fatigue, which could lead to deterioration in neuromuscular performance (Komi, 2000). This study support's the use of plyometric exercise 15 to 30-second before 1RM test to initiate PAP and subsequent enhancement in maximum strength performance.

In summary, the results of this study suggest that the use of warm-up protocol that includes plyometric exercise with short recovery could be beneficial for maximal strength performance enhancement. However, the unique findings were recovery period between the end of the conditioning activity and the beginning of the performance to create PAP. From this study it appears that in order to induce optimal performance enhancement, setting short recovery period (15-30 second) between the end of the warm-up and the beginning of the performance could provide the greatest benefit for the maximum strength performance. Because the relationship between the level and method of potentiality necessary to augment performance is variable, researchers and sport coaches will have to determine what the optimum warm-up for their individual athlete could be to maximize gains.

Practical Application

Our findings do support previous studies that have demonstrated the positive effect of post activation muscle potentiality (Gourgoulis et. al., 2003; Hamada et. al., 2000; Masamoto, et. al., 2003). This has important implications for the increasing of athletic testing protocols. Based upon these findings it is recommended that performance of the plyometric exercise precede 1-RM squat test to maximize maximal strength performance in athletes.

Coaches and trainers should consider the potential impact of pre-event plyometric exercises on muscular strength when measurement of 1RM strength should be emphasized. When rest interval length between plyometric exercises and 1RM attempt was longer than 30-second [about 60-second] significant effect was not observed, therefore, it was concluded that there was an important relationship between short rest interval length after a plyometric exercise as a warming-up procedure and muscular performance that could be due to neuromuscular stimulation; although in our investigation, neuromuscular mechanisms related to the effects of plyometric exercise and rest interval length on maximum strength performance was not evaluated.

Results of our investigation related to lower extremity in order to generalization of this idea to another part of the body recommended that future studies be researched on the impact of plyometric exercise on 1RM performance in upper body. In addition, results of our investigation related to trained men that had performed strength training and plyometric training previously, therefore the testing protocols had used in this study did not recommend non-athletes or beginners with limited strength training experience due to the potential for injury, and these results may not be applicable to women because all subjects in our study were men.

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