FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 5, N° 2, 2007, pp. 163 - 169

Scientific Paper

THE ACUTE EFFECTS OF HEAVY VERSUS LIGHT-LOAD SQUATS ON SPRINT PERFORMANCE

UDC 796.42.12:132

Rahman Rahimi

Department of Physical Education & Sport Science,
Islamic Azad University of Mahabad, Mahabad, Iran
E-mail: Rahman.Rahimi@yahoo.com

Abstract. *The aim of this study was to determine whether performing heavy versus light-load squats prior to sprinting would improve running speed. Twelve elite soccer league players (Age, 22.4 1 years; height, 178 5 cm; body mass, 89 12 kg) performed two sets of four repetitions using light (LS=60% of 1RM), moderate (MS=70% of 1RM), or heavy load squats (HS=85% of 1RM) and a control (C) warm-up condition on randomized separating conditions over the course of two weeks. After a 4-minute post-warm up, the subjects completed a timed 40-meter sprint. The results of this study indicated that the running speed had improved significantly (P<0.05) after LS (-1.9%), MS (-1.77%), and HS (-2.98%) warm-ups compared to C. When compared to squat protocols, significant differences were observed between LS (60% of 1RM) and HS (85% of 1RM) only. The data from this study suggest that performing squats prior to sprinting may improve 40-m sprint times. However, in order to induce optimal running speed enhancement, it is necessary to set the intensity of the warm-up protocol with high-dynamic loading intensities (> 80% of 1RM).*

Key words: *warm-up, sprint, postactivation potentiation*

1. INTRODUCTION

The purpose of the warm-up is to prepare the athletes to execute the training program. During the warm-up, body temperature increases, which is considered to be one of the main functions of facility factors that has a positive effect on muscles, tendons and ligaments. A large amount of research on warm-ups was conducted during the 1950s, '60s, and '70s (Asmussen & Boje, 1945; Bobbert, 1990; Elam, 1986, Pacheco, 1957; Richards, 1968). There are 2 types of warm-ups: the nonspecific and specific type. Nonspecific techniques involve movements not directly related to the actual activity which is to be performed,

Received September 9, 2007

whereas specific warm-up includes practice of the activity or exercise which is to be performed (Chu, 1996). Another kind of warm-up, known as potentiation or postactivation potentiation (PAP) is defined as an increase in the contractile ability of muscles after a bout of previous contractions; it has recently received an increased amount of attention. The methods used to induce PAP in humans vary; however, they mainly consist of either an isometric maximum voluntary contraction (MVC) (Gullich, 1996) or a dynamic movement that involves either high force, low velocity movements such as a squat or a bench press (Hkysomallis et al., 2001; Jensen & Ebben, 2003) or low force, high velocity movements such as hopping or jumping (Masamoto et al., 2003; Radcliffe et al., 1996).

Although the exact mechanism or mechanisms that initiate the PAP are still being researched, one common PAP mechanism theory involves the concept of myosin light chain phosphorylation, in which the actin-myosin interaction is more sensitive to the release of Ca^{2+} than the sarcoplasmic reticulum (Sale, 2002). It is speculated that the PAP can enhance the ability of a motor unit to achieve discharge by creating a condition in which the release of neurotransmitter substances at chemical synapses from la afferents is at a higher level prior to voluntary contraction (Lev-Tov et al., 1983)

Gullich and Schmidtbleicher (1996) used unilateral, isometric leg-press trials that were 5 seconds in duration at a hip angle of 95° and a knee angle of 120° with varying number of sets and rest periods in order to elicit a PAP response. It was determined in this study that a protocol of 3 MVCs 5 minutes apart and 3 minutes before testing produced the best results. In a study by Young and Elliot (2001), a protocol similar to the one used by Gullich and Schmidtbleicher (1996) was used to elicit the PAP; however, a short rest period (30 seconds) may have lead to fatigue, canceling out the potentiation and therefore resulting in no significant increase in performance.

Dynamic protocols as used by Radcliffe and Radcliffe (1996) included a comparison of 2 different potentiating protocols, 1 utilizing a squat and 1 a snatch. They found that only athletes who performed the snatch protocol achieved a statistically significant increase in the distance of the horizontal jump. Studies by Gourgoulis et al. (2003), Jensen & Ebben (2003), and Young et al. (1998) all used back squats involving various types of loading to initiate the PAP, and all of these methods appeared successful in eliciting the PAP.

The vertical jump is a common method of assessing the PAP level; however, protocols other than jumping have also been used. Masamoto et al. (2003) investigated the influence of PAP on 1 repetition (1RM) squat strength; in the case of upper body potentiation, Hkysomallis & Kid-gell (2001) used explosive push-ups as a dependent variable and recently, Mcbride et al. (2005) investigated the effects of heavy-load squats and the loaded countermovement jump (LCMJ) on sprint performance. They concluded that using a heavy load squat may improve performance but the LCMJ appears to have no significant effect. To date no studies have compared the acute effects of heavy versus light-load squats on a repeated ballistic movement activity such as sprinting. Using a potentiation protocol to enhance sprint performance could provide vital information, because running speed is critical in many athletic events. The purpose of this study was to determine the acute effects of heavy versus light-load squats on 40-m sprint performance.

Experimental Approach to the Problem

The primary research hypothesis of this investigation was that a dynamic resistance movement protocol would improve sprinting performance. Each subject participated in 4 testing sessions, randomized and counterbalanced over a two-week period, involving the 3 potentiation protocols (light load squat, moderate load squat vs. heavy load squat) and the C protocol, in order to assess the effects of different squat training on a 40-m sprint performance, and which acted as its own control group. A rest period of at least 2 days was given between testing sessions to allow adequate recovery time. The potentiation protocol consisted of two sets of four repetitions using light (LS=60% of 1RM), moderate (MS=70% of 1RM), and heavy load squats (HS=85% of 1RM).

2. METHODS

Subjects

Twelve trained football players volunteered for this study (age, 22.4 ± 1 years; height, 178 ± 5 cm; body mass, 89 ± 12 kg). All of the subjects were familiar with the Squat protocol as part of their strength and conditioning training program. Additionally, the running of a 40-m sprint was part of their athletic testing throughout the season. The subjects signed a human subject's informed consent form before participating in this study and completed a medical history questionnaire in which they were screened for any possible injury or illness. Subjects participated in 4 testing sessions, randomized and counterbalanced over a 2-week period, involving the 3 potentiation protocols (Light load squat, moderate load squat vs. high load squat) and the C protocol, in order to assess the effects of different squat training on a 40-m sprint.

1RM testing

One repetition maximum for the back squat was determined using the protocol outlined by Baechle and Earle (2000). 1RM in the back squat exercise was determined during 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. Once the 1RM was determined, 85, 70, and 60% of the subject's 1RM was selected for the loads used in testing (Table.1).

Table 1. Descriptive characteristics of the participants

Characteristic	Mean	SD
Age (Y)	22.4	1.0
Height (cm)	178	5
Body Mass (kg)	89	12
1RM (kg)	183	16

PAP protocol

All of the participants completed 4 different warm-up protocols (LS, MS, HS, and C) and were tested on the 40-m sprint test after each warm-up. The subjects wore the same shoes for each testing session. In order to control the possible effects of a ballistic warm-up on the performance, all of the subjects completed a 5-minute warm-up on a recumbent stationary bike at standardized resistance at a cadence of 70 rpm (McBride et al., 2005). Following this, the subjects walked slowly for 4 minutes to maintain body temperature. The PAP protocols involved two sets of four repetitions of the squat with light load (LS=60% of 1RM), moderate load (MS=70% of 1RM), and heavy load squat (HS=85% of 1RM). Each set was separated by a two-minute rest period. Subjects were given a four-minute walking recovery before going on to the PAP assessment portion (40-m sprint test) of the study. For the C protocol, the subjects completed the five-minute warm-up, followed by the four-minute walking period and then proceeded directly to the assessment portion of the testing.

40-m sprint test

The sprint time for the 40-m sprint was measured using a stopwatch (Sportline 410 Alpha Sport Stopwatch, RYP Sports, Inc). No assistance such as instructions on running or starting techniques was given during the PAP assessment portion of the study, nor was any encouragement given. The subject was instructed to run as fast as possible during the test and to make sure to run all the way through to the clearly marked finish line. The same indoor track surface was used each time; in addition, the subjects were instructed to wear the same shoes for each test.

Statistical Analyses

One-way analysis of variance (ANOVA) with repeated measures was used to determine whether there were significant differences in sprint time between the treatment groups. The 0.05 level was selected for the *F* significance. Post hoc tests (0.05) were conducted using the Bonferroni analysis. Each C performance was considered to be 100% of an individual subject's maximum performance. Performances from the treatment groups were converted to percentages of C. The results are summarized as mean ± SD (Table.2). All of the statistical calculations were performed using the SPSS program version 12.0 for Windows (SPSS Inc., Chicago, IL).

3. RESULTS

The ANOVA indicated significant differences among the running speed of the 4 groups ($F^{1,2,3,4}$=13.201, $P<0.001$). A post hoc procedure revealed that the running speed significantly improved ($P<0.05$) after LS (1.09%), MS (1.77%), and HS (2.98%) in comparison to C. Furthermore, the HS group performed significantly better than the LS group ($P<0.05$), (See Table. 2).

Table 2. Mean ± SD of 40-m running speed (second) of the four groups

Group	N	Mean	SD	Percent Change
Control	12	5.366	0.021	
Light-load squat	12	*5.307	0.016	- 1.09%
Moderate-load squat	12	*5.271	0.091	- 1.77%
Heavy-load squat	12	†*5.243	0.034	- 2.98%

*Significant differences compared to C at P<0.05.
† Significant differences compared to LS at P<0.05.

4. Discussion

A novel approach in this study was to examine the effect of an intensity loading range of three warm-up procedures (e.g., two sets of four reps. squat at 60, 70, or 85% of 1RM) to maximize sprint performance. The primary findings of this study indicate that an acute positive effect on sprint performance was promoted after a warm-up protocol including high-intensity resistance training (i.e., 70-85% of 1RM). An increase in muscle performance following a warm-up protocol showed an intensity-dependent relationship, which means the highest warm-up loading intensities can have the greatest positive effects on subsequent sprint performance enhancement.

The exact mechanism responsible for the decrease in 40-m sprint time post heavy-load squat (HS) protocol is unclear. However, the mechanism that enhanced the contractile properties of the muscle is more likely to be related either the theory of of myosin light chain phosphorylation, as suggested by Sale (2002) or by an increased level of excitation of active motor units (Gulljch et al., 1996; Lev-Tov et. al., 1983; Trimble & Harp, 1998).

Saez de Villarreal et al. (2007) administrated several warm-up protocols (the countermovement jump "CMJ" with and without the extra load (80-95% of 1RM) and the drop jump) and found the CMJ was improved by a high intensity dynamic loading protocol (e.g., 80, 95% of 1RM). 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 & Schmidtbleich-er (1996) found that the 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 the CMJ was improved by 2.39%. This research has shown that PAP response may be an effective way of temporarily increasing the CMJ. It must be borne in mind that a high CMJ correlates well with sprint velocity (Kukolj et al., 1999; Young et al., 1995). Based upon these findings, activities that promote a higher CMJ may have also been expected to promote a faster sprint time. Our findings are consistent with this fact and have shown that high intensity resistance training elicited a PAP response to promote sprinting performance.

Based on previous research (Gulljch & Schmidtbleicher, 1996; Hamada et al., 2000, Villarreal et al., 2007), it was speculated that initiating a PAP may be related to the 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 that warm-up intensity is a strategy for optimizing PAP and for subsequent sprint performance enhancement.

McBride et al. (2005) concluded that using a heavy load squat (1 set of 3 repetitions at 90% 1RM) may improve a performance but the LCMJ (1 set of 3 repetitions at 30% 1RM) appears to have no significant effect on sprint performance. In our study there were significant differences in running times after load squats (two sets of four reps. squat at 60, 70, or 85% of 1RM) as opposed to the results of the control group. This discrepancy in the results of the two studies may be due to training volume. McBride et al. (2005) used low volume of work in comparison to the one used in this study; therefore, it can be concluded that a high volume of work may be needed to create the PAP so that selective recruitment of fast-twitch muscles can occur.

In summary, the results of this study suggest that using of warm-up protocol which includes resistance training with a sub-maximal load may be beneficial for running speed performance enhancement. However, the unique findings were the intensity and volume of work to create the PAP. From our study as well as other ones, it would appear that in order to induce optimal performance enhancement, setting the intensity of the warm-up protocol with heavy-dynamic loading intensities (>80 of 1RM) may provide the greatest benefit for running speed. Because the relationship between the level and method of potentiation necessary to augment performance varies, researchers and sport coaches will have to determine what the optimum warm-up for their individual athlete may be to maximize gains.

PRACTICAL APPLICATIONS

As could be expected, the entire resistance training protocol had a significant effect on running speed. This should be accounted for by the use of squat exercises in order to induce optimal running speed enhancement. However, this study showed that high intensity resistance training, 4 minutes prior to a 40-m sprint, induced greater degree PAP response than moderate or low intensity training, which results in a more pronounced running speed. This concept could be applied to any sport activity requiring a single bout of maximal running speed. Strength and conditioning practitioners should carefully consider the type of warm-up activity utilized for their athletes before various sporting activities. The objective is for the athlete to use resistance training during warm-up sprinting activities in order to recruit more motor units during the warm-up so that during the testing period, the subsequent contractions will provide larger power outputs.

Acknowledgements. *The author would like to express his appreciation to the subjects for their participation in this study, also to* ***Mr. Younes Rahimi*** *for his support throughout the course of this project.*

REFERENCES

1. AsMussen, E., & Boje, O. (1945). Body temperature and capacity for work. *Ada Phys Scand,* 10, 1-22.
2. Baechle, T. R., & Earle, R. (2000). *Essential of strength training and conditioning.* NSCA, Champaign, IL: Human Kinetics, 291-316.
3. Bishop, D. (2003) Warm-up II. Performance changes following active warm-up and how to structure warm-up. *Sports Med,* 33 (7), 483-498.
4. Bobbert, M.F. (1990). Drop jumping as a training method for jumping ability. *Sports Med,* 9, 7-22.
5. Chu, D.A. (1996). *Explosive Power & Strength*. Champaign, IL: Human Kinetics.
6. Elam, R. (1986). Warm-up and athletic performance: A physiological analysis. *NSCA J* 8, 30-32.
7. Gourgoulis, V.N., Aggeloussis, N., Kasimatis, P., Mavromatis, G. & Garas, A. (2003). Effect of submaximal half-squats warm- up program on vertical jumping ability. *J. Strength Cond Res,* 17 (2), 342-344.
8. Gullich, A., & Schmidtbleicher, D. (1996). MVC-induced short- term potentiation of explosive force. *New Studies in Athletics*, 11, 67-81.

9. Hamada, T., Sale, D.G., MacDougall, J.D., & Tarnopolsky, M.A. (2000). Postactivation potentiation, fiber type, and twitch con traction time in human knee extensor muscles. *J Appl Physio,* 88, 2131-2137.
10. Hkysomallis, C., & Kidgell. D. (2001). Effect of heavy dynamic resistive exercise on acute upper-body power. *J Strength Cond Res,* 15, 426-430.
11. Jensen, R.L., & Ebben, W.P. (2003). Kinetic analysis of complex training rest interval effect on vertical jump performance. *J Strength Cond Res,* 17, 345-349.
12. Kukolj, M., Ropret, R., Ugrakovic, D., & Jakic, S. (1999). Anthropometric, strength, and power predictors of sprinting performance. *J Sports Med Phys Fitness,* 39, 120 122.
13. Lev-Tov, A., Pintek, M.J., & Buhke, R.E. (1983). Posttetanic potentiation of group la EPSPs: Possible mechanisms for differential distribution among medial gastrocnemium motoneurons. *J Neurophysiol,* 50, 379-398.
14. Masamoto, N., Larson, R., Gates, T., & Faigenbaum, A. (2003). Acute effects of plyometric exercise on maximum squat performance in male athletes. *J Strength Cond Res,* 17, 68-71.
15. McBride, J.M., Nimphius, S., & Erickson, T.M. (2005). The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. *J Strength Cond Res* 19(4), 893-897.
16. Pacheco, B.A. (1957). Improvement in jumping performance due to preliminary exercise. *Res Q,* 28, 55-63.
17. Radcliffe, J.C., & Radcliffe, J.L. (1996). Effects of different warm-up protocols on peak power output during a single response jump task. *Med Sci Sports Exerc*, 28, S189.
18. Richards, D.K. (1968). A two-factor theory of the warm-up effect in jumping performance. *Res Q,* 39, 668-673.
19. Saez de Villarreal, E.S., Gonzalez-Badillo, J.J. & Izquierdo, M. (2007). Optimal warm-up stimuli of muscle activation to enhance short and long-term acute jumping performance. *Eur J Appl Physiol*, 100 (4), 393-401.
20. Sale, D.G. (2002). Postactivation potentiation: Role in human performance. *Exerc Sports Sci Rev,* 30, 138-143.
21. Trimble, M.H. & Harp, S.S. (1998). Post exercise potentiation of H-reflex in humans. *Med Sci Sports Exerc,* 30, 933-941.
22. Young, W.B., McLean, B. & Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *J Sports Med Phys Fitness,* 35, 13-19.
23. Young, W.B., Jenner, A. & Griffiths, K. (1998). Acute enhancement of power performance from heavy load squats. *J Strength Cond Res,* 12, 82-84.
24. Young, W. & Elliot, S. (2001). Acute effects of static stretching, proprioceptivc ncuromuscular facilitation stretching and maximal voluntary contractions on explosive force production and jumping performance. *Res Q Exerc Sport,* 72, 273-279.

AKUTNI EFEKAT ČUČNJEVA SA VELIKIM OPETEREĆENJEM U ODNOSU NA ČUČNJEVE SA MALIM OPTEREĆENJEM NA BRZINU TRČANJA U SPRINTU

Rahman Rahimi

Cilj ovog rada bio je da se odredi da li će vežbanje čučnjeva sa većim ili manjim opterećenjem imati bolji pozitivan uticaj na brzinu trčanja. Dvanaestorica elitnih fudbalera (godine starosti, 22,4±1 godina; visina, 178±5 cm; težina, 89±12 kg) vežbali su tokom perioda od dve nedelje po dva seta od po četiri ponavljanja čučnjeva sa malim opterećenjem (LS=60% 1RM), sa srednjim opterećenjem (MS=70% 1RM), ili sa velikim opterećenjem (HS=85% 1RM, kao i kontrolno zagrevanje (C) uz pomoć proizvoljno odabranih kriterijuma za podelu. Nakon dodatnih četiri minuta zagrevanja, ispitanicima je merena brzina na sprintu 40 metara. Rezultati ovog istraživanja pokazuju da je brzina trčanja značajno uvećana (P<0,05) nakon LS (-1,9%), MS (-1,77%), i HS (-2,98%) kao vidova zagrevanja u odnosu na obično zagrevanje C. Nakon poređenja protokola čučnjeva, mogu se uočiti značajne razlike samo između LS (60% 1RM) i HS (85% 1RM). Podaci koji su dobijeni u toku ovog istraživanja dovode nas do zaključka da vežbanje čučnjeva pre sprinta može da poboljša brzinu trčanja kod sprinta na 40 metara. Ipak, da bismo došli do optimalnog uvećanja brzine, neophodno je odrediti nivo intenziteta protokola zagrevanja uz pomoć visoko dinamičkog intenziteta opterećenja (> 80% 1RM).

Ključne reči: *zagrevanje, sprint, postaktivaciona potencijacija*