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The Effect of Plyometric Warm-Ups Applied in Different Sets Using Resistance Bands on Jump Performance

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Abstract

The aim of this study is to investigate the effect of vertical jumping performed in different sets using resistance bands with vertimax device on jump performance as a PAP warm-up stimulus. Fifteen athletes (age: 20.00±2.33; height: 175.07±7.23; weight: 68.71±14.36) from short and middle distances of athletics who have been doing exercise regularly at least 5 days a week for a minimum of 5 years were participated in this study. The athletes participating in this study were firstly warmed up on a treadmill at a speed of 8 km/h for 5 minutes and then 5 minutes of passive rest was applied. After the passive rest period, the athletes were randomly sampled and one of the PAP warm-up protocols consisting of 1, 2 and 3 sets of 10 repetitions with 80 lb resistance on the Vertimax device or without any resistance was applied. The athletes who performed any warm-up protocol were applied. The warm-up protocols that the athletes did not perform were randomly applied in at least 48 hours breaks. Repeated measures of ANOVA test were used to analyze the results of the variables of the athletes participating in the study. The results of the analysis showed that there are significant differences in squat and multi-jump values after warm-up protocols without applying any resistance and 1, 2 and 3 sets of PAP warm-up applications that consisting of 10 repetitions on the Vertimax device ($p<0.05$). The squat jump height values were found to be significantly higher in 1, 2 and 3 sets of PAP warm-up applications with resistance bands than warm-up protocols without applying any resistance ($p<0.05$). On the other hand, squat jump height values after 2 and 3 sets of PAP warm-up applications with resistance bands were found to be significantly higher than 1 set of PAP warm-up applications with resistance bands ($p<0.05$). The multiple jump height values were found to be significantly higher in 2 and 3 sets of PAP warm-up applications with resistance bands than warm-up protocols without applying any resistance ($p<0.05$). In conclusion, we can say that the vertical jump warm-up applications with resistance bands that includes different sets on the vertimax device as PAP stimulus have a significant effect on jump performance depending on the number of sets.

Keywords: Post activation potential, jumping, resistance bands

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Direnç Bantları Kullanarak Farklı Setlerde Uygulanan Pliometrik Isınmaların Sıçrama Performansına Etkisi

Özet

Bu çalışmanın amacı, vertimax cihazı ile direnç bantları kullanarak farklı setlerde uygulanan dikey sıçramanın PAP ısınma uyaranı olarak sıçrama performansına olan etkisini incelemektir. Çalışmaya minimum 5 yıldır ve haftada en az 5 gün düzenli olarak spor yapan atletizmin kısa ve orta mesafelerinden 15 sporcu (yaş: 20,00±2,33; boy: 175,07±7,23; kilo: 68,71±14,36) katılmıştır. Çalışmaya katılan sporculara ilk olarak koşu bandında 8 km/saat hızda 5 dk süren bir ısınma uygulanmış ve sonrasında 5 dk'lık pasif dinlenme gerçekleştirilmiştir. Pasif dinlenme sonrasında sporculara rastgele örneklem yöntemine göre herhangi bir dirençsiz ya da Vertimax cihazında 80 lb' lik dirençle 10 tekrardan oluşan 1, 2 ve 3 setlik PAP ısınma protokollerinden biri uygulanmıştır. Herhangi bir ısınma protokolünü gerçekleştiren sporcu gerçekleştirmediği ısınma protokolünü en az 48 saat ara vererek uygulamıştır. Çalışmaya katılan sporcuların değişkenlerine ait sonuçların analizinde tekrarlı ölçümlerde ANOVA testi kullanılmıştır. Yapılan analiz sonucunda; herhangi bir direnç uygulaması yapılmadan ve Vertimax cihazında 10 tekrardan oluşan 1, 2 ve 3 setlik PAP ısınma uygulamaları sonrası squat ve çoklu sıçrama değerleri arasında farkın anlamlı olduğunu göstermiştir ($p<0.05$). 1 set, 2 set ve 3 setlik direnç bantları ile yapılan PAP ısınması sonrası squat sıçrama yüksekliği değerleri dirençsiz yapılan ısınma uygulamasından anlamlı derecede yüksek bulunmuştur ($p<0.05$). 2 ve 3 set uygulanan PAP ısınması sonrası squat sıçrama yüksekliği değerleri 1 set uygulanandan anlamlı derecede yüksek bulunmuştur ($p<0.05$). Diğer yandan 2 ve 3 set uygulanan PAP ısınması sonrası çoklu sıçrama yükseklik değerleri dirençsiz yapılan ısınma uygulamasından anlamlı derecede yüksek bulunmuştur ($p<0.05$). Sonuç olarak, PAP uyaranı olarak vertimax cihazı ile direnç bantları kullanarak farklı setlerde uygulanan dikey sıçramanın set sayısına bağlı olarak sıçrama performansına etkisinin olduğunu söyleyebiliriz.

Anahtar Kelimeler: Post aktivasyon potansiyeli, sıçrama, direnç bantları

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1. INTRODUCTION

The warm-up is a preparatory training that athletes use to achieve high performance and protect from injuries during training and matches (Sotiropoulos et al., 2010). It is important for athletes to include warm-up exercises in their training programs, especially before they do intense training (Harmancı et al., 2017; Hawley et al., 1989; Shellock, 1983). Although the effects of different warm-up protocols on various sports activities have been examined (Alves et al., 2010; Andrews et al., 2011; Chatzopoulos et al., 2007; Gourgoulis et al., 2003; Hilfiker et al., 2007; Kilduff et al., 2007; Linder et al., 2010; Matthews et al., 2010), additional scientific studies are needed to examine the specific warm-up structures of athletes to achieve optimum performance (Lima et al., 2014).

Post activation potential (PAP) is defined as an advanced neuromuscular state in which observed an increase in muscle contraction force after a maximal or near-maximal contraction (Lima et al., 2014; Hodgson et al., 2005). Three hypotheses were stated describing the increase in sportive performance after PAP stimulus (Lima et al., 2014). The first hypothesis is that PAP stimulation makes the actin-myosin chain more sensitive to the calcium released from the sarcoplasmic reticulum, then stronger muscle contraction occurs by phosphorylation of the myosin regulatory light chains. (Lima et al., 2014; Tillin and Bishop, 2009; Hodgson et al., 2005). The second hypothesis is that preloading activities accelerate neural impulses by increasing the excitation potentials at the synaptic junction and spinal cord levels (Lima et al., 2014). Third hypothesis; preloading activity causes a change in the length of the muscle, resulting in a reduction in the pennation angle. Thus, this angular change may allow power to be transferred more directly from the muscle fiber to the tendon (Lima et al., 2014; Tillin and Bishop, 2009). In addition to the widespread studies using resistance tools (Bevan et al., 2010; Linder et al., 2010; Matthews et al., 2009), there are also studies using plyometric exercises as PAP stimulation Ciocca et al., 2021; Turner et al., 2015; Maloney et al., 2014; Till and Cooke, 2009; Kilduff et al., 2007).

While some of the studies using plyometric studies as PAP response indicated that subsequent performance improved (Ciocca et al., 2021; Turner et al., 2015; Kilduff et al., 2007), others found no significant difference (Till and Cooke, 2009, McBride et al., 2005). We can attribute this contradiction observed among studies to methodological differences (recovery time between PAP stimulus and subsequent performance, number of repetitions, number of sets, training background, etc.). Therefore, the purpose of this study was to investigate the effect of vertical jumping performed in different sets using resistance bands with vertimax device as a PAP warm-up stimulus on jump performance.

2. MATERIALS & METHODS

Research Group

Fifteen athletes (age: 20.00±2.33; height: 175.07±7.23; weight: 68.71±14.36) from short and middle distances of athletics who have been doing exercise regularly at least 5 days a week for a minimum of 5 years were participated in this study. Athletes who voluntarily participated in the study were informed about the study design and signed an informed consent form. This study was carried out after the ethics committee decision by Kütahya Dumlupınar University Social and Human Sciences Ethics Committee (03.05.2023-210). Informed consent form, regarding the process of the study and possible risks, was signed by the athletes participating in the study. Athletes were asked not to engage in intense physical activity, to adjust their sleep patterns and not to use alcohol or stimulants 24 hours before measurements performed during the study. Height and body weight measurements of the athletes were made just before the study started. In order to eliminate the effect of the day, all measurements were made between 09:00 and 11:00 in the morning.

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Data Collection Tools

Body Weight

Body weight measurements (with shorts, T-shirt and bare feet) of the athletes participating in this study were measured on a scale (Tanita HD 358, Tokyo, Japan) with an accuracy of 0.1 kg.

Body Height

Body height was measured with a wall mounted stadiometer (Holtain Ltd. U.K.) to the nearest 0.1 cm at anatomic standing structure, barefoot, head at frontal plane position.

Vertical Jump Measurements

The squat jump and 10 repetitive multiple jump measurements of the athletes were determined by vertical jump measurement device (Vert jump Brand Motion Sensitive Sensor; USA). The device consists of a belt wrapped around the waist of the person and a transmitter placed on the belt wrapped that determines the jump distance according to flight time. The measurements of the squat jump were started in a normal standing position (with both feet in contact with the ground). Then, subjects were asked to bend their leg at an angle of approximately 90° with free hands and to apply force as fast as possible to jump for maximum height. The measurements were repeated two times and the best measurement score was determined as the measurement result. At the end of the test, the jump distance values of the squat jump were recorded automatically by the software program of the device. The measurements of the 10-repetition multiple jumps were started in a normal standing position with free hands. After that, subjects were asked to bend their leg at an angle of approximately 110° and to apply force as fast as possible to jump for maximum height during a 10-repetition multiple jump test. The data in the transmitter is instantaneously transferred to the software program installed on the phone via bluetooth connection after the jump measurement.

Figure 1. PAP warm-up protocols consisting of 10 repetitions with resistance bands on the Vertimax® device

Post Activation Potential (PAP) Warm-Up Protocol

First of all, the athletes participating in the study applied a warm-up for 5 minutes at 8 km/h on a treadmill (Proforce Q3 Treadmill). After warm-up protocol on the treadmill, 5 minutes of passive rest was performed. Then, one of the 1, 2 and 3 sets of PAP warm-up protocols consisting of 10 repetitions with 80 lb resistance on the Vertimax device or no resistance was applied to the athletes according to the random sampling. The athlete, who made any warm-up protocol, applied the warm-up protocol that he did not perform at least 48 hours apart. After each PAP warm-up protocol, 5 minutes of passive rest was applied and then squat jump and 10 repetitive jump measurements were performed.

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Analysis of Data

The Kolmogorov-Smirnov test was used to conduct whether the data showed normal distribution or not. After the statistical analysis, we observed that the values of all variables had a normal distribution ($p>0.05$). Jump height results including squat and 10 repetition jump tests of the athletes were examined with repeated measures of ANOVA after the PAP warm-up applied by the athletes with 3 different sets using resistance bands or no resistance. If there was any difference between the measurements, The Bonferroni method can be used to compare different sets after the warm-up protocol. SPSS 17.0 package program for Windows was used for statistical analysis.

3. RESULTS

The results of the squat jump and 10 repetition multiple jump values of the athletes after the 1, 2 and 3 sets of PAP warm-up protocol consisting of 10 repetitions with resistance and without applying resistance are presented in Table 1.

Table 1. Repeated measure of ANOVA results of the athletes jumping values after pap warm-up protocol containing resistive jumping in different sets and without resistance

Variables	n	Without Resistance	1 Set PAP Warm-up	2 Set PAP Warm-up	3 Set PAP Warm-up	F	P
		Mean±sd	Mean±sd	Mean±sd	Mean±sd		
Squat Jump Height (cm)	15	59,41±11,15[a,b,c]	62,95±10,35[a,d,e]	65,20±10,46[b,d]	66,40±8,81[c,e]	14,295	0000
Mean Multiple Jump Heigth (cm)	15	51,11±9,49[a,b]	51,90±8,54	53,91±8,80[a]	52,84±8,76[b]	3,927	0,015

Repeated measures of ANOVA results showed that there was a significant difference in squat and multi-jump height values after the 1, 2 and 3 sets of PAP warm-up protocol consisting of 10 repetitions with resistance and without applying resistance ($p<0.05$). The squat jump height values were found to be significantly higher in 1, 2 and 3 sets of PAP warm-up applications with resistance bands than warm-up protocols without applying any resistance ($p<0.05$). On the other hand, squat jump height values after 2 and 3 sets of PAP warm-up applications with resistance bands were found to be significantly higher than 1 set of PAP warm-up applications with resistance bands ($p<0.05$). The multiple jump height values were found to be significantly higher in 2 and 3 sets of PAP warm-up applications with resistance bands than warm-up protocols without applying any resistance ($p<0.05$).

4. DISCUSSION AND CONCLUSION

PAP is a theory that states a muscle's history of contraction affects the mechanical performance of subsequent muscle contractions (Lorenz, 2011). It has been stated that fatiguing muscle contractions reduce muscle performance, but short-term, high-intensity, and less extensive loads of muscle contractions may increase muscle performance (Lorenz, 2011; Stone et al., 2008). In order to obtain an optimal power response after the PAP stimulus, variables that may affect the outcome must be taken into account. It has been reported that properties such as exercise type, recovery time, muscle characteristics, fitness level of the person, gender, training background, the protocol that implemented (Chatzopoulos et al., 2007), the intensity, volume and load of the stimulus that applied in related to PAP (Suchomel et al., 2016; Chatzopoulos et al., 2007) have an increasing effect on sportive performance. The biomechanical similarity of the movements performed during the PAP stimulus to subsequent exercise may also have a significant effect on performance (Suchomel et al., 2016).

In our study in which examined the jumping performance, movements performed during the resistive PAP stimulus biomechanically similar to subsequent exercise may have had a significant effect on subsequent performance. The current literature suggests that stronger people use PAP stimulus more effectively for subsequent performance compared to weaker ones (Suchomel et al., 2016; Berning et al., 2010; Chiu et al., 2003; Koch et al., 2003). Studies have shown that people with high power levels can eliminate fatigue more quickly when using PAP stimulus and subsequently, they can perform more quickly than those with lower power levels (Suchomel et al., 2016; Jo et al., 2010).

Another factor that affects the performance improvement after PAP stimulus may be gender. However; while some of the studies carried out stated that men can get a better performance output than women in response to PAP stimulus (Tsolakis et al., 2011; Terzis et al., 2009; Jensen and Ebben, 2003), others stated that similar results can be obtained (Witmer et al., 2010; McCann and Flanagan, 2010). Studies stating that men achieve better performance in terms of PAP stimulus explained this difference with differences in fiber structure (Terzis et al., 2009; Rixon et al., 2007). It has been stated that the percentage of type II muscle fibers and the cross-sectional area of the muscle in men are higher than in women, and this result may be effective in obtaining a better PAP response in favor of men (Terzis et al., 2009). However, more studies are needed to support this view. In our study, only male athletes were used as a participant group. The comparison between men and women has not been evaluated as it is beyond the scope of this study.

Training history is also one of the important components that may affect sportive performance after PAP stimulus. Differences in physical characteristics and muscle structure between athletes and non-athletes, trained people are more advantageous in terms of being able to activate the motor unit in a larger amount, differences between groups in resistance to fatigue and strength levels are effective features in the change of power values after the PAP stimulus (Suchomel et al., 2016). Studies on this subject have shown that well-trained athletes can get a better result after PAP stimulus than non-trained athletes or those with less physical activity (Chiu et al., 2003, Gourgoulis et al., 2003). In our study, participant group consists of athletes who do exercise regularly and competitors. This result may have been effective in getting better results in terms of jump performance after the PAP warm-up. Another factor affecting performance gain after PAP stimulus may be recovery time. The length of the rest interval used after PAP stimulus can determine whether subsequent performance will be achieved better (Suchomel et al., 2016; Ciocca et al., 2021; Turner et al., 2015; Kilduff et al., 2007). The rest interval should neither be short enough to cause fatigue to decrease performance after PAP, nor long enough to eliminate the effect of PAP on performance (Weber et al., 2008; Hodgson et al., 2005). The rest interval after PAP stimulus should neither be short enough to cause fatigue and reduce performance, nor be long to negate the effect of PAP stimulus on subsequent performance (Weber et al., 2008; Hodgson et al., 2005). Most of the studies have selected 3-8 minutes time as the most appropriate rest interval to achieve performance gain after the PAP stimulus (Lima et al., 2014, Linder 2010; Chatzopoulos, et al., 2007). In our study, 5 minutes was chosen as the rest period.

Most studies used free weights with heavy loads (> 85%) as a PAP stimulus to determine its effect on power performance (Bevan et al., 2010; Boullosa et al., 2013; Villarreal et al., 2007), while the other used plyometric activities as PAP stimulus considering their kinematic similarity with subsequent performance (Ciocca et al., 2021; Turner et al., 2015; Maloney et al., 2014; Till and Cooke, 2009; Kilduff et al., 2007). In most studies using plyometric activities as a PAP stimulus, vertical jumps consisting of different sets and repetitions were used (Ciocca et al., 2021; Turner et al., 2015; Maloney et al., 2014; Till and Cooke, 2009; Kilduff et al., 2007; McBride et al., 2005). However, after the literature review, we could not find any study examining the effect of the number of sets on the PAP response using

plyometric exercises. While some of the studies stated that plyometric preconditioning activities as a PAP response had an effect on subsequent power performance (Ciocca et al., 2021; Turner et al., 2015; Kilduff et al., 2007), the others showed no effect (Till and Cooke, 2009; McBride et al., 2005). Differences between studies can be attributed to factors such as differences in study design, individual changes in muscle fiber structure, training history, recovery time, load and volume applied to athletes (Chatzopoulos et al., 2007; Suchomel et al., 2016; Xenofondos et al., 2010). In different studies conducted in this area, different repetitions and sets of application forms have been used. Till and Cooke (2009) stated that PAP warm-up, which includes 5 vertical jumps, did not have a significant effect on 10 m and 20 m sprint performance. Similarly, McBride et al., (2005) found that there was no significant effect on sprint performance after 1 set and 3 repetitions of resistant multi-jump PAP warm-up. However, in both of these studies, the preload of the PAP stimulus included jumps in the vertical direction. The sprint movement applied after PAP stimulus is mostly for horizontal components. Therefore, the movements applied during the PAP stimulus and the movement applied afterwards are different from each other. In addition, the number of repetitions and sets used in these studies is less than the other studies mentioned in the literature. This result suggests whether the stimulus is sufficient to generate a PAP response. In our study; 10 repetitive jump height values after 2 and 3 sets of PAP warm-up applications with resistance bands were found to be significantly higher than 1 set of PAP warm-up with resistance bands or without resistance. On the other hand; various sportive performance component increases were observed after PAP warm-up based on plyometric jump with higher repetitions (Maloney et al., 2014; Turner et al., 2015; Ciocca et al., 2021). In addition, these studies include jump movements without additional resistance. In our study, we observed that 2 sets and 3 sets of PAP stimulation were more effective than 1 set of PAP stimulation by using extra resistance bands. As a result, we can state that vertical jumps, in which PAP stimulus is obtained by using resistance bands, may have a significant effect on subsequent jumping performance depending on the number of sets.

5. LIMITATIONS AND SUGGESTIONS

Our study consists of 1, 2 and 3 sets of pap warm-up protocol. Effects of pap warm-up includes over 3 sets were not evaluated. It may be recommended to conduct further research on the effects of pap warm-up over 3 sets.

Conflicts of Interest: The authors declare that they have no conflict of interest.
Author Contributions: Study Design-RT; HH, Data Collection-RT; HH, OY, Statistical Analysis-RT; HH, Manuscript Preparation-RT; HH; OY, All authors read and approved the final manuscript.
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