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The Effects of Physical Fitness on Postactivation Potentiation in Professional Soccer Athletes

Mauro Antonio Guerra Jr, MSc[1]
Leonardo Carvalho Caldas, MSc[1]
Helder L. De Souza[1]
Jason Tallis, PhD[2]
Michael J. Duncan, PhD[2]
Lucas Guimarães-Ferreira, PhD[1]

[1]Federal University of Espirito Santo, Vitoria, Brazil
[2]Coventry University, Coventry, UK

Address for Correspondence: Lucas Guimarães-Ferreira, PhD, Federal University of Espirito Santo, Vitoria, ES Brazil, email: lgtrainer@yahoo.com.br

ABSTRACT

Purpose: To investigate the relationship of the response to postactivation potentiation (PAP) with scores of physical fitness. **Methods:** 24 professional male soccer players undertook tests of agility, muscular power, aerobic capacity and body composition. Conditioning activities (CA) were performed consisting of plyometrics exercises and sprints with sled towing. In the first and second sessions, body composition, agility, power and aerobic capacity were assessed. At the third session, countermovement jumps (CMJ) were performed with 1, 3 and 5 minutes after the execution of the CA. **Results:** Significant differences were found for CMJ height 1, 3 and 5 minutes after the conditioning activity compared to baseline values (3.58%, 5.10%, 5.48%, respectively). There was a significant positive correlation between the level of general physical fitness and PAP (CMJ height increase) 5 min post ($r = 0.73$). When the athletes were divided into groups with higher and lower physical fitness, the conditioning activity caused a significant increase in CMJ height in both groups, but a significant difference ($p < 0.05$) was observed at all times after PAP induction, with better performance in higher versus lower fitness level. **Conclusion:** The results suggest that a plyometrics exercises associated with sled towing sprints as a conditioning activity results in an increase in CMJ performance in athletes and that physical fitness directly influences the PAP occurrence, with higher fit players demonstrating an enhanced PAP response.

Keywords: Postactivation potentiation, physical conditioning, performance, plyometrics.

INTRODUCTION

Postactivation potentiation (PAP) can be defined as an increase in neuromuscular performance after a skeletal muscle work overload (23). The manifestation and degree of PAP in response to previous stimuli are controversial and varies among individuals (39). Characteristics of the conditioning activity (CA), such as the modality of exercise, volume, intensity and recovery time, along with individual characteristics (e.g. training level, genetics) can influence the manifestation and magnitude of potentiation (31,39). Research has also suggested that athletes seems to present a higher potentiation response than moderately-trained and untrained subjects (39).

The use of PAP to enhance athletic performance is not new. Gülich and Schmidtbleicher (12) proposed the inclusion of strength exercises in the warm-up routines in addition to conventional exercises. The explanation for this practice was based on initial studies that demonstrated the possibility to increase strength and power performance in subsequent activities (11,12). Other types of exercises have also been used as CA to induce a PAP response, including plyometric exercises (6–10), and sprints with or without the use of external load (10,40).

The magnitude and manifestation of PAP has also been associated with individual factors such as physical fitness level, type and time of training, genetics (composition of muscle fiber types), age and sex (9,14,26,30). However, recent meta-analytical data by Wilson et al (39) suggested that age and sex were not associated with different PAP responses, but training status did have an influence. Wilson et al. (39) identified that highly-trained

individuals presented an increased PAP response compared to their lesser trained counterparts. Recently, Seitz et al (29) reported that rugby league players with higher muscular strength, after an activity comprised of single-set back squats with 90% 1RM, expressed PAP earlier and with a higher magnitude, when compared to those with less muscular strength (1RM in back squat < 2 x body mass) (29). Additionally, Suchomel et al. (31) investigated the temporal responses and magnitude of the PAP response in adult males divided in two groups based on their muscular strength level. Participants performed the squat jump (SJ) immediately and every minute for 10 minutes following potentiation complexes that included ballistic or non-ballistic concentric-only half-squat performed at 90% of their 1 repetition maximum (1RM). The results revealed that those with a greater 1-RM develop PAP earlier and produced greater peak power.

The literature in relation to PAP has not fully addressed the extent to which conditioning/fitness level influences the response to a conditioning stimulus. The effects of training status on the PAP response has already been previously discussed by Wilson et al. (39) as an area where future studies on PAP are need. The present study sought to address this issue. This study has two main objectives: a) to examine the effects of a combined plyometric and sled towing stimulus (as conditioning activity) on PAP response measured via the assessment of countermovement jump (CMJ) performance in professional soccer players; b) to identify the relationship between the general of physical level and the response of PAP. It was hypothesized that a) the PAP protocol would result in an improvement in CMJ performance; and b) the PAP response will be of higher magnitude in those individuals with a higher level of physical conditioning.

METHODS

Experimental Approach to the Problem

The investigation employed 24 male professional soccer players aiming to examine the effect of plyometric and sled towing exercise on CMJ performance on four time points: baseline, 1, 3 and 5 minutes. The CMJ was used as an indicator of neuromuscular performance in response to a series of plyometric exercise and sled towing which were used as conditioning activities (CA) to induce a PAP response. Athletes were tested for body composition, muscle power, agility and aerobic power. These data were used to separate the squad in two groups: lower and higher general physical fitness. The CMJ performance after the CA was analyzed and compared between groups to assess the effects of physical fitness on PAP response.

Subjects

Twenty-four professional soccer athletes were recruited from a soccer club of Espirito Santo State, Brazil. The club was the runner-up in the state championship that year. The characteristics of the participants are presented in Table 1. All subjects were accustomed to the plyometric and sled towing exercises required for the study, as such techniques were incorporated into the current training regime. The tests were conducted during the regular season, when all players were living at the club facility and subjected to the same exercise and diet regimen during all data collection period. The procedures used in this study were approved by the Human Research Ethics Committee of the Federal University of Espirito Santo.

Table 1

Physical analysis

Participants were assessed on three separated days. During the first day, body composition and maximum aerobic capacity were assessed. On day two, muscle power and agility tests were assessed. Finally, 72 hours after, participants completed the PAP protocol and perform the CMJ 1, 3, and 5 minutes post CA. The protocols used in the present study are as follow:

Body composition: skinfold measures (triceps, subscapular, suprailiac, calf) were used to measure body fat percentage (%BF), as described by Costa (6).

Muscle power: the vertical height of SJ was chosen for the measure of muscle power. In the SJ, subjects were required to remain in a static position with a 90° knee flexion angle for 2-s before jumping and were executed with the hands fixed on the hips. All jumps were performed on a contact platform with the *software Jump Test* (CEFISE, Sao Paulo, Brazil). A total of five attempts were allowed for each jump, interspersed by 15-s. The average of the two best attempts were retained for later analysis.

Agility: The agility T-test was chosen to evaluate the change of direction performance and was administered following recommended guidelines (21). On the "go" command, each athlete sprinted forward 9.14-m and touch a cone with the right or left hand. They then shuffled to the left 4.57-m and touched a cone with the left hand. Athletes then shuffled to the right 9.14-m and touched a cone with the right hand. They then shuffled to the left 4.57-m back to the center cone and touched the cone with left or right hand. Participants then ran or moved backward as quickly as possible to cross the finish line. The time to complete each trial was recorded in seconds using a photocell system with Speed Test software (CEFISE, Sao Paulo, Brazil). The best time of three attempts was used, rest interval time between the trials was 5 minutes.

Aerobic power: For measure of the aerobic power, VO_{2max} was estimated via completion of the Yo-Yo Intermittent Recovery Test level 1 (YYIRTL1) as described by Krustrup et

al. (18). The YYIRTL1 consisted of 20-m shuttle runs performed at increasing velocities, with 10 seconds of active recovery between runs, until exhaustion. Audio cues of the aerobic test were recorded on a software (Winlaborat; Buenos Aires, Argentina). The test was ended when participants twice failed to reach the front line in time (objective evaluation) or the participant felt unable to complete another shuttle at the dictated speed (subjective evaluation). The total distance covered during the YYIRTL1 was considered as the test score.

Procedures

All testing took place between 10am and 12pm in the morning to control for any diurnal variation. Before testing, volunteers completed a warm-up consisting of 5 minutes of jogging at a self-select intensity. This mode and intensity of exercise was chosen to ensure it was not unfamiliar with the players and is congruent with prior work (27) which used a similar jogging type warm-up as a control for the same purposes as the current study.

1-minute following completion of the warm-up, baseline CMJ was assessed. CMJs were performed starting from a standing position after which players were asked to jump as high as possible with a rapid, preparatory downward eccentric action. All jumps were completed keeping the hands on the iliac crest to avoid an influence of the upper limbs on jump performance. Two repetitions of the CMJ were performed at the following time points: before CA and at 1, 3, and 5 minutes after, as used by Tobin and Delahunt (36).

The CA consisted of 2 sets of 15 ankle hops, 3 sets of 5 hurdle hops, and 3 sets of 20-meter sprints with sled towing resulting in a total of 45 jumps and 60 meters sprinting with external load. Ankle hops were performed with a stiff leg action and a fast reactive rebound off the floor bilaterally. Hurdle hops involved a tuck jump movement to clear

the height of each hurdle, set at 50 cm, performed as fast as possible. For the sled towing a load of 15% of body weight was used, which is considered a moderate load (22). Thirty seconds rest was given between each set of every activity. These exercises were selected as they reflect typical exercises performed by these players in their training program. CMJ height was recorded as the dependent variable and was used in the analysis to compare the post-intervention performance. Previous investigations demonstrated that plyometric exercises enhance CMJ performance in a 5 minutes window (36,37). As the objective of the current study was to examine the effects of plyometrics and sled towing stimulus in PAP, we choose 3 time points: 1, 3, and 5 minutes post conditioning activity.

Physical conditioning level

For an analysis of physical fitness, the Standard Ten (STEN) score was used based on the values for body composition, muscle power, agility and aerobic capacity. This score indicates the approximate position of an individual with respect to the set of values and, therefore, to other individuals from that sample. The STEN score is defined by reference to a normal distribution and use the following formula: STEN Score = [(Athlete's Score - Mean Value) / Standard Deviation] x 2 + 5.5 (19).

Each assessed physical fitness test provided a value of 1 to 10 representing the individual score in each physical test applied and, in the end, provided an equated metric for all physical parameters used at the study (all variables using the same scale) (34). The score associated with the general physical fitness was the mean value of STEN score from the four aspects assessed as determinants of general physical fitness (body composition, muscle power, agility and aerobic power). Mean STEN score in the current context represents an overall holistic and standardized assessment of fitness level. STEN scores indicate an individual's approximate position (as a range of values) with respect to the

population of values and, therefore, to other people in that population. The individual STEN scores are defined by reference to a standard normal distribution and are considered a valid method to represent an individual's overall performance relative to their population (4) Using this mean score, the 50th percentile (P50) was calculated to separate the sample in two groups: those with higher fitness (above P50) and lower fitness (below P50).

Statistical Analyses

Results are presented as Mean ± Standard Deviation (SD). Data were analyzed for normality (Gaussian distribution) using the Shapiro-Wilk test. As data were normally distributed, parametric analyzes were used. Repeated measures one-way analysis of variance (ANOVA) was used to evaluate the differences in CMJ performance in four moments: before the conditioning activity (baseline) and 1, 3 and 5 minutes after the conditioning stimulus. Groups of higher and lower fitness were compared using the 2-way ANOVA with repeated measures for the time factor. The Bonferroni post-test was applied for multiple comparisons in both cases. Pearson correlation coefficient (r) was used to access the correlation between STEN Scores and PAP response (CMJ height post – pre). A significance level of 5% ($p < 0.05$) was adopted. For all analyses, the statistical software GraphPad Prism v.8.0 (San Diego, USA) was used.

The effect size (Cohen's D) was calculated using the following equation for paired groups: [(M1 - M2) / ((SD1 + SD2) ÷ 2)]; with M1 = baseline mean; M2 = mean post potentiating stimulus in 1, 3 or 5 minutes; SD1 = standard deviation baseline; SD2 = standard deviation post potentiating stimulus in 1, 3 or 5 minutes (5). Magnitude-based inferences (1) were used to determine differences between baseline and T1, T3, and T5 moments. Inferences were calculated using the differences on mean values and the 90%

confidence intervals. A change of 1 cm at jump height was considered the smallest worthwhile change (positive: + 1 cm; or negative: − 1 cm).

RESULTS

As presented in Table 2, when submitted to the CA, athletes performed significantly higher CMJ after 1 minute, 3 minutes and 5 minutes compared to baseline ($P < 0.05$), indicating the PAP response.

Table 2

Individual values of VO_2max, agility T-test performance, squat jump height and body fat were transformed for STEN scores. A Mean STEN score was calculated and used to separate the subjects in two groups with higher (above P50) and lower (below P50) general physical fitness. The mean STEN score, presented a positive correlation ($r = 0.73$; $p < 0.001$) with the CMJ performance (jump height post – pre) 5 minutes post the conditioning stimulus, as indicated in Table 3.

Table 3

The PAP response for both groups, with higher and lower physical fitness, was analyzed. As presented in Table 4, the group above P50 exhibited a significant increase at CMJ height 1, 3, and 5 minutes post compared to baseline. Conversely, the below P50 group increased CMJ performance only 3- and 5-minutes post stimulus, albeit with a reduced magnitude. The group above P50 presented increases in jump height of 4.8, 6.6, and 6.9% at 1, 3, and 5 minutes post CA, while the Below P50 group presented increases of 2.2, 3.7, and 4.1 % at the same time points. Two-way ANOVA main effect for the group factor ($F[1,22] = 4.42$; $p = 0.047$), main effect for time factor ($F[3,66] = 28.57$; $p < 0.001$), and for interaction ($F[3,66] = 2.56$; $p = 0.062$).

DISCUSSION

The present study addressed a key gap in the literature relating to PAP responses in athletes. One of the main findings of the present study was that a plyometric session in combination with repeated sprints with sled towing resulted in an acute increase in vertical jumping performance in professional soccer players. CMJ height increased by 3.79%, 5.21% and 5.68% at 1, 3 and 5 minutes after the CA. This is the first study to date to examine this issue in professional soccer players although the results of the present study align with prior work conducted on professional rugby players using only plyometrics exercises to induce PAP (36).

Previous research using jumping exercises as CA have also reported an acute improvement in CMJ performance (2,3,37). De Villareal et al. (37) compared various types of warm-ups in volleyball players. In a total of five different conditions, overloading jumps, squats with different submaximal loads, and drop jumps were compared to specific standard exercises for the warm-up of the volleyball players (ankle hops, split squat jump, standing long and reach and rim jump). The type of activity that resulted in better CMJ performance (6.96%) after 5 minutes of recovery were the specific standard volleyball exercises consisting of plyometric exercises similar to those used as CA at the present study. The modalities of exercise used as CA for the occurrence of PAP was a topic evaluated by a recent meta-analysis conducted by Seitz and Haff (28). The use of plyometric exercises had a greater effect size (0.47) when compared to resistance training at high-intensity (effect size: 0.41) and moderate-intensity (effect size: 0.19). Together, those data support the use of plyometric exercises as CA seems to be an appropriate option for PPA manifestation.

In the current study it was demonstrated that PAP occurred in the first minute post CA, which differs from previous research that employed resistance exercises with medium or high loads as CA. For example, Naclerio et al. (20) with American football and baseball players, observed a reduction in CMJ performance immediately after the CA, with PAP occurring only after 4 minutes. Similarly, Crewther et al. (8) found improvement in performance from the fourth minute onwards. It is suggested that, depending on the characteristics of the exercises employed as CA, the effects of fatigue could still be present immediately after the CA and, in those cases, it is not possible to demonstrate PAP (23).

The studies conducted by Cottle et al. (7) and Kawamori et al. (16) reported an improvement at initial impulse at the ground contact in sprints with the use of sled towing, as well as an improvement of the initial impulse and propulsive force when compared to the condition without sled. It is possible that together with the plyometric stimulus, the sled-towing resulted in improvements in the initial acceleration and force generated during the propulsive phase of vertical jump, resulting in improved CMJ performance.

In the meta-analysis conducted by Wilson et al. (39), the effect-size for PAP after CA was 0.89, 0.29 and 0.14 for athletes, trained and untrained individuals respectively, suggesting that those with better conditioning respond more to the PAP protocols. The same can be seen in recovery time after CA, which generally indicates that the recovery interval between 7-10 minutes would bring better benefits than between 3-7 minutes. However, when the level of training is considered, the best results observed occurred between 3-7 minutes in individuals with higher training status.

It has already been mentioned in the literature that trained individuals and athletes could better respond to PAP compared to untrained individuals. This is due to the higher level of strength and greater activity of myosin regulatory light chain phosphorylation

(13,26,32,35) in trained individuals. Kilduff et al. (17) found a moderate correlation (r = 0.63) between the value of 1RM and CMJ after conditioning exercises in professional rugby players, with the objective to verify the optimal recovery time for the occurrence of PAP after 3RM in the half-squat and in the bench press. Previous studies have highlighted the importance of muscle strength for the potentiation response (30,32,35). Based in these studies, it seems that individuals with higher strength levels can present an increased PAP response when compared to those with less strength.

We have demonstrated herein that athletes with higher general fitness (above P50 group) presented a higher potentiation response, which also occurs earlier, than the lower general fitness group (below P50). As previously suggested by Stone et al. (30), Terzis et al. (33), and Seitz et al. (29) we believe that a greater level of general physical fitness would induce less fatigue during the conditioning activity and allow faster recovery, resulting in increased manifestation of PAP. It is important to note that as only the higher fitness group showed clear increases in CMJ it suggests that fatigue may have influenced/overlapped the PAP response. It is possible that due to their higher fitness status the high fitness group were able to complete the conditioning session in a manner that avoided fatigue development, but that this was not the case for the low fitness group. Eliciting an optimal PAP response can be challenging in athletes in a manner that maximises the post-CA PAP response whilst minimises fatigue. It is difficult to directly determine whether the responses observed were due to PAP or fatigue, an issue common to the PAP studies, but previous investigations have suggested that fatigue dissipates faster than potentiation (15,24). The higher in CMJ performance observed on better conditioned athletes may be due to their ability to resist to fatigue or recover faster from it. The use of a non-standardised warm-up in the current study might also be considered a limitation in this context. The current study suggests that athletes of lower overall

conditioning do not elicit a PAP response whereas those of a higher fitness status do. There is a need, therefore, to investigate the adapting of warm-up protocols to best elicit the desired PAP response in all athletes.

The current study demonstrated that a single session of plyometric exercises in conjunction with sled towing sprints improved vertical jump performance. Moreover, the level of physical fitness of the athlete has influence in the PAP response, as those with higher physical fitness presented greater improvements in CMJ performance. It is possible that athletes with greater physical fitness would be able to recover faster and/or present less fatigue after performing the conditioning activities.

PRACTICAL APPLICATIONS

The current work corroborates previous data that demonstrated that PPA strategies can present a higher magnitude in athletes or people with higher physical fitness. Our results suggest a short-term, easy-to-apply warm-up model that can improve subsequent activities involving muscle power and speed. In addition, PPA, manifested in our warm-up model, has been suggested as a possible strategy to be used in halftime game intervals to improve performance in the early stages of the second game period (25). In addition, research has shown that performance appears to be negatively affected in the first 15 minutes of the second half, so that appropriate rewarming strategies could counteract such deleterious effects (38).

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