Effect of Varying Recovery Duration on Postactivation Potentiation of Explosive Jump and Short Sprint in Elite Young Soccer Players

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Abstract

Köklü, Y, Köklü, Ö, Işıkdemir, E, and Alemdaroğlu, U. Effect of varying recovery duration on postactivation potentiation of explosive jump and short sprint in elite young soccer players. *J Strength Cond Res* 36(2): 534–539, 2022—The purpose of this study was to investigate the effects of postactivation potentiation (PAP) on vertical jump and sprint performances with different recovery durations. Twelve elite young soccer players (average age: 17.0 ± 0.6 years; body mass: 67.0 ± 5.4 kg; height: 175.0 ± 3.5 cm) voluntarily performed countermovement jump (CMJ) and 30-m sprints (with 10-m split times) under unloaded and 4 different recovery duration conditions (R1: 1 minute, R2: 2 minutes, R3: 3 minutes, and R4: 4 minutes) after a set of 3 repetitions of half-squat exercises at 90% of 1-repetition maximum. Electromyographic assessments of both limbs' vastus lateralis (VL) and semitendinosus (ST) muscle activity were also made during the tests. Vertical jump height, sprint time, and VL and ST muscle activity root mean square (RMS) values were analyzed. The results show that players demonstrated significantly better CMJ, 10-, and 30-m sprint performances in the R4 condition compared with the unloaded condition ($p < 0.05$). The players also showed significantly higher RMS values for VL and ST muscle activity in the CMJ and 30-m test performances for both legs in the R4 condition compared with the unloaded, R1, R2, and R3 conditions ($p < 0.05$). According to these results, if sports scientists and coaches desire to increase the PAP effect after heavy resistance training, 4 minutes of recovery time instead of 1, 2, or 3 minutes for CMJ, 10-, and 30-m sprint performances is recommended.

Key Words: football, optimal time, EMG, explosive activity

Introduction

During a match, soccer players generally cover a distance of 8.6–14.2 km and perform 1,000 to 1,400 four- to six-second activities times (9,26). Therefore, soccer coaches have a particular focus not only on the technical characteristics of soccer players but also on the development of their physical capacities, such as muscular strength, speed, and endurance (22). Specifically, it is necessary to develop players' explosive characteristics, such as vertical jump height and short-distance running speed. With this in mind, physical and tactical training have mainly been reorganized according to players' high energy needs during high-intensity performance (1).

Many coaches combine resistance and plyometric training, which has proven to be more effective than traditional training for athletes who need high levels of explosive performance (24). These training methods are called complex or combined training. In this new approach, resistance training is performed before a sport-specific explosive task with similar biomechanical features (14). One of these methods is called postactivation potentiation (PAP) referring to an initial muscular activation with moderate/high load intensity, which results in acute improvements in muscle power and performance in subsequent explosive activities (25). Postactivation potentiation is used to develop physical training sessions or before competitions for its potential positive effect on athletic performance. The PAP effect has been demonstrated by Maloney et al. (18), who found significant improvements in jump height and change of direction speed after heavy loading due to repeated maximal voluntary contractions. McBride et al. (19) also found that 40-m sprint performance improved after a half squat loaded with 1 set of 3 repetitions at 90% of the subject's 1-repetition maximum (1RM).

Studies have shown that many factors, such as muscle fiber type (11), muscle strength level (28), sex (30), training experience (6), and type of contraction (3), should be considered to achieve the optimum PAP effect. In addition to all these factors, it seems crucial to ascertain the appropriate recovery duration for the optimal PAP effect.

Previous studies have examined different recovery durations ranging from 0 to 24 minutes to obtain an optimal PAP effect (16,17,29). In many studies, a 4-minute rest interval is used to achieve the PAP effect before the vertical jump and sprint performances (31). However, some contradictory results have been observed in the explosive performance of players. For example, Kilduff et al. (17) reported that the optimal recovery duration to maximize the effect of PAP on countermovement jump (CMJ) performance was 8 minutes in rugby players, whereas Titton and Franchini (29) found that a 1-minute recovery duration was enough to promote a significant increase in vertical jump height. However, because no previous studies have examined the effects of changes of recovery duration (from 1 to 4 minutes) on muscle activation during the vertical jump and sprint performance on

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Journal of Strength and Conditioning Research 36(2)/534–539

young soccer players, the purpose of this study was to investigate the effects of PAP with these different recovery durations. It was hypothesized that 3–4 minutes of recovery duration after a set of 3 repetitions of half-squat exercises at 90% of 1RM would result in a better PAP effect than 1–2 minutes of recovery duration on a vertical jump and sprint performances in elite young soccer players.

Methods

Experimental Approach to the Problem

An experimental, cross-sectional research design was used to test the study hypothesis. The experimental design of this study is shown in Figure 1. The first week, players participated in 3 sessions. These sessions consisted of familiarization with the half squat, 10- to 30-m sprints, and CMJ tests. In the fourth session, measurements of height, body mass, and 1RM half squat were taken for each player. At the second and third weeks, players performed 10- to 30-m sprints and CMJ tests following the unloaded and the PAP protocol, which consisted of 3 repetitions at 90% 1RM with 4 different recovery durations (R1: 1 minute, R2: 2 minutes, R3: 3 minutes, and R4: 4 minutes) (Figure 2). A standardized warm-up procedure consisting of 5 minutes of unloaded cycling at standardized resistance at a cadence of 60 rpm with 2 minutes of rest, followed by 10 unloaded half squats and 1 minute rest, was undertaken before the data collection. All players performed all the sessions in a random order, and they were separated by at least 48 hours. Three sessions took place each week. The matches were played on Sunday, and sessions were scheduled on Monday, Wednesday, and Friday. During all test conditions, the players were fitted with electromyographic (EMG) electrodes on the vastus lateralis (VL) and semitendinosus (ST) of both legs. Electromyographic was monitored during all tests.

Subjects

Twelve male young soccer players without musculoskeletal injuries or other health problems (mean ± *SD*: average age: 17.0 ± 0.6 years; body mass: 67.0 ± 5.4 kg; height: 175.0 ± 3.5 cm; soccer training experience: 5.5 ± 0.8 years; 1RM half squat: 94.2 ± 1.2 kg; relative 1RM half squat: 1.45 ± 0.24 $1\text{RM}\cdot\text{kg}^{-1}$) voluntarily participated in this study. All the players were members of a Turkish first division youth team, competing in an elite academy league. The players underwent 90-minute training sessions 5 days per week and played an official match at the weekends. All players had at least 1-year weight-training experience in their team. Written informed consent was obtained from all the subjects and also from their parents. All players and parents were notified regarding the research procedures, requirements, benefits, and risks before giving informed consent. The Pamukkale University Ethics Committee approved the study and conducted in a manner consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki.

Procedures

One Repetition Maximum Protocol. The test protocol used for the 1RM half-squat test in this study was the one used by Brown and Weir (5). After the standardized warm-up, the players performed a specific warm-up of 8 repetitions at approximately 50% of the estimated 1RM followed by another set of 3 repetitions at 70% of the estimated 1RM. After these, lifts were performed as single repetitions and with increasingly heavier weights until the player could not continue. This procedure was repeated until 1RM was determined. The 1RM half-squat tests were completed on Smith machine equipment (Esjim, Eskişehir, Turkey), with the barbell constrained to move along the vertical axis. The 1RM test result was determined within 3–5 trials. A 3-minute rest interval was given between trials. The 1RM half-squat test value was used to calculate the 90% of 1RM value for the PAP protocol.

Vertical Jump Test. Countermovement jump performance was assessed using a small pressure-sensitive contact mat (Smart Speed; Fusion Sport, Brisbane, Australia) in an indoor sports hall. During the testing, the players were asked to keep their hands on their hips to prevent any influence of arm movements on the CMJs and to avoid coordination as a confounding variable in the assessment of the leg extensors (4). Each player performed 2 maximal CMJs with 30-second recovery time. The players were asked to jump as high as possible; the highest jump was then recorded in centimeters.

10- and 30-m Sprint Test. After 30 seconds of CMJ performances, the players performed 2 maximal 30-m sprints (with 10-m split times also recorded). Sprint performance was measured using timing gates (Newtest, Oy, Finland) positioned at 10 m and 30 m from the start line in an indoor sports hall. There was a recovery period of 1 minute between the 30-m sprints. The shortest time taken to cover the 30-m distance in the sprint test

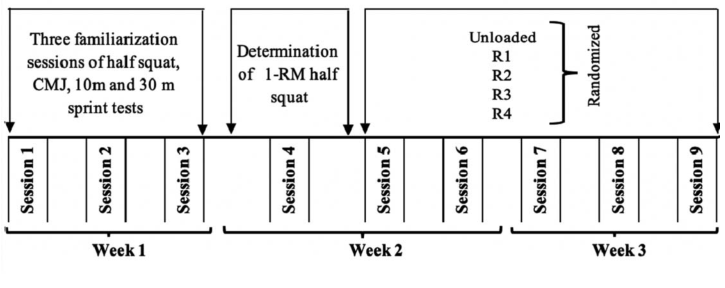

Figure 1. Experimental study design. CMJ = countermovement jump; R1 = 1-minute recovery duration; R2 = 2-minute recovery duration; R3 = 3-minute recovery duration; R4 = 4-minute recovery duration; RM = repetition maximal.

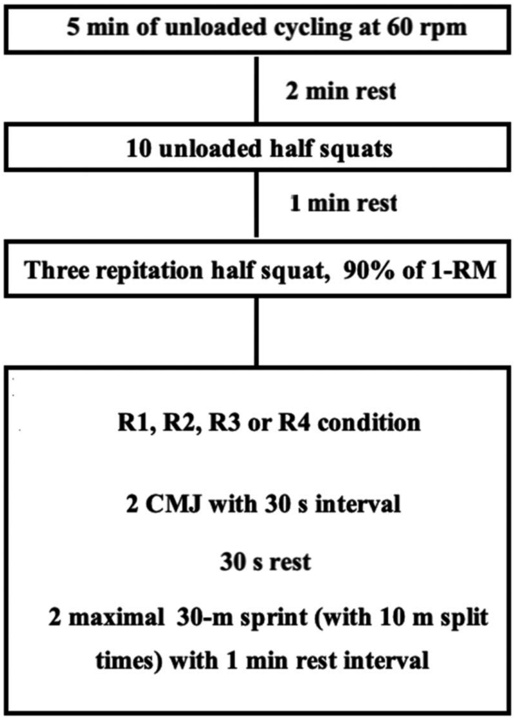

Figure 2. Postactivation potentiation protocol. CMJ = countermovement jump; R1 = 1-minute recovery duration; R2 = 2-minute recovery duration; R3 = 3-minute recovery duration; R4 = 4-minute recovery duration; RM = repetition maximal; rpm = revolutions per minute.

was used in the data analysis. Also, the percentages of the best performance in the CMJ, which were obtained either by the first or second jump for the 5 conditions, were calculated (unloaded = 96.23%, R1 = 95.96%, R2 = 96.90%, R3 = 95.60%, R4 = 95.71%, respectively).

Electromyographic Measurements. Muscle activity was measured using a wireless EMG with a sampling rate of 1 kHz (BTS Bioengineering, Milano, Italy) with electrodes on the muscles of both legs. The muscle areas were measured, shaved, abraded, and cleaned with an isopropyl alcohol pad before electrode placement, and Ag-AgCl electrodes were placed on the mid-belly of the VL and ST muscles according to the recommendations of SENIAM (13). A permanent marker pen was used to track the position of the electrodes to ensure electrode placement was consistent across test sessions, and the same researcher placed the electrodes during the whole study. Adhesive tape was used to secure the wireless EMG probes to the leg, and EMG signals were transmitted to a computer interface receiver (BTS, Bioengineering).

The best CMJ height and 30-m sprint time attempts were chosen for EMG analysis, and 10-m sprint signals were extracted from the 30-m sprint data. The raw EMG signals for all tests were band-pass filtered, with the high-pass filter set to 20 Hz and the low-pass filter set to 500 Hz using a second-order Butterworth filter (8). The filtered signals were rectified, and then, the envelope was computed using mobile root mean square (RMS) (time epoch = 100 $\text{m}\cdot\text{sec}^{-1}$). The EMG signal obtained during the unloaded test conditions (reference activity) was processed, and peak RMS values were calculated for amplitude normalization (10,21). The mean RMS values were computed for VL and ST and normalized with respect to the peak RMS of the reference activity. The EMG was then analyzed as a percentage of the maximal activation found in the reference activity.

Statistical Analyses

All results were reported as means (M) and *SD*. A 1-way analysis of variance for repeated measurements was used to determine differences between the 5 conditions (i.e., R1–R4) on CMJ height, 10- to 30-m sprint performance, and EMG signals. The coefficient of variation (CV) value was calculated within players. Before using parametric tests, the assumption of normality was verified using the Shapiro-Wilk test ($p > 0.05$). Effect size correlations were calculated to determine practical differences between the 5 conditions (η^2, where <0.1, 0.1, 0.3, and 0.5 represent trivial, small, medium, and large, respectively) (7). The Bonferroni post hoc test was applied to make pairwise comparisons between the 5 conditions (i.e., R1–R4); and Cohen's *d* (*d*) values were also calculated to determine the practical differences for these comparisons (0.20–0.49, 0.50–0.79, and 0.8 and above were considered to represent small, medium, and large differences, respectively) (7). Moreover, intraclass correlation coefficients (ICC) were calculated to measures the reliability of measurements, and the *SEM* was determined to measure the dispersion of sample means. The level of statistical significance was set at $p \leq 0.05$.

Results

Maximum CMJ height and the best 10- and 30-m sprint performances were found under the R4 condition, whereas the lowest CMJ height and the worst 10- and 30-m sprint performances were found in the unloaded condition (Table 1). One-way repeated analysis of variance showed statistically significant differences among the 5 conditions in terms of CMJ ($F_{(4,44)} = 1.412$, $p = 0.041$, $\eta^2 = 0.114$, small effect), 10-m sprint performance ($F_{(4,44)} = 1.906$, $p = 0.033$, $\eta^2 = 0.148$, small effect), and 30-m sprint performance ($F_{(4,44)} = 5.612$, $p = 0.001$, $\eta^2 = 0.338$, medium effect).

Bonferroni post hoc pairwise comparisons revealed that players in the R4 condition showed significantly better CMJ ($SEM = 0.368$; ICC = 0.939; $d = 1.041$), 10-m sprint performance ($SEM = 0.019$; ICC = 0.666; $d = 1.200$), and 30-m sprint performance ($SEM = 0.035$; ICC = 0.708; $d = 1.305$) than under the unloaded condition.

The mean RMS values of VL and ST muscles in the CMJ, 10-, and 30-m sprint test performances among the 5 conditions are presented in Table 2. There were significant differences among the 5 conditions in terms of mean RMS in the CMJ performance (right VL: $F_{(4,44)} = 23.892$, $p = 0.001$, $\eta^2 = 0.685$, large effect; right ST: $F_{(4,44)} = 22.755$, $p = 0.001$, $\eta^2 = 0.674$, large effect; left VL: $F_{(4,44)} = 19.233$, $p = 0.001$, $\eta^2 = 0.636$, large effect; left ST: $F_{(4,44)} = 63.434$, $p = 0.001$, $\eta^2 = 0.852$, large effect) and 30-m test performance (right VL: $F_{(4,44)} = 17.208$, $p = 0.001$, $\eta^2 = 0.610$, large effect; right ST: $F_{(4,44)} = 17.752$, $p = 0.001$, $\eta^2 = 0.617$, large effect; left VL: $F_{(4,44)} = 10.143$, $p = 0.001$, $\eta^2 = 0.480$, large effect; left ST: $F_{(4,44)} = 9.765$, $p = 0.001$, $\eta^2 = 0.470$, large effect).

Bonferroni post hoc pairwise comparisons showed a statistically significant effect in CMJ height R4 vs. unloaded condition (right VL: $SEM = 5.419$, ICC = -0.209, $d = 1.583$; right ST: $SEM = 4.835$, ICC = 0.022, $d = 1.784$; left VL: $SEM = 5.565$,

Table 1

Soccer players' average vertical jump, 10-, and 30-m sprint test performances.*

	Unloaded		R1		R2		R3		R4		
	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	ES
CMJ (cm)	37.43 ± 3.43†	9.2	38.21 ± 4.1	10.7	38.37 ± 3.38	8.8	38.44 ± 2.98	7.7	38.76 ± 3.82	9.8	0.114
10 m Sprint(s)	1.99 ± 0.09†	4.5	1.95 ± 0.07	3.6	1.94 ± 0.05	2.6	1.94 ± 0.07	3.6	1.91 ± 0.07	3.7	0.148
30 m Sprint(s)	4.67 ± 0.14†	3.0	4.56 ± 0.1	2.6	4.53 ± 0.15	3.3	4.53 ± 0.12	2.6	4.52 ± 0.16	3.5	0.338

*CMJ = countermovement jump; CV = coefficent of variance; R1 = 1-minute recovery duration; R2 = 2-minute recovery duration; R3 = 3-minute recovery duration; R4 = 4-minute recovery duration; ES = effect size.

†Significantly different from R4.

ICC = −0.164, *d* = 1.337; left ST: *SEM* = 2.751, ICC = −0.079, *d* = 2.978), R4 vs. R1 (right VL: *SEM* = 5.240, ICC = 0.119, *d* = 1.755; right ST: *SEM* = 4.409, ICC = 0.416, *d* = 1.956; left VL: *SEM* = 6.222, ICC = −0.342, *d* = 1.000; left ST: *SEM* = 2.793, ICC = 0.127, *d* = 3.033), R4 vs. R2 (right VL: *SEM* = 5.121, ICC = 0.077, *d* = 1.527; right ST: *SEM* = 5.088, ICC = 0.221, *d* = 1.662; left VL: *SEM* = 5.513, ICC = −0.086, *d* = 1.183; left ST: *SEM* = 2.795, ICC = 0.160, *d* = 2.235), R4 vs. R3 (right VL: *SEM* = 5.361, ICC = −0.035, *d* = 1.782; right ST: *SEM* = 5.051, ICC = 0.062, *d* = 1.550; left VL: *SEM* = 5.078, ICC = 0.041, *d* = 1.715; left ST: *SEM* = 1.158, ICC = 0.855, *d* = 2.950). In addition, bonferroni post hoc pairwise comparisons also a showed statistically significant effect in 30-m test performance R4 vs. unloaded condition (right VL: *SEM* = 5.131, ICC = −0.145, *d* = 1.621; right ST: *SEM* = 2.803, ICC = −0.065, *d* = 2.412; left VL: *SEM* = 6.068, ICC = −0.417, *d* = 0.974; left ST: *SEM* = 5.028, ICC = −0.293, *d* = 1.469), R4 vs. R1 (right VL: *SEM* = 4.397, ICC = 0.073, *d* = 1.416; right ST: *SEM* = 3.134, ICC = −0.002, *d* = 2.256; left VL: *SEM* = 4.605, ICC = 0.001, *d* = 1.197; left ST: *SEM* = 5.335, ICC = −0.221, *d* = 1.139), R4 vs. R2 (right VL: *SEM* = 3.312, ICC = 0.560, *d* = 1.743; right ST: *SEM* = 3.757, ICC = 0.202, *d* = 1.095; left VL: *SEM* = 4.535, ICC = −0.067, *d* = 1.627; left ST: *SEM* = 3.041, ICC = 0.479, *d* = 1.489), R4 vs. R3 (right VL: *SEM* = 4.681, ICC = 0.336, *d* = 1.204; right ST: *SEM* = 4.282, ICC = −0.107, *d* = 1.214; left VL: *SEM* = 5.530, ICC = −0.098, *d* = 0.955; left ST: *SEM* = 3.508, ICC = 0.718, *d* = 1.030).

Discussion

The purpose of this study was to investigate the effects of PAP with different recovery durations on a vertical jump and sprint performance in elite young soccer players, showing that the length of recovery affected vertical jump height, sprint performances, and muscle activation of the players.

This study indicated that R4 condition after 1 bout of high-intensity resistance exercise resulted in higher CMJ height (3.55%), faster 10-m (4.02%), and 30-m (3.21%) sprint performance compared with unloaded condition. Although these percentages of changes in CMJ, 10-, and 30-m performances seem small, these differences may help to the defender to prevent a shot at goal, an earlier contact to the ball by an attacker to shoot at goal or jump higher than the opponent (12). In addition, large effect sizes in CMJ, 10-, and 30-m sprint performances between unloaded and R4 conditions indicated that the differences were also practically meaningful. Moreover, in all conditions, there were low CVs in CMJ, 10-, and 30-m sprint performances ranged between 2.6 and 10.7% in the current study. Parallel to this study findings, McCann and Flanagan (20) found that 4-minute recovery

Table 2

Soccer players' mean RMS values of vertical jump, 10-, and 30-m sprint test.*

	Unloaded		R1		R2		R3		R4		
	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	Mean ± *SD*	CV (%)	ES
CMJ											
Mean RMS RIGHT VL (%)	24.71 ± 4.17†	16.88	22.56 ± 10.00†	44.33	27.34 ± 8.17†	29.88	21.34 ± 7.68†	35.99	54.41 ± 16.55	30.42	0.685
Mean RMS RIGHT ST (%)	23.90 ± 6.41†	26.82	23.93 ± 12.40†	51.82	24.50 ± 12.36†	50.45	26.67 ± 8.97†	33.63	53.78 ± 15.67	29.14	0.674
Mean RMS LEFT VL (%)	21.03 ± 5.13†‡	24.39	25.25 ± 7.30†‡	28.91	24.21 ± 6.53†‡	26.97	16.64 ± 5.44†	32.69	46.79 ± 17.11	36.57	0.636
Mean RMS LEFT ST (%)	21.26 ± 3.73†‡§‖	17.54	20.30 ± 6.08†‡§	29.95	28.00 ± 6.43†‡	22.96	37.79 ± 6.37†	16.86	49.63 ± 8.38	16.88	0.852
10 m Sprint											
Mean RMS RIGHT VL (%)	32.82 ± 6.02	18.34	36.73 ± 6.73†	18.32	37.82 ± 9.29	24.56	37.43 ± 9.89	26.42	43.25 ± 8.24	19.07	0.293
Mean RMS RIGHT ST (%)	36.21 ± 7.48	20.66	35.65 ± 7.35	20.62	36.30 ± 8.15	22.45	42.79 ± 17.79	41.58	43.19 ± 8.89	20.58	0.207
Mean RMS LEFT VL (%)	35.35 ± 3.84	10.86	35.50 ± 6.57	18.50	33.19 ± 6.13	18.46	32.73 ± 6.90	21.08	39.49 ± 5.46	13.82	0.225
Mean RMS LEFT ST (%)	39.85 ± 3.60	9.03	38.85 ± 3.41	8.78	37.53 ± 6.36	16.95	35.62 ± 7.08	19.88	40.12 ± 7.56	18.84	0.970
30 m Sprint											
Mean RMS RIGHT VL (%)	19.64 ± 5.92†	30.14	26.88 ± 3.06†	11.38	28.45 ± 7.62†	26.78	28.92 ± 12.46†	43.08	48.44 ± 15.51	32.01	0.610
Mean RMS RIGHT ST (%)	21.50 ± 4.31†	20.04	20.42 ± 6.91†	33.85	30.64 ± 11.92†	38.90	26.89 ± 11.35†	42.20	44.89 ± 8.35	18.60	0.617
Mean RMS LEFT VL (%)	22.85 ± 9.40†	41.13	24.24 ± 5.57†	22.97	20.43 ± 10.53†	51.54	25.03 ± 10.53†	42.06	43.32 ± 14.94	34.48	0.480
Mean RMS LEFT ST (%)	20.67 ± 7.12†	34.44	25.12 ± 9.78†	38.93	30.56 ± 5.40†	17.67	33.72 ± 18.46†	54.74	46.24 ± 13.56	29.32	0.762

*CMJ = countermovement jump; RMS = root mean square; VL = vastus lateralis; ST = semitendinosus; CV = coefficent of variance; R1 = 1-minute recovery duration; R2 = 2-minute recovery duration; R3 = 3-minute recovery duration; R4 = 4-minute recovery duration; ES = effect size.

†Significantly different from R4.

‡Significantly different from R3.

§Significantly different from R2.

‖Significantly different from R1.

duration was significantly better than 5-minute recovery duration in terms of baseline vertical jump height. Iacano et al. (15), who compared the acute effects of 2 PAP protocols using traditional or cluster-set configurations on CMJ performance, also found vertical jump heights showed significant increases, (by between 3.7 and 4.2%) after 4 minutes of recovery compared with baseline vertical jump heights. This study findings thus support previous research which has suggested that a 4-minute recovery is advised between the high-intensity resistance exercise and subsequent explosive tasks such as jump and sprint performances to observe increased power output (28,31). On the other hand, Kilduff et al. (17) investigated CMJ at baseline and durations of 15 seconds and 4, 8, 12, 16, 20, and 24 minutes after 3 sets of 3 repetitions at 87% 1RM in rugby players. They reported that the optimal recovery duration to maximize the effect of PAP on CMJ performance was 8 minutes in rugby players. Also, Titton and Franchini (29) measured CMJ at 1, 3, 5, and 10 minutes after 4 different intensities (40, 60, 80, and 100%) of 1RM squat exercise, finding that a 1-minute recovery duration was sufficient to promote a significant increase in the vertical jump. The reason why the findings were different from those of this study could be explained by the difference of players' muscle fiber structure, strength level, training experience, and experimental designs of the studies.

Another underlying mechanism of PAP is enhanced neural stimulability within muscle fibers (28). In this study, muscle fiber type was not assessed, but muscle activation was assessed using surface EMG. According to the results, the R4 condition CMJ and 30-m sprint performances after a 1-bout high-intensity resistance exercise induced significantly higher EMG values than all other conditions. This result also is in line with CMJ and sprint performance findings. Until now, only a few studies have examined the effects of PAP with EMG analysis. Similar to our findings, Mina et al. (23) evaluated the magnitude and changing in CMJ performance after traditional free-weight and variable resistance squat exercises after a specific warm-up. They found significant increase in mean concentric VL EMG activity (27.5–33.4%). Unlike our study, Barnes et al. (2) compared the effects of 6 warm-up procedures on peak power output during the high-pull exercise; EMG results were not significantly different neither between pre– and post–warm-up nor between procedures in any of the investigated muscles. In another study, the hex bar deadlift and back squat exercise response investigated between different levels of athletes was also compared, and results showed no significant changes in the EMG variables (27). Nonetheless, there are a limited number of studies investigating the effects of different recovery durations on muscle activity; therefore, this study emphasized a wide range of variability within the EMG data with significant changes in muscle activation.

The limitation of this study is that both the players and their parents were informed regarding the research procedures, benefits, and risks before the intervention as a standard procedure. Therefore, players may have made more effort unintentionally during the 4-minute recovery trial compared with other conditions so that this brief may have possibly caused a placebo effect on the current observed results. Another limitation of this study is that vertical jump performance may have affected sprint performance and muscle activity, but to minimize this effect, the sequence of tests and the rest duration between the tests were standardized in 5 conditions, in which the only variable was recovery duration.

Practical Applications

In conclusion, performance tests and EMG signals show that elicited after the PAP following heavy resistance exercise has a positive effect on CMJ, 10-, and 30-m sprint performance in young soccer players. In addition, sports scientists and coaches should keep in mind that the PAP protocols in warm-up have the greatest effect on single explosive activities such as jumping and sprinting. Therefore, these findings suggest that the PAP method can be used to increase the performance of the players in a warm-up section in conditioning trainings (i.e., plyometrics) or before the sprint and vertical jump tests. However, it is essential to note that the loads used by the coaches to create the PAP effect on the players need to be close to maximal loads (>80% 1RM), so for this type of training, players must have a particular strength training background. Thus, it is recommended that coaches and sports scientists use this type of training in the second half of the preparation period and during the season. Also, if sports scientists and coaches desire to reach the optimal time to elicit the PAP effect after heavy resistance exercise, it is recommended to use 4 minutes of recovery duration instead of 1, 2, or 3 minutes on CMJ, 10-, and 30-m sprint performance. Finally, there is no study in the literature on whether the use of PAP after heavy resistance exercise in prematch warm-up contributes to the sprint and vertical jump performances of players in the early part of the match. Therefore, this issue can be examined in the future studies.

Acknowledgments

The authors thank all the players for their time and effort during the tests. No conflicts of interest are declared.

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