

EFFECTS OF STATIC AND DYNAMIC POST-ACTIVATION POTENTIATION PROTOCOLS ON CHANGE OF DIRECTION PERFORMANCE IN ADOLESCENT SOCCER PLAYERS

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Summary: Purpose: The study aimed to investigate the temporal effects of static and dynamic post-activation potentiation (PAP) conditioning activities on agility performance. **Material and Methods:** Fourteen male adolescent soccer players participated in the study. Participants performed three different conditioning activities randomly on non-consecutive days. Conditioning activities consisted of static, dynamic, and control protocols. The dynamic protocol was performed with the dynamic squat at 85% of 1-repetition maximum while the static protocol was performed 3 repetitions x 3 seconds of the isometric squat. The control protocol only completed a standardized warm-up. After the baseline measurements were taken, all protocols completed the agility test in 15th seconds, 2,4,6,8,10,12,14th minutes. Repeated measures in ANOVA were used to determine differences between PAP protocols and the Bonferroni post hoc test was employed to determine which protocol caused a significant difference. **Results:** There was no significant difference between protocols in baseline ($p < .925$, $\eta^2 = 0.006$), however, the control protocol caused a significant difference in 15th seconds and 2nd minutes compared to static and dynamic protocols ($p < .001$, $\eta^2 = 0.73, 0.72$, respectively). In the 4th and 6th minutes static and dynamic protocols caused a significant difference compared to control ($p < .001$, $\eta^2 = 0.46-0.89$, respectively), and in the 8th-minute static and dynamic protocols reached the peak performance ($p < .001$, $\eta^2 = 0.96$). Although in the 10-12-14th minutes static and dynamic protocols' performance values gradually reduced. However, they always were better compared to the control protocol ($p < .001$, $\eta^2 = 0.91-0.93-0.96$, respectively). **Conclusions:** Adolescent soccer players can benefit from both static and dynamic PAP protocols before competition or halftime to improve performance.

Keywords: Isometric, Agility, Football, 1RM, Puberty, Manoeuvrability.

Introduction

The muscle's reaction to a movement is related to the previous contraction history of that muscle. During the implementation of movements, muscle fatigue can impair force production or power output, thereby reducing explosive performance over a period of time (Blazevich & Babault 2019). Although muscular contraction creates fatigue, it leads to potentiation in the muscle. The occurrence of fatigue normally weakens muscle contraction. However, Post-Activation Potentiation (PAP) also known as conditioning activity (CA), causes increased contractile response after contractions due to myosin light chain phosphorylation (Robbins 2005; Till & Cooke 2009). It is accepted that the increase in fatigue and contraction response develop together, and the force is produced by the muscle after contraction is the result of the balance between fatigue and potentiation (Gossen & Sale 2000; Rassier & Macintosh 2000).

The effects of PAP are well studied for change of direction, repeated sprint, straight sprint speed, and jump performance (Low et al. 2015; McBride et al. 2005; Sanchez-Sanchez et al. 2018; Sole et al. 2013; Till & Cooke 2009; Zois et al. 2011). However, the temporal effects of PAP conditioning activity were not investigated in these studies. Studies examining the temporal effects of PAP showed that the PAP effect occurs at different minutes. In support of this, it was indicated in a study that back squat conditioning activity produced better results in the vertical jump performance in the 4th minute than in the 5th minute (McCann & Flanagan 2010). Bevan et al. showed that the jump squat conditioning activity caused better sprint performance in the 8th minutes than 4-12-16th minutes (Bevan et al. 2010). In another study Orjalo et al. (2020) showed that the barbell hip thrust conditioning activity led to an improvement in the change of direction performance in 4-8-12, and 16th minutes. In addition to the importance of rest intervals to create the PAP effect (Bevan et al. 2009, 2010; Kilduff et al. 2008; Zois et al. 2011), it is well-known that the PAP mostly is a personalized response (Lockie et al. 2018). In these mentioned studies, it was well examined the effects of PAP on the types of contractions and gender-related temporal responses. However, any of these studies' experimental groups did not consist of the adolescent population.

The increase in the number of adolescents who specialize in a single sport and train for a sport throughout the year gradually increases, and parallelly the sport demands more performance from adolescents. The rise in demands (Brenner et al. 2007, 2016; Fitness 2000) creates a necessity of designing a study on the adolescent population to investigate the effects of PAP. Agility, coordination, power, and speed are significant skills for athletes and continue to develop during adolescence. Therefore, it is pivotal to examine the effects of PAP in the adolescent population, especially on agility which is an ability that is frequently used by athletes

during training or competition (Nimphius 2021). As a result, practitioners can use these methods to optimize or provide further development of agility performance (Chatzopoulos et al. 2007; Docherty et al. 2004; French et al. 2003; Okuno et al. 2013; Pääsuke et al. 2000).

A study showed that PAP activity did not cause a significant difference between male adolescents and preadolescents in plantar flexor performance (Pääsuke et al. 2000). Another study showed that isometric half-squat PAP conditioning activity did not improve the squat jump performance of the adolescents while enhancing the squat jump performance of male adults in the 20th seconds and 4th minutes (Arabatzis et al. 2014). Only one study examined the temporal effects of change of direction in the adolescent population, and the study indicated that isometric PAP conditioning activity in 1-3-5 and 7th minutes did not reveal a positive effect on the change of direction performance (Marshall et al. 2019). Since there are a few studies that investigated the temporal effects of PAP in adolescents, more studies are needed considering the type of muscle contraction and different load responses to the PAP protocols. Thus, the present study aims to examine the temporal effect of different PAP conditioning activities on change of direction in adolescents. The study hypothesizes that both two different (static and dynamic) PAP conditioning activities with different types of contraction will positively influence temporal agility performance.

Material and methods

Participants

Fourteen adolescent male soccer players participated in the study (Average Age: 15.2±0.69 years, Height: 1.66±0.08 cm, Weight: 52.07±6.70 kg, Training Age: 5.07±0.61 years). All measurement and experimental procedures were completed in the competition-specific training phase of the preparatory period. The inclusion criteria of athletes were attending 4 times training sessions for at least 2 hours each a week and playing a friendly game once a week. The ethical committee's permission was obtained from the university. The participants and parents were informed about the possible risks of injuries, and the signed permission of parents was taken. In all phases of the study, the "Helsinki Declaration" was followed.

Study Design

The study was designed randomly and counterbalanced to examine static and dynamic post-activation potentiation protocols' effects on temporal agility performance. A familiarization session was performed in the Illinois test one week prior to all the procedures being implemented. The protocols were performed on 3 separate days. Two days before the experimental process, the participants' anthropometric measurements and one-repetition

maximal (1RM) squat strength were measured. Before implementation of all the protocols, the standardized warm-up procedure was followed [jogging (10 minutes), dynamic stretching for lower and upper extremities (5 minutes), and 1 set and 5 repetitions of bodyweight squat with a preferred depth]. After completion of the warm-up, the protocol's (control, static, and dynamic) baseline measurement was obtained. Two minutes later after baseline measurement was completed, participants attended one of the protocols. Athletes performed the Illinois agility test with the maximum effort at eight separate times in the 15th seconds, 2-4-6-8-10-12, and 14th minutes (Figure 1). During the isometric squat, the knee joint flexion angle was set at 120-130 degrees with a goniometer in the feet shoulder-width apart and the toes pointed slightly to the lateral side. Participants performed 3 maximal isometric efforts lasting 3 seconds with 1 minute of rest between efforts (Blazevich et al. 2002). During the dynamic squat, the participants were asked to perform 3 repetitions of squats at 85 % of 1 RM. Squat was performed in accordance with the rules of the International Powerlifting Federation (Technical Rules Book of the International Powerlifting Federation 2022). Forty-eight hours intervals were given between each protocol.

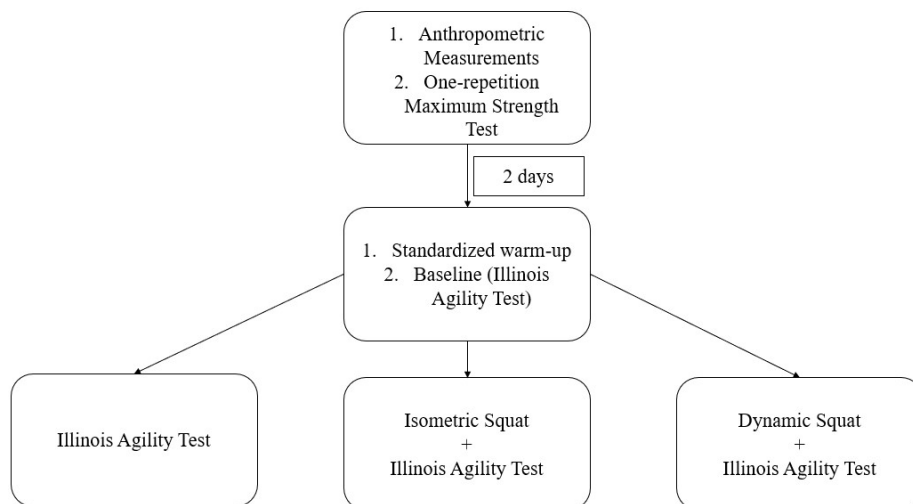


Figure 1
Study Design

Procedures

Determination of One-Repetition Maximal Strength

While calculating the one-repetition maximal (1RM) squat strength, an Olympic barbell and the weight plates that can attach to the barbell were used as material. The 1RM was calculated by the indirect method (estimation). Participants were asked to squat with an estimated weight which was adjusted by the practitioner not exceeding 10 repetitions. Then, using Epley's formula, 1RM squat values were determined (Wood et al. 2002).

Agility Test

Illinois Agility Test was used as the agility test. Photocells were positioned at the start and finish points (SE-200 Photocell Gate, Istanbul, Turkey). Four cones 10 m in length and 5 m in width to each other were placed. The other four cones are sequenced and separated 3.3 m from each other was positioned in the middle of the course. When participants are ready, started the test in the following sequence 1) 10 m run and turn, 2) go to middle and slalom through cones, 3) run to next cone up right corner, 4) run to finish point (Amiri-Khorasani et al. 2010).

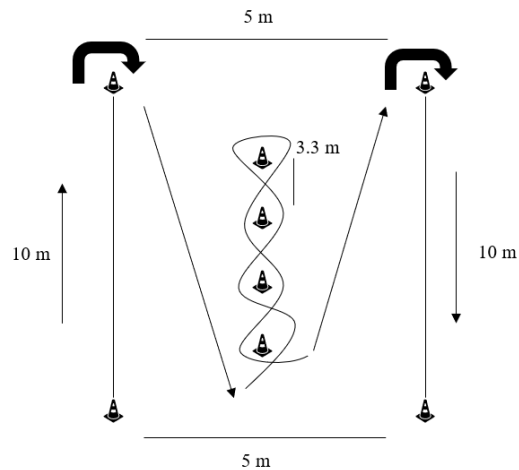


Figure 2
Illinois Agility Test

Statistical Analysis

Descriptive statistics of the study were calculated. Normality values of data were determined by using the Shapiro-Wilk test. Repeated measures in the ANOVA test were used to determine the effects of PAP protocols and temporal differences as the 3 (protocol) x 9 (time) design. Bonferroni post hoc test was used to determine which protocol causes the differences. Partial eta squared was used to estimate inter-group interactions and the interpretations were accepted in accordance with Cohen's guide >0.01 small effect, >0.06 medium effect, and >0.14 large effect (Watson 2021). The statistical significance value was set at $p \leq 0.05$. Jeffrey's Amazing Statistics Program (JASP) was used for the statistical analyses (JASPTeam 2021).

Results

Descriptive statistics of the athletes were shown in Table 1. The temporal effects of protocols were shown in Table 2. The mean values of the protocols were shown in Figure 3. A significant difference was found intra-values of static, dynamic, and control protocols ($p < .001$; $\eta_p^2 = 0.88, 0.67, \text{ and } 0.75$, respectively). There was no significant difference between baseline

values of the protocols ($p < .925$; $\eta_p^2 = 0.006$). After protocols were performed, there was a significant difference between protocols in 15th seconds, 2-4-6-8-10-12-14th minutes. ($p < .001$; $\eta_p^2 = 0.46-0.96$). There was a significant difference between the control protocol compared to static and dynamic protocols in the 15th seconds and 2nd minutes ($p < .001$, $\eta_p^2 = 0.73-72$, respectively). There was a significant difference between dynamic and static protocols compared to control in the 4th and 6th minutes ($p < .001$, $\eta_p^2 = 0.46-89$, respectively). Dynamic and static protocols' values peaked in the 8th minute and there was a significant difference between protocols ($p < .001$, $\eta_p^2 = 0.96$). Dynamic and static protocols' values started to decrease in 10-12-14th minutes and reached near baseline values, however, a significant difference continued between dynamic and static protocols compared to control protocol ($p < .001$, $\eta_p^2 = 0.91-93-96$, respectively).

Table 1
Descriptive Statistics (N = 14)

	Mean	Standard Deviation
Age (years)	15.21	0.69
Height (cm)	166.0	0.08
Body Mass (Kg)	52.07	6.70
Training Age (Year)	5.07	0.61
1RM (Kg)	59.92	5.83

Table 2
Temporal Effects of Protocols (Mean and Standard Deviation)

	Control Protocol	Static Protocol	Dynamic Protocol	F Value	Significance Level	η_p^2
Baseline	16.83 ± 0.80	16.71 ± 0.92	16.80 ± 0.50	0.078	.925	0.006
15 sec	16.83 ± 0.80	18.56 ± 0.78	18.97 ± 0.67	36.271	.001**	0.73
2 min	17.89 ± 0.99	18.10 ± 0.96	18.93 ± 1.06	33.438	.001**	0.72
4 min	18.03 ± 0.86	17.85 ± 0.89	17.50 ± 1.06	11.262	.001**	0.46
6 min	18.27 ± 0.94	16.74 ± 1.08	16.90 ± 0.90	114.040	.001**	0.89
8 min	18.69 ± 0.85	15.79 ± 1.05	15.71 ± 0.99	384.625	.001**	0.96
10 min	19.00 ± 1.14	16.57 ± 1.09	16.65 ± 1.03	142.718	.001**	0.91
12 min	19.11 ± 0.89	17.09 ± 0.95	17.59 ± 1.04	177.463	.001**	0.93
14 min	20.70 ± 0.91	18.09 ± 0.61	17.27 ± 0.75	326.591	.001**	0.96
F Value	105.735	28.890	43.866			
Significance Level	.001**	.001**	.001**			
η_p^2	0.88	0.67	0.75			

** $p < .001$

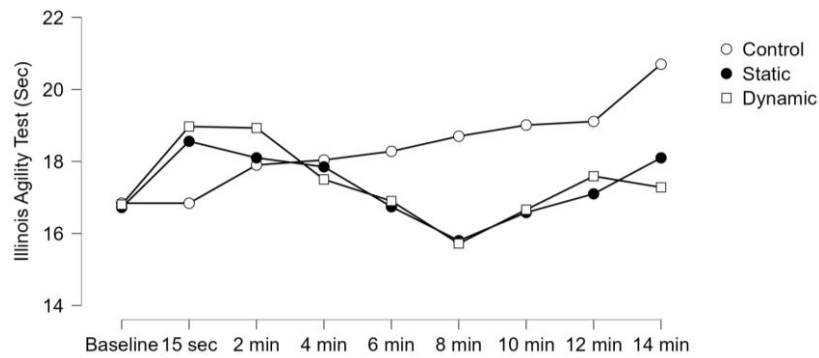


Figure 3
Mean Values of the Protocols on Illinois Agility Test Performance

Discussion

The study was designed to investigate the temporal effects of static and dynamic PAP conditioning activities on change of direction (COD) performance. Although static and dynamic PAP conditioning activities caused performance impairment in the first minutes of the experiment as a result of fatigue, static PAP conditioning activity's performance improved starting by 2nd minute while dynamic protocol's performance increased starting by 4th minute. These two experimental conditioning activities' performances peaked in the 8th minute and then performance gradually started to decrease. Even though this decrement continued until the 14th minute two experimental conditioning activities' performance values were always higher compared to the control activity.

There are only a few studies that investigated the temporal effects of dynamic PAP conditioning activities on COD performance. In the current study, dynamic squat PAP conditioning activity was performed at 85 % of 1RM as 1 x 3 repetitions, and performance started to enhance in the 4th minute, peaked in the 8th minute, and after this time, it gradually decreased. It was reported that post-activity-related decrements in performance occur as a result of fatigue (Blazevich & Babault 2019). Rassier and MacIntosh reported that post-activity strength depression (fatigue) is due to decreased peak or average myoplasmic calcium sensitivity (Rassier & Macintosh 2000). Additionally, the decreased sensitivity is a result of the decreased relationship of calcium/troponin or reduced strength production of cross-bridge formation during contraction (Rassier & Macintosh 2000). Orjalo et al. reported that barbell hip thrust PAP activity (85 % of 1RM, 3 sets x 5 repetitions) positively influenced the change of direction performance of both males (23.95 ± 3.24 years) and females (22.60 ± 2.21 years) in the 4th ($p < 0.001$), 8th ($p < 0.004$), 12th ($p < 0.028$), and 16th minutes ($p < 0.001$) (Orjalo et al. 2020). In the mentioned research, the 5-0-5 test was used for the change of direction performance. The average completion time of this test is 3 seconds, on the other hand, the Illinois test's average completion time is between 13-19 seconds (Nimphius 2021). Hence,

sustained performance improvement for 16 minutes could be the result of 4 minutes long rest intervals for the selected COD test, and it may have helped participants to recover fully. Petisco et al. indicated that conditioning activities performed with loads at 80 % of 1RM with 1 set and 5 repetitions were more effective to create a PAP effect on jumping, repeated, and non-repeated change of direction performance compared to loads at 60 % of 1RM with 1 set and 10 repetitions and 100 % of 1RM with 1 set and 1 repetition in young athletes (21.6 ± 3.2 years) (Petisco et al. 2019). However, this study did not investigate temporal changes. Chatzopoulos et al. showed that 5 minutes rest intervals ($d = 1.96, d = 1.23$) were more effective to improve 10 and 30 m sprint performance compared to 3 minutes rest intervals ($d = 0.39, d = 0.27$) with the load at 90 % of 1RM (1 set x 10 repetitions) (Chatzopoulos et al. 2007). Nevertheless, again this study did not report the temporal effects of PAP conditioning activity. Rahimi showed that 36.6 m sprint performance improved more with high loads at 85% of 1RM compared to relatively lower loads at 60 and 70 % of 1RM (2 sets and 4 repetitions) after 4 minutes rest intervals were given ($d = 4.35, d = 3.16, d = 1.44$, respectively) (Rahimi 2007). Based on indicated adult studies and the current study's dynamic conditioning activity findings, it could be said that moderate-high and high loads are more effective to create the PAP effect.

Identical to dynamic PAP conditioning activities, there are limited studies that investigated the temporal effects of static PAP conditioning activities on the change of direction performance in the adolescent population. In the current study, static conditioning activity was performed with a two-side fixed 20 kg Olympic barbell as 3 repetitions x 3 seconds with 1-minute rest intervals. Unlike dynamic PAP conditioning activity, performance enhancement started in the 2nd minute in the static conditioning activity, and similar to dynamic conditioning activity, it peaked in the 8th minute and gradually decreased. Arabatzi et al. investigated the temporal effects of isometric squat on squat jump performance in the 20th second and 4th minute (Arabatzi et al. 2014). In the study, adult males squat jump performance improved in terms of both jump height and peak rate of force development. However, the adolescent population only enhanced the peak rate of force development, and any advancement was not observed in jump height. The authors indicated that jumping is a complex task. Due to this fact, contractile properties of muscle are not the sole decisive factor for jump performance but also motor control and technical competencies may influence performance (Arabatzi et al. 2014). The authors did not report the load of the isometric PAP protocol. It is pivotal to report the load-related information given that relatively long or short rest intervals corresponding to the selected load may cause impairments in the performance (Arabatzi et al. 2014). In the current study, as aforementioned PAP conditioning activity was performed with a 20 kg Olympic barbell, and this fixed load coincided with between 29 and 47 % relative strength levels of the

athlete group. Besides indicated relative strength levels, the group may have benefited from the type of contraction. In support of this, Lim and Kong indicated that isometric contraction efforts cause more muscle fiber activation compared to dynamic contraction efforts (Lim & Kong 2013). Even though they failed in proving the hypothesis which is isometric PAP conditioning activities positively influence sprint performance in athletes (22.4 ± 3.2 years) (Lim & Kong 2013). This explanation may support the current study's static PAP conditioning activity's results on agility performance. Similar to Lim and Kong's study, Till and Cooke showed that 3 x 3 seconds isometric maximum voluntarily contractile PAP conditioning activity did not improve both sprint and jump performance (Till & Cooke 2009). In this study, the rest interval was 1 minute, in their meta-analysis study, Wilson et al. showed that effects size was higher in prolonged rest intervals such as 7 - 10 minutes compared to 3 - 7 minutes (0.70 - 0.54, respectively) (Wilson et al. 2013). Again, it seems like the rest intervals are one of the most important factors to create the PAP effect. Similar to the current study's design, there was only one study that investigated the temporal (1-3-5-7th minutes) effects of isometric PAP conditioning activity on the change of direction performance (Marshall et al. 2019). In this study, elite rugby players (16 ± 0.41 years) performed progressively increasing isometric PAP conditioning activity (50-75-90 % of 1RM) as 3 x 3 seconds and the conditioning activity did not improve the change of direction performance ($p > 0.05$). Marshall et al. reported that the adolescent growth spurt process of their athlete group may have impaired strength and the change of direction-related performances (Lloyd et al. 2015; Marshall et al. 2019).

Conclusions

Based on the study's findings, both static and dynamic can be used to improve the agility performance of adolescent soccer players in pre-competition or halftime warm-ups. The static protocol may be preferable since high loads may be difficult to reach during pre-competition and halftime. It should be kept in mind that both static and dynamic conditioning activities' performance peaks in the 8th minute and the time adjustment should be in accordance with it. According to the current study's findings, proper rest intervals should be given to benefit the PAP effect in both static and dynamic protocols.

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