

# Acute effects of prolonged intermittent low-intensity isometric warm-up schemes on jump, sprint, and agility performance in collegiate soccer players

**AUTHORS:** Pojskić H<sup>1,2</sup>, Pagaduan JC<sup>3</sup>, Babajić F<sup>1,2</sup>, Užičanin E<sup>1,2</sup>, Muratović M<sup>1,2</sup>, Tomljanović M<sup>4</sup>

<sup>1</sup> School of Physical Education and Sport, University of Tuzla, Bosnia and Herzegovina

<sup>2</sup> Center for Sports Excellence, Tuzla, Bosnia and Herzegovina

<sup>3</sup> College of Human Kinetics, University of the Philippines – Diliman, Philippines

<sup>4</sup> School of Kinesiology, University of Split, Croatia

**ABSTRACT:** The aim of the present study was to compare the effects of different warm-up interventions on jump, sprint and agility performance in collegiate soccer players. Twenty-one healthy male college soccer players (age:  $20.14 \pm 1.65$  years; body height:  $179.9 \pm 8.34$  cm; body mass:  $74.4 \pm 13.0$  kg; % body fat:  $9.45 \pm 4.8$ ) participated in the study. Subjects underwent four different randomized warm-up protocols separated by at least 48 hours. The warm-up schemes were: 1. no conditioning contraction protocol (NCC); 2. dynamic stretching (DS); 3. prolonged intermittent low-intensity isometric exercise (ST); and, 4. ST with an additional external load equal to 30% of body weight (ST + 30% BW). All interventions were preceded by a general warm-up. Results from one-way repeated measures ANOVA demonstrated a significant difference in countermovement jump (CMJ) at  $F(3,60) = 10.2$ ,  $\eta^2 = 0.337$ ,  $p < 0.01$ . Post hoc analysis revealed a significant difference in CMJ performance in DS when compared to NCC and ST + 30% BW. No significant difference in CMJ was observed between DS and ST. CMJ scores in NCC, ST, and ST + 30% BW were non-significant. There was a significant difference in speed;  $F(3, 60) = 6.61$ ,  $\eta^2 = 0.248$ ,  $p < 0.01$ . Post hoc analysis revealed significantly better time in DS than NCC and ST. However, no difference in speed was observed between DS and ST + 30% BW. Similarly, speed was similar in NCC, ST and ST + 30% BW. A significant difference in agility performance was also observed;  $F(3, 60) = 24.1$ ,  $\eta^2 = 0.546$ ,  $p < 0.01$ . Post hoc analysis revealed significantly greater performance gains in DS than NCC. No significant difference in agility was observed in DS, ST and ST + 30% BW. In conclusion, a prolonged intermittent low-intensity isometric protocol using bodyweight only showed similar benefits with dynamic stretching in countermovement jump performance. When the same isometric condition with additional load equal to 30% of bodyweight was applied, effects in speed and agility were similar to dynamic stretching.

**CITATION:** Pojskić H, Pagaduan JC, Babajić F, Užičanin E, Muratović M, Tomljanović M. Acute effects of prolonged intermittent low-intensity isometric warm-up schemes on jump, sprint, and agility performance in collegiate soccer players. *Biol Sport*. 2015;32(2):129–134.

Received: 2014-01-29; Reviewed: 2014-05-15; Re-submitted: 2014-05-21; Accepted: 2014-08-07; Published: 2015-02-16.

## INTRODUCTION

Warm-up is generally promoted as an ergogenic activity that is believed to assist athletes achieve their full physical potential in training or competition [1,2]. Warm-up raises body temperature, increases nerve conduction velocity, elevates muscle enzyme activity, and augments dilation of blood vessels that provide blood flow for better muscle oxidation during work. The aforementioned physiological mechanisms facilitate greater muscle force and power production [3,4], which are important in team sports requiring acceleration, deceleration, or change of direction [5]. Coaches use different warm-up conditions [6,7,8,9]. Recent studies suggest that aerobic warm-up and dynamic stretching are beneficial for sprint, jump, and agility tasks [1,6,8,10,11]. On the other hand, static stretching schemes with intensity at or above a point of discomfort or used with duration not longer than 45 s are scrutinized in performance settings for delivering detrimental effects [12,13]. Con-

trastingly, a cyclic static stretch may seem to reduce the debilitating effects of static stretching [14].

Some coaches use complex training in warm-up sessions. Complex training involves a set of strength training exercise (isometric or dynamic) followed by a biomechanically similar plyometric exercise [15]. This concept is based on a phenomenon called post activation potentiation (PAP). PAP is defined as acute enhancement of muscular power output produced by performing a preload stimulus before an actual activity [16]. It is known that any previous muscle activity can trigger both PAP and fatigue mechanisms [17]. Contractile history of a muscle is said to have a positive effect on muscle performance, especially in terms of twitch contractions, rate of force development and explosive movements [18]. This improved muscular performance can be attributed to increased phosphorylation of myosin light chains and increased motor neuron excitability [15]. Stud-

Corresponding author:

**Pagaduan JC**

Mailing address: College of Human Kinetics, University of the Philippines – Diliman, Diliman, Quezon City, Philippines 1101  
e-mail: jcpagaduan@gmail.com

## Key words:

post activation potentiation  
fatigue  
conditioning contraction  
countermovement jump  
external load

ies revealed that use of heavy multi-joint resistance training with preload of 1–3 sets and 1–5 repetitions of 75–100% 1RM [19,20] or high velocity exercises with 1–3 sets and 3–5 repetitions of 10–40% of 1RM [21,22] are effective stimuli for PAP. In a similar vein, isometric conditions using single-joint exercises of 1–3 sets with 3–10 s of maximum voluntary isometric contraction (MVIC) 1–3 min prior to performance [23,24] or multi-joint isometric exercises of single or multiple sets [22,25,26] were found to produce PAP.

Most of the studies in loaded isometric warm-up schemes used a maximum or near maximum load. To the researchers' knowledge, no studies have been performed on prolonged intermittent low-intensity isometric exercises in warm-up settings. Such a void in the current literature failed to explain possible mechanisms of isometric exercises as conditioning contractions on performance. Thus, the purpose of the present study was to compare the effects of different warm-up interventions on jump, sprint and agility performance in soccer players using a within-subject repeated measures experimental design. It was hypothesized that low-intensity intermittent isometric exercise as a preconditioning stimulus in warm-up would positively influence the jump, sprint and agility performance.

## MATERIALS AND METHODS

**Subjects.** Twenty-one healthy male college soccer players (age:  $20.14 \pm 1.65$  years; body height:  $179.9 \pm 8.34$  cm; body mass:  $74.4 \pm 13.0$  kg; % body fat:  $9.45 \pm 4.8$ ) with no reported injuries for the past six months agreed to participate in the study. The subjects had been consistently participating in regular soccer training sessions for a total of 10 hours per week and strength and conditioning training for 3 hours per week. Prior to experimentation, they were asked to refrain from strenuous training at least 48 hours and sleep at least 6–8 hours. Tobacco, alcohol and caffeine consumption were also prohibited. The participants were allowed a light meal at least three hours prior to each testing session. Fluid consumption in small amounts was also encouraged during the testing sessions. Players were told they were free to withdraw from the study at any time without penalty. Signed informed consent forms were collected from all players after a detailed verbal and written explanation of the experimental design, purpose of the study, testing protocols, research benefits and potential risks of the study. The study was approved by the ethical committee of Tuzla University and conformed to the principles of the Declaration of Helsinki on human experimentation [27].

### Procedures

The study was carried out at the Exercise Science Laboratory of the Faculty of Physical Education and Sport, Tuzla University, from 8:00 a.m. to 10:00 a.m. for four experimentation sessions with 48 hours between each session. Figure 1 presents the experimental procedures of the study. On day 1, anthropometric data were collected. Body height was measured to the nearest 0.01 m with a portable stadiometer (Astra scale 27310, Gima, Italy). Body weight, body fat percentage and fat free mass were measured using a bioelectric body

composition analyzer (Tanita TBF-300, increments 0.1%; Tanita, Tokyo, Japan). Then the subjects were randomly assigned to experimental warm-up treatments: no conditioning contraction protocol (NCC), dynamic stretching (DS), static squat (ST), and ST with an additional external load equal to 30% of bodyweight (ST + 30% BW). The randomization process continued until all the subjects had performed all the interventions.

All experimental protocols were preceded by a 5 min general warm-up (GW). In GW, the subjects ran at a preset pace which was equivalent to 12 circles around an 86 m circumference area ( $\approx 1000$  m). They completed the first 4 circles in 30 s per circle (speed:  $\approx 10.3$  km/h). For the second 4 circles, 25 s per circle was required (speed:  $\approx 12.4$  km/h). 20 s per circle was encouraged in the last 4 circles (speed:  $\approx 15.5$  km/h). A 10 min rest period was provided between the end of the running and testing session. NCC was executed without any additional contraction exercises after GW.

DS was executed 1 min after the GW protocol. The DS consisted of 7 exercises performed in 7 min. Each exercise was performed for 2 sets of 20 s with a rest interval of 10 s between sets. The rest interval between exercises was 10 s.

In order to try to elicit PAP effects by prolonged intermittent low-intensity isometric exercises we used two protocols: static squat (ST), and ST with an additional external load equal to 30% of a subject's bodyweight (ST + 30% BW). Both protocols were executed 1 min after the running protocol.

In ST, the subjects performed a squat position (5 times per minute) with a rest interval of 30 s in between squat exercises. Subjects were asked to sit down during the rest period. Knee angle for the squat was approximately  $100^\circ$ . The proper stature was checked and corrected by the examiner when needed. Similar procedures with ST were followed in ST + 30% BW with the subjects holding a barbell (20 kg) on their shoulders during the squat position (Figure 2.). An additional load was used to attain an external load equal to a subject's 30% bodyweight. Both protocols lasted for 7 min.

After 2 min of an intervention, the participants performed performance tests that consisted of the countermovement jump test (CMJ),

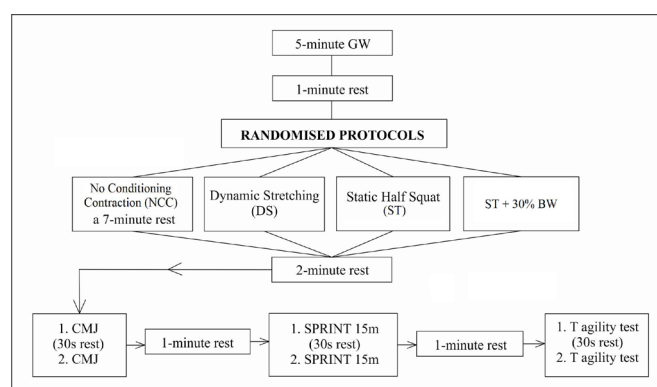


FIG. 1. Experimental design.

## Warm-up: intermittent low intensity isometric protocols

15 m sprint test and the modified agility test. Each test was performed twice with intra test rest period of 30 s and with a 1 min inter test rest interval. That means that the first of two CMJ tests was performed 2 min after an intervention, the first of two 20 m sprint tests was performed 3.5 min after an intervention, and the first of two modified T agility tests was performed 5 min after an intervention.

### Measures

#### Vertical Jump

Countermovement jump (CMJ) was measured using a commercial portable device (OptoJump System, Microgate, Bolzano, Italy). Each subject performed two maximal CMJ jumps, allowing 30 s of recovery in between, according to the protocol described by Bosco et al. [28]. The first jump was performed 2 min and the second one 2 min and 30 s after one of the applied conditioning protocols. The highest score was used for analysis. The subjects were encouraged to jump as high as possible, starting at their own volition. The reliability coefficients (ICC and Cronbach's alpha) of CMJ were fairly high in this study (.96).

#### Speed

In the speed test, the subjects performed two maximal 15 m sprint tests in an indoor parquet floor with a 30 s recovery between each. The first sprint was performed at 3 min and 30 s and the second one 4 min after one of the applied conditioning protocols. The best score was used for analysis. The starting position for this test was 1 m behind an automated timer (Speedtrap II, Brower Timing Systems, Draper, UT, USA) which was approximately in line with the athlete's waist. The subjects were encouraged to sprint as fast as possible,

starting at their own volition. The reliability coefficients (ICC and Cronbach's alpha) of the sprint test were fairly high in this study (.89).

#### Agility

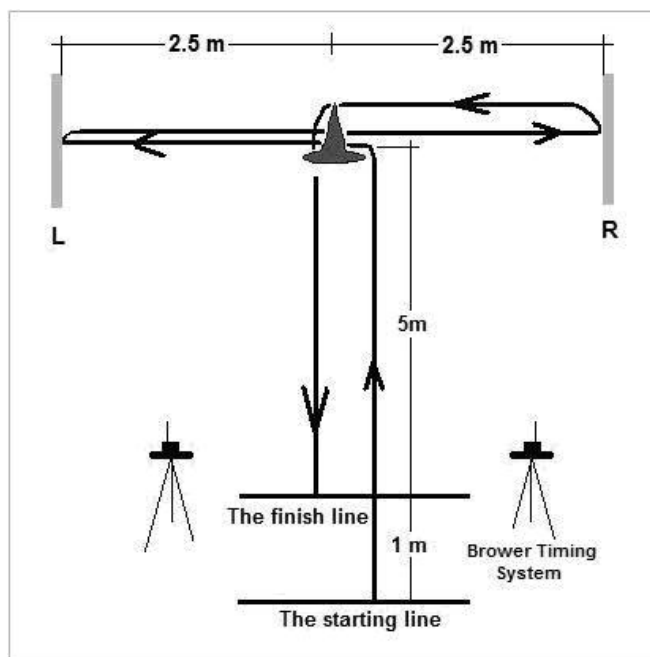
Agility was tested using a modified agility T test (Figure 3). In this test, an athlete sprints for 5 m, lateral shuffles to the left for 2.5 m, and proceeds to right lateral shuffling for 5 m. Then, the athlete shuffles to the left for 2.5 m and backpedals for 5 m. The athletes started 1 m behind the 5 m sprint distance at their own volition. Time was detected using Speed trap II, Brower Timing Systems, Draper, UT, USA. All the tests were performed for two trials with the best result recorded for analyses. The first trial was performed 5 min and the second one 5 min and 30 s after one of the applied conditioning protocols. The subjects were encouraged to complete the test as fast as possible starting at their own volition. The reliability coefficients (ICC and Cronbach's alpha) of the test were fairly high (.86).

#### Statistical Analyses

Descriptive statistics (mean and standard deviation) were calculated for each test and for the each applied protocol. Data sets were checked for normality using the Kolmogorov-Smirnov test and by the visual observation of normality plots. Reliability and validity were assessed with an intraclass correlation coefficient (ICC), Cronbach's alpha reliability coefficients ( $\alpha$ ) and the coefficient of variation (CV). One-way repeated measures ANOVA was used to determine any significant difference in performance among the interventions. Effect size was established using partial eta squared ( $\eta p^2$ ). Bonferroni post hoc contrast was applied to conduct pairwise comparison between interven-



**FIG. 2.** Static squat position and static squat position with an additional external load.



**FIG. 3.** The modified T agility test.

tions. Statistical significance was set at  $p < 0.05$ . All statistical analyses were performed using a commercial statistical package (SPSS Inc., Chicago, IL; Version 14.0).

## RESULTS

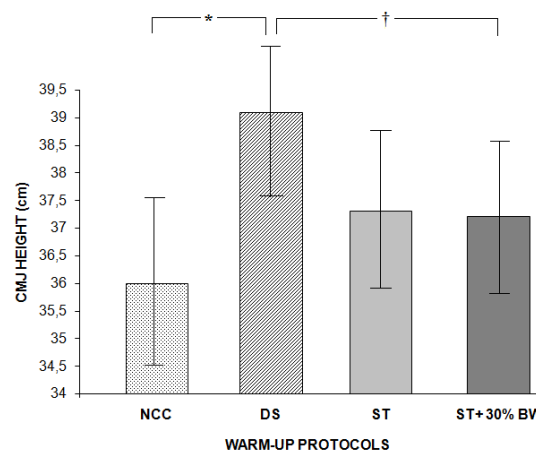
Mean and standard deviation (SD) of countermovement jump, speed, and agility in no conditioning and conditioning contractions schemes are presented in Table I. One-way repeated measures ANOVA revealed a significant difference in CMJ performance at  $F(3,60) = 10.2$ ,  $\eta^2 = 0.337$ ,  $p < 0.01$ . Post hoc analysis showed that CMJ after DS was significantly higher than NCC ( $p < 0.00$ ) and ST + 30% BW ( $p = 0.004$ ), while ST showed similar results compared to DS. CMJ at NCC was not significantly different compared to ST and ST + 30% BW. Also, no significant difference in CMJ was identified between ST and ST + 30% BW.

There was a significant difference in speed across interventions,  $F(3, 60) = 6.61$ ,  $\eta^2 = .248$ ,  $p < 0.01$ . Post hoc analysis showed that speed in DS was faster than NCC ( $p = 0.003$ ) and ST ( $p = 0.018$ ), but similar to ST + 30% BW. On the other hand, speed in NCC was not significantly different compared to ST and ST + 30% BW. No significant difference in speed was observed between ST and ST + 30% BW as well.

There was a significant difference in agility performance across schemes at  $F(3, 60) = 24.1$ ,  $\eta^2 = 0.546$ ,  $p < 0.01$ . Post hoc analysis showed that time in NCC was higher than DS ( $p < 0.001$ ), ST ( $p < 0.001$ ), and ST + 30% BW ( $p < 0.001$ ). DS showed similar agility performance with ST ( $p = 0.472$ ) and ST + 30% BW. The difference in agility between ST and ST + 30% BW was not significant. Figures 4, 5 and 6 depict differences of the CMJ, speed and agility performance in no conditioning and conditioning contraction schemes.

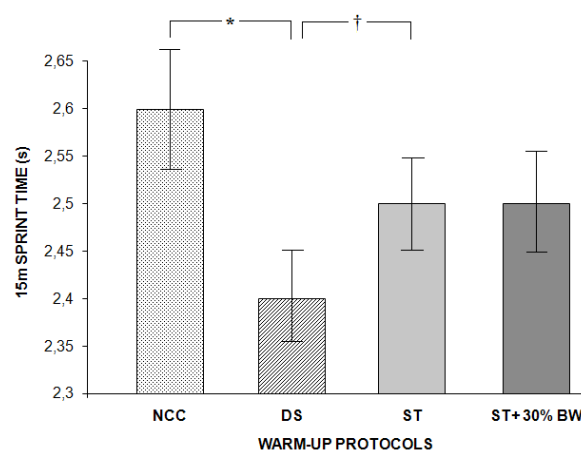
## DISCUSSION

The aim of the present study was to compare the effects of different warm-up interventions on jump, sprint and agility performance in collegiate soccer players. In jumping, DS showed superior effects on CMJ than NCC and ST + 30% BW protocols. No significant difference in CMJ between DS and ST was observed. Although not statistically significant, prolonged low-intensity isometric protocols showed greater CMJ compared to NCC. The greatest gains in CMJ after DS can be attributed to higher body temperature that increased nerve conduction velocity, elevated muscle enzyme activity, and increased dilatation of blood vessels and blood flow to the activated muscles, which provided better muscle oxidation during work [3,4,29,30]. Additionally, DS has been suggested to elicit PAP by increasing the rate of cross-bridge formation [31], which enabled greater muscle force and power production. On the other hand, previous studies [6,8,11] supported low CMJ output after NCC. When comparing CMJ in DS with the ST + 30% BW protocol, it can be observed that higher CMJ height was achieved after the DS protocol. The ST + 30% BW protocol may have produced a fatig-



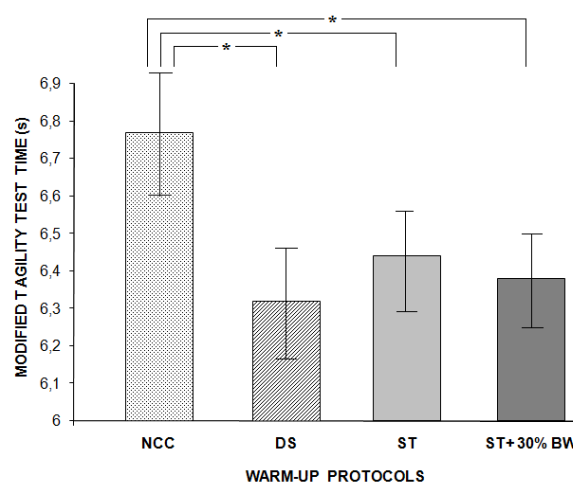
**FIG. 4.** Effect of warm-ups involving dynamic stretching and isometric stimulus on CMJ performance.

\*Values significantly different from those obtained in NCC protocol;  $p < 0.05$ . †Values significantly different from those obtained in DS protocol;  $p < 0.05$ .



**FIG. 5.** Effect of warm-ups involving dynamic stretching and isometric stimulus on sprint performance.

\*Values significantly different from those obtained in NCC protocol;  $p < 0.05$ . †Values significantly different from those obtained in DS protocol;  $p < 0.05$ .



**FIG. 6.** Effect of warm-ups involving dynamic stretching and isometric stimulus on agility performance.

\*Values significantly different from those obtained in NCC protocol;  $p < 0.05$ . †Values significantly different from those obtained in DS protocol;  $p < 0.05$ .

**TABLE I.** Countermovement jump, speed, and agility in no conditioning contractions and conditioning contractions schemes

Tests	Preconditioning protocols			
	NCC	DS	ST	ST+ 30% BW
CMJ (cm)	36.0 ± 5.1	39.1 ± 5.0 *	37.3 ± 5.6	37.2 ± 5.1 †
15 m sprint (s)	2.6 ± 0.13	2.4 ± 0.10 *	2.5 ± 0.09 †	2.5 ± 0.10)
Modified agility T test (s)	6.77 ± 0.35	6.32 ± 0.29 *	6.44 ± 0.27 *	6.38 ± 0.23 *

Note: values are mean ± SD

\* Values significantly different from those obtained during NCC protocol;  $p < 0.05$ .

† Values significantly different from those obtained DS protocol;  $p < 0.05$ .

NCC - no conditioning contraction; DS – dynamic stretching; ST – static squat; ST+30%BW – static squat with an additional external load of 30% of the subjects' body weight.

ing effect that elicited no PAP or masked the potential PAP effect. This can be supported by non-significant CMJ results between DS and ST. In another light, Dunkan and Sapstead [25] implied a longer rest interval for loaded isometric contractions to exhibit PAP. The CMJ results of the current study are difficult to compare with other studies because of the difference in preconditioning contraction stimulus.

The comparative effects of different preconditioning protocols on sprint performance were similar to those obtained in jumping performance. The DS protocol showed superior effects on sprint performance compared to NCC and ST. This is to some extent in accordance with the results of Fletcher and Jones [7], who reported enhancement in sprint performance after dynamic stretching compared to static stretching. The DS protocol resulted in relatively greater enhancement of sprint time than the ST + 30% intervention, but the difference was not statistically significant. It is possible that the ST protocol with an additional load of 30% body weight produced better neuromuscular stimulation than ST, which led to PAP after 3.5-4 min of preconditioning contraction. Another possible explanation is that PAP presented by ST only lasted for 2 min after warm-up cessation.

Preconditioning protocols for agility performance demonstrated significant differences between the NCC and other protocols. Although comparison of DS, ST and ST + 30% BW showed no significant difference in agility, it should be noted that DS produced the best results. This is probably due to the fact that a longer rest period enabled PAP. Existence of PAP after 4 min is in accordance with the results of Lowery et al. [32], who reported that vertical jump height and power increased and peaked after 4 min. In addition, Gouvêa et al. [33] reported in their meta-analysis that a rest interval of 8 to 12 min can produce a significantly greater PAP effect than shorter rest periods.

Intensity and rest interval are important factors in PAP. Lowery et al. [32] suggested that high-intensity workloads may prolong the duration of PAP. Other studies have reported a lower magnitude of PAP with decreased exercise intensity [34,35]. Additionally, intermittent protocols with a 30 s rest period may also facilitate PAP [36]. Comparing loaded and unloaded low-intensity intermittent isometric exercise suggests that ST produced lesser fatigue and its effects were

observed after a shorter period of time compared to loaded ST. However, ST may have produced a lower magnitude of PAP after a longer period of time. On the other hand, loaded ST delivered higher PAP stimulation but needed a longer rest period to overcome fatigue.

The findings of the study failed to agree with the current literature involving various mechanical stimuli in PAP. Thus, there is a need for further studies incorporating prolonged intermittent low-intensity isometric exercises with different duration of muscular tension and different post-conditioning rest intervals. Other limitations included non-measurement of body temperature and quantification of muscle activity across interventions, which could help in explaining the underlying mechanisms of PAP and fatigue from experimental protocols. Also, performance tests were not administered in a randomized order, which failed to provide clearer information on how rest intervals affect performance. The hypothesis that low-intensity intermittent isometric exercise as a preconditioning stimulus can positively influence jump, sprint and agility performance was supported by the study.

## CONCLUSIONS

Any previous muscle activity can trigger the mechanism of PAP [17]. Although PAP was not directly measured in this study, we can assume that isometric contractions in warm-up most likely influenced PAP and physical performance. However, its magnitude proved to be dependent on isometric load and rest interval. The hypothesis that low-intensity intermittent isometric exercise as a preconditioning stimulus can positively influence jump, sprint and agility performance was confirmed. The present study showed that prolonged intermittent low-intensity isometric protocols improved performance similar to dynamic stretching. This implies that such protocols for the warm-up session can be used as an alternative to dynamic stretching.

## Acknowledgements

The authors are grateful to the subjects for their kind cooperation during experimentation sessions. We would like to thank also the anonymous reviewers for their helpful comments and suggestions.

**Conflict of interests:** the authors declared no conflict of interests regarding the publication of this manuscript.

## REFERENCES

1. Gelen E. Acute effects of different warm-up methods on jump performance in children. *Biol Sport*. 2011;28(2):133-138.
2. Hedrick A. Physiological responses to warm-up. *J Strength Cond Res*. 1992;14(5):25-27.
3. Gray S, DeVito G, Nimmo M. Effect of active warm-up on metabolism prior to and during intense dynamic exercise. *Med Sci Sports Exerc*. 2002;34(12):2091-2096.
4. Starkie RL, Hargreaves M, Lambert D, Proietto J, Febbraio M. Effect of temperature on muscle metabolism during submaximal exercise in humans. *Exp Physiol*. 1999;84(4):775-784.
5. Dawes J, Roozen M. Developing Agility and Quickness. NSCA - National Strength & Conditioning Association, Human Kinetics, Champaign, IL;2012.
6. Chaouachi A, Castagna C, Chtara M, Brughelli M, Turki O, Galy O, Chamari K, Behm DG. Effect of warm-ups involving static or dynamic stretching on agility, sprinting, and jumping performance in trained individuals. *J Strength Cond Res*. 2010;24(8):2001-2011.
7. Fletcher IM, Jones B. The effect of different warm up stretch protocols on 20 meter sprint performance in trained rugby union players. *J Strength Cond Res*. 2004;18(4):885-888.
8. Pagaduan JC, Pojskić H, Užičanin E, Babajić F. Effect of various warm-up protocols on jump performance in college football players. *J Hum Kin*. 2012;35(4):89-98.
9. Samson M, Button D, Chaouachi A, Behm D. Effects of dynamic and static stretching within general and activity specific warm-up protocols. *J Sport Sci Med*. 2012;11(2):279-285.
10. Costa PB, Ryan ED, Herda TJ, Walter AA, Hoge KM, Cramer JT. Acute effects of passive stretching on the electromechanical delay and evoked twitch properties. *Eur J Appl Physiol*. 2010;108(2):301-310.
11. Hough P, Ross EZ, Howatson G. Effects of Dynamic and Static Stretching on Vertical Jump Performance and Electromyographic Activity. *J Strength Cond Res*. 2009;23(2):507-512.
12. Behm DG, Chaouachi A. A review of the acute effects of static and dynamic stretching on performance. *Eur J Appl Physiol*. 2011;111(11):2633-2651.
13. Simic L, Sarabon N, Markovic G. Does pre-exercise static stretching inhibit maximal muscular performance? A meta-analytical review. *Scand J Med Sci Sports*. 2013;23(2):131-148.
14. Ghasemi M, Bagheri H, Olyaei G, Talebian S, Shadmehr A, Jalaei S, Kalantari KK. Effects of cyclic static stretch on fatigue recovery of triceps surae in female basketball players. *Biol Sport*. 2013;30(2):97-102.
15. Hodgson M, Docherty D, Robbins D. Post-activation potentiation: underlying implications for motor performance. *Sports Med*. 2005;35(7):585-595.
16. Robbins, DW, Docherty D. Effect of loading on enhancement of power performance over three consecutive trials. *J Strength Cond Res*. 2005;19(2):898-902.
17. Batista MAB, Ugrinowitsch C, Roschel H, Lotufo R, Ricard MD, Tricoli VAA. Intermittent exercise as a conditioning activity to induce postactivation potentiation. *J Strength Cond Res*. 2007;21(3):837-840.
18. Xenofondos A, Laparadis K, Kyranoudis A, Galazoulas C, Bassa E, Kotzamanidis C. Postactivation-potentiation: factors affecting it and the effect on performance. *J Phys Ed Sport*. 2010;28(3):32-38.
19. Chatzopoulos DE, Michailidis CJ, Giannakos AK, Alexiou KC, Patikas DA, Antonopoulos CB, Kotzamanidis CM. Postactivation potentiation effect after heavy resistance exercise on running speed. *J Strength Condition Res*. 2007;21(4):1278-1281.
20. Chiu LZ, Fry AC, Weiss LW, Schilling BK, Brown LE, Smith SL. Postactivation potentiation response in athletic and recreationally trained individuals. *J Strength Cond Res*. 2003;17(4):671-677.
21. Judge LW, Bellar D, Judge M. Efficacy of potentiation of performance through overweight implement throws on male and female high-school weight throwers. *J Strength Cond Res*. 2010;24(7):1804-9.
22. West DJ, Cunningham DJ, Crewther BT, Cook CJ, Kilduff LP. Influence of ballistic bench press on upper body power output in professional rugby players. *J Strength Cond Res*. 2013;27(8):2282-7.
23. Miyamoto N, Wakahara T, Ema R, Kawakami Y. Further potentiation of dynamic muscle strength after resistance training. *Med Sci Sports Exerc*. 2013;45(7):1323-30.
24. Pearson SJ, Hussain SR. Lack of association between postactivation potentiation and subsequent jump performance. *Eur J Sport Sci*. 2014;14(5):418-425.
25. Duncan MJ, Sapsstead G. Acute effect of isometric mid-thigh pulls on postactivation potentiation during stretch-shortening cycle and non-stretch-shortening cycle vertical jumps. *Medicina Sportiva*. 2013;17(1):7-12.
26. Lim JJ, Kong PW. Effects of isometric and dynamic postactivation potentiation protocols on maximal sprint performance. *J Strength Cond Res*. 2013;27(10):2730-6.
27. WMADH. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *J Am Med Assoc*. 2000;284(23):3043-3045.
28. A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol*. 1983;50(2):273-282.
29. Bishop D. Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. *Sports Med*. 2003;33(6) 439-454.
30. Young W, Behm D. Should static stretching be used during a warm-up for strength and power activities? *Strength Cond J*. 2002;24(6):33-37.
31. Houston ME, Grange RW. Myosin phosphorylation, twitch potentiation, and fatigue in human skeletal muscle. *Can J Physiol Pharm*. 1990;68(7):908-913.
32. Lowery R, Duncan NM, Loenneke JP, Sikorski EM, Naimo MA, Brown LE, Wilson FG, Wilson JM. The effects of potentiating stimuli intensity under varying rest periods on vertical jump performance and power. *J Strength Cond Res*. 2012;26(12):3320-3325.
33. Gouvêa AL, Fernandes IA, César EP, Silva WA, Gomes PS. The effects of rest intervals on jumping performance: a meta-analysis on post-activation potentiation studies. *J Sports Sci*. 2013;31(5):459-67.
34. Behm DG, Button DC, Barbour G, Butt JC, Young WB. Conflicting effects of fatigue and potentiation on voluntary force. *J Strength Cond Res*. 2004;18(2):365-372.
35. Vandervoort AA, Quinlan J, McComas AJ. Twitch potentiation after voluntary contraction. *Exp Neurol*. 1983;81(1):141-152.
36. Wilson JM, Duncan NM, Marin PJ, Brown LE, Loenneke JP, Wilson SM, Jo E, Lowery RP, Ugrinowitsch C. Meta-analysis of postactivation potentiation and power: effects of conditioning activity, volume, gender, rest periods, and training status. *J Strength Cond Res*. 2013;27(3):854-9.