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Acute responses to a potentiation warm-up protocol on sprint and change of direction in female football players: a randomized controlled study

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Abstract

Objectives To evaluate the acute effect of exposure to a potentiation warm-up protocol compared to a usual warm-up program.

Design Randomized parallel control trial.

Setting Synthetic grass in the club's facilities (Portugal).

Participants Seventeen female football players (age: 23.9 ± 3.9 years), were randomly allocated to a control ($n=8$) and an experimental group ($n=9$). To allocate the players, a table was computer-generated by a research team member with no involvement in the trial.

Intervention The control group performed their usual warm-up program, while the experimental group performed a potentiation warm-up protocol with jumps combined with sprints with change of direction.

Main outcomes measures The players were tested pre- and post-intervention for a 40-m linear sprint and pre-planned change of direction using the T-test.

Statistical analysis An intention-to-treat analysis was performed, with all the participants originally randomized being involved. The normal distribution was verified by the Shapiro-Wilk test. The assumption of sphericity was analyzed. Effect sizes were calculated using partial eta squared.

Results No significant pre-post differences in the T-test and in the 40-m sprint were detected for any group. However, in the T-test, large effect sizes in time increments were observed within the experimental (0.27 s; $p > 0.05$, $\eta_p^2 = 0.176$) and control groups (0.06 s; $p > 0.05$, $\eta_p^2 = 0.176$). Also, in the 40-m sprint, large effect sizes in time increments were observed within the experimental (0.05 s; $p > 0.05$, $\eta_p^2 = 0.251$) and control groups (0.09 s; $p > 0.05$, $\eta_p^2 = 0.251$).

Conclusions The performance-enhancing ability of the potentiation method performed at warm-up was not verified when applied to female football players. Thus, the potentiation methods may not improve sprint and COD ability for this population. However, the lack of statistical significance may have been due to reduced statistical power, as three

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of four effects suggest acute performance impairment after a supposed potentiation-oriented warm-up. Nevertheless, the presence of a statistical type 2 error cannot be ruled out.

Registration number (retrospectively registered) NCT06555185; Project URL: <https://clinicaltrials.gov/study/NCT06555185>.

Keywords Performance enhancement, Warm-up, Sprint, Change of direction, Women's football

Background

A warm-up has the potential to enhance physical qualities for better athletic performance in training and competition [1]. Warming up before training sessions is expected to increase body temperature [2] and physical readiness [1, 3], and provides an opportunity to mentally prepare for the training contents through strengthening concentration and self-confidence [4]. Previous research suggested that warm-up protocols should have dynamic movements that increase body temperature and range of motion, enhance motor unit excitability, improve kinesthetic awareness and work on technique by reinforcing critical motor programs [5]. Recently, warm-up protocols aiming to improve acute performance and employing potentiation methods have been proposed in the literature [1, 6]. These potentiation methods are characterized by a variety of exercises exploring the stretching-shortening cycle [7], promoting the ability of the neural and musculotendinous systems to produce maximum power [8].

Regarding the potentiation effects, Post-Activation Potentiation (PAP) and Post-Activation Performance Enhancement (PAPE) are two of the most studied phenomena, however, some differences distinguish these two mechanisms [9]. The phenomenon of PAP is associated with an increase in contractile muscle force in response to maximal voluntary contractions, enhancing subsequent muscle contractions, measured as the maximal contraction force evoked by supramaximal electrical stimulation [9]. The literature suggests a time window to optimize the PAP, with a recovery period between 1- to 3-minutes (min) [10]. Conversely, PAPE refers to the increased maximal voluntary strength, power, or velocity (i.e., dynamic or isometric) following a conditioning contraction [9]. Accordingly, different training protocols have been used, such as plyometric exercises [6], resistance training [11], sprint training [12], the flywheel paradigm [13], and change of direction (COD) drills [14]. For PAPE, the performance-enhancing effects may be observed after a resting period, peaking 3- to 10-min after a conditioning contraction [10, 15].

Bearing in mind that traditional warm-ups may also enhance subsequent performance [3], even if not specifically targeting PAP or PAPE, we will adopt a broader concept of potentiation warm-up, i.e., a general acute benefit for subsequent performance. Additionally, despite being well-studied in men [7, 14], the data available on

acute potentiation effects of warm-up should be carefully interpreted for women, due to major anthropometrics, strength, and fitness differences between both sexes [16, 17], large disparities in explosive actions [18], apart from the greater performance variability observed in female compared to male athletes [19].

However, the effectiveness of these protocols depends on the balance between fatigue and potentiation [20, 21], which is affected by a variety of factors, including training experience [9], resting time using an optimal time-window [20], the intensity of the conditioning activity performed [22], the volume of warm-up [1], muscle fibre type and sex [23]. Therefore, this study aims to determine if the performance of female football players is affected after the exposure to a potentiation protocol. It is hypothesized that performance in the selected physical tests will improve significantly and meaningfully after performing the chosen potentiation protocol compared to the control group's warm-up.

Methods

Trial design

This study followed the CONSORT guidelines, using a randomized parallel trial in a single highly trained female football team classified as Tier 3 (i.e., highly trained/national level) [24], competing in the Portuguese top division. Players were recruited at the beginning (September) of the 2022/23 season and the follow-up was carried on the second half (March-April) of the 2022/23 season. A convenience and purposive sampling were used, and the participants were randomized into an experimental (EXPG, potentiation warm-up) and a control group (CONG, team's usual warm-up). The EXPG had a familiarization week with the potentiation protocol prior to the intervention period, while the CONG continued the usual warm-up program. Both groups were tested before and after performing the warm-up. The physical tests and intervention protocol took place during the competitive period.

All training sessions and physical tests were performed on the synthetic grass in the club's facilities (temperature, 15–20 °C; wind, 5,6–22,2 km/h). The tests were applied by members of the technical staff, who were not blinded to the interventions. The technology used was objective and reliable, hardly influenced by knowledge of the interventions to which the participants were assigned [25].

This research was approved by the ethical committee of the Faculty of Sport of the University of Porto, with the following approval code assigned CEFAD 03 2022 and performed in accordance with the ethical standards of the Declaration of Helsinki (64th WMA Assembly, Fortaleza, Brazil, 2013).

Participants

Seventeen female football players (23.9 ± 3.9 years of age, range 18 to 31; 12.2 ± 4.7 years of experience, range 6 to 23) were randomly allocated between a CONG ($n=8$) and an EXPG ($n=9$), using the Excel Software and the Random function, by a member of the research team with no involvement in the trial. The allocation sequence was concealed from the researcher implementing protocols until the beginning of the interventions. Inclusion criteria: players from any playing position (except goalkeepers, by their coaches' decision) able to train without limitations. Subjects were excluded if they had

any existing medical conditions that could compromise participation. All participants were informed about the purpose, content, and potential risks and benefits of the study, and signed an informed consent. In the CONG, two of the eight eligible athletes did not perform the 40-m sprint test due to muscle discomfort during that test. In EXPG, all the players completed all the assessments (Fig. 1). Sample power calculations were not performed for this study, due to the reduced number of players available in the female football team, and all players available were recruited for the study.

Experimental and active controls

The interventions lasted three weeks. During the first week, all players involved in the study were familiarized with the physical tests, which were performed before training sessions (T-test always before the 40-m sprint test). The intervention was carried out in the following two weeks, in a total of four training sessions (i.e., twice

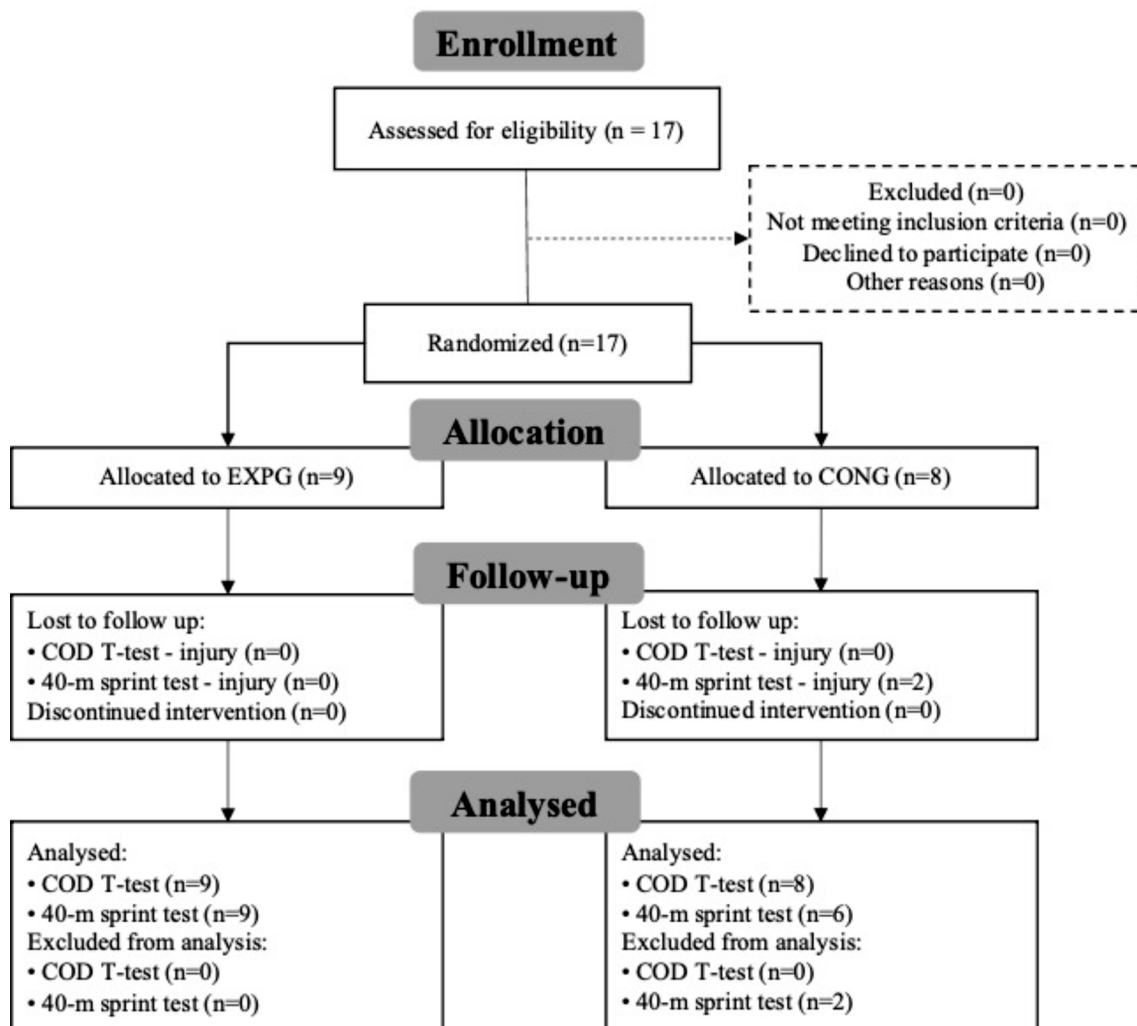


Fig. 1 Participants flow diagram. CONG - Control group; EXPG - Experimental intervention group

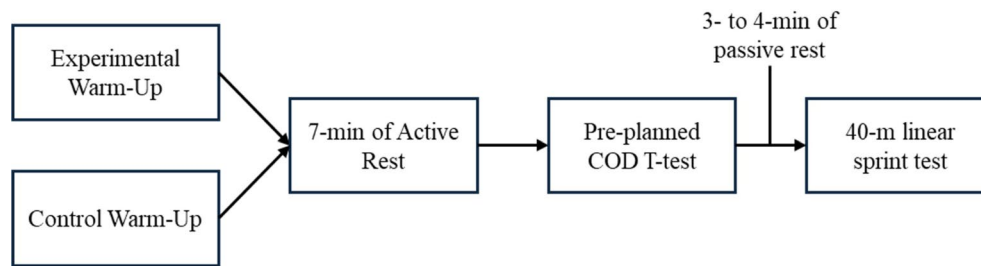


Fig. 2 Experimental design of the study

Table 1 Experimental and control warm-up design

Experimental warm-up design				
Sets	1st Set	2nd Set	3rd Set	4th Set
Exercises	6 hurdle jumps + 15-m sprint with COD	6 lateral hurdle jumps + 10-m sprint with COD	6 bouncy strides + 15-m sprint with COD	6 broad jumps + 10-m sprint with COD
Repetitions and rest interval between repetitions	3 repetitions (90s rest between repetition)	3 repetitions (90s rest between repetition)	3 repetitions (90s rest between repetition)	3 repetitions (90s rest between repetition)
Rest interval between sets	90s of rest between sets			
Control warm-up design				
Sets	1st phase		2nd phase	
Exercises	Slow jogging + light skipping + dynamic stretches		Football-specific exercises with and without ball, with accelerations, COD, jumping hurdles and ball possession games	
Duration	5 min		15 min	
Rest between phases	Light active rest (jogging) during the transition time between phases			

Note: COD – Change of direction

a week). The data collection of the physical tests started in the second week. The initial data collection took place at the onset of the first training session. The second data collection was executed at the conclusion of the third week, following the conclusion of the fourth protocol session. During the testing sessions both groups rested actively for 7-min before starting the T-test, and more 3- to 4-min of passive rest until starting the 40-m linear sprint, as presented in Fig. 2. The duration of each session was ~20-min for both groups.

The intervention used a modified version of a previously used protocol [14], while the CONG followed their usual warm-up. Both groups engaged in warm-up sessions of identical duration, conducted at the same time of day, with the participants wearing their normal football shoes. Both warm-up protocol designs are detailed in Table 1.

Outcomes

T-test

Pre-planned COD was assessed through the T-test [26], and applied according to standardized procedures described elsewhere [27]. However, forcing the participant to touch on each cone is not uniform [28], and

this step was withdrawn. We implemented course directions used previously [27]. The validated and reliable WICHRO® Wireless photocell system (Chronojump®), which consists of two pairs of barriers containing the photocell and its double reflector, was used [29], and the test started and ended on the same pair of barriers. Each player performed each test once due to the time limitation for collecting the test data.

40-m linear sprint

The same WICHRO® Wireless photocell system was used for the 40-m linear sprint [30]. The time was counted in seconds (s) and thousandths of a second (ms) with an error of ± 0.001 s [31]. After a 5 s countdown, the participants ran forward following the route marked by cones, one at 0 m indicating the start place and the other at 40 m indicating the finish place. Participants started the test from a standing start position with the front foot approximately 2 cm behind the first cone.

Statistical analysis

An intention-to-treat analysis was performed, with all the participants originally randomized being involved. The normal distribution was verified by the Shapiro-Wilk

test. The statistical analysis involved descriptive statistics, inferential statistics, and data are presented by mean \pm standard deviation. and then a mixed repeated measures ANOVA (i.e., within- and between-factors) was used. The assumption of sphericity was analyzed. Effect sizes were calculated using partial eta squared (η_p^2) and will be classified as small (0.010–0.059), moderate (0.060–0.137), and large (>0.137) [32]. Statistical significance was assumed at $p < 0.05$. Statistical analysis was performed using the IBM SPSS (*Statistical Package for the Social Sciences*) version 27.

Results

Results obtained in the pre-planned COD T-test and in the 40-m sprint test, for both groups, are presented in Table 2. The ANOVA analysis indicated neither a significant time nor group vs. time interaction effect, nor between groups for both tests.

T-test

In the pre-planned COD T-test, the decrements in performance observed in the EXPG (0.27 s) and the CONG (0.06 s) were not statistically significant, however, it presented a main time effect with a large effect size ($p > 0.05$, $\eta_p^2 = 0.176$).

40-m Sprint Test

In the 40-m sprint test, it was observed non-significant decrements in performance in the EXPG (0.05 s) and in the CONG (0.09 s). However, it presented a main time effect with a large effect size ($p > 0.05$, $\eta_p^2 = 0.251$).

Discussion

To our knowledge, this was the first study to examine the effects of a potentiation protocol performed in the warm-up on the sprint and COD ability in highly trained female football players. The main results do not support our initial hypothesis, showing that the potentiation warm-up protocol failed to enhance the performance in the speed and COD tests, and indeed likely generated more fatigue than potentiation. Despite lack of statistical significance, effect sizes supported performance decrements post-warm-up.

A systematic review which examined the effects of PAPE on sprint and COD performance in athletes from different sports observed that only one study revealed strong evidence that such protocols may improve sprint performance and limited evidence for improvements in COD ability [33]. However, this study consisted of collegiate women that were merely physically active. The authors also reported that such enhancements have large individual variations in responses and are context-dependent, requiring further research to draw clear conclusions, especially in COD ability [33]. Therefore, an imbalance between fatigue and potentiation should be considered when interpreting the presented results, as well as the familiarization time with the protocol and the total volume of pre-conditioning exercise performed that might play a key role.

A direct comparison of our results to similar studies is hampered because research is often conducted in males. In the study of Aloui et al. [14], 34 male football players showed improvements in both sprint performance and COD ability after being exposed to a potentiation warm-up protocol for eight weeks. However, these results may not be comparable to our study due to possible chronic adaptations, which may explain the improvements in contrast to the results of our study. Another study using potentiation methods through trunk jumps, linear sprints and COD drills performed as a re-warm-up strategy, acutely enhanced the COD ability assessed by the T-test, however, this intervention was also carried out in male soccer players [34]. The study of Zisi et al. [35] involving sprinters from both sexes, investigated the effects of plyometric training on 30-m sprint test, and the results revealed an improvement in the subsequent performance of the acceleration phase of the 5-m and 10-m sprint by 1.7% and 1.1%, respectively, compared to baseline. However, non-significant results were observed in the 30-m sprint test between groups, which is parallel to our results, since a protocol that included plyometric training was also followed.

Some of the contrasting results may be explained by potential differences in response to the training stimuli between sexes, where men tend to exert higher potentiation effects [36, 37], and the transitory enhanced

Table 2 Comparison between pre- and post-protocol performance in the 40-m sprint test and the pre-planned COD t-test for EXPG and CONG

Test	Groups	Pre-Protocol (s)	Post- Protocol (s)	Change (s)	Δ (%)	p-value			ES
						Time	G×T	Group	Time η_p^2
Pre-planned COD t-test	EXPG	8.95 \pm 0.27	9.22 \pm 0.24	0.27 \pm 0.26	2.93	0.094	0.258	0.555	0.176
	CONG	8.97 \pm 0.52	9.03 \pm 0.31	0.06 \pm 0.48	0.66				
40-m sprint test	EXPG	6.17 \pm 0.24	6.22 \pm 0.25	0.05 \pm 0.08	0.80	0.057	0.548	0.253	0.251
	CONG	6.02 \pm 0.12	6.11 \pm 0.17	0.09 \pm 0.18	1.47				

Note: Statistical analysis of mixed repeated measures ANOVA 2(group) \times 2(time). Values presented as mean \pm SD; p - significance value of the mixed repeated measures ANOVA test; η_p^2 - partial eta squared; CONG - Control group; EXPG - Experimental intervention group; G×T - interaction between group and time; ES - effect size

performance promoted by potentiation strategies also tends to be shorter in women, limiting its use in sports competitions [38]. A possible mechanism for the lower potentiation effect on women may be due to a lower type-II muscle fibre composition when compared to men [37]. Moreover, the study used as reference for designing the experimental protocol was developed for young male football players [14], and such a training program may not be the most appropriate for female athletes. A recent systematic review on COD improvements through plyometric training [39] suggested an ideal protocol of 2 weekly sessions for 6–9 weeks with a rest interval between sessions of 48–72 h, and a training volume of 1–6 exercises at maximum intensity with a rest period between sets of 60–90 s, which is similar (except the number of weeks) to the protocol adopted in our study. Even though the experimental protocol used in the present study involved a multicomponent training program, where plyometric exercises were combined with acceleration and COD work, this combination of different training components has previously been tested in male athletes [7, 40], while maintaining the same plyometric training volume recommended for plyometric-exclusive training programs. However, such training volumes and rest times are likely unsuitable for female since they were specifically designed for male athletes, and further studies with female populations are requested for the development of more sex-specific potentiation protocols.

As the results indicated a large effect size in diminishing subsequent performance after the potentiation warm-up, the lack of significant differences may be attributed to the reduced sample size. Moreover, the sample being underpowered may have result in false negatives (i.e., non-detection of significant differences due to poor power). The hypothesis of acute fatigue should also be raised as a potential cause, as it may explain the impaired neuromuscular performance in such protocols [21, 41, 42]. However, it is difficult to draw strong conclusions regarding this cause due to the several factors that impact potentiation effects [20, 21, 33, 41, 42].

On the other hand, considering the results obtained in this study, the most plausible reasons for the results may be related to the small sample size, the time frame of exposure, and the total volume of exercises, with the last two being suggested as determinant factors in the success of interventional protocols [43]. Nevertheless, applied research with national-level (or higher) players is scarce, particularly in women, and therefore, studies with this type of participants are of utmost importance, even if involving small sample sizes. Correspondingly, regarding the time frame between the potentiation activity and the tests performed in this study, it might have been too long to induce performance improvements, considering that more recent literature suggests a 2- to 8-min recovery

interval [15]. This limitation has a significant impact, especially since the participants are women, who experience an earlier loss of the potentiation effect compared to men [38].

In addition, our work does not allow us to conclude whether the potentiation protocol elicited a level of acute fatigue that explains the decrement in performance, due to a lack of an additional experimental group performing the same potentiation protocol but under a lower dose. Therefore, future research should evaluate this scenario and more studies with a larger sample size and various experimental groups are needed to corroborate the findings of the present study regarding the acute effects of potentiation methods in female football players.

Conclusion

The performance-enhancing ability of the potentiation method performed at warm-up was not verified when applied to female football players. Thus, for this population, the potentiation methods may not be effective in improving sprint and COD ability. However, the competitive phase, volume of training, fatigue induced by the potentiation method and recovery time should be considered when coaches plan to apply such types of protocols aiming to improve performance acutely. The selection of a proper ratio of training volume and rest time is a crucial factor for the usefulness of potentiation warm-ups in female athletes. Therefore, for the development of further potentiation warm-up protocols, it seems plausible to consider lower volumes and longer rest periods than previously used in male athletes, to avoid eventual deleterious effects generated by excessive fatigue.

Abbreviations

COD	Change of direction
CONG	Control group
EXPG	Experimental group
PAP	Post-activation potentiation
PAPE	Post-activation performance enhancement

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13102-024-01015-z>.

Supplementary Material 1

Acknowledgements

We would like to extend our gratitude to the football players who participated in this study and to the coaching staff and management of the football club for their cooperation and support. Special thanks to the research assistants and volunteers for their help with data collection.

Author contributions

TZ, JA and IB were responsible for conceptualizing the project. TZ and RM were responsible for curing the data. RM and JA were responsible for the study's methodology. JA and IB were responsible for the supervision. TZ and RM wrote the original draft. All authors reviewed & edited the manuscript.

Funding

The author(s) reported there is no funding associated with the work featured in this article. CIFI₂D is financed by the Portuguese Foundation for Science and Technology, under the DOI <https://doi.org/10.54499/UIDB/05913/2020>. Open access funding provided by UiT The Arctic University of Norway (incl University Hospital of North Norway)

Data availability

The datasets generated and analysed during the current study are available in the Mendeley Data repository, <https://data.mendeley.com/datasets/2cwcz2vx4v/1>.

Declarations

Ethics approval and consent to participate

This research was approved by the ethical committee of the Faculty of Sport of the University of Porto, with the following approval code assigned CEFAD 03 2022 and performed in accordance with the ethical standards of the Declaration of Helsinki (64th WMA Assembly, Fortaleza, Brazil, 2013). All participants were informed about the purpose, content, and potential risks and benefits of the study, and signed an informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Received: 23 July 2024 / Accepted: 4 November 2024

Published online: 12 November 2024

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