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Research article

Effects of peppermint oil inhalation on vertical jump performance in elite young professional soccer players: A double-blinded randomized crossover study

Alex Ambrosio Rites [a,b], Pablo Merino-Muñoz [c,d], Fabiano Ribeiro [b], Bianca Miarka [a], Veronica Salermo [a], Diego Viana Gomes [a], Ciro José Brito [d,*], Esteban Aedo-Muñoz [d]

[a] *Postgraduate Program in Physical Education. Federal University of Rio de Janeiro, Brazil*
[b] *Fluminense Football Club, Brazil*
[c] *Núcleo de investigación en ciencias de la motricidad humana, Universidad Adventista de Chile, Chile*
[d] *Escuela de Ciencias de la Actividad Física, el Deporte y la Salud, Facultad de Ciencias Médicas, Universidad de Santiago de Chile, Chile*

A R T I C L E I N F O

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A B S T R A C T

Aims: To evaluate peppermint essential oil (PEO) inhalation's effect on young soccer athletes' motor performance.
Methods: A randomized crossover design was used to test the effect of the PEO. Eleven U-17 soccer players were evaluated into two conditions (PEO and Placebo – PLA). The players were tested in squat jump and countermovement jump and inhaled PEO or PLA and 10 min later performed the physical tests again. A mixed ANOVA was performed to test the hypotheses.
Results: Main effects were found for the time in jumping height in the CMJ ($p = 0.037$). No main and interaction effects were found in the SJ variables.
Conclusion: From the results, decrease CMJ performance acutely, both conditions presented decrease in JH, but based in effect size, PLA decrease is higher (more sample size for corroborate this) possibly due to improvements in the eccentric yielding sub-phase, where mentioned phase could be reflecting neural changes (required experimental verification). The PEO could be the interest in trainers for use before of match or in the half-time for minimize the decreased of physical performance by the rest.

1. Introduction

Soccer is one of the world's most widely played and complex sports, where players require technical, tactical, and physical skills for success [1,2]. During high-intensity activities, performance can be compromised due to fatigue, potentially increasing the risk of injury, or reducing the ability to sustain activity. Therefore, one of the biggest challenges for physical trainers and coaches is manipulating training variables to improve performance during training sessions and matches long [3,4]. It is a general belief that physical exercise challenges the body's homeostasis and elicits a measurable physiological response. Notably, there is a substantial increase in muscle metabolism, which triggers an increase in the blood circulatory system and gas exchange [5]. For this, in addition to a formal training program, there are other strategies to prevent or delay fatigue, such as supplements and aromatherapy [6].

* Corresponding author. Universidad de Santiago de Chile. Avenida Libertador Bernardo O'Higgins nº 3363. Estación Central. Santiago. Chile.
E-mail address: ciro.brito@usach.cl (C.J. Brito).

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Aromatherapy uses fragrance inhalation of essential oils formed by aromatic plants [7]. Fragrance inhalation of essential oils is used for various physical, psychological, and cognitive purposes. This therapy has emerged as a possible ergogenic aid in recent years. Initially, Lavender aromatherapy was considered a recovery method to reduce diastolic blood pressure and heart rate [8]. Essential oils are complex mixtures of strongly odoriferous volatile compounds that are synthesized in various plant organs and have diverse ecological functions. Aromatic essential oils are frequently considered as potential new treatments for various disorders, including fatigue [9]. Some these essential oils such as peppermint and eucalyptus are present in many medicines for external application and have been used to treat muscle pain conditions and headache syndrome [10]. Another substance how ammonia (gas) has demonstrated controversial effects in neuromuscular performance [11–13] unlike essential peppermint essential oil (PEO) which has demonstrated positive effects [14].

Peppermint (also known as Mentha) is a genus in the taxonomic family Lamiaceae (mint family), and it is widely distributed across the temperate regions of the world. It is a complex mixture of biologically active secondary metabolites, such as menthol, menthone, neomenthol and iso-menthone, and so forth [14]. PEO positively influences conditioning abilities during sports. Among these improvements, we can mention cognitive ability, improved attention, and visual-motor response [15]. PEO can increase alertness and mental clarity [16]. According to Pournemati et al. [6], the improvement in performance through PEO may be related to its action on cell membranes by regulating the flow of Ca^{2+} (Calcium). PEO, with its active ingredients, is believed to reduce oxidative stress and inflammation induced by exercise and thus relieve exercise-induced fatigue and improve exercise performance [4,5]. Numerous types of essential oils exist with varying compositions and effects. However, one such example is Eucalyptus globules, which contains 1, 8-cineole (eucalyptol) that has important pharmacological activities, including antioxidant and anti-inflammatory effects. The molecular formula of 1,8-cineole, a monoterpene, is C10H18O, and its molecular weight is 154,24 g/mol. This compound can significantly improve respiratory function and is, therefore, often used to treat respiratory diseases, such as dyspnea, bronchitis, rhinitis, and asthma [4].

According to Meamarbashi and Rajabi [17], studies have been conducted on the effectiveness of various natural products in improving sports performance. Few studies have examined the effects of oil inhalation on performance in high-intensity actions, and the underlying mechanisms are still unclear and need further investigation [14]. To the best of our knowledge, there are no studies to date on the effect of PEO inhalation on the performance of professional soccer players. This research subject seems to be interesting for football, thus, crucial actions in soccer, such as accelerations, sprinting, and changes of direction, have moderate to strong relationships with variables derived from countermovement jump (CMJ) and squat jump (SJ) through evaluation on strength platforms [18–21]. The CMJ and the SJ are easy to implement, non-invasive, and do not produce fatigue in athletes [22]. Therefore, evaluating the vertical jump has become essential in assessing the lower extremity strength of soccer players [19,20,23,24]. Thus, our study aimed to evaluate the effect of PEO inhalation on vertical jump performance in elite youth soccer athletes. We hypothesize that PEO inhalation results in an ergogenic effect for performed jumps when compared to PLA.

2. Methods

2.1. Participants

A non-random convenience sampling was done. Eleven young players (sub-17 years) of first division Brazilian team (age = 17.5 ± 0.32 years, corporal mass = 64.7 ± 7.67 kg, height = 175.1 ± 8.01 cm). Tus, soccer athletes were initially selected according to the following inclusion criteria: (a) training continuously in the intervention month and competing regularly in the past and current year; (b) not present physical diseases on the day of the evaluations; (c) being in the category under 17 years old; (d) the athlete himself and the legal guardian sign the Free and Informed Consent Form; (e) completed all phases of this study; (f) $\geq$ 3 years' experience in professional soccer and had experience with CMJ, SJ, and procedures used throughout the experimental training). The athletes trained for five days and had two days of recovery, described in Fig. 1.

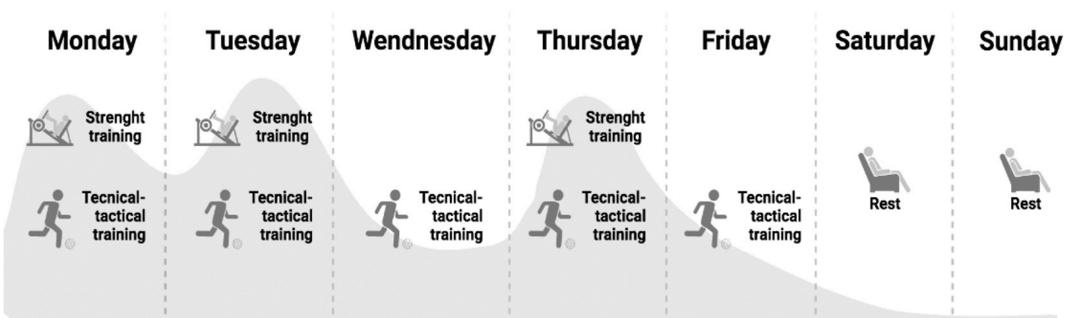

Fig. 1. Model of training load in one-week.

2.2. Experimental design

The present study is a quantitative experimental, randomized crossover, double-blinded, placebo-controlled approach. Only the oil administrator knew which was PEO and with placebo oil. The tests were always carried out in the same period (8:00 a.m.). During the sessions of intervention, no interventions were made regarding food intake or hydration status. The athletes were instructed not to use any type of substance containing caffeine and to avoid physical activity in the last 48 h. The athletes who used ergogenic substances, prescription drugs, supplements that are on the Word Anti-Doping Agency list, or present recent injuries, were excluded from the study. The procedures performed were previously approved by the Local Research Ethics Committee (protocol 4.366.750) and followed the Declaration of Helsinki (World Medical Association, 2013).

2.3. Procedures

The players were evaluated on three occasions at the club's training center. The first visit was carried out with an anthropometric assessment, weight, and height, with the second and third visit the athletes were subjected to the testing protocol using PEO and fractionated coconut oil how placebo condition (PLA). Before the start of the jump, players performed a 5-min standardized warm-up, consisting of low-to-moderate speed running, light individual calisthenics, and stretching exercises followed by short bursts of high-speed running, carried out by the team's physical trainer.

After this, they were evaluated through the vertical jump. Five minutes later, they inhaled PEO or a PLA substance, and after 10 min, they were reevaluated again to see the effect of the PEO. A drop of concentrated oil from the brand dōTERRA© (Rio de Janeiro, Brazil) with menthol, menthone, neomenthone, and iso-menthone active ingredients was placed on the athletes' hands. They rubbed the hand and took five strong breaths. This procedure was repeated one week later (Fig. 2).

2.4. Materials

The jumps were performed on two PASCO PS-2141 force platforms previously validated for this task [25]. Each player performed three jumps, separated by a 20-s pause for each jump [19,26]. The signals were recorded through PASCO CAPSTONE software with a sampling frequency of 1000 Hz, where they were exported to a spreadsheet and then processed by a MatLab 2021a script created by one of the authors. The variables described below were calculated for each jump, and the average of the attempts was analyzed [26].

2.5. Tests

For the countermovement jump (CMJ), players were instructed to descend, ascend as fast as possible, and seek the highest possible height according to the procedures described by Barillas et al. [27]. For both jumps the players were instructed for maintain the hands on the hip in all moments of jump. The following variables were analyzed: jump height through take-off velocity, jump time, push-off distance, peak force, eccentric yielding, braking, and concentric impulse [19,26,28]. For the squat jump (SJ), players were instructed to go up as fast as possible and seek the highest possible height [27]. The following variables were analyzed: jump height through take-off velocity, jump time, peak force, and rate of force development (jump initiation to peak force) [29]. For both jumps, the onset of movement was established by the method of five standard deviation of a baseline (weight of subject). A mathematical integration of ground reaction force was used for calculating velocity and displacement and define end of braking phase (CMJ), jump height (both jumps) and push-off distance (CMJ).

2.6. Statistical analysis

The normality of the variables was analyzed using the Shapiro-Wilk test and the normality assumption was assumed, then

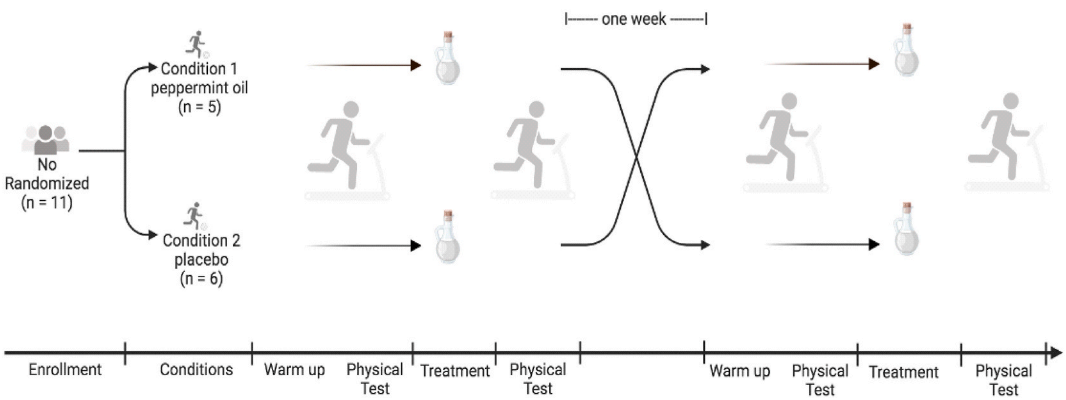

Fig. 2. Fashion of experimental design.

descriptive statistics was expressed how mean and standard deviation. A mixed ANOVA was performed with intra-condition factors (pre and post) and between-condition factors (PEO and PLA), and the interaction effect was also analyzed. The effect size was estimated as partial eta squared (ηp^2) and will be interpreted categorically through the following thresholds: trivial <0.01; small from 0.011 to 0.06; moderate from 0.061 to 0.14 and large >0.141 [30]. In the case of finding differences, Bonferroni *post-hoc* tests were performed and effect size was calculated as Cohen's d using the following thresholds for categorization: trivial 0 to 0.2; small from 0.21 to 0.6; moderate from 0.61 to 1.2; large from 1.21 to 2 and very large >2 [31]. Absolute intra-test reliability was determined through the coefficient of variation (CV) expressed as a percentage, calculating the CVs per athlete and averaging to the whole sample, considering acceptable values < 10 % for sport testing [32] and relative reliability through the intraclass correlation coefficient (ICC) with a mixed model of two factors of absolute agreement type of single measured form [33], using the following thresholds for qualitative categorization: <0.49 poor; 0.5 to 0.74 moderate; 0.75 to 0.89 good and >0.9 excellent [34] presenting their 95 % confidence intervals. An alpha of 0.05 was established for main and interaction effects and 0.1 for post-hoc. All the statistics were carried out using JASP open free software.

3. Results

Table 1 shows the descriptive statistics concerning CMJ performance. Main large effects were found for the time in jumping height ($p = 0.037$ and $\eta p^2 = 0.2$) and an interaction large effect in yielding impulse ($p = 0.05$ and $\eta p^2 = 0.18$) without post-hoc differences ($p > 0.1$).

Fig. 3 (A–D) showed the individual results when the participants performed the tests in PEO and PLA conditions. Negative small effect size was founded in both conditions for JH (decrease). Positive small effect size (increase) in yielding impulse was founded for PLA condition and small negative for PLA condition (decrease).

Table 2 shows the descriptive statistics of the SJ. No main effect and interaction were found in the SJ variables.

Table 3 shows absolute and relative reliability of CMJ and SJ variables, respectively. No ICC showed a significant difference ($p < 0.05$).

4. Discussion

The main objective of the present study was to analyze the effect of PEO inhalation on the physical performance of young elite soccer players. Our main findings were a decrease of jump height in the CMJ in both condition and an interaction effect in yielding impulse. Few studies have analyzed the effects of PEO on physical performance, Pournemati et al. [6] analyzed the effect on aerobic performance in women immediately after inhaling PEO, finding no effect compared to PLA. Meamarbashi and Rajabi [17] analyzed the effect of 10-day consumption of peppermint oil in water on aerobic performance, finding improvements in several performance indicators. Shepherd and Peart [35] also analyzed the consumption of PEO in water for ten days in a crossover design with a PLA, where no effect on aerobic performance was found. Another study investigated the effect of acute oil and water consumption on neuromuscular performance in young, healthy subjects, finding improvements at 5 min and 1-h post-consumption, while the PLA condition maintained their performance in the vertical jump [15]. A problem with the latter study is that calculating jump height is not mentioned, where methods such as flight time present systematic and random errors [36]. Our results corroborates the findings of the Rambo et al. [37], where no improvement in jump height was observed, but they not tested jump before the inhalation.

Some mechanisms that could interfere with physical performance have been mentioned, such as increasing cellular energy metabolism by stimulating the central nervous system, as menthol can stimulate the adrenal cortex to increase energy and reduce blood lactate levels [15]. Menthol has been found to exhibit concentration-dependent tonic γ-aminobutyric acid and nicotinic receptor binding properties and significant suppression of acetylcholinesterase, potentially increasing the synaptic availability of acetylcholine

Table 1
Differences in CMJ variables between moments and conditions.

Variables	Condition	Pre	Post	Time		Condition		IE	
		M±SD	M±SD	p	ηp^2	p	ηp^2	p	ηp^2
Jump height (cm)	PEO	32.4 ± 4.4	30.8 ± 4.6	**0.037**	**0.20**	0.63	0.01	0.62	0.01
	PLA	33.9 ± 6.8	31.3 ± 6.0						
Jump time (s)	PEO	0.75 ± 0.05	0.77 ± 0.06	0.63	0.01	0.19	0.08	0.10	0.13
	PLA	0.79 ± 0.06	0.78 ± 0.06						
Push-off distance (cm)	PEO	41.1 ± 5.1	40.3 ± 4.7	0.15	0.10	0.30	0.05	0.64	0.01
	PLA	43.5 ± 4.7	41.7 ± 5.3						
Braking impulse (N*s)	PEO	169 ± 42.3	171 ± 45.0	0.20	0.08	1.0	<0.01	0.46	0.03
	PLA	166 ± 47.8	175 ± 56.2						
Yielding impulse (N*s)	PEO	59.2 ± 13.2	64.5 ± 17.0	0.57	0.02	0.47	0.03	**0.05**	**0.18**
	PLA	67.6 ± 18.6	64.7 ± 19.4						
Concentric impulse (N*s)	PEO	347 ± 42.2	341 ± 35.4	0.10	0.13	0.60	0.01	0.94	<0.01
	PLA	355 ± 35.6	349 ± 38.8						

*Difference vs post (same Condition) $p < 0.1$; M: mean; SD: standard deviation; ηp^2: partial eta squared; IE interaction effect; PEO: peppermint essential oil; PLA: placebo condition.

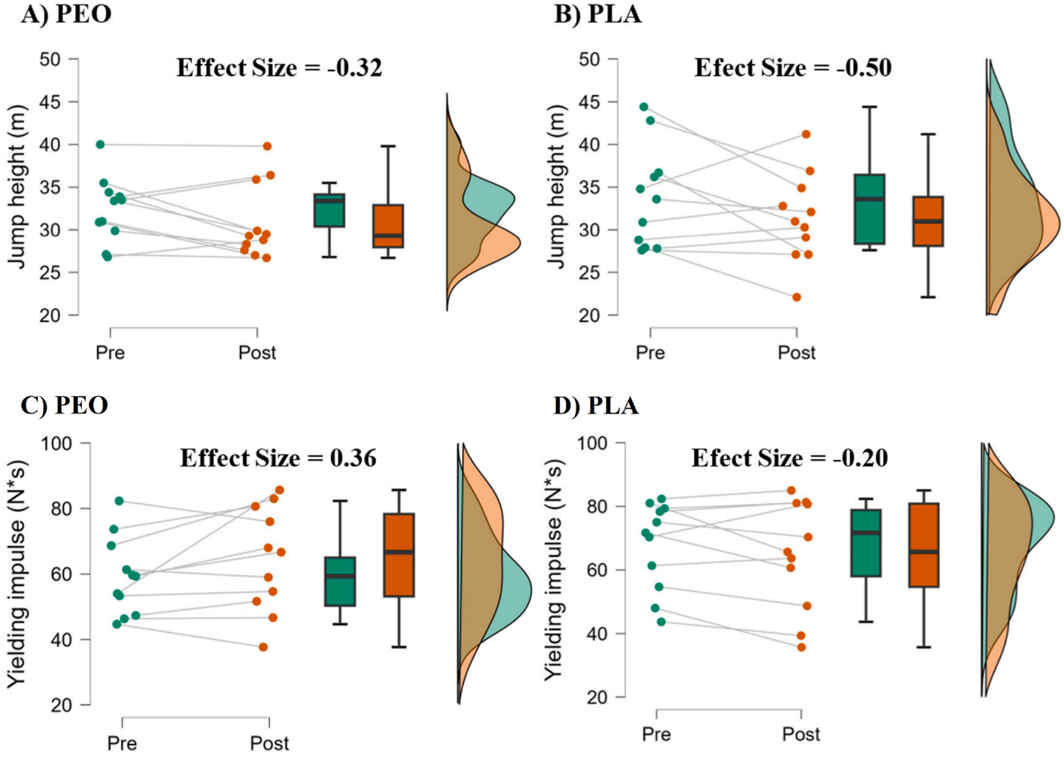

Fig. 3. Individual jump height (A and B) and yielding impulse (C and D) for both conditions over time. Negative effect is decrease in jump height and positive effect is increase in yielding impulse and vice versa.

Table 2
Differences in squat jump variables between moments and conditions.

Variables	Condition	Pre	Post	Time		Condition		IE	
		M ±SD	M ±SD	p	ηp^2	p	ηp^2	p	ηp^2
Jump height (cm)	PEO	35.0 ± 3.9	34.3 ± 4.9	0.20	0.1	0.65	0.01	0.70	<0.01
	PLA	34.0 ± 5.8	33.7 ± 4.8						
Jump time (s)	PEO	0.3 ± 0.04	0.3 ± 0.04	0.77	<0.01	0.97	<0.01	0.71	0.01
	PLA	0.3 ± 0.05	0.3 ± 0.05						
Peak force (N/kg)	PEO	24.5 ± 2.1	24.8 ± 2.2	0.24	0.07	0.66	0.01	0.85	<0.01
	PLA	24.4 ± 2.5	23.8 ± 2.6						
RDF (N/s/kg)	PEO	65.7 ± 14.8	77.3 ± 27.4	0.23	0.07	0.57	0.02	0.96	<0.01
	PLA	73.0 ± 26.7	73.6 ± 36.5						

M: mean; SD: standard deviation; ηp^2: partial eta squared; IE: interaction effect; PEO: peppermint essential oil; PLA: placebo condition. RFD: rate of force development.

[14]. PEO can increase Ca2+ concentration and prolong the depolarization response, a neuroprotective property under oxidative stress in DAO cells [38,39]. In addition, PEO can increase lung capacity in healthy subjects to provide more oxygen to the brain and reduce fatigue [9]. Concerning changes in the yielding impulse, it has been mentioned that this phase is possibly associated with the absorption phase of muscle slack [28]. This central nervous system stimulation could improve slack muscle absorption by decreasing electromechanical delay [40].

In relation at not differences in jump time, in a study where two conditions performing CMJ with differences in jump height were compared, it was found that the condition with higher height had shorter jump time and shorter concentric phase time [41]. However, our data did not observe differences in jumping time, so times in specific phases could have increased and others decreased. Concerning the SJ, no differences were found in both conditions, highlighting that this jump isolates a concentric muscle action [40], and just like the CMJ, where the concentric impulse had no changes, changes in mechanisms corresponding to the eccentric action are highlighted. In the study of Meamarbashi [15], the PLA maintained their vertical jump height at 5 and 60 min compared to their baseline level but did not mention what type of jump was performed (SJ or CMJ).

The present study has limitations regarding the sample size and the fact that a control condition was not used. However, some articles show that a less sample size and variables of gender, height, and body mass does not affect with this design [42]. Other

Table 3
Absolute and relative reliability of CMJ and SJ variables.

CMJ	Pre				Post			
First visit	CV	ICC	IL	UL	CV	ICC	IL	UL
Jump height	9.15	0.71	0.33	0.93	7.66	0.94	0.87	0.97
Jump time	3.83	0.42	0.05	0.76	3.84	0.94	0.87	0.97
Push-off distance	5.56	0.80	0.56	0.94	5.22	0.94	0.87	0.97
Braking impulse	14.0	0.92	0.84	0.97	14.1	0.55	0.28	0.78
Yielding impulse	11.6	0.87	0.74	0.94	10.2	0.86	0.73	0.94
Concentric impulse	2.81	0.94	0.87	0.97	2.31	0.93	0.86	0.97
Second visit								
Jump height	9.13	0.42	0.06	0.76	8.36	0.73	0.44	0.91
Jump time	5.96	0.30	−0.01	0.68	4.55	0.61	0.28	0.86
Push-off distance	7.45	0.45	0.10	0.78	7.20	0.62	0.26	0.86
Braking impulse	16.1	0.50	0.11	0.81	14.1	0.72	0.40	0.91
Yielding impulse	17.0	0.32	−0.02	0.70	14.3	0.34	0.01	0.71
Concentric impulse	4.74	0.69	0.36	0.90	3.75	0.75	0.47	0.92
SJ	**Pre**				**Post**			
First visit	**CV**	**ICC**	**CV**	**ICC**	**CV**	**ICC**	**CV**	**ICC**
Jump Height	2.22	0.92	0.79	0.98	3.40	0.89	0.73	0.97
Jump Time	3.60	0.68	0.36	0.89	2.09	0.96	0.90	0.99
Peak Force	1.44	0.93	0.82	0.98	1.60	0.95	0.86	0.98
Rate of force development	10.1	0.51	0.14	0.81	10.6	0.92	0.79	0.97
Second visit	**CV**	**ICC**	**IL**	**UL**	**CV**	**ICC**	**IL**	**UL**
Jump Height	5.87	0.74	0.46	0.91	6.70	0.20	−0.14	0.63
Jump Time	3.75	0.82	0.58	0.94	5.12	0.73	0.45	0.91
Peak Force	3.49	0.82	0.60	0.94	2.27	0.92	0.79	0.98
Rate of force development	10.7	0.82	0.59	0.94	15.2	0.76	0.48	0.92

* All ICC $p < 0.05$; CV coefficient of variation; ICC intraclass correlation coefficient; IL inferior limit 95 % confidence interval; UL upper limit 95 % confidence interval.

limitation is the control of cognitive fatigue (or mental fatigue) which can affect motor performance [43]. The last limitation is the not acceptable (above 10 % of CV) and poor (under 0.49 ICC) reliability of some variables in different times moments. Future studies should consider other crucial physical performance tests in soccer, such as changes of direction, adding a control condition group, and internal use (PEO in water), maintain crossover designs and testing in another gender and sport populations.

5. Conclusion

From the results, decrease CMJ performance acutely, both conditions presented decrease in JH, but based in effect size, PLA decrease is higher (more sample size for corroborate this) possibly due to improvements in the eccentric yielding sub-phase, where mentioned phase could be reflecting neural changes (required experimental verification). The PEO could be the interest in trainers for use before of match or in the half-time for minimize the decreased of physical performance by the rest. However, further studies are needed to analyze the best method of consumption; inhalation, consumption in water, oil on the tongue, and the amount and time of consumption, instantaneous and long-term effect, to observe the effects on aerobic and neuromuscular performance with crossover designs.

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CRediT authorship contribution statement

Alex Ambrosio Rites: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Pablo Merino-Muñoz:** Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Conceptualization. **Fabiano Ribeiro:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Bianca Miarka:** Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Formal analysis. **Veronica Salermo:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Diego Viana Gomes:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation. **Ciro José Brito:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Formal analysis, Data curation. **Esteban Aedo-Muñoz:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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