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Can compression stockings reduce the degree of soccer match-induced fatigue in females?

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ABSTRACT

Soccer-induced fatigue and performance are different between the sexes. The effect of compression stockings (CS) use on fatigue during the soccer match in females is unknown. Thus, we evaluated the impact of CS use during a female soccer match on match-induced fatigue. Twenty soccer players were randomly allocated to two groups (n = 10 for each group): CS and Control (regular socks), and equally distributed within two teams. At rest (baseline 48-h before the match) and immediately post-match, we assessed agility T-test, standing heel-rise test and YoYo Intermittent Endurance Test level 2 (YoYoIE2) performance. Effort during the match (heart rate and rating of perceived exertion) was similar ($p > 0.05$) between groups. The YoYoIE2 performance was decreased post-match ($p < 0.05$) equally for both groups. Otherwise, the CS group exhibited a greater post-match performance ($p < 0.05$) for the agility T-test and heel-rise test (large effect sizes). Therefore, we conclude that the use of CS during an amateur female soccer match resulted in less match-induced fatigue.

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Introduction

The soccer match demands have been extensively described (da Mota, Thiengo, Gimenes, & Bradley, 2016; Datson et al., 2014). Players usually cover distances greater than 10-km per match with more than 2.5-km at high speeds (>14 km.h^{-1}) (da Mota et al., 2016), performing countless changes of direction, acceleration, and deceleration (Russell et al., 2016). These high-intensity actions may lead to match-induced fatigue (Krustrup, Zebis, Jensen, & Mohr, 2010; Russell et al., 2016), with relevant sex differences in performance pattern (Bradley, Dellal, Mohr, Castellano, & Wilkie, 2014), and muscle damage after soccer match (Souglis, Bogdanis, Chryssanthopoulos, Apostolidis, & Geladas, 2018). Krustrup et al. (2010) confirmed that the perturbations in work rate during the last 15-min of a match were a result of match-induced fatigue as

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performance during the Yo-Yo intermittent endurance test level 2 (YoYoIE2) was decreased immediately after a female elite soccer match.

The soccer match fatigue may be related to match-induced muscle damage (Marques-Jimenez et al., 2018; Silva et al., 2018). Compared to basketball, volleyball, and handball, a soccer match was reported to be the most demanding sport with muscle damage indices (e.g., creatine kinase [CK]) ~2–3 times higher than the other team-sports (Souglis, Bogdanis, Giannopoulou, Papadopoulos, & Apostolidis, 2015). Additionally, high-intensity activities performed during a soccer match were correlated with muscle damage markers (e.g., CK and myoglobin) resulting in acute and residual soccer match-related fatigue for up to 72-h post-match (Silva et al., 2018). Given the impact of these activities, strategies to minimize soccer-induced muscle damage and fatigue may be highly relevant to enhance athlete's recovery (Lundberg & Weckström, 2017; Marques-Jimenez et al., 2018).

Researchers have studied several interventions to improve performance (or recovery of performance), once minimal enhancement can determine success in sports (Hopkins, Hawley, & Burke, 1999). For example, wearing colored glasses (Londe et al., 2018), pneumatic compression (Heapy et al., 2018), kinesiology tape (Farquharson & Greig, 2017; Trecroci, Formenti, Rossi, Esposito, & Alberti, 2017), and compression garments (Marques-Jimenez et al., 2018), among others. Compression garments are postulated to assist athletic performance and recovery (Marques-Jimenez et al., 2018). The mechanisms for these compression-induced enhancements have been postulated to include a reduction in the mechanical stress to muscle tissue (Valle et al., 2013), higher activation of surface mechanoreceptors generating better proprioception (Born, Sperlich, & Holmberg, 2013; Kraemer et al., 1998) and improvements in venous flow (Dascombe, Hoare, Sear, Reaburn, & Scanlan, 2011). Specifically involving soccer, a study showed that players wearing compression garments during a match and three days post-match (7-h each day) had attenuated exercise-induced muscle damage biomarkers response (Marques-Jimenez et al., 2018). Anoher study showed that compression garment reduced muscle damage (measured by muscle biopsy) and delayed onset of muscle soreness following decline running (Valle et al., 2013). Although these two studies showed benefits from the compression garments for soccer, both had only males in their sample and sexual differences exist in match performance (Bradley et al., 2014) and also in soccer-induced muscle damage (Souglis et al., 2018). Also, the exercise-induced muscle damage was non-specific (i.e., continuous running) (Valle et al., 2013), and soccer play consists of several intermittent changes of directions (accelerations/decelerations), decision making and technical-tactical proficiency (Russell et al., 2016) impacting the degree of muscle damage. Additionally, a systematic review concluded that a "real match" induced greater muscle damage than other types of exercises, even soccer-specific (e.g., small-sided games 4 vs. 4 format) (Silva et al., 2018).

Markers of muscle damage typically involve invasive assessments such as blood-based CK (Meneghel et al., 2014; Souglis, Papapanagiotou, et al., 2015), but muscle function tests are indirect markers (Byrne, Twist, & Eston, 2004). Specific tests can be used easily on a field for different sports (da Silva, Ide, de Moura Simim, Marocolo, & da Mota, 2014; Mota et al., 2011; Trecroci, Longo, Perri, Iaia, & Alberti, 2018), providing practical assessment post-exercise (Ide et al., 2011; Simim et al., 2017, 2018, 2013), including match-induced muscle damage and fatigue in soccer (Krustrup et al., 2010; Lundberg & Weckström, 2017).

The benefits of compression garments use on indirect markers of muscle damage and fatigue in a real match in females is unknown, and sex can influence performance characteristics (Bradley et al., 2014) and also soccer-induced muscle damage (Souglis et al., 2018). Therefore, this study aimed to evaluate the effect of compression stocking (CS) use during an amateur female soccer match on match-induced fatigue indicators. We hypothesized that the use of CS would reduce soccer-induced fatigue indicators (i.e., specific physical tests performances) following a soccer match.

Methods

Two teams of amateur female soccer players (n = 20; goalkeepers were not included) with a playing experience of 7.3 ± 5.5 years participated in the study (age 20.6 ± 3.9 years; 164 ± 0.04-cm; 59.6 ± 11.6-kg). All players experienced 5.5 ± 0.8 hours of training and 1.5 ± 0.5 matches per week, and none had a history of injury that contraindicated participation in this study. The Institutional Ethical Committee for Human Experiments approved the research study (Federal University of Triangulo Mineiro – 993.636/2015), and all players provided written informed consent for the study.

Experimental design of the study

Players were assessed for physical performance measures and perceptual scores (i.e., recovery, comfort, stocking tightness, and exertion) within 48-h before (Baseline) and immediately following soccer match where players wore compression (CS) or regular socks (Control) (Figure 1). All players completed the performance tests in the same order, before and after the match. Assessors of performance/perception were blinded to the sock conditions (i.e., CS or control) while the players were blinded about performance results during the study (Marocolo et al., 2017). The players were familiar with all procedures (e.g., tests and rating scales) as they had used them on a regular basis for fitness/recovery evaluations. All players were instructed to maintain regular eating patterns during the study and avoid caffeine and alcohol consumption, and strenuous exercise for 48-h before assessments (da Silva, Simim, Marocolo, Franchini, & da Mota, 2015).

Randomization of the experimental and control groups

Randomization of experimental conditions (CS or Control) was undertaken immediately before the match and involved equalizing by playing position and teams (Figure 2). This process ensured that each condition was utilized by one central defender, one side defender, one defensive midfield, one offensive midfield and one forward for each team (Figure 2). Therefore, five players of each team undertook each condition with a total of 10 players for each of the CS and Control groups. The tactical formations were 4-4-2 for both teams, and coaches selected the players of each team to have a balanced match. All players wore regular playing uniforms with only the CS group employing different socks.

The CS were new commercially available products (Sigvaris®, Performance line, 69% polyamide, 17% polyester and 14% elastane) with the degree of compression maximal at the ankle that graduated by 20 to 30-mmHg along the lower leg (ankle to knee). Calf and ankle circumferences of each player were measured to ensure that the correct sizes of CS were worn by players by manufacturer's guidelines. All players wore CS with shin guards worn over stockings comfortably and secured not to add compression.

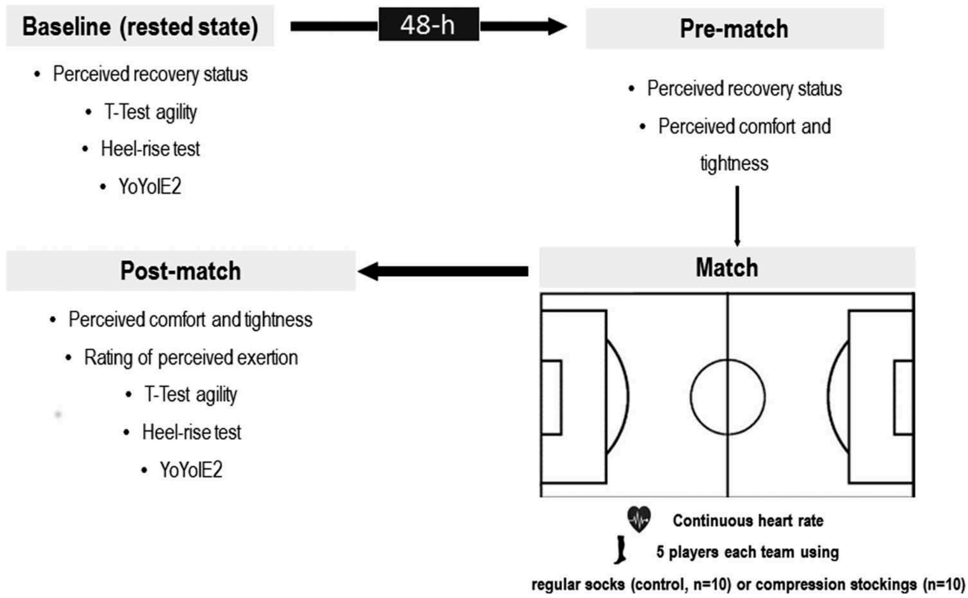

Figure 1. Experimental Design. YoYoIE2 = Yo-Yo intermittent endurance test level 2.

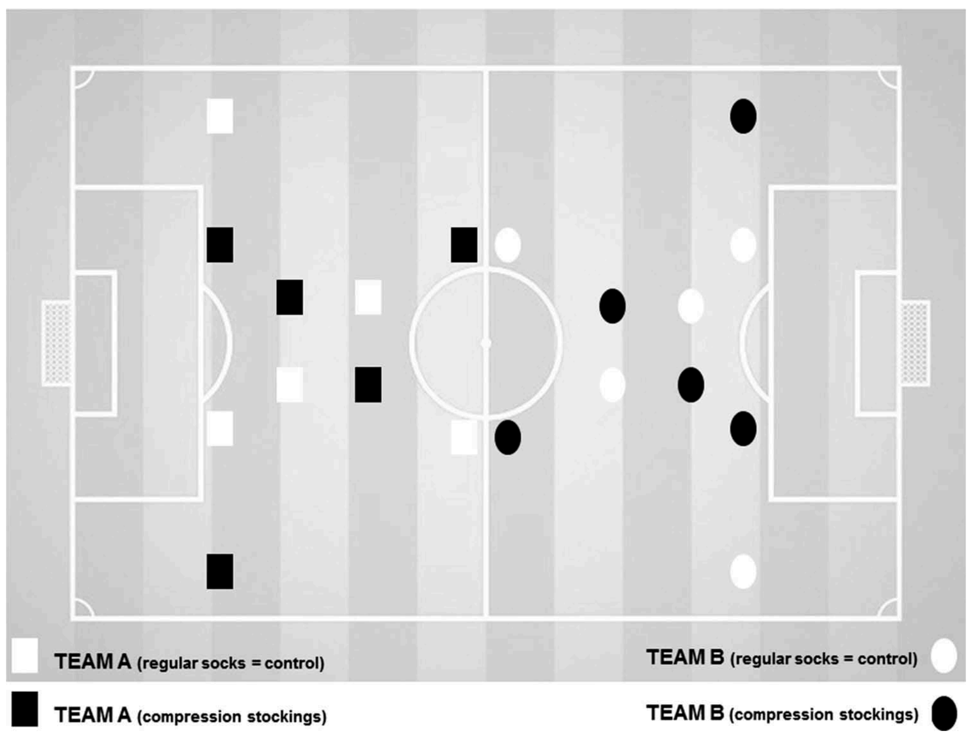

Figure 2. Randomization of compression stockings (CS, N = 10) and regular socks (Control, N = 10) groups based upon player position.

Warm-up before the physical tests

Before the initial physical tests, all players completed a standardized 15-min warm-up developed by the teams' fitness coach that involved jogging, soccer-specific movements and stretching.

T-test agility

Agility has been considered important for soccer players (Negra et al., 2017). The T-test was selected as it provides a valid and reliable (Noyes, Barber-Westin, Smith, & Campbell, 2013) assessment of agility, leg power and velocity (Pauole, Madole, Garhammer, Lacourse, & Rozenek, 2000) essential for soccer players (Negra et al., 2017). The test consists of a T formation that involves players sprinting from the starting point (straight line) to a cone placed 9.14-m away. Then, the players shuffle to their left without crossing their feet to another cone placed 4.57-m away. After touching this cone, they shuffle to their right to a third cone placed 9.14-m away, followed by shuffling back to the middle cone, and a backward run to the starting position. Two trials were completed (3-min passive rest between) with the best time recorded using a photocell system (Speed Test 6.0 CEFISE®, São Paulo, Brazil).

Standing heel-rise test

A valid and reliable endurance test to assess calf muscle performance (Ross & Fontenot, 2000) was conducted to focus on the muscle group most affected by the CS. Players stood with their arms extended parallel to the floor with their hands against a wall to ensure balance without assistance. Using the dominant kicking limb, players performed maximal plantar flexions using a standard heel-rise apparatus and in synchrony with a digital metronome (60 movements.min^{-1} consisting of 30 ascents and 30 descents per minute). The knee of the assessed limb remained fixed and extended at all times while the other limb was maintained at approximately 90° of flexion. Players performed as many repetitions as possible until they could no longer perform the task in time with the metronome (i.e., failed to complete maximal plantar flexions for two consecutive actions).

Yo-yo intermittent endurance test level 2 (YoYoIE2)

To assess the intense, intermittent, exercise performance capacity of players, the YoYoIE2 was undertaken by all on an outdoor soccer pitch (the same where the match occurred). Players completed repeated shuttle runs (2 × 20-m) at progressively increasing speed (>□12 km.h^{-1}) and guided by specific audio (5-s to recovery in a marked 2.5 × 2-m area after the finishing line) in line with test guidelines (Bradley et al., 2014). Failure to reach the finish line by the audio tone on two consecutive occasions resulted in players being withdrawn from the test and the last completed shuttle recorded as their test outcome (Bradley et al., 2011). The players performed the YoYoIE2 in groups of ten players (always the same group), and they received similar verbal encouragement during the tests. The YoYoIE2 is a reproducible and straightforward (Bradley et al., 2011) test relevant for soccer players, including females (Bradley et al., 2014), and has been reported to detect performance decrements after a soccer match for female players (Krustrup et al., 2010).

Match intensity, and perceived recovery and comfort

The soccer match was performed at 4:00 pm within warm environmental conditions (29° C; 45% relative humidity) on a regular soccer pitch with natural grass (100-m x 70-m) following official rules (2 x 45-min halves, 15-min interval) with one minor modification: substitutions were not allowed.

During the match and testing, the players had *ad libitum* water intake access. Perceived recovery was then assessed using a validated 10-point scale (Laurent et al., 2011) that has been used previously (Marocolo et al., 2016, 2016). Players then completed a 20-min lower limb, drainage activity where they lay supine with their lower limbs 30-cm above the trunk. After the 20-min period, players from the CS group identified their perceived stocking comfort and tightness using an 11-point scale ranging from 0 "uncomfortable/extremely tight" to 10 "very comfortable/extremely loose" (Faulkner, Gleadon, McLaren, & Jakeman, 2013). All players then undertook the standardized 15-min pre-match, warm-up.

Heart rate (HR) was continuously recorded during the match by wireless cardiac monitors (Polar Team System Pro®, Kempele-Finland). Recorded data was transmitted to a computer and analysed using commercial software to calculate mean and peak match HR (POLAR Team^2, version 1.4.5). Immediately, post-match, perceived CS comfort and tightness were recorded from players within the CS group while a rating of perceived exertion (RPE) using a scale ranging from 0 "rest" to 10 "maximum was recorded from all players (individually) ~20-min following the match (Alexiou & Coutts, 2008).

Statistical analysis

Data normality was verified by the Shapiro-Wilk test with normal distributed data (e.g., performance tests and HR) analyzed by two-way ANOVA (group x time) and Tukey's HSD post-hoc analyses. Unpaired t-tests tested match HR data (mean, peak and % peak). For the perceptual data (i.e., non-normal distribution), the following analyses were conducted: a) Kruskal-Wallis test for recovery analysis; b) Mann-Whitney test for RPE; c) Wilcoxon's test for CS comfort and tightness. The level of statistical significance was 5% with absolute differences between groups and/or time-points noted with 95% confidence intervals, and effect size (ES; Cohen *d*) calculated to determine the magnitude of practical relevance (just for performance tests data) as follows: trivial (<0.2), small (>0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0) and very large (>2.0) (Batterham & Hopkins, 2006). All analyses were performed using Graphpad® software (Prism 6.0, San Diego, CA, USA).

Results

Perceived recovery status, perceived CS comfort and tightness, RPE and HR during the match were not significantly different across time points or between groups (Table 1).

At Baseline, no differences ($p < 0.05$) were found between groups for all three physical performance tests (Figure 3). The Table 2 presents the statistic results of two-way ANOVA for the physical tests performed.

Compared to Baseline, post-match, agility T-test performance was maintained for the CS group (mean diff. = –0.3180; 95% CI of diff. = –0.8199 to 0.1839; $p > 0.05$) while it was

Table 1. Perceived recovery status, perceived comfort and tightness, rating of perceived exertion, and heart rate values for players wearing compression stockings and regular socks (Control) at baseline, during and post-match.

	Compression Stockings	Control	p value
Perceived recovery (AU)			
Baseline	9.8 ± 0.4 [9.5 – 10]	9.7 ± 0.7 [9.2 – 10]	0.99
Pre-match	9.8 ± 0.4 [9.5 – 10]	9.8 ± 0.4 [9.5 – 10]	0.99
Perceived stocking comfort and tightness (AU)			
Pre-match	5.7 ± 1.1 [4.9 – 6.5]		
Post-match	5.6 ± 0.5 [5.2 – 5.9]		0.99
Rating of perceived exertion – RPE (AU)			
Post-match	7.9 ± 1.0 [7.2 – 8.6]	8.6 ± 0.5 [8.2 – 9]	0.13
Match Heart Rate (bpm)			
Mean	156.3 ± 4.2 [153.3 – 159.3]	156.8 ± 4.8 [153.4 – 160.2]	0.80
Peak	186.4 ± 2.9 [184.3 – 188.5]	188.6 ± 2.9 [186.5 – 190.7]	0.11
Mean (% peak)	84.3 ± 1.6 [83 – 85.4]	83.2 ± 2.6 [81.3 – 85]	0.28

Data are presented as mean ±standard deviation and [Lower – Upper confidence interval 95%]; AU = arbitrary units; bpm = beats per minute.

significantly worse (mean diff. = −0.9260; 95% CI of diff. = −1.428 to −0.4241; $p < 0.0001$) for the Control group (Figure 3) with a large ES (1.25) for CS vs. Control, post-match (mean diff. = −0.7040; 95% CI of diff. = −1.206 to −0.2021; $p < 0.0011$).

Figure 3 shows that during the heel-rise test, performances were reduced from Baseline values for both groups post-match (CS: mean diff. = 5.200; 95% CI of diff. = 0.1756 to 10.22; $p < 0.01$; Control: mean diff. = 5.300; 95% CI of diff. = 0.2756 to 10.32; $p < 0.01$) with the decrement greater for the Control group (ES = 1.27 Control vs. CS).

Figure 3 shows also that the performance during the YoYoIE2 was similar between groups at Baseline and was reduced equally for both groups (CS: mean diff. = 216.0; 95% CI of diff. = 110.1 to 321.9; $p < 0.001$; Control: mean diff. = 200.0; 95% CI of diff. = 94.12 to 305.9; $p < 0.001$) post-match (ES = 0.13).

Discussion

Our main finding was that CS use during an amateur female soccer match positively influenced (large ESs) agility (T-test) and lower limb muscular endurance (standing heel-rise) performances following the match. These benefits were higher than that observed with regular socks (Control) and confirmed a protective effect of CS on agility ability and calf function that may be crucial for soccer match performance (Dalen, Jorgen, Gertjan, Geir Havard, & Ulrik, 2016; Russell et al., 2016). This study is the first to investigate the CS use effect on specific tests that are considered as indirect markers of match-induced muscle damage and fatigue (Byrne et al., 2004; Krustrup et al., 2010). The current findings are relevant because there are sexual differences in match performance (e.g., distances covered and pass completion rates) and in soccer match-induced muscle damage (Bradley et al., 2014; Souglis et al., 2018). Thus, our study is unique and provides evidence of the practical benefits that may assist specifically female athletes and coaches.

A recent study showed that male players wearing compression garments during a match and also during three days post-match (7-h each day) presented lower exercise-induced muscle damage biomarkers response (e.g., CK, LDH) (Marques-Jimenez et al., 2018). The reduction in the structural damage associated with neutrophil infiltration and

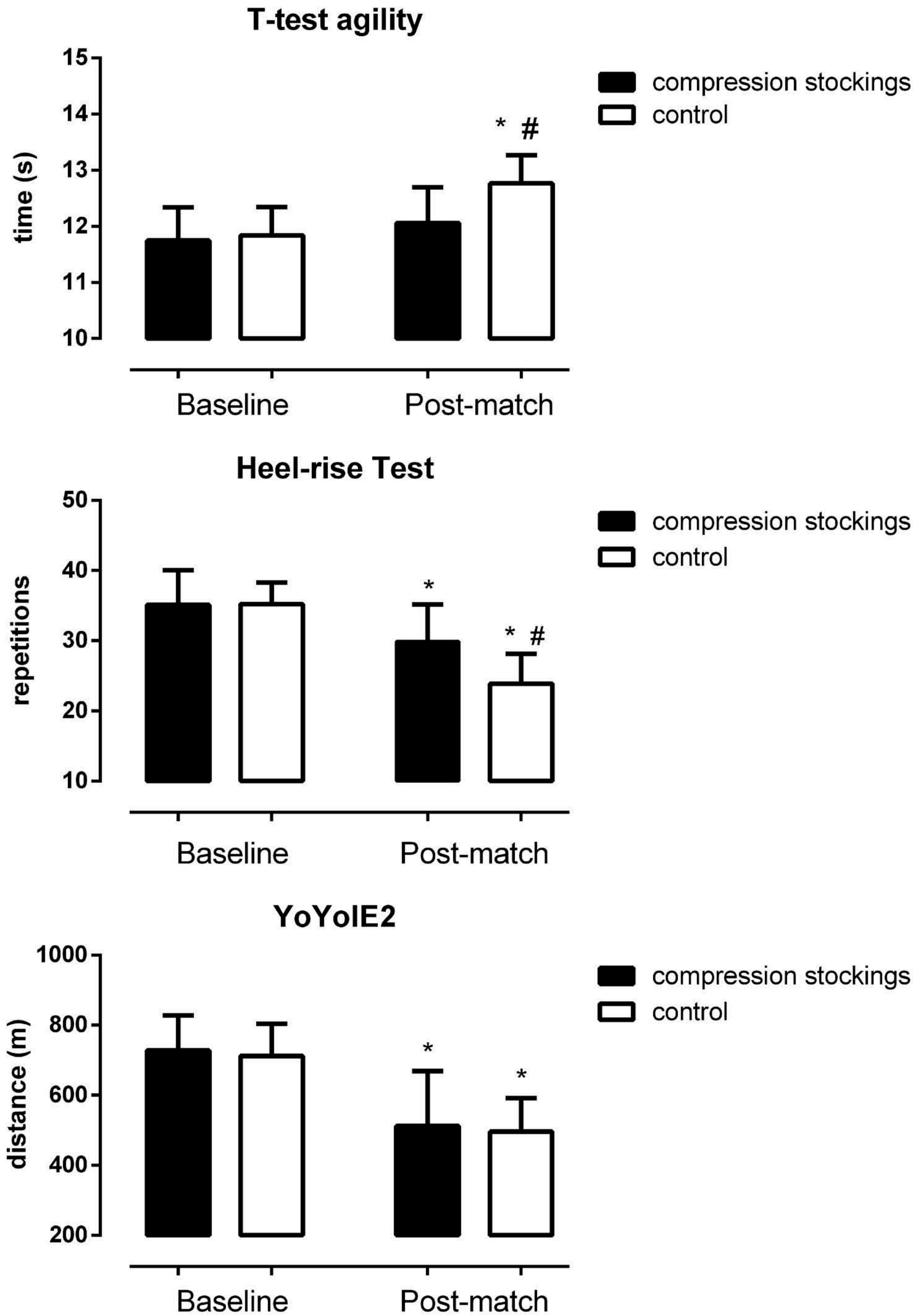

Figure 3. Test results for the T-test Agility, Heel-rise and Yo-Yo intermittent endurance level 2 (YoYoIE2) tests at 48-h before (Baseline) and following (Post-match) a soccer match for players wearing compression stockings (CS) and regular socks (Control). Data are mean ±standard deviation. *$p < 0.05$ post-match vs. Baseline. # $p < 0.05$ Control vs CS.

Table 2. Statistic results of two-way ANOVA for the physical tests performed 48-h before (Baseline) and immediately following a female soccer match where players wore compression or regular socks (Control).

Variable	two-way ANOVA interaction and main effect	p value
Agility T-test	$F_{3,\ 27} = 12.67$	<0.0001
Heel-rise test	$F_{3,\ 27} = 17.02$	<0.0001
YoYoIE2 test	$F_{3,\ 27} = 20.89$	<0.0001

edema due to compression would explain the lower response of CK, and the associated higher venous return would improve the removal of myofibrillar proteins (Kraemer et al., 2001; Kraemer, French, & Spiering, 2004; Marques-Jimenez et al., 2018). It is difficult to compare our findings with theirs (Marques-Jimenez et al., 2018), because several reasons: they used different compression garments (stocking, full-leg, and shorts), their players were males and wore the compression garments not just during the match, but on 3-day recovery, and they assessed invasive biomarkers of match-induced muscle damage. However, even so, probably our findings are in line with them reinforcing the CS use during the soccer match and also the feasibility of specific tests as indirect indicators of soccer match-induced muscle damage and fatigue (Byrne et al., 2004; Krustrup et al., 2010).

The relative internal exercise intensity during the match was high with a RPE of ~8 and ~84% maximum HR, and similar to a previous study of elite female soccer players (85.6 ± 2.3% maximum HR; ~8.2 RPE) (Souglis, Papapanagiotou, et al., 2015). Despite this high effort, there were no differences in match intensity indicators between groups (CS and Control) with this similarity (i.e., RPE and HR responses) ensuring that different matches experiences did not impact players' physical performance results. Others have reported a similar effect of CS on HR and RPE for different kinds of exercises (Ali, Creasy, & Edge, 2011; Barwood et al., 2013; Born et al., 2013), but we could not find any RPE evaluation during soccer matches using CS. Our results of similar perception of CS comfort and tightness between pre- and post-match revealed that CS use was unlikely to impede player action during a match and therefore CS may be a potential performance enhancer.

In the current study, post-match agility performance was comparable to that reported for female high-school (and amateur) soccer players (Kutlu, Yapici, & Yilmaz, 2017; Noyes et al., 2013). Importantly, post-match agility was unchanged for the CS group but substantially reduced (~8%) for Control (large ES) indicating that CS use was able to sustain agility performance despite match-induced fatigue found (e.g., YoYoIE2 performance ~30% decrement post-match). This CS-induced effect was evident despite similar match workloads (i.e., HR and RPE) for CS and Control groups. Mechanisms for this effect may involve greater activation of surface mechanoreceptors and better proprioception during CS use (Born et al., 2013; Kraemer et al., 1998). Monitoring of player movements and workloads via wearable technologies during matches may confirm the beneficial impact of CS on in-match, player movements.

Match performance can be significantly influenced by muscle damage with soccer one of the most demanding sports inflicting higher muscle damage (e.g., CK responses) (Souglis, Papapanagiotou, et al., 2015). Previously, compression garments showed reduced muscle damage (measured by muscle biopsy) and delayed the onset of muscle soreness in amateur soccer players following decline treadmill running (Valle et al., 2013). In the current study, muscle damage was indirectly assessed by the standing heel-rise test, an endurance test that assesses the resilience of the triceps surae muscle within a closed kinetic chain (Ross & Fontenot, 2000). Our results indicated that the soccer match reduced ($p < 0.0001$) the number of heel-rise repetitions in both groups, (CS = -14.8% vs. control = -32%) most likely due to match-induced muscle damage and fatigue (Silva et al., 2018; Souglis et al., 2015; Souglis, Bogdanis, et al., 2015; Souglis, Papapanagiotou, et al., 2015). However, the post-match result (Figure 3, number of repetitions) for the CS group was substantially (~18%) higher than the Control group (large ES, 1.27) likely due to less muscle damage and fatigue as a result of the CS (Marques-Jimenez et al., 2018; Valle et al., 2013). Potentially, the CS could have reduced muscle fiber activation and fatigue with greater movement economy (Born et al., 2013). Further, we cannot disregard a potential biomechanical effect of CS assisting the eccentric phase of running movements (Doan et al., 2003) during the match (Fatouros et al., 2010). Futures studies are encouraged to confirm these results with direct markers of muscle damage and extended experimental design (e.g., the time course of performance markers at 24, 48, 72-h after a match). Given the potential reduction in muscle damage and fatigue with CS (Born et al., 2013; Marques-Jimenez et al., 2018; Valle et al., 2013), CS use may provide a simple approach for injury prevention as most injuries (57%) during soccer matches are associated with fatigue inducement (Ekstrand, Hägglund, & Waldén, 2010).

Our current study identified helpful responses for the CS group (i.e., agility and calf endurance) following the soccer match. However, CS was unable to influence YoYoIE2 performance with both groups exhibiting a similar ~30% decrement post-match (Figure 3). The performance drop post-match in YoYoIE2 (~30% here) was less than a previous study (~60%) of elite female athletes (Krustrup et al., 2010) with the potential lack of CS effect possibly due to the degree of match-induced fatigue. Additionally, the minimal effect may be a result of the muscle groups engaged explicitly in the test being different to those influenced predominantly by the CS (i.e., calf in heel-rise test vs. quadriceps/hamstrings in YoYoIE2). Future studies may confirm the benefits of CS use and type (calf based vs. upper leg focussed) in elite soccer populations who exhibit substantial match-induced decrements in YoYoIE2 performance.

Some limitations should be noted. This study assessed short-term indicators of physical performance with longer-term follow-up likely to show the full benefit of CS use during soccer matches (i.e., to account for inter- and intra-player match variation). Time-motion analyses (e.g., total distance covered in high-speed, number and intensity of accelerations and decelerations), a holistic (i.e., integration of physical, tactical and technical aspects) evaluation of the soccer match (da Mota et al., 2016), and muscle strength/power test were not examined due to logistical restrictions. Also, direct evidence of muscle damage (e.g., muscle biopsy) was not collected due to team preference. Future studies incorporating these technologies and design will contribute to a greater understanding of CS benefits for practical application by athletes and coaches. However, we highlight the applied features of the current study with a guaranteed transfer to the "real world," overcoming potential limitation extending our knowledge the effect of CS on exercise-induced muscle damage, fatigue, and performance.

The present study demonstrated that compared to regular socks (Control), the use of CS during a soccer match resulted in greater post-match agility and calf endurance performance indicating less match-induced fatigue in amateur female soccer players. The extent of CS benefits for soccer match performance and future injury risk remains to be investigated further to assist players and coaches to optimise performance and match success.

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