COMPRESSION STOCKINGS USED DURING TWO SOCCER MATCHES IMPROVE PERCEIVED MUSCLE SORENESS AND HIGH-INTENSITY PERFORMANCE.

ABSTRACT

Evidence on the use of compression stockings (CS) during soccer matches is limited. Thus, we evaluated the acute effects of CS on match-based physical performance indicators and perceptual responses during two consecutive soccer matches with 72-h recovery. Twenty outfield players were randomly allocated to CS (20-30 mmHg) or control group (non-CS) and performed two matches (five players using CS or regular socks per team/match). Match loads (rating of perceived exertion [RPE] x minutes; CS ~830 vs. control 843 [arbitrary units]) and HR responses (both CS and control ~86% HRpeak) did not differ (*p* > 0.05) between CS and control groups. Whilst total distance covered did not differ (*p* > 0.05) between groups, CS increased distances (Effect size [ES] = 0.9 - 1.32) in higher-speed zones (> 19-km.h^{-1} CS ~550-m vs. control ˜373-m) alongside an increased number of accelerations (-50.0 to -3.0 m/s^2) than control (CS: 33.7 ± 11.2 vs control: 23.8 ± 7.9; $p = 0.003$; ES = 1.04). Perceived recovery did not differ (*p* > 0.05) between groups for either match, but was worse in the second match for both groups. Perceived muscle soreness increased in control post-match two (from 3.1 ± 1.9 to 6.3 ± 1.6 AU; $p < 0.0010$), but did not in CS (from 2.8 ± 1.4 to 4.1 ± 1.9 AU; $p = 0.6275$; ES = 1.24 CS vs. control post-match). Accordingly, CS use during two soccer matches with 72-h recovery reduces perceived muscle soreness in the second match and increases higher-speed match running performance.

KEYWORDS: compression garments; athletes; team sports; ergogenic; recovery

INTRODUCTION

Soccer performance requires a complex interaction of cognitive decision making, technical and tactical mastery within the context of well-developed physical capacities (9,11,25). The physical load of soccer matches results in post-match fatigue and is linked to a combination of various factors, such as glycogen depletion, dehydration, and muscle damage (31,35). The fatigue associated with the matches usually is exacerbated in schedules requiring multiple games within 72-96-h. For example, data from 27 soccer teams (over 11 seasons) showed that matches with short recovery (≤ four days) were associated with increased muscle injury rates when compared with more extended recovery periods (≥ six days) (5). A recent systematic review (39) concluded that soccer matches induce perceptual and biochemical alterations (e.g., muscle damage) and that 72-h between matches is insufficient for a full recovery (39). Consequently, strategies to minimize the soccer-induced fatigue and muscle damage are of concern to the coaching staff and sports scientists, particularly during scheduling with a shorter recovery time between matches (33).

Compression stockings (CS) were proposed initially to improve the venous return and to prevent deep venous thrombosis, as evidenced by increased femoral vein blood flow velocity in hospitalized patients (38). Nowadays, athletes use CS as a strategy to accelerate recovery from training/competition demands, to improve performance and relieve symptoms of muscle soreness (32). For example, Valle et al. (40) showed that compression garments (i.e., right compressed and left thigh no compression) reduced the muscle damage and delayed onset of muscle soreness in soccer players, suggesting a lower extent of muscle vibration and thus less mechanical stress to tissue. Although they presented robust evidence (i.e., muscle biopsy) of the effectivity from compression garment, the authors did not mention the specific pressure of garment used, and also the exercise performed was unspecific for soccer players (i.e., decline running), limiting the practical application to soccer.

Specifically for soccer, Marques-Jimenez et al. (29) tested players wearing different compression garments (from 15 to 30 mmHg - stocking, full-leg, and shorts) during a match and three days post-match (7-h each day) and found lower exercise-induced muscle damage biomarkers (e.g., CK, LDH), providing rationale for the use of compression garments during soccer (29). However, the authors investigated only a single match and in the ‘real world’ context may be difficult to control the recovery period as the authors did (i.e., during days post-match) (29). For example, in countries with higher temperatures and limited access to air-conditioning rooms, the use of CS post-match for several hours might be uncomfortable due to the higher skin temperatures from CS use (14). Also, ordinarily following post-match most players are released from their training routine and have free time to enjoy therefore with limited control from the technical staff. Thus, logistically CS are easier available for within match play (e.g., uniform issues with the whole body garment) and could assist in schedules with short time in-between matches. Nevertheless, no study has investigated the effectiveness of using CS only during soccer matches (i.e., not during recovery period) with short time between-matches for performance and recovery indicators. Therefore, this study evaluated the effects of using CS on the match-based physical performance indicators, heart rate responses and perceptual measurements in under-20 soccer players during two matches separated by 72-h. We hypothesized that CS would minimize the local stress and improve performance indicators, especially in the second match, because compression garments reduced muscle damage and delayed onset of muscle soreness (40).

METHODS

Experimental Approach to the Problem

The effect of CS on indicators such as total distance in different speed zones, mean heart rate and reported perceived recovery, muscle soreness and exertion were evaluated in two matches separated by 72-h. Both matches started at the same time (i.e., 3:30 p.m) and occurred on a natural grass pitch (105-m x 68-m; temperatures - Match one: 30°C; 48% relative humidity; Match two: 24°C; 80% relative humidity). The official FIFA® rules were applied, except substitutions that were not allowed. Hydration was allowed *ad libitum* during the matches. For the first match, the players´ dietary intake profile was recorded and players required replicating during the following match day. To certify the replication of diets, the players were personally questioned with dietary recall at the beginning of each visit (21). The coach organized the teams to maintain the physical/technically balanced though physical tests routinely performed (i.e., YoYo intermittent recovery test II) and the perceptions of technical staff. The tactical formations were 4-4-2 for both teams and remained the same in both matches. The players wore regular playing uniforms, with only the CS differing. The CS were used only during the matches (i.e., not after the game or during the 72-h interval between the two matches). Matches were conducted on Tuesday and Friday, with all players participating in two standardized training sessions (3:30 pm, Wednesday, and Thursday) between matches. We calculated the internal load (rating of perceived exertion [RPE] x total duration in minutes (19) for both sessions to ensure equal training load between groups. Before and after each match the body mass was measured using a medical beam scale (Health-O-Meter®, model 402EXP, Badger Scale Inc., Milwaukee, United States).

Subjects

Twenty-two soccer players (under-20 yrs) who regularly compete in the state, national and international tournaments volunteered in the study (excluding goalkeepers; Table 1). Experimental procedures were approved by the local Ethical Committee for Human Experiments and were performed by the Declaration of Helsinki. All procedures were explained to volunteers, and they signed an informed consent form before data collection.

No player reported any cardiovascular, respiratory, metabolic disease, injury or muscle pain before the study. Subjects did not use specific recuperative therapeutic resources (e.g., cryotherapy, massage, and stretching) and were instructed to avoid analgesic, anti-inflammatories and pharmacological, and to abstain from caffeine alcoholic beverages (10,30) during the period of this study.

*****Table 1 near here*****

Randomization of the experimental and control groups

The distribution of experimental conditions (CS or regular) was undertaken immediately before the first match and balanced by the playing position. This process included one central defender, one side defender, one defensive midfield, one offensive midfield and one forward wearing CS or regular socks (Figure 1). Therefore, five players of each team used regular socks (control group n = 10) or CS (n = 10), and we kept the same players and the same conditions for both consecutive matches.

*****Figure 1 near here*****

Compression stockings (CS) and regular socks (control)

The CS used in the current study had a compression of 20-30 mmHg (¾ model with closed toe, Sigvaris® Performance; composed of 69% polyamide, 17% polyester and 14% elastane). To meet the proper sizes of stockings were performed measurements beforehand according to the manufacturer (i.e., calf/ankle circumferences and shoe size). The CS were used during the matches, but not during the post-match recovery period (72-h). The players in the CS group wore the CS from 20-min before the warm-up and removed them 10-min post-match. All athletes already had experience with CS before (e.g., post-match recovery or during prolonged travel). However, in order to check potential confounding placebo or nocebo effects (28), before matches subjects were asked: "Do you expect any effect on your performance if CS are used during the game”? After the matches, all players were asked if they knew which version they used.

To check the perception of garment comfort (CS group), we recorded (before and after the matches) the following scores: 0= “very uncomfortable” to 10= “very comfortable”; tightness 0= “very slack to 10= “very tight”; and pain (0= “no pain” to 10= “very painful”), respectively (1). The control group wore regular socks commonly used in soccer matches, with the same color of CS and the only difference was the compression. All players (CS and control groups) also used shin guards worn over CS or regular socks (control), secured comfortably by a support that did not add compression.

Perceptual measures of recovery, muscle soreness, and exertion

Assessors who collected data (rating of muscle soreness, the rating of perceived recovery, RPE, HR responses and physical indicators) were blinded with regards to the condition interventions (i.e., control or CS) until the end of the study to ensure primary control in studies with potential ergogenic effects (8). Before the warm-up, athletes indicated their perceived recovery status scale (24), described elsewhere (26-28). Before and after matches, athletes were asked to express the perceived of muscle soreness on a scale (0= “normal absence of soreness” to 10= “very intense sore”). They were instructed to indicate the level of general (non-trauma related) muscle soreness in the calf region when moving or using it (3). Between 20-30-min after the matches players were asked their RPE (CR-10 Borg) (15). The internal load of the matches was determined by multiplying the RPE by the total duration of minutes (19). Athletes were already familiar with the scales mentioned because the staff usually applied them on a weekly basis.

Physical indicators and heart rate

Each player wore a heart rate (HR) monitor coupled with Global Positioning Satellite (GPS) device (10-Hz) and accelerometer (100-Hz) in the same chest strap (Polar Team Pro 2®, Electro Oy, Kempele, Finland). The device (HR monitor, GPS and accelerometer) was started at the beginning of the match and stopped only during the interval and at the end of the matches. All data were digitized and immediately stored in the computer for off-line processing. Current reliability of this specific brand for GPS and accelerometer measurement is missing in the research literature, though players used the same device in both matches (36). Further, recent reviews on the validity and reliability of GPS systems in team sports concluded that 10-Hz GPS devices are the most valid and reliable across linear and team sport simulated running (37).

For the current study, speed zones and category of accelerations are displayed in Table 2, accordingly (12,23). Total distance was represented by the sum of the distances covered in all zones. The players remained blind to the data from GPS and heart rate until after the study conclusion (26).

*****Table 2 near here*****

Statistical Analysis

Data are presented as mean ± SD. The Shapiro-Wilk test was applied to verify the normality of the data. We used the Wilcoxon test (non-normality data) for values of comfort, tightness, and pain related to CS using during matches, RPE and internal load. Unpaired t-tests were used to compare body mass changes between pre and post-match. For all other variables moment comparisons (match one vs. match two) and condition (CS vs. control), we applied the two-way analysis of variance, which was followed by a post-hoc Tukey's test with statistical significance set at 0.05. Effect size (ES; Cohen *d*) was calculated (mean difference divided by the pooled standard deviation) to determine the magnitude of practical relevance (only if a significant "$p < 0.05$" effect was found), classified as: trivial (<0.2), small (> 0.2-0.6), moderate (> 0.6-1.2), large (> 1.2-2.0) and very large (> 2.0) as recommended by Batterham and Hopkins (4). All analyses were conducted using GraphPad® (Prism 6.0, San Diego, CA, USA).

RESULTS

All players participated in both matches (180-min total, no absences or substitutions). The expectation of effect on performance (using CS) during the game were: four players (40%) no influence; two players (20%) negative influence and four players (40%) positive influence. After the matches, all players from CS answered correctly about the version of socks they used.

The values of comfort, tightness, and pain related to CS using during matches were within acceptable ranges (comfort 6.7 to 7.2, tight 6.7 to 7 and pain between 1.1 and 1.6) and there was no difference (Wilcoxon test; $p > 0.05$) between matches. The internal load did not differ for both training sessions between matches: CS = 172.5 ± 36 and 371 ± 99 arbitrary units (AU); control = 165 ± 59 and 374 ± 84 AU, for session one (Wilcoxon test; $p = 0.7364$) and two (Wilcoxon test; $p = 0.9332$) respectively. The body mass changes did not differ (Unpaired t test) between CS and control in both matches: match one CS = -1.89 ± 0.92% vs. control = -1.98 ± 0.99% ($p = 0.8431$); match two CS = -1.50 ± 0.81% vs. control = -1.98 ± 0.37% ($p = 0.1005$).

Pre-match perceived recovery for both conditions and matches did not differ (interaction and main effects from two-way ANOVA: $F_{3, 27} = 12.67$; $p > 0.9999$): match one – CS: 7.6 ± 0.5 AU; control: 7.6 ± 1.5 AU and match two - CS: 6.0 ± 1.2 AU; control: 6.0 ± 1.1 AU. However, both CS and control showed a lower rating of perceived recovery ($p = 0.0241$) in match two (~6 AU) when compared with the match one (~7.6 AU).

Two-way ANOVA revealed the use of CS prevented an increment in the rating of muscle soreness in the match two (interaction and main effects $F_{7, 63} = 4.528$; $p = 0.0004$; Figure 2). Specifically, control showed an increase in the rating of muscle soreness post-match two that was not observed in CS ($p = 0.0010$, ES 1.24, Figure 2).

*****Figure 2 near here*****

Mean and peak heart rate, RPE, internal load (RPE x minutes played) and number of sprints were not different ($p > 0.05$) between matches or groups (Table 3 shows details such as interactions and main effects, p values). No significant differences ($p > 0.05$) were found between groups or matches for total distance covered and also for distances covered in lower speed (zones 1, 2 and 3) (Figure 3). However, distances covered in the higher speed (zones 4 and 5; > 19.1 km.h^{-1}) were lower in match one in control group than CS (see Figure 3; zone 4 p = 0.0152 and ES = 1.32; zone 5 p = 0.322 and ES = 0.91). Importantly, figure 3 shows also that in match two the CS group covered higher distances in zone 4 (p = 0.0483; ES = 0.83). The acceleration frequency only showed significant differences for those performed between -50 to -3 m.s² in match one (CS: 33.7 ± 11.2 vs control: 23.8 ± 7.9; ES = 1.04; interaction and main effects $F_{3,27}$ = 7.139; p = 0.0011).

*****Table 3 near here*****

*****Figure 3 near here*****

DISCUSSION

This is the first study to investigate the acute effects of using CS during two soccer matches with 72-h recovery. Our main findings are that the use of CS blunted the increase in perceived muscle soreness after the second match, possibly promoting increased high-intensity running in the ensuing match (7,34). Accordingly, regardless of the mechanisms, the use of CS during matches with short recovery time (e.g., 72-h) in-between seems an appropriate strategy to minimize the soccer-induced fatigue and muscle damage.

All players completed both matches, provided a correct assessment of the condition they were in (CG vs. control); highlighting the difficulty of blinding subjects in compression garment studies. However, the results of expectation about any potential effect on match performance (using CS) during the games were balanced; in that, a lower percentage (40%) of the players expected positive influence from CS and 60% expected no impact or negative influence from CS. Despite a higher percentage of players expecting no influence or adverse effect from CS (60%), the current findings showed beneficial impacts from CS. Further, this finding is in the context of (19) comparable internal load responses between CS and control group prior training sessions and without differences in body mass change between respective matches i.e., no effect of prior training or dehydration to explain match two responses. Additionally, all players started the matches in a similar perceived recovery state, ensuring the comparison between CS and control groups and suggesting no effect from CS in the recovery perception. However, the decrement in the perceived recovery in the second match (vs. match one) in both groups corroborates that 72-h between matches are not enough to completely restore the players (24,39).

Our results did not show differences in the matches loads (RPE x minutes) or HR responses between and conditions (i.e., CS vs. control), suggesting no influence of CS on internal load. These findings confirm previous research showing no effect of CS on cardiovascular measures during the 10-km running performance (2). Also, the match data reported here for HR (i.e., HR peak ~190 bpm and HRmean ~86% of peak) (20) and distances covered (9) were similar to others, indicating the competitive nature of the matches and reinforcing the experimental design to test our hypothesis.

A relevant finding was that the control group showed an increase in muscle soreness after the match two, but the CS presented maintenance over both matches (Figure 2). Post-match increases in muscle soreness are expected response given the intermittent, high-intensity nature of match-based acceleration/deceleration, and resultant muscle damage (20,35,36,39).

The maintenance of perceived soreness observed with CS compares favorably with other studies showing timelines of reduced post-exercise soreness (40). While a placebo effect is often reported, the prevention in the increment (found in control group) in post-match soreness with CS is of importance when extended match periods require two or more matches with 72-h recovery. As longer fixtures are standard (e.g., four matches in ~10 days), the use of CS during the soccer matches may be an essential strategy to reduce perceived soreness in such setting (6).

The total distance covered (~9.6 km) and the number of sprints (~26 sprints) did not differ between matches and groups. Although low-intensity activities are predominant on the soccer matches (9), the high-intensity running is decisive for success (e.g., goal scoring or avoidance) (7,34). Interestingly, we observed a higher performance in the CS group for the distances covered in top speed velocities (i.e., zone 4: 19.1 to 22.99 $km.h^{-1}$ and zone 5: ≥ 23 $km.h^{-1}$) in both matches with moderate and large ES. In explanation, it is feasible the improved perceived muscle soreness promoted by the CS aided the increased match distances observed during match two. Previous research reports mixed findings on the effect of CS on sprint efforts in intermittent-sprint exercise (14,17). However, the novelty of the current study is the nature of the two matches performed in five days. Given no differences (in muscle soreness) were found in match one, but rather that in match two the improved efforts (and reduced soreness) were evident, it may be that CS are a useful tool for such circumstances (e.g., short recovery between matches). Soccer match demands eccentric actions which are related to high muscle damage (16,35,36). Previous studies showed that compression garments could reduce muscle damage (29,40) and assisting the eccentric phase of running movements (13). Therefore, the superior performance found here in the CS group probably was due to the mechanical protection of eccentric actions (40) performed during the matches

(16,35,36). For instance, amateur soccer players exhibited lower muscle damage (measured by muscle biopsy) after a downhill running (treadmill) when using compression shorts. The authors attributed the less muscle damage to a smaller muscle vibration in the compression group (40). Besides, Marques-Jimenez et al. showed that players wearing compression garments during a soccer match (and also during three days post-match: 7-h each day) had lower CK and LDH levels (29). They attributed the lower exercise-induced muscle damage response (due compression) to a reduction in the structural damage related with neutrophil infiltration and edema, and the higher venous return improving removal of myofibrillar proteins (22,29).

The ability to accelerate/decelerate is relevant for soccer matches (11,36). In this sense, we checked the effect of CS on the acceleration profile. Our results showed no difference between matches/conditions in the frequency of accelerations, but CS group performed a higher number of top decelerations (-50 to -3m.s^2) in match one (ES = 1.04, moderate). As decelerations are associated with eccentric muscular actions and higher exercise-induced muscle damage/soreness for several days (18,36), it is interesting to note that, even covering higher distances in top velocities on the two matches, the CS group did not show an increment on muscle soreness indicator. A noteworthy finding in the present study was that players using CS did not report higher scores for muscle soreness, despite performing larger distances in top speeds (Figure 3) and also higher deceleration frequency (in match one).

Despite these findings, limitations from the current study are present and worthy of consideration. These include the difficulty in establishing a placebo condition of the CS because they imply a tightening sensation. Other limitations are not performing a cross-over treatment for obvious reasons, no quantification of diet and also the recovery is multifactorial (e.g., diet, sleeping, muscle fiber types) and complex what makes challenging to control in field studies. Finally, the variability often reported in high-speed running data from GPS is also noted as a limitation from only two matches reported here.

In summary, the use of CS during the soccer matches seems to minimize increment of local muscle soreness perception in the second match. Also, the use of CS promotes more substantial distance covered in high-intensities activities in young soccer players during two consecutive matches separated 72-h in-between. Such evidence suggests a protective effect to the muscles covered by CS during the matches performed with a short time (i.e., 72-h) in-between**.** Futures studies should try to understand the mechanism underline CS benefits for soccer, and to investigate if chronically CS could collaborate reducing injury risk associated with short recovery (≤ four days) between matches (5).

PRACTICAL APPLICATIONS

Many soccer teams are involved in matches with a short time of recovery (e.g., 72-h between two matches or 3 matches in 7 days) during the season. Therefore, to find appropriate training and recovery strategies to ensure optimal performance during competitions are vital. Our results showed that the use of CS minimized the increment of local muscle soreness perception, especially in the second match and promoted more considerable distance covered in high-intensities activities (which are most decisive for soccer). Therefore, we recommend the use of CS during the matches in games performed within a short time (i.e., 72-h) of recovery in-between. We also suggest evaluating if the player feels comfortable with such garments and use accordingly (or not).

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Figure legends

Figure 1 – Randomization of compression stockings (*n* = 10) or regular stockings (control, *n* = 10). Same players and conditions in both matches.

Figure 2 - Rating of muscle soreness pre and after the matches. Control group reported an increment in the rating on the second match compared with pre-values (* $p = 0.0010$; ES = 1.2). ANOVA two way interaction and main effects $F_{7, 63} = 4.528$; $p = 0.0004$; ES = effect size; Values are mean ± SD.

Figure 3 – Distances covered in different speed zones for compression stockings (*n* = 10) and control (*n* = 10) groups in match one and match two. * means CS higher distance covered ($p < 0.05$; ES = 0.9) than control in the same zone. ANOVA two way interaction and main effects: Total distance $F_{3, 27} = 0.7042$ and $p = 0.5578$; Zone 1 $F_{3, 27} = 0.3130$ and $p = 0.8158$; Zone 2 $F_{3, 27} = 2.120$ and $p = 0.1210$; Zone 3 $F_{3, 27} = 1.886$ and $p = 0.1558$; Zone 4 $F_{3, 27} = 5.786$ and $p = 0.0034$; Zone 5 $F_{3, 27} = 4.290$ and $p = 0.0134$. ES = effect size; Values are mean ± SD.