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ORIGINAL ARTICLE

Physiological and physical responses to wearing compression garments during soccer matches and recovery

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ABSTRACT

BACKGROUND: There is not enough information on the effects of compression therapy in soccer players during recovery after matches. The objective of this study was to examine the effect of wearing compression garments during soccer matches and during recovery period on physical responses.

METHODS: Eighteen semi-professional soccer players participated in this study. A two-stage crossover design was chosen. Participants acted as controls in one match and were assigned to an experimental group (compression stockings group, full-leg compression group, shorts group) in the other match. Participants in experimental groups played the match wearing assigned compression garments and were worn in the 3 days post-match, for 7 hours/day. Blood lactate concentration, arterial oxygen saturation of hemoglobin, perceived exertion, perceived recovery, anaerobic power (vertical jump, sprint, change of direction) and aerobic capacity (Yo-Yo Intermittent Recovery level 2) were measured. Internal and external loads were measured during both matches.

RESULTS: Using compression garments may slightly increase lactate during and after soccer matches and only full-leg garments can moderately attenuate the reduction of arterial oxygen saturation of hemoglobin. Wearing compression garments can be useful between 24-48 hours post-exercise to promote psychological recovery, especially with full-leg garments and compression shorts. Decreases in anaerobic power can be attenuated but not significantly, mainly with full-leg compression garments or compression shorts. Compression garments could also have positive effect on aerobic capacity, but we cannot exclude a placebo effect.

CONCLUSIONS: Compression garments could be moderately beneficial, but effects are not significant.

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KEY WORDS: Soccer - Metabolism - Perception - Compression stockings - Athletic performance.

For successful performance, soccer players must be able to perform explosive actions repeatedly without any loss in efficiency. These high demands imply mechanical and metabolic stress which might induce physiological changes during competition or exhausting training sessions.[1] Moreover, soccer demands may potentially influence the time course of recovery, characterized by a decline in physical performance over the following hours and days.[2, 3] Soccer players usually need 48-72 hours to restore hematological changes,[4] exercise-induced muscle damage (EIMD) and anaerobic performance decrements,[2, 3] although several improvements have been demonstrated 24 hours post-match.[5] Competition schedules in soccer often require teams to play matches with only a few days of recovery between them. That insufficient recovery time may result in underperformance and increase the risk of injuries.[6] Consequently, the ability to recover from intense training or match is a key aspect of performance.

Recently it has been reported that central processes contribute significantly to the neuromuscular fatigue experienced in the days post-match, but the magnitude and slower recovery of peripheral fatigue indicates that it is the resolution of muscle function that primarily explains the recovery of neuromuscular fatigue post-match.[7] Therefore, any strategy which contributes to recovery of muscle function following high-intensity exercise could be useful in soccer players.

Compression garments may produce beneficial changes because physical and mechanical properties can maintain muscle structure and function.[8] They can diminish muscle oscillation upon landing from a vertical jump,[9, 10] provide structural support to muscles and joints, and improve muscle regeneration.[11] It has also been suggested that graduated compression garments increase blood flow velocity and arterial perfusion and improve peripheral circulation and venous return.[12-15] Thus, we can hypothesize that compression garments would mitigate the physical response to a soccer match.

There is a lack of studies carried out in field or in real conditions, so effects of recovery strategies after specific soccer tasks are still unknown. In fact, only one study with soccer players and compression garments has already been carried out, but it used a fatiguing protocol which does not replicate specific competition demands.[16] Therefore, the aim of this study was to evaluate physiological and physical responses to wearing compression garments during soccer matches and during recovery.

Materials and methods

Eighteen semi-professional soccer players (mean age: 24±4.07 years; mean height: 177±5 cm; mean body weight: 71.8±6.28 kg; mean BMI: 22.73±1.81 kg/m^2) participated in this study. All participants were healthy, without serious musculoskeletal injuries in the past 6 months. Musculoskeletal, metabolic, cardiovascular, respiratory, hematological or endocrine exercise disorders were also considered as exclusion criteria. Before given their informed consent for participation in the research study, players were fully informed about the objectives, risks and discomforts of the experiment. This study was conducted in accordance with the 1964 Declaration of Helsinki. It was also approved by the Ethics Committee of the University of the Basque Country (CEISH/357/2015/MARQUÉS JIMÉNEZ).

In order to reach the aim of the study we adopted a crossover design with two friendly soccer matches played and a 72-hour recovery phase when measurements were performed. Between data-collection periods, participants train together with the entire training squad (avoiding detraining symptoms), and it was not influenced by researchers. All participants took part in a pilot test four weeks before baseline measurements, when instructions of each test performed were provided.

Participants were randomly divided into three groups: stockings group (SG) (N.=6, height 179±7 cm, weight 67.85±6.98 kg, BMI 21.1±1.8 kg/m^2), full-leg group (FLG) (N.=6, height 176±4 cm, weight 73.08±3.54 kg, BMI 23.51±0.89 kg/m^2), shorts group (QG) (N.=6, height 178±5 cm, weight 74.47±6.59 kg, BMI 23.57±1.81 kg/m^2). Ten participants acted as their own control (CG) (N.=10, height 1.77±5 cm, weight 71.18±5.7 kg, BMI 22.92±2.38 kg/m^2) wearing no compression garment on a separate occasion. Data of SG, FLG and QG were mixed together for statistical analysis (experimental group [EG], N.=18, height 1.78±5 cm, weight 71.8±6.28 kg, BMI 22.72±1.82 kg/m^2). Each participant in the experimental condition played the match wearing one type of graduated compression garment (Compressport, Genève, Switzerland), and kept wearing them 7 hours/day during 3 days post-match (players put on them each day after testing session). Three types of compression garments were used, whose pressure ranges correspond to clinical medical grade II: compression stockings (SG, 20-25 mmHg at ankle, 15-20 mmHg at calf), compression tights (FLG, 25-30 mmHg at calf, 15-20 mmHg at thigh), and compression shorts (QG, 15-20 mmHg at thigh). Sizes were assigned according to the manufacturer's recommendations.

Soccer matches were performed on an artificial turf pitch (102×63 m). Data collection was obtained in a multisport covered pavilion beside the soccer pitch, where environmental conditions were similar in both periods. All the procedures were performed at the same time of the day to avoid circadian variation.

One day pre-match, participants were required to perform 3 countermovement jump (CMJ) with 3-minute recovery between attempts, 2 sprints over 20 m (10 m data was also obtained) with a 3-minute resting period between sprints, 2 T-tests according to the protocol described by Semenick (1990),[17] and the Yo-Yo Intermittent Recovery Test level 2 (YYIR2). One hour before the match, blood lactate concentration ([La$^-$]) and arterial oxygen saturation of hemoglobin (SaO_2) where measured, and rating of perceived exertion using the Borg's 6-20 scale (RPE) and perceived recovery using the Total Quality Recovey scale (TQR) were subjectively collected. These measurements were considered as baseline (pre-match). [La$^-$] and SaO_2

were only measured at half time and post-match. RPE was measured at half time, post-match, 24, 48 and 72 h post-match whereas TQR were only measured 24, 48, and 72 hours post-match. CMJ, 10-, 20-m sprint and T-Test were performed again immediately after the matches, 24, 48, and 72 hours post-match, but YYIR2 were only measured post-match and 72 hours post-match. A standard warm-up was conducted after blood samples and perceptual data collection, and before physical performance tests.

Anthropometric characteristics of the participants were measured with SECA mechanical medical scale with a height rod (Seca, Bonn, Germany). Blood $[La^-]$ was measured with Lactate Pro2 (Arkray, Shiga, Japan) from a hyperemized ear lobe using the second blood drop and the ear lobe previously cleaned with alcohol. SaO_2 from a hyperemized finger was obtained while players were seated and hold their index finger on a stable surface. Skin surface was cleaned with antiseptics before and after the test. A finger pulse oximeter clamp was used (OXYM2001; Quirumed, Valencia, Spain). Height jump was measured by Optojump Next (Microgate, Bolzano, Italy), and sprinting time was measured by photocell gates (Microgate Racetime2, Bolzano, Italy; Chronoprinter 505, Tag Heuer, Switzerland) placed 0.4 m above the ground. Participants started 0.5 m away from the starting point and began the test when they were ready.

External and internal match loads were monitored using a short-range telemetry and triaxial accelerometer incorporated within the GPS (Polar Team Pro, Polar Electro, Kempele, Finland). External loads indicators recorded were: total distance covered (TD; m), maximal running velocity (V_{max}; km/h), number of sprints (>23 km/h), number of maximum intensity decelerations (MD; -3.0 m/s^2), number of high intensity decelerations (HD; -2.9 to 2.0 m/s^2), number of high intensity accelerations (HA, 2.0 to 2.9 m/s^2) and number of maximum intensity accelerations (MA, 3.0 m/s^2). Average heart rate ($\%HR_{avg}$), maximal heart rate ($\%HR_{max}$) and time spent (min) at various intensities were recorded. Match-HR data was expressed as percentage of HR_{max} and classified into five intensity zones: 50-59%, 60-69%, 70-79%, 80-89%, and >90% of HR_{max}.

Participants were advised to avoid physical activity, alcohol and caffeine 24 h before baseline measurements and during study and were instructed to drink 0.5 liters of water at night in order to normalize hydration status. Participants had also to refrain from taking anti-inflammatory drugs, acetaminophen, corticosteroids, sedatives, anticoagulants, painkillers, nutritional supplements or other prescription drugs, and refrain from receiving massages, topical creams, heat or cold treatments such as sauna or hydrotherapy, stretching, or any plausible recovery strategy for 7 days before the study and during it. Players recorded their dietary intake 24 hours before baseline measurement and had to replicate it every day. Nevertheless, breakfast was standardized for all participants and had to be 3 hours before data collection.

Statistical analysis

Descriptive statistics are reported as means and standard deviations. We used the Shapiro-Wilk test (N.<30) to evaluate whether the data were normally distributed (P<0.05). All variables analyzed were normally distributed, thus parametric tests were performed. After using Levene's test for the homoscedasticity analysis, we used the *t*-test for independent samples (P<0.05) for parametric data of internal-external load. Remaining variables were analyzed using two-way ANOVA with the Bonferroni *post-hoc* test (similar variances) or Tamhane's T2 test (different variances) for pairwise comparisons (P<0.05). Pearson's correlation coefficient (P<0.01) was also used. Effect size (ES) was calculated with Hedges' g (P<0.05) to quantify the size of the difference between two groups. Beforehand, data were transformed from absolute values to relative values with respect to pre-match. Effect sizes were evaluated as trivial (0-0.19), small (0.20-0.49), medium (0.50-0.79) and large (≥0.80).[18] Statistical analyses were carried out by SPSS 20.0 software (SPSS, Chicago, IL, USA), while ES analysis were conducted using Review Manager 5.3.5 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark).

Results

The descriptive analysis of internal and external loads measured during soccer matches is shown in Figures 1 and 2. There were no significant differences in internal-external load between matches, so results described below cannot be linked to match-to-match variability or detraining symptoms. Results of $[La^-]$ and SaO_2 are shown in Table I, perceptual response is shown in Table II, and results of physical performance are shown in Table III.

Significant correlations were also found (>0.95; P<0.01) between internal-external load outcomes (considering data averaged over the entire match) and post-match measurements. Immediately post-match we have found a significant correlation between 10-m sprint and 20-m sprint (*r*=0.976; P<0.01) in the CG, 10-m sprint and 20-m sprint (*r*=0.991; P<0.01) and 10-m sprint and T-Test

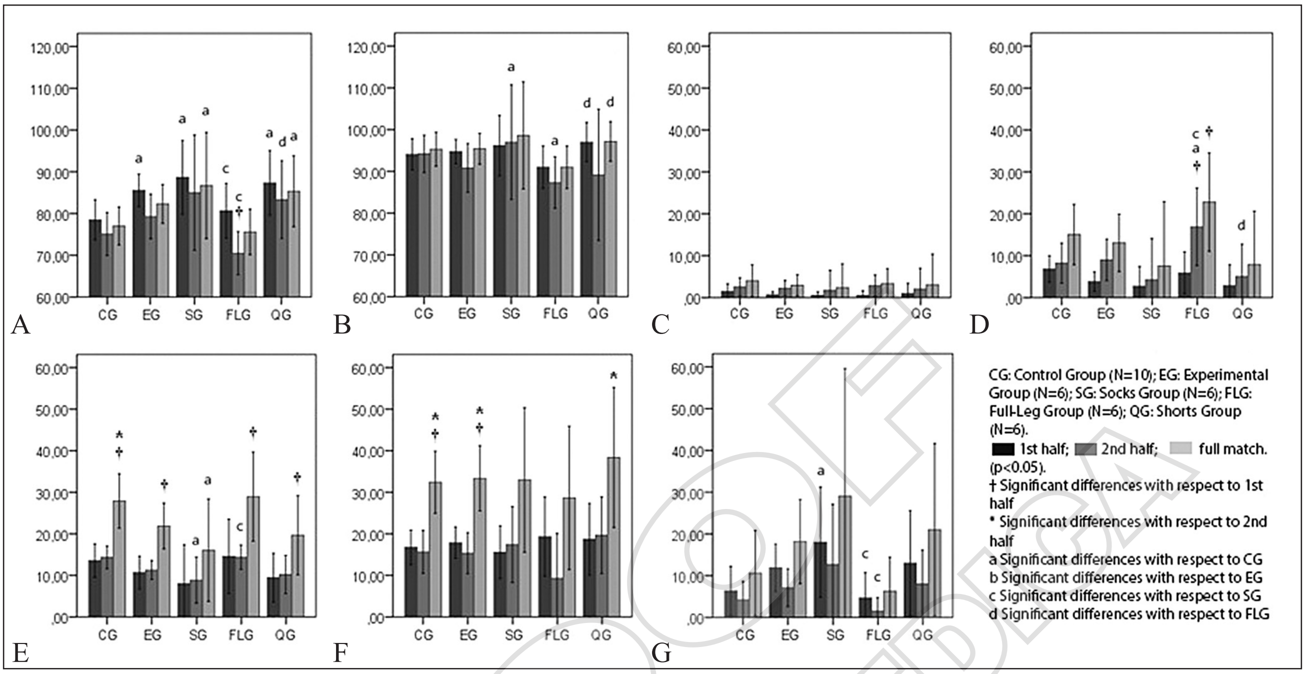

Figure 1.—Internal load during both matches: A) $\%HR_{avg}$; B) $\%HR_{max}$; C) time (min) at 50-59% HR; D) time (min) at 60-69% HR; E) time (min) at 70-79% HR; F) time (min) at 80-89% HR; G) time (min) at 90-100% HR.

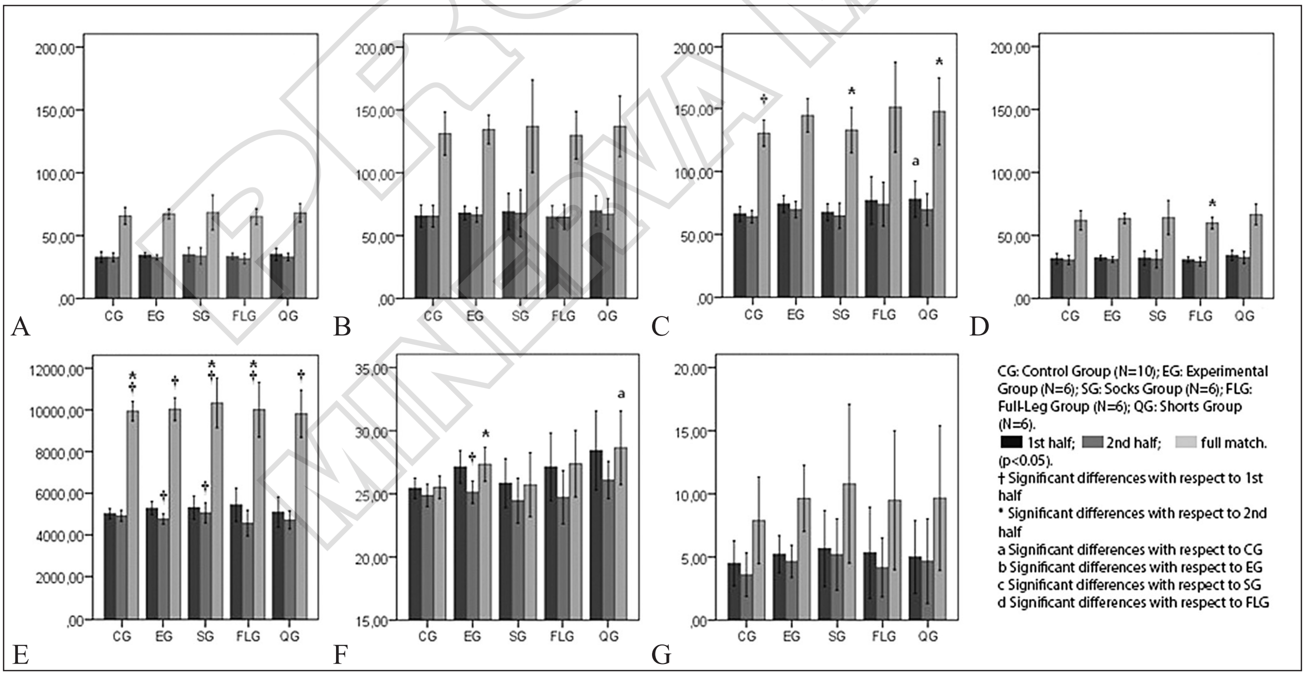

Figure 2.—External load during both matches: A) number of maximum decelerations (-3.0 m/s^2); B) number of high decelerations (-2.9; -2.0 m/s^2); C) number of high accelerations (2.0; 2.9 m/s^2); D) number of maximum accelerations (3.0 m/s^2); E) total distance covered (m); F) maximum running velocity (km/h); G) number of sprints (>23 km/h).

TABLE I.—*Mean differences in lactate and SaO2 relative effect size in the pre-match and 72 hours post-match.*

Variable	CG (N.=10)	EG (N.=18)	SG (N.=6)	FLG (N.=6)	QG (N.=6)
Lactate, mmol/L					
Pre-match	1.8±0.61	1.68±0.49	1.68±0.33	1.55±0.55	1.8±0.6
Half time	3.34±2.28	5.12±3.03	6.37±4.53	3.12±0.69†	5.87±1.66[a]
		0.84 (0.03, 1.65)	1.04 (-0.05, 2.13)	0.48 (-0.55, 1.50)	1.54 (0.36, 2.72)
Post-match	3.75±2.7†	5.16±3.83	3.23±1.46	4.77±3.21†	7.48±5.14†
		0.42 (-0.37, 1.21)	-0.21 (-1.29, 0.87)	0.53 (-0.50, 1.56)	0.83 (-0.23, 1.90)
SaO_2 (%)					
Pre-match	98.2±0.69	97.44±1.85	97.67±1.03	96.67±2.88	98±1.1
Half time	97.3±1.49	96.94±1.39	97±0.63	97.17±1.72	96.67±1.75
		0.25 (-0.52, 1.03)	0.43 (-0.59, 1.46)	0.63 (-0.42, 1.67)	-0.15 (-1.17, 0.86)
Post-match	96.6±2.59	96.56±1.58	95.67±1.75†	97.17±0.98	96.83±1.72
		0.27 (-0.51, 1.06)	-0.16 (-1.24, 0.91)	0.70 (-0.35, 1.75)	0.18 (-0.83, 1.20)

Data presented as mean±SD and effect size (95% CI).
CG: control group; EG: experimental group; FLG: full-leg group; QG: quad group; SaO_2: arterial oxygen saturation of hemoglobin; SG: socks group.
†Statistically significant difference *versus* pre-match (P<0.05); #significant difference *versus* half time (P<0.05); [a] significant difference *versus* CG (P<0.05).

TABLE II.—*Mean differences in RPE and TQR and relative effect size in the pre-match, half time, post-match, 24, 48, and 72 hours post-match.*

Variable	CG (N.=10)	EG (N.=18)	SG (N.=6)	FLG (N.=6)	QG (N.=6)
RPE, a.u.					
Pre-match	6.3±0.48	6.28±0.46	6.33±0.52	6.33±0.52	6.17±0.41
Half time	10.3±2.58†	9.56±1.62†	10±1.67	8.83±1.47	9.83±1.72
		-0.37 (-1.15, 0.41)	-0.02 (-1.04, 0.99)	-0.58 (-1.62, 0.46)	0.03 (-0.98, 1.04)
Post-match	13.3±3.53† #	12.83±2.79† #	13.33±2.07†	11.83±3.54	13.33±2.8†
		-0.12 (-0.90, 0.65)	0.00 (-1.01, 1.01)	-0.39 (-1.42, 0.63)	0.09 (-0.93, 1.10)
24 h post-match	13±1.83†	9.89±3.64† * [a]	10.67±4.93	10.17±3.54 †	8.83±2.48* [a]
		-0.91 (-1.73, -0.10)	-0.57 (-1.61, 0.46)	-1.10 (-2.21, 0.00)	-1.56 (-2.75, -0.37)
48 h post-match	10.8±1.62†	9.83±2.92† *	10.67±3.98	9±2.28	9.83±2.48
		-0.33 (-1.11, 0.45)	-0.03 (-1.04, 0.98)	-0.77 (-1.82, 0.29)	-0.41 (-1.43, 0.62)
72 h post-match	9.8±0.92† * $	8.94±1.73† *	9±1.79	8.67±2.34	9.17±1.17† *
		-0.46 (-1.25, 0.32)	-0.47 (-1.50, 0.56)	-0.55 (-1.58, 0.49)	-0.40 (-1.42, 0.63)
TQR, a.u.					
Pre-match	19.3±0.95	19.67±0.77	19.67±0.52	19.5±1.22	19.83±0.41
24 h post-match	12±1.15†	14.67±2.63† [a]	13.83±2.4†	16.33±3.08 [a]	13.83±1.83† [a]
		1.11 (0.27, 1.94)	0.86 (-0.21, 1.93)	2.25 (0.90, 3.60)	0.97 (-0.12, 2.05)
48 h post-match	14.7±1.42† $	15.72±1.18†	15.5±1.52†	16.33±1.21 [a]	15.33±0.51†
		0.52 (-0.27, 1.31)	0.29 (-0.73, 1.31)	0.94 (-0.14, 2.02)	0.13 (-0.88, 1.15)
72 h post-match	15.6±1.27† $	16±2.28†	16.83±1.33† $	14.83±3.19†	16.33±1.75† $
		0.05 (-0.72, 0.83)	0.62 (-0.42, 1.66)	-0.30 (-1.31, 0.72)	0.17 (-0.85, 1.18)

Data presented as mean±SD and effect size (95% CI).
a.u: arbitrary units; CG: control group; EG: experimental group; FLG: full-leg group; QG: quad group; RPE: rating of perceived exertion; SG: socks group; TQR: total quality recovery.
†Significant difference *versus* pre-match; #significant difference *versus* half time; *significant difference *versus* post-match; $significant difference *versus* 24 h post-match; [a] significant difference *versus* CG.

(*r*=0.959; P<0.01) in the GS, and [La⁻] and 10-m sprint (*r*=-0.986; P<0.01) in the QG. At 24 h post-match we have found a significant correlation between 10-m sprint and 20-m sprint (*r*=0.976; P<0.01) in the FLG. At 48 h post-match we have found significant correlations between 10-m sprint and 20-m sprint (*r*=0.987; P<0.01) in the EG, TQR and time spent at 90-100% HR (*r*=0.962; P<0.01), and 10-m sprint and 20-m sprint (*r*=1.000; P<0.01) in the SG, 10-m sprint and 20-m sprint (*r*=0.971; P<0.01) in the FLG, and 10-m sprint and $\%HR_{máx}$ (*r*=-0.986; P<0.01) in the QG. At 72 h post-match we have found significant correlations between 10-m sprint and 20-m sprint (*r*=0.976; P<0.01) in the CG, and 20-m sprint and time spent at 50-59% HR (*r*=0.968; P<0.01), 20-m sprint and time spent at 60-69% HR (*r*=0.951; P<0.01) and T-Test number of MA (*r*=0.960; P<0.01) in the QG.

Table III.—*Mean differences between in physical performance and relative effect size in the pre-match, post-match, 24, 48, and 72 hours post-match.*

Variable	CG (N.=10)	EG (N.=18)	SG (N.=6)	FLG (N.=6)	QG (N.=6)
CMJ height, cm					
Pre-match	36.71±5.18	36.81±4.81	38.84±3.84	37.62±5.84	33.98±3.8
Post-match	33.4±5.42	35.52±6	36.73±7.06	37.39±6.58	32.64±4.07
		0.96 (0.13, 1.79)	0.66 (-0.45, 1.77)	2.16 (0.83, 3.49)	1.03 (-0.06, 2.12)
24 h post-match	35.46±5.14	36.51±4.82	39.19±4.19	36.44±5.92	33.91±2.95 [c]
		0.36 (-0.43, 1.15)	0.61 (-0.50; 1.71)	0.06 (-0.96, 1.07)	0.45 (-0.58, 1.47)
48 h post-match	35.82±5.29	37.27±4.79	39.09±4.75	37.68±5.9	35.03±3.23
		0.57 (-0.23, 1.37)	0.44 (-0.65, 1.53)	0.39 (-0.63, 1.42)	0.92 (-0.16, 2.00)
72 h post-match	35.79±4.51	36.59±5.49	38.53±5.62	36.89±6.97	34.34±3.37
		0.29 (-0.49, 1.08)	0.23 (-0.85, 1.31)	0.03 (-0.98, 1.04)	0.95 (-0.13, 2.03)
10-m sprint, s					
Pre-match	1.8±0.07	1.79±0.08	1.76±0.06	1.78±0.09	1.82±0.07
Post-match	1.86±0.11	1.81±0.14	1.82±0.19	1.75±0.12	1.86±0.12
		-0.38 (-1.17; 0.41)	0.01 (-1.06, 1.09)	-1.11 (-2.22, -0.01)	-0.33 (-1.35, 0.69)
24 h post-match	1.84±0.08	1.8±0.09	1.78±0.11	1.75±0.08 [a]	1.87±0.05 [c d]
		-0.27 (-1.06, 0.51)	-0.14 (-1.22, 0.93)	-0.98 (-2.07, 0.10)	0.26 (-0.76, 1.28)
48 h post-match	1.78±0.06	1.79±0.09	1.79±0.1	1.74±0.08	1.84±0.07 [d]
		0.38 (-0.41, 1.16)	0.79 (-0.33, 1.92)	-0.49 (-1.52, 0.54)	0.77 (-0.29, 1.82)
72 h post-match	1.81±0.06	1.78±0.1	1.76±0.13	1.74±0.07	1.84±0.86
		-0.15 (-0.93, 0.63)	-0.08 (-1.16, 0.99)	-0.52 (-1.55, 0.51)	0.12 (-0.90, 1.13)
20-m sprint, s					
Pre-match	3.12±0.08	3.09±0.11	3.06±0.1	3.08±0.13	3.13±0.12
Post-match	3.26±0.19†	3.2±0.26	3.26±0.45	3.11±0.1	3.24±0.19
		-0.16 (-0.94, 0.62)	0.22 (-0.86, 1.30)	-0.80 (-1.86, 0.26)	-0.27 (-1.28, 0.75)
24 h post-match	3.18±0.11	3.13±0.17	3.11±0.22	3.04±0.12 [a]	3.23±0.91 [d]
		-0.17 (-0.95, 0.61)	0.04 (-1.11, 1.03)	-1.16 (-2.27, -0.04)	0.48 (-0.55, 1.52)
48 h post-match	3.1±0.08*	3.09±0.15	3.09±0.24	3.02±0.13	3.18±0.09 [d]
		0.20 (-0.58, 0.98)	0.45 (-0.64, 1.54)	-0.89 (-1.96, 0.18)	0.95 (-0.13, 2.03)
72 h post-match	3.14±0.06	3.11±0.17	3.09±0.23	3.07±0.83 [a]	3.18±0.16
		-0.04 (-0.82, 0.74)	0.05 (-1.03, 1.12)	-0.48 (-1.50, 0.55)	0.20 (-0.82, 1.21)
T-test, s					
Pre-match	9.33±0.21	9.53±0.31	9.58±0.26	9.61±0.29 [a]	9.39±0.36
Post-match	10.04±0.37†	9.89±0.7	10.34±0.99	9.68±0.41	9.74±0.57
		-0.58 (-1.38, 0.22)	0.17 (-0.91, 1.25)	-1.80 (-3.04, -0.56)	-1.38 (-2.53, -0.22)
24 h post-match	9.79±0.21†	9.81±0.42†	9.61±0.42	9.96±0.49	9.86±0.37†
		-0.59 (-1.39, 0.21)	-1.39 (-2.61, -0.17)	-0.38 (-1.40, 0.65)	-0.01 (-1.02, 1.00)
48 h post-match	9.44±0.3*	9.4±0.37* [$]	9.43±0.51	9.31±0.12 [$]	9.46±0.38
		-0.71 (-1.52, 0.10)	-0.71 (-1.82, 0.40)	-1.15 (-2.26, -0.04)	-0.13 (-1.14, 0.89)
72 h post-match	9.33±0.32*	9.41±0.34* [$]	9.39±0.38	9.29±0.3 [$]	9.53±0.35
		-0.36 (-1.15, 0.42)	-0.56 (-1.66, 0.54)	-1.01 (-2.10, 0.08)	0.42 (-0.60, 1.45)
YYIR2 distance, m					
Pre-match	648±102.93	622.22±109.95	626.67±135.45	606.67±77.63	633.33±127.54
Post-match	384±105.32†	395.29±113.91†	380±123.29†	413.33±112.19†	406.67±122.42†
		0.30 (-0.48, 1.09)	-0.14 (-1.21, 0.94)	0.64 (-0.40, 1.68)	0.49 (-0.54, 1.53)
72 h post-match	580±118.13*	575.56±114.39*	600±16.49*	540±90.33	586.67±135.45
		0.36 (-0.43, 1.15)	0.66 (-0.45, 1.76)	-0.05 (-1.06, 0.96)	0.52 (-0.51, 1.56)

Data presented as mean±SD and effect size (95% CI).

CG: control group; CMJ: countermovement jump; EG: experimental group; FLG: full-leg group; QG: quad group; SG: socks group; YYIR2: Yo-Yo Intermittent Recovery Test Level 2.

†Significant difference *versus* pre-match; *significant difference *versus* post-match; [$]significant difference *versus* 24 h post-match; [a] significant difference *versus* CG; [b] significant difference *versus* EG; [c] significant differences *versus* SG; [d] significant difference *versus* FLG.

Discussion

The present results show that compression garments could be moderately beneficial for the recovery after soccer matches, but effects are not significant. The use of magnitude-based ES statistics can appropriately express practically meaningful outcomes that may not reach statistical significance because, sometimes, a statistically significant result means only that a huge sample size was used.[19] Furthermore, a very small and not significant (1%) increase in a performance variable can yield success in competitive sport, thus a small-to-moderate effect size may not be statistically significant but may be practically important. Considering that we have calculated relative ES, effect of compression garments is favorable to treatment when increases in those measurements which increase respect to pre-match as a result of soccer demands are smaller than increases in CG (when ES is negative). It is also favorable to treatment when decreases in those measurements which decrease respect to pre-match as a result of soccer demands are smaller than decreases in CG (when ES is positive).

No significant differences between groups have been found in most of the variables representative of internal-external loads, confirming a limited influence of compression therapy in soccer players during a friendly match. Results from experimental studies showed that HR responses of soccer players depend on playing position[20] and previous studies did not find significant differences in HR wearing either compression garments or non-compression garments,[21, 22] thus finding a relation between HR responses and compression garments is complicated. For most of the external load variables, we did not find significant differences between groups, suggesting that wearing compression garments did not influence running performance.

Several researchers have observed a reduction in [La–] in the second half compared to the first.[23, 24] However, our results show a different trend. Except in GS, in which [La–] follows this pattern, other groups showed a continuous increase in [La–], but with a very small difference between half time and post-match in CG and EG. ES values show that [La–] increases when compression garments are used during matches, except in SG at post-match (ES=-0.21). Reduction in [La–] in the second half compared to the first are frequently observed with specific reference to both the total distance covered and high intensity actions decrements, as well as the lower muscle glycogen content and glycolytic capacity.[23, 24] Our results show that the total distance covered, and intensity of actions performed during matches are lower in the second half than the first in all groups. Consequently, no significant increases in [La–] in experimental groups must be associated to compression therapy. Enhanced [La–] removal and oxidation when compression garments are worn have previously related to hemodynamic improvements.[25] Nevertheless, our findings support the hypothesis that external pressure on the muscles probably retained La- in the previously active muscle with compression garments rather than being cleared more quickly without,[26, 27] explaining the higher post-match [La–] compared to half time, and in the experimental groups compared to CG. However, [La–] obtained post-match are not high, so we may not assume this response as truly harmful for players´ performance. Further studies with soccer players are necessary to confirm whether playing a friendly match or training with compression garments increases post-exercise [La–], on the basis that previous results showed that wearing compression garments during recovery from exercise facilitates high [La–] elimination.[27]

No significant differences between groups were identified in SaO_2 at any measurement time, but there was a significantly lower SaO_2 post-match compared to pre-match in SG (97.67±1.03 *vs.* 95.67±1.75; $P<0.05$). As match-time goes by, no significant decrements were observed in SaO_2 in all groups except in FLG, in which there is no significant increase. ES show a limited mitigation in SaO_2 reductions except in FLG, in which SaO_2 increases. It has been demonstrated that graduated compression stockings may achieve their beneficial effects in patients with venous insufficiency by reducing venous pooling and improving deeper tissue oxygenation,[12] but it seems unlikely that it would result in an increase in SaO_2 during maximal or sub-maximal exercises (RSA), despite the expected increased blood volume.[22] A study on marathon athletes showed no difference in SaO_2 between those athletes who ran with compression stockings (25-20 mmHg) and those who did not wear any compression garments.[28] Although there were decreases in SaO_2 post-race compared to pre-exercise values, differences between groups were not significant. The small effect of compression garments in eliminating [La–] shown in that study[28] suggests the lack of effect of compression stockings on venous return, although no hemodynamic variables were measured in that study. Likewise, we did not measure hemodynamic variables and [La–] was not attenuated in our study, so we can only suggest that external pressure on the muscles probably retained La- in the previously active muscle,[26, 27] and a plausible effect of full-leg compression garments in hemodynamic during soccer matches, although we cannot corroborate it. The increased blood flow velocity and improved peripheral circulation and venous return facilitated by compression garments[12, 14, 15] could influence cardiac preload and affect cardiac output.[29] HR_{avg} in FLG was lower than that of SG and QG, hence cardiac preload and cardiac output may have also been improved by the increased venous return in the GFL, but we cannot confirm it. The plausible cause of the no significant SaO_2 increase in FLG as match-time goes by may be the size of the area covered by the full-leg compression garment.

Inconsistent findings have been previously found on perceived exertion immediately after exercise and during recovery[22, 30] and those reported of perceived recovery.[31, 32] It seems that the perceptual benefits of compression garments are only experienced during recovery in high-intensity intermittent sports. Our results support this hypothesis. In our study RPE peaks at post-match in each group, and then gradually decreases. According to ES obtained, the influence of compression therapy on perceived fatigue during recovery is greater than during exercise, and it is especially greater 24 hours post-match. FLG presented the lowest RPE value both at half time and at post-match and ES values show the moderately effect of full-leg garment on RPE reduction. During recovery, full-leg garment and compression shorts seems to be more effective in decreasing RPE than compression socks, probably associated with the greatest body region covered by these garments. Perceived recovery was the lowest at 24 hours post-match, but ES indicate that compression therapy can be associated with an improved perception of recovery, specially using full-leg garment and compression shorts. Therefore, perceptual responses suggest that wearing compression garments during recovery can be useful during 24-48 hours post-exercise to promote psychological recovery from high-intensity exercise, regardless of possible physiological changes. A plausible reason may be that participants felt comfortable when wearing compression garments, but we cannot exclude the placebo effect as a possible contributing factor to the subjective response.

Wearing compression garments during exercise may decrease muscle oscillation during landing from jumps and attenuate impact forces, hence reducing structural damage resulting from impact forces.[9, 10, 21, 33, 34] This decrease in vibration reduces the mechanical tissue stress,[16] so combined effects of all these factors could potentially attenuate the physical performance impairment. During recovery, compression seems to attenuate strength decrements by reducing the number of muscle fibers affected by EIMD, promote better recovery of the membrane structure and a more stable alignment of muscle fibers (dynamic casting), reduce certain movement of the tissues, offer "dynamic immobilization," and reduce swelling and delayed onset of muscle soreness (DOMS).[11, 35-37] These factors may facilitate the functional recovery of the muscle and could explain the disturbances observed, but some other mechanisms might be responsible for the attenuation of the performance decrements.[35] In fact, the loss of muscle strength can also be related to neural disorders.[38] Compression garments could also improve neurotransmission and mechanical efficiency due to a better stimulation of muscle afferences and better muscle excitation through the pressure applied to the skin.[9, 10, 21]

There was no significant time effect on vertical jump performance (absolute values), nor differences between experimental groups (EG, SG, FLG, QG) and CG, but performance is slightly impaired at post-match and during recovery (not significantly). As relative ES indicate, wearing compression shorts have a relative moderate effect on reducing strength impairment and vertical jump decrement during recovery, whereas post-match decrements can be attenuated largely using full-leg garments. This may be due to a likely influence in the membrane structure, accelerating the recovery of contractile force and the process of excitation-contraction coupling.[39] Although no significant effects have been reported in some studies,[34, 40] others researchers have shown positive effects of full-leg compression during recovery in team sports.[32, 41] The positive effect on vertical jump performance seems to be greater with medical grade II compression garments,[42] like those used in our study.

Sprint performances over 10 and 20 m were slightly reduced (not significantly) between post- and 24 hours post-match, although they were both recovered 48 hours post-match. Relative ES of EG shows a small positive effect of compression garments on sprint performance, but relative decrements can be attenuated largely using full-leg garments. Another study showed that 10-m sprint performance was not recovered with respect to a control group 48 hours post-exercise, but athletes who wore full-leg garments showed similar performance in 30-m sprint compared to pre-exercise values, whereas the performance of a control group was still significantly lower than pre-exercise levels.[40] Peak speed impairment during maximal exercise may be explained by a reduction in voluntary muscle activation,[3] possibly because of an inhibition caused by DOMS.[43] However, the lack of significant effect of compression garments on sprint performance has been observed in team sport players.[44, 45]

T-test performance is significantly impaired at post- and 24 hours post-match in CG, whereas is significantly impaired only at 24 hours post-match in EG and QG; 24-48 hours seems to be enough to recover agility T-test performance, whether or not athletes were wearing compression garments. Previous studies have shown that there were no significant differences between compression and control groups on the ability to change direction or agility test 48 hours post-exercise.[40, 45] However, ES show that the relative performance impairment is lower using stockings and full-leg garments than compression shorts. In athletes with EIMD, agility test performance is negatively affected by alterations in the stretch-shortening cycle, because of increased knee stiffness and a central inhibition in strength by neural mechanisms.[38, 46] It is likely, therefore, that a change in the recruitment order of motor units and a better stimulation of muscle afferences and muscle excitation through the pressure applied to the skin,[33] linked to the mechanical support facilitated by compression garments, promote faster recovery in tasks including changes of direction.

Aerobic performance (YYIR2) was significantly impaired after the match compared to pre-match, but it is significantly increased respect to post-match at 72 hours post-match in CG, EG and SG. Relative ES of our study indicates that compression garments could have a positive effect on the ability of the player to perform until exhaustion. Contrasting results were previously observed. Although it seems that compression therapy has a small positive effect on time to exhaustion,[47] a limited effectiveness of compression therapy has also been shown in maintaining performance during a second bout of exercise to exhaustion.[28, 48] It seems that wearing compression garments during recovery after exercise enhances blood flow velocity and cardiac output,[25] and a increased blood flow may increase carbohydrates metabolism, enhancing muscle glucose availability and, ultimately, glycogen synthesis.[35, 49] Nevertheless, it was reported that wearing compression shorts with 37-mmHg reduced blood flow both in the deep and superficial regions of the muscle tissue during recovery from high intensity exercise, but did not affect glucose uptake, which was independent of blood flow.[50] Further studies with a placebo condition are required to confirm whether aerobic performance is improved during recovery when athletes use compression garments and to identify the underlying mechanisms.

Conclusions

Our results show that the use of compression garments during a friendly soccer match may slightly increase [La$^-$] during and after soccer matches, but Full-Leg garments can moderately attenuate the reduction of SaO_2. Perceptual responses suggest that wearing compression garments during recovery can also be useful during 24-48 hours post-exercise to promote psychological recovery from high-intensity exercise, especially full-leg garments and compression shorts. Decreases in anaerobic power (vertical jump, sprint, change of direction) can be attenuated but not significantly, mainly when soccer players use full-leg compression garments or compression shorts. Compression garments could also have a positive effect on aerobic capacity (YYIR2), but we cannot exclude a placebo effect. Thus, we could advise soccer players to use them because no negative effects have been found.

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