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Research article

Negative Associations between Perceived Training Load, Volume and Changes in Physical Fitness in Professional Soccer Players

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Abstract

The purpose of this study was to examine the usefulness of the rating of perceived exertion training load for monitoring changes in several aerobic fitness and neuromuscular performance variables during 9 weeks of soccer training in young professional players. Nineteen male soccer players (20.2 ± 1.9 years) belonging to the same reserve team of a Spanish La Liga Club participated in this study. Countermovement jump (CMJ), CMJ arm swing, single leg CMJ, a sprint running test (i.e., 5 m and 15 m times) and an aerobic fitness running test were performed at the start of the pre-season (Test 1) and 9 weeks later (Test 2). During 9 weeks, after each training session and match, players reported their rating of perceived exertion (RPE) separately for respiratory (RPEres) and leg musculature (RPEmus) effort. The training load (TL) was calculated by multiplying the RPE value by the duration in minutes of each training session or match. Accumulated RPEmus, and associated TL, as well as accumulated training volume were negatively correlated with the changes in most physical fitness attributes after 9 weeks of training (r = -0.51 to -0.64). Present results suggest that a high perception of leg muscular effort associated with training sessions and matches, as well as an excessive accumulation of training volume (time), can impair the improvement in several physical fitness variables believed to be relevant for on-field soccer performance. Therefore, the independent assessment of leg muscular effort to quantify TL can be an interesting additional monitoring measure in soccer training.

Key words: Soccer, training load**,** RPE, physical fitness.

Introduction

Individual training adaptations in response to chronic exposure to physical exercise are related to athletes' individual physical fitness level and the magnitude (i.e., intensity and duration) of the prescribed training load (TL) (Impellizzeri et al., 2005). As a result, the quantification of the individual responses to a given external TL is important to optimize physical fitness performance. However, in a team sport such as soccer, the extensive use of group exercises where inter-player TL differences vary depending on the type of ball-drill performed (Los Arcos et al., 2014) make the prescription of training difficult in relation to individual characteristics (Impellizzeri et al., 2005). For instance, those players with the highest VO_{2max} showed the lowest percentage of VO_{2max} during the small group play (Hoff et al., 2002). Therefore, the remarkable differences in TL accumulation between soccer players (Akubat et al., 2012; Impellizzeri et al., 2005; Manzi et al., 2013) and the difficulty to ensure an appropriate level of training stimulus for each soccer player, when a team-based training approach is undertaken, suggest how important the quantification of the individual's TL is (Alexiou and Coutts, 2008) and the relevance of this information that makes possible the identification of the players with insufficient or excessive TL and individual training strategies.

The quantification of TL is generally based on both external (e.g., distance, power output, number of repetitions) and internal (e.g., oxygen uptake, heart rate, blood lactate, rate of perceived exertion) indicators of effort intensity (Buchheit, 2014). In order to know the stimulus for exercise-induced adaptations, Foster et al. (2001) proposed the session-rating of perceived exertion (sRPE) as a practical tool for evaluating internal TL in endurance and team sport athletes (Foster et al., 1996, 2001, 1995; Foster, 1998). This method requires from the players to subjectively rate the intensity of the entire training session using a modified version of category ratio scale (CR-10 scale) developed by Borg et al. (1998), the Foster's 0–10 scale (Foster et al., 2001). This intensity value is then multiplied by the total duration (minutes) of the training session to create a single measure of internal TL (sRPE-TL) in arbitrary units (AUs) (Foster et al., 2001). Previous investigations have shown sRPE-TL to compare favourably with more sophisticated methods of quantifying TL such as heart rate (HR) in endurance (Foster et al., 2001), team sport (Alexiou and Coutts, 2008; Casamichana et al., 2013; Foster et al., 2001; Impellizzeri et al., 2004; Scott et al., 2013), and resistance-trained athletes (Day et al., 2004). Specifically for soccer training, several studies have described substantial positive correlations between sRPE-TL and HR-based TL (Alexiou and Coutts, 2008; Casamichana et al., 2013; Impellizzeri et al., 2004; Scott et al., 2013). Thus, the sRPE-TL appears to be a good indicator of the global internal load for soccer training (Impellizzeri et al., 2004). Furthermore, RPE method is easy, versatile and cheap (Borg, 1982), it does not require technical expertise and the TL is measured quickly without chance for technical errors (Alexiou and Coutts, 2008).

Despite the potential limitations of HR measures to

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quantify TL in team sports (Borresen and Lambert, 2009), previous training studies have generally reported substantial and positive associations between the changes in HR-based TL and physical fitness parameters in soccer players (Akubat et al., 2012; Castagna et al., 2011; 2013; Manzi et al., 2013). For example, after 6 to 8 weeks of pre-season training, large to very-large correlations were reported between training time spent at high-intensity (> HR at 4 $mmol \cdot l^{-1}$) and changes in running speed at 2 and 4 $mmol \cdot l^{-1}$ of blood lactate (Castagna et al., 2011; 2013), maximal oxygen uptake (VO_{2max}) (Castagna et al., 2013) and performance in the Yo-Yo IR1 (Castagna et al., 2013). Moreover, after 8 weeks of pre-season training, Manzi et al. (2013) reported large to very-large correlations between HR-derived individualised training impulse (iTRIMP) TL and changes in the running speed at 4 $mmol \cdot l^{-1}$ of blood lactate and performance in the Yo-Yo IR1. Similarly, Akubat et al. (2012) reported a large association between the HR-derived iTRIMP and changes in the running speed at 2 $mmol \cdot l^{-1}$ of blood lactate in young soccer players after six week of in-season training. Interestingly, in this last study authors did not find any substantial association between changes in several aerobic fitness variables (i.e., running speed at 2 $mmol \cdot l^{-1}$ and 4 $mmol \cdot l^{-1}$ of blood lactate) and overall sRPE-TL (Akubat et al., 2012). Thus, despite the reported validity and advantages of the RPE derived TL (Alexiou and Coutts, 2008; Impellizzeri et al., 2004), it is still unclear how useful this measure is for monitoring changes in physical fitness performance in soccer players.

To our knowledge, all previous soccer studies that have assessed the relationship between longitudinal changes in TL and physical fitness performance have only paid attention to aerobic fitness variables (Akubat et al., 2012; Castagna et al., 2011, 2013; Manzi et al., 2013). In addition to aerobic fitness, neuromuscular factors (i.e., strength, power, speed) are important performance determinants of soccer match-play physical performance (Stølen et al., 2005) and are heavily taxed during matches and training sessions (Ascensão et al., 2008; Krustrup et al., 2006; Mohr et al., 2004; Rampinini et al., 2011; Robineau et al., 2012; Thorlund et al., 2009). Despite neuromuscular factors being perceived as crucial for soccer physical performance, to the best of our knowledge, no previous study has assessed the relationship between changes in TL and neuromuscular fitness parameters in soccer. In order to evaluate these associations between RPE-derived TL and both aerobic and neuromuscular fitness components, the differentiated use of respiratory sRPE-TL (sRPEres-TL) and muscular sRPE-TL (sRPEmus-TL) (Aliverti et al., 2011; Borg et al., 2010; Green et al., 2009; Mahon et al., 1998) may offer, also in team sports (Arcos et al., 2014; Yanci et al., 2014; Weston et al., 2014), an interesting alternative to the global sRPE.

The purpose of this study was, therefore, to examine the usefulness of sRPEres-TL and sRPEmus-TL for monitoring changes in several aerobic fitness and neuromuscular performance variables during 9 weeks of soccer training in young professional players.

Methods

Subjects

Nineteen young professional male soccer players (20.2 ± 1.9 years, height 1.81 ± 0.07 m, body mass 73.8 ± 7.3 kg) belonging to the same reserve team of a Spanish La Liga Club participated in this study. Two players were excluded from the final analysis due to long-term injuries (> 4 weeks) and three other players could not perform the second physical fitness assessment. Eventually, the group was reduced to 14 players (6 defenders, 5 midfielders, and 3 forwards; 20.6 ± 1.7 years, height 1.79 ± 0.06 m, body mass 73.5 ± 7.0 kg). One player did not complete the jump and sprint tests due to acute injury during the second physical fitness assessment. Players were professional and their training regimen was identical to the 1st Division team. As such, players were not involved in any other professional activity aside soccer. They competed during the 2011–2012 in the Spanish 2ndB division Championship. Players had between 0-3 years of competitive experience in this Championship and at least 10 years of soccer training experience. Goalkeepers were excluded from the study. All participants were notified of the research procedures, requirements, benefits and risks before giving informed consent. The study was conducted according to the Declaration of Helsinki, and the study was approved by the local Ethics Committee.

Experimental design

This study was performed during pre-season (5 weeks) and in-season competitive periods (4 weeks), from July to September. Before and after the 9 weeks, the subjects were tested to determine physical fitness performance. Players trained 5-8 times a week (31 training sessions in total) and played 1-2 friendly matches per week (8 friendly matches in total) during pre-season, while they trained 4-6 times a week (19 trainings in total) and played an official match per week (4 official matches in total) during the competitive period. Furthermore, during the competition period an additional friendly match was played. During pre-season, friendly matches were played in the middle of the week (Wednesday) and in the weekend (Saturday or Sunday). All official matches were played during weekends. The participants that played lesser minutes (substitutes) during the competition period typically performed individual physical practice during match day to increase their weekly load.

Physical fitness assessment and training

To assess physical fitness performance, the players completed the same physical testing battery twice: on the second day of the first week (T1) and at the start of the 10th week (T2). Before each testing session, a standardized warm-up was performed consisting in 5 min self-paced low-intensity running, mobility exercises, strides and acceleration drills. The players avoided any strenuous exercise in the 24 prior hours to this test session. Physical fitness testing included the evaluation of jumping performance (i.e., countermovement jump (CMJ), arm swing CMJ and single leg CMJ), sprinting (i.e., 5 m and 15 m times) and aerobic fitness running test (i.e., lactate thresholds). Testing venue, time of the day and order of tests were identical during both testing sessions.

Jumping height: The testing session started with the jumping tests using a contact mat (Newtest, Oulu, Finland). Three different jump tests were administered in the following order: CMJ, CMJ arm swing (CMJAS), single CMJ with dominant (CMJD) and no-dominant leg (CMJND). The CMJ jumps were performed according to the procedures proposed by Bosco et al. (1983). The players performed three CMJ and CMJAS (with minimum 20 s recovery between each repetition). Two CMJD and CMJND trials were performed. The best performance (i.e., highest jumping height) for each of the different jumps was retained for further analysis.

Sprinting speed: Ten minutes after the completion of the jumping tests and after a non-standardized, individual warm-up period that included low-intensity running and several acceleration runs, players undertook a sprint running test. The sprint test consists of three maximal sprints of 15 m, with a 120 s rest period between each sprint, on an indoor court. The recording of running time was performed using photocell gates (Newtest OY, Oulu, Finland) placed 0.4 m above the ground with an accuracy of 0.001 s. The subjects commenced the sprint when ready from standing start, 0.5 m behind the line. Stance for the start was consistent for each subject. The time was automatically activated as the subject crossed the first gate at the 0 m mark and split times were recorded at 5 m and 15 m. The run with the fastest time was selected for further analysis.

Aerobic fitness: Finally, the aerobic fitness test consisted of four-stage sub-maximal runs separated by 3 min of recovery run around the artificial grass soccer pitch (100x50m). The running speeds were 12 $km \cdot h^{-1}$ (10 min), 13 $km \cdot h^{-1}$ (10 min), 14 $km \cdot h^{-1}$ (10 min) and 15 $km \cdot h^{-1}$ (5 min) for the first, second, third and fourth stages, respectively (Gorostiaga et al., 2009). Players with a previously known low aerobic fitness (4 players) started the test at 11 $km \cdot h^{-1}$ (10 min). Running speeds were dictated in form of audio-cues broadcasted by a pre-programmed computer (Balise Temporelle, Bauman, Switzerland). Immediately after each running stage, earlobe capillary blood-samples were obtained for the determination of lactate concentrations $[La]_b$ (Lactate Pro LT-1710^{TM}, ArkRay Inc Ltd, Tokyo, Japan) from hyperaemic earlobe. Individual data points for the exercise blood lactate values were plotted as a continuous function against time. The exercise lactate curve was fitted with a second degree polynomic function (Gorostiaga et al., 2009). From the equation describing the exercise blood lactate curve, the velocity associated with a blood lactate concentration of 3 $mmol \cdot l^{-1}$ (V_3) was interpolated (Gorostiaga et al., 2009). Three variables were considered for future analysis: blood lactate accumulation at 12 $km \cdot h^{-1}$ (Lac12), blood lactate accumulation at 13 $km \cdot h^{-1}$ (Lac13) and running velocity associated with a $[La]_b$ of 3 $mmol \cdot l^{-1}$ (V_3).

Training contents and schedule

Training sessions were typically organized as *technical/tactical* (TT) and *physical and technical/tactical training* (PT/TT) sessions. During TT sessions, the players performed soccer activities (technical drills, small sided games and/or modified soccer games), while during PT/TT the players undertook 15-20 minutes of physical fitness work such as strength training (horizontally and vertically oriented exercises), aerobic fitness (continuous running and interval training) or injury prevention exercises before soccer activities. During pre-season, 2-3 TT sessions and 3-4 PT/TT sessions per week were planned, while during in-season the TT sessions and PT/TT sessions were 3 and 1-2 per week, respectively.

Training load quantification

Practice and competition internal load data collection started at the beginning of the pre-season after T1 (i.e., 13th of July), and finished with the last official match before T2 (i.e., 15th of September). In order to quantify TL the sRPE-TL method (Foster et al., 2001) was used. Ten-min after each training and friendly or official match (Arcos et al., 2014; Ngo et al., 2012) and using Foster's 0-10 scale (Foster et al., 2001) soccer players were asked by the same person (i.e., fitness coach) on all occasions to rate their perceived level of exertion separately for respiratory and leg musculature effort (Aliverti et al., 2011; Arcos et al., 2014; Borg et al., 2010; Green et al., 2009; Los Arcos et al., 2014; Weston et al., 2014; Yanci et al., 2014): respiratory rate of perceived exertion (RPEres) and muscular rate of perceived exertion (RPEmus). The players were allowed to mark a plus sign (interpreted as 0.5 point) alongside the integer value (Algrøy et al., 2011; Seiler and Kjerland, 2006). All the players were familiarized with this method. Then, all training and match respiratory and muscular RPEs declared during the study were summed independently: sumRPEres (sum of all respiratory efforts) and sumRPEmus (sum of all muscular efforts). Furthermore, the sRPE-TL, in our case respiratory sRPE-TL (sRPEres-TL) and muscular sRPE-TL (sRPEmus-TL), was calculated multiplying RPE value by the duration of the training or match (Foster et al., 2001) and the total sRPE-TL accumulated during the 9-weeks was considered. The duration of a training session was recorded for each player from the start to the end of the session, including recovery periods but excluding stretching exercises. The match duration excluded the warm-up and in-between half-time rest. During a month, the players rated they perceived exertion also 30 min after each training session to compare this value with the rating obtained 10 min after the session (Uchida et al., 2014).

Statistical analyses

Descriptive results are presented as means ± standard deviations (SD). A paired t-test was used to compare the RPE values at 10 and 30 min. Furthermore, the intra-players variability was calculated to know the reproducibility between the RPE magnitude 10 min and 30 min after the training, using the intraclass correlation coefficient (ICC) (Atkinson and Nevill, 1998). A paired t-test was also used to compare team mean sRPEres and sRPEmus, between pre-season and in-season and among the 9 weeks. In order to know the inter-player variation in total volume, sRPEres, sRPEmus, sumRPEres and sumRPEmus during the study the coefficient of variation

Table 1. Team mean training volume, sRPE TL and sumRPE during the study (9 weeks). Data are means (±SD).

Training volume (min)	CV (%)	sRPEres TL (AU)	CV (%)	sRPEmus TL (AU)	CV (%)	sumRPEres	CV (%)	sumRPEmus	CV (%)
4600 (274)	5.5	16613 (2899)	16.2	17086 (2875)	15.7	209 (31)	14.0	214 (33)	14.5

sRPE TL: session-rating of perceived exertion training load; sumRPE: sum of perceived exertions; CV: coefficient of variation; sRPEres TL: respiratory session-rating of perceived exertion training load; sRPEmus TL: muscular session-rating of perceived exertion training load; sumRPEres: sum of all respiratory perceived exertions; sumRPEmus: sum of all muscular perceived exertions.

(CV) (Atkinson and Nevill, 1998) was calculated. To compare the results from T1 to T2 in all physical fitness tests paired t-tests were used. Practical significance was also assessed by calculating the Cohen's d effect size (Cohen, 1988). Effect sizes (ES) between < 0.2, 0.2-0.6, 0.6-1.2, 1.2-2, and 2.0-4.0 were considered as trivial, small, moderate, large and very large, respectively (Hopkins et al., 2009). Probabilities were also calculated to establish whether the true (unknown) differences were lower, similar or higher than the smallest worthwhile difference or change (0.2 x between-subject SD, based on Cohen's effect size principle). Quantitative chances of higher or lower differences were evaluated qualitatively as follows: < 1%, almost certainly not; 1−5%, very unlikely; 5−25%, unlikely; 25−75%, possible; 75−95%, likely; 95−99%, very likely; > 99%, almost certain. If the chance of having higher or lower values than the smallest worthwhile difference were both > 5%, the true difference was assessed as unclear.

Pearson's product-moment correlation coefficients were used to determine the relationships between total activity volume, sRPEres, sRPEmus, sumRPEres, sumRPEmus, and changes in physical fitness performance. The magnitude of correlation (*r* (90% Confidence limits)) between test measures were assessed with the following thresholds: < 0.1, trivial; = 0.1–0.3, small; < 0.3–0.5, moderate; < 0.5–0.7, large; < 0.7–0.9, very large; and < 0.9–1.0, almost perfect (Hopkins et al., 2009). If the 90% confidence limits overlapped positive and negative values, the magnitude was deemed unclear; otherwise, that magnitude was deemed to be the observed magnitude. Data analysis was performed using a modified statistical Excel spreadsheet (Hopkins, 2006).

Results

No substantial differences were found between the sRPE magnitudes declared 10 or 30 min after the training sessions (n = 207) for sRPEres (2.8 ± 1.1 vs 2.8 ± 1.1; p = 0.29; ES = -0.02, 90% confidence limits [-0.05;0.03]; most likely trivial) nor sRPEmus (2.8 ± 1.2 vs 2.8 ± 1.2; p = 0.13; ES = -0.03, 90% confidence limits [-0.06;0.00]; most likely trivial). ICC and TEM were 0.96 (90% confidence limits [0.96-0.97]) and 0.21 (90% confidence limits [0.19;0.23]) for the sRPEres, respectively, while ICC was 0.97 (90% confidence limits [0.96;0.97]) and TEM 0.21 (90% confidence limits [0.20;0.23]) for sRPEmus magnitude.

Team mean total training volume, sRPEres-TL, sRPEmus-TL, sumRPEres and sumRPEmus during the study is presented in Table 1.

Looking into pre-season (5 weeks) and in-season (4 weeks) periods separately, the weekly team mean sRPEres-TL and sRPEmus-TL were greater in the preseason (Figure 1). However, session team mean sRPEres-TL and sRPEmus-TL was similar almost for all weeks (Figure 2).

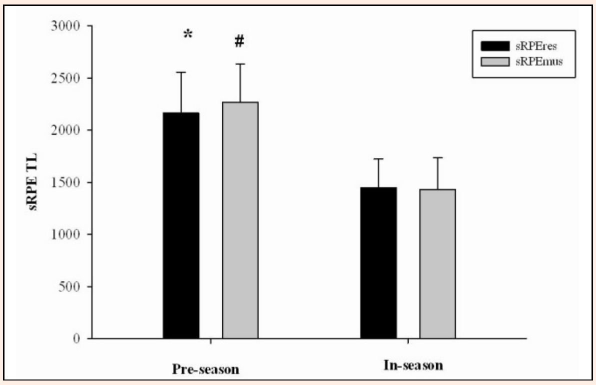

Figure 1. Team mean weekly sRPEres and sRPEmus TL during pre-season (W1-5) and in-season (W6-9). * Significant differences (p < 0.01) in sRPEres-TL between pre-season and in-season; # Significant differences (p < 0.01) in sRPEmus-TL between pre-season and in-season.

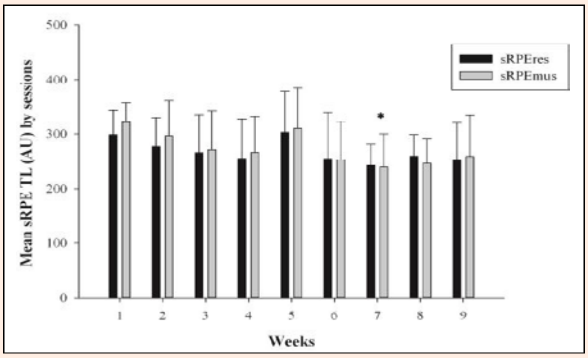

Figure 2. Session team mean sRPEres TL and sRPEmus TL week to week and differences among all weeks. * Significant differences in sRPEmus-TL between W1 and W7, p < 0.05

As displayed in Table 2, substantial improvements were found from Test 1 to Test 2 in sprint times (5 m: ES = -0.85 (0.41), very likely; 15 m: ES = -0.42 (0.28), likely l) and in aerobic fitness (V_3: ES = 0.34 (0.49), possibly Lac12: ES = -0.34 (0.46), possibly; Lac13: ES = -0.35 (0.37), likely).

Table 3 shows the correlations between different methods of quantification of the TL and changes in physical fitness performance.

Large and negative correlations were found between both sRPEmus-TL and sumRPEmus and change in jump performance in CMJD and CMJnD. Figure 3 shows

Table 2. Results, change in mean (%) and difference of the fitness and anthropometrics parameters from Test 1 (T1) to Test 2 (T2). The data are mean (±standard deviation).

	n	T1	T2	Change in mean (%)	*P*	ES	Rating	
Body fat (%)	14	10.9 (.9)	10.5 (.6)**	-3.9 (2.2)	.006	-.55 (.30)	Very likely small ⇓	0/3/97
Body mass (kg)	14	73.5 (7.0)	73.0 (6.7)	-.1 (.1)	.096	-.07 (.07)	Trivial ⇔	0/100/0
CMJ (cm)	14	41.9 (4.3)	42.9 (4.2)	2.6 (2.6)	.110	.23 (.24)	Likely small ⇑	60/40/0
CMJAS (cm)	14	50.1 (4.9)	50.6 (3.7)	1.3 (2.9)	.510	.12 (.30)	Trivial ⇔	31/64/4
CMJD (cm)	13	25.0 (2.8)	25.1 (3.1)	.3 (4.8)	.867	.03 (.35)	Trivial ⇔	21/66/13
CMJnD (cm)	13	25.2 (3.1)	25.7 (3.1)	2.1 (3.0)	.264	.15 (.23)	Trivial ⇔	36/63/1
5 m (s)	13	.97 (.03)	.95±0.02**	-2.3 (1.1)	.003	-.85 (.41)	Very likely moderate ⇑	0/1/99
15 m (s)	13	2.29 (.05)	2.27 (.05)*	-1.0 (.7)	.022	-.42 (.28)	Likely small ⇑	0/10/90
V_3 (km·h^{-1})	14	12.5 (.5)	12.7 (.4)	1.3 (1.8)	.238	.34 (.49)	Possibly small ⇑	69/27/4
Lac12 (mmol·l^{-1})	14	2.5 (.8)	2.2 (.5)	-8.0 (14.1)	.215	-.34 (.46)	Possibly small ⇑	3/27/70
Lac13 (mmol·l^{-1})	14	3.9 (1.1)	3.5 (1.1)	-10.8 (13.1)	.118	-.35 (.37)	Likely small ⇑	1/23/76

ES: effect size; CMJ: countermovement jump; CMJAS: countermovement jump with arm swing; CMJD: dominant leg countermovement jump; CMJnD: non dominant countermovement jump; V_3: running velocity associated with a $[La]_b$ of 3 mmol·l^{-1}; Lac: lactate. ** Significant differences between T1 and T2 at p < 0.01. * Significant differences between T1 and T2 at p < 0.05.

Table 3. Pearson's product-moment coefficients *(90% confidence interval)* for different methods of quantification of the TL correlated to changes in fitness parameters from T1 to T2.

	n	sRPEres TL (AU)	sRPEmus TL (AU)	sumRPEres (AU)	sumRPEmus (AU)	Training Volume (min)
Δ (%) CMJ	14	-.44 (-.77;-.04)	-.20 (-.59;.28)	-.43 (-.75;-.04)	-.17 (-.59;.26)	-.42 (-.75;.11)
Δ (%) CMJAS	14	-.29 (-.69;.26)	-.40 (-.69;.00)	-.25 (-.68;.27)	-.38 (-.68;.02)	**-.51 (-.80;.02)**^{L}
Δ (%) CMJD	13	-.23 (-.61;.25)	**-.54 (-.87;-.13)**^{L}	-.27 (-.64;.19)	**-.61 (-.87;-.24)**^{L}	-.27 (-.67;.24)
Δ (%) CMJnD	13	-.30 (-.66;.10)	**-.52 (-.75;-.17)**^{L}	-.30 (-.66;.10)	**-.53 (-.76;-.21)**^{L}	-.39 (-.72;.02)
Δ (%) 5 m	13	-.37 (-.71;.01)	-.00 (-.45;.44)	-.34 (-.70;.06)	.06 (-.43;.49)	**-.54 (-.82;-.15)**^{L}
Δ (%) 15 m	13	-.49 (-.80;-.26)	-.15 (-.55;.23)	-.38 (-.78;-.09)	-.02 (-.48;.37)	**-.64 (-.83;-.39)**^{L}
Δ (%) V_3	14	-.30 (-.62;.18)	-.45 (-.75;-.02)	-.17 (-.52;.27)	-.33 (-.68;.12)	-.31 (-.70;.23)
Δ (%) Lac12	14	.01 (-.66;.53)	-.29 (-.73;.18)	.13 (-.56;.61)	-.20 (-.67;.27)	-.21 (-.67;.29)
Δ (%) Lac13	14	-.36 (-.70;.10)	**-.57 (-.87;-.09)**^{L}	-.28 (-.61;.16)	-.48 (-.79;.02)	-.37 (-.74;.07)

TL: training load; T1: test 1; T2 =test 2; sRPEres TL: respiratory session-rating of perceived exertion; sRPEmus TL: muscular session-rating of perceived exertion; sumRPEres: sum of all respiratory perceived efforts; sumRPEmus: sum of all muscular perceived efforts; CMJ: countermovement jump; CMJAS =arm swing countermovement jump; CMJD: dominant leg countermovement jump; CMJnD: non dominant countermovement jump; V_3: running velocity associated with a [La]b of 3 mmol·l^{-1}; La: lactate.

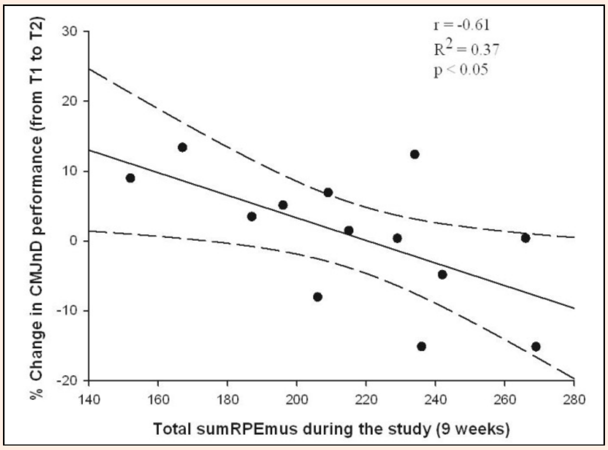

Figure 3. The relationship between sumRPEmus TL and percentage change in CMJnD from Test 1 (T1) to Test 2 (T2) (n = 13).

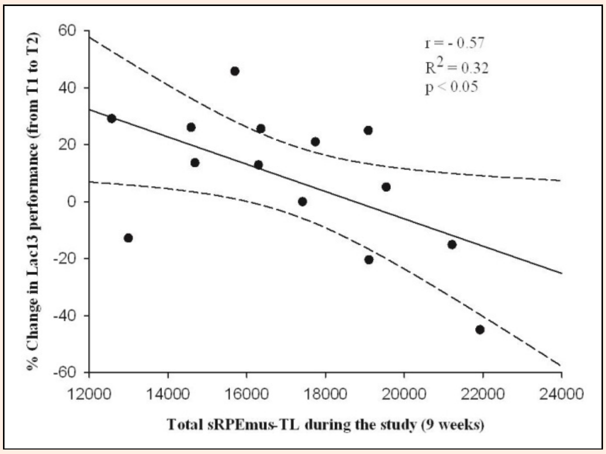

Figure 4. The relationship between sRPEmus TL and percentage change in lactate concentration at 13 km·h^{-1} (Lac13) from Test 1 (T1) to Test 2 (T2) (n = 14).

the correlation between sumRPEmus and changes in jump performance in CMJnD. Similarly, large negative correlation was described between sRPEmus-TL and changes in performance at 13 km·h^{-1} (Lac13) (Figure 4) and between activity volume and change in sprint performance (i.e., 5 m and 15 m) and CMJAS jump.

Discussion

The purpose of this study was to examine the usefulness of the perceived exertion-derived TL for monitoring changes in several aerobic fitness and neuromuscular parameters during 9 weeks of soccer training in young professional players. The main finding of the present study was that the accumulated perceived (leg) muscular exertion, and the associated training load, and the accumulated training volume were negatively correlated with the changes in most physical fitness attributes after 9 weeks of training. That is, higher training volume and feelings of strain in the leg muscles were typically associated with impairments in physical fitness performance.

Looking into both periods (i.e., pre-season and in-season) separately, the mean weekly sRPEres-TL and sRPEmus-TL were substantially higher for the first one: the mean sRPE-TL was 2164 ± 395 vs. 1449 ± 274 for sRPEres while 2270 ± 365 vs. 1434 ± 300 AU for sRPEmus (Figure 1). These differences between pre-season and in-season weekly TL are in agreement with those reported in previous studies (Algrøy et al., 2011; Impellizzeri et al., 2006; Jeong et al., 2011) where overall sRPE-TL was used. Despite these differences in mean weekly TL, average session (daily) TL were very similar between all weeks (Figure 2). Therefore, the greater weekly mean sRPEres-TL and sRPEmus-TL during pre-season can be attributed to the higher frequency of training sessions and matches (i.e., 5-8 trainings and 1-2 friendly matches a week).

Several studies have previously investigated the association between HR-based TL and changes in different aerobic fitness parameters in soccer players (Akubat et al., 2012; Castagna et al., 2011, 2013; Manzi et al., 2013). All those aforementioned studies found linear dose-response relationships. That is, the more training accumulated at higher intensities the greater the improvements in aerobic fitness. For example, Castagna et al. (2011) reported very large to large associations between the training time spend at high intensity (i.e., > HR at 4 $mmol.L^{-1}$ lactate threshold) and the changes in speed at 2 ($r = 0.84$, $p = 0.001$) and 4 $mmol.L^{-1}$ ($r = 0.65$, $p = 0.001$) of blood lactate after 6 weeks of pre-season training in elite soccer players. Similarly, the same authors (Castagna et al., 2013) found that training spent at high intensity (i.e., > HR at 4 $mmol.L^{-1}$ lactate threshold) positively related to changes in speed at 2 ($r = 0.78$, $p = 0.002$) and 4 $mmol.L^{-1}$ ($r = 0.60$, $p = 0.03$) of blood lactate, maximal oxygen uptake ($r = 0.65$; $p = 0.02$) and Yo-Yo IR1 ($r = 0.66$; $p = 0.01$) after 8 weeks of pre-season training in elite-standard male soccer players. Despite the large to very large positive associations previously reported between HR- and RPE-based TL in soccer training (Alexiou and Coutts, 2008; Casamichana et al., 2013; Impellizzeri et al., 2004; Scott et al., 2013), only negative, most of them unclear, associations were obtained between most of the RPE-derived TL indicators and observed changes in aerobic fitness (Table III). Somehow surprisingly, the only substantial association was a large negative correlation between the muscular RPE-derived TL and ΔLac13 (Table III). That is, the higher the perceived TL the smaller the improvement in Lac13. Previous studies reported no significant associations between RPE-based TL and training-induced changes in markers of aerobic fitness in youth soccer players (Akubat et al., 2012; Brink et al., 2010) and rugby players (Coutts et al., 2003; Gabbett and Domrow, 2007). Possible reasons for the different findings are the alternative RPE scales and population investigated in each study. For example, all previous studies (Akubat et al., 2012; Brink et al., 2010; Coutts et al., 2003; Gabbett and Domrow, 2007) employed the global Borg RPE scale, while the present study used the differentiated muscular and respiratory RPE (Arcos et al., 2014). In addition, the current study dealt with professional players, while previous studies focused on young and/or sub-elite populations.

While a large negative association between sRPEmus-TL and changes in Lac13 was reported, the magnitude of this association ($r = -0.57$) indicates that only ~ 33% of the variance in Lac13 changes can be explained by the sRPEmus-TL. While such magnitude can be certainly relevant in a practical, “real-life” setting, it also suggests the presence of substantial individual responses. This might prevent practitioners to use this measure as a definitive monitoring tool with all the players. Nevertheless, taken together, present and previous results seem to suggest that, unlike HR-derived TL methods, RPE accumulated TL does not appear to fit positive, dose-response relationships with aerobic fitness in soccer players.

A new finding of the present study was the negative correlation between the changes in neuromuscular fitness parameters (i.e., jumping and sprinting) and accumulated TL and training time (Table III). Specifically, single leg CMJ displayed large ($r = -0.52$ to -0.61) correlations with sRPEmus and sRPEmus-TL, while total accumulated training time showed a large negative correlation with both bilateral jumping (CMJAS: $r = -0.51$) and sprinting (5 m: $r = -0.54$; 15 m: $r = -0.64$). That is, the players who perceived the prescribed training load as harder were more likely not to improve single leg CMJ performance as much at the players with lower perceived load. Similarly, players that accumulated higher training volume were most likely to show an impaired sprinting performance from T1 to T2. To the authors’ knowledge, no previous studies have examined the relationship between TL and neuromuscular fitness parameters in soccer. However, Gabbett and Domrow (2007) reported that increases in RPE-derived training load during the early-competition training phase decrease agility performance in sub-elite rugby players.

Conclusion

Present results suggest that a high perception of leg muscular effort associated with training and matches, as well as an excessive accumulation of training volume (time), can impair several physical fitness factors believed to be relevant for on-field soccer performance. Therefore, the independent assessment of muscular effort to quantify TL can be an interesting additional monitoring measure in soccer training. The fact that the magnitude of most correlations, despite being meaningful, was less that 0.70 (indicating less than 50% of shared variance between the two variables) appears to indicate the presence of substantial individual (between-player) responses in the reported associations. This warrants caution when using leg perceived exertion and/or training volume as sole indicators of load tolerance in soccer players. Moreover, taken together, present and previous results seem to suggest that, unlike HR-derived TL methods, RPE accumulated TL does not appear to fit positive, dose-response relationships with aerobic fitness in soccer players. Thus, despite that several cross-sectional have validated the use of the sessions RPE as a proxy of HR-derived physiological stress arising from soccer practice, the present longitudinal data indicate that RPE- or HR-derived measures of exercise intensity/load in soccer training could not be used interchangeably.

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Key points

- The purpose of this study was to examine the usefulness of the perceived exertion-derived TL for monitoring changes in several aerobic fitness and neuromuscular parameters during 9 weeks of soccer training in young professional players.
- A high perception of leg muscular effort associated with training and matches, as well as an excessive accumulation of training volume (time), can impair several physical fitness factors believed to be relevant for on-field soccer performance.
- The independent assessment of muscular effort to quantify TL can be an interesting additional monitoring measure in soccer training.

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