A New Tool to Measure Training Load in Soccer Training and Match Play

Article *in* International Journal of Sports Medicine · January 2012

DOI: 10.1055/s-0031-1297952 · Source: PubMed

6 authors, including:

António Rebelo
University of Porto
81 PUBLICATIONS **1,448** CITATIONS

André Seabra
University of Porto
256 PUBLICATIONS **1,716** CITATIONS

José Oliveira
University of Porto
218 PUBLICATIONS **2,702** CITATIONS

Peter Krustrup
University of Southern Denmark
297 PUBLICATIONS **14,168** CITATIONS

A New Tool to Measure Training Load in Soccer Training and Match Play

Authors A. Rebelo[1], J. Brito[1], A. Seabra[1], J. Oliveira[2], B. Drust[3], P. Krustrup[4,5]

Affiliations Affiliation addresses are listed at the end of the article

Key words
- VAS scores
- RPE
- TRIMP
- Yo-Yo IE2
- Yo-Yo IR1
- time-motion analyses

Abstract

An accurate evaluation of training load is paramount for the planning and periodization of training. The aim of the present study was to evaluate the relationship between a new method to monitor training load in soccer (Visual Analogic Scale training load; VAS-TL), and two established heart rate-based methods (TRIMP and Edwards' method). 51 soccer players (age 15.6 ± 0.3 years) answered 2 questions to assess perceived exertion and fatigue (VAS1-TL, and VAS2-TL) after training sessions and official matches. Performance in the Yo-Yo tests, VAS scores and heart rate of training sessions and matches, and match activity were analysed. We found significant correlations ($r = 0.60–0.72$; $p < 0.05$) between VAS-TL, TRIMP, and the Edwards' training load method, with the highest correlations achieved in the matches. Although the different methods to monitor training load were correlated with the distance covered during the match ($r = 0.53–0.78$; $p < 0.05$), only VAS1-TL was associated with high-intensity activities ($r = 0.43–0.54$; $p < 0.05$). The new VAS-based perceived exertion method to monitor training load is easy to apply and is sensitive to differences in positional role and physical capacity. Thus, the applied method may be used in addition to the usual training load methods, allowing for daily quantification of individual training load in soccer.

accepted after revision
November 07, 2011

Bibliography
DOI http://dx.doi.org/10.1055/s-0031-1297952
Published online: January 1, 2012
Int J Sports Med 2012; 33: 297–304 © Georg Thieme Verlag KG Stuttgart · New York
ISSN 0172-4622

Correspondence
Dr. Antonio Rebelo
Faculty of Sport – University of Porto
Centre of Research Education
Innovation and Intervention in Sport
R. Dr. Placido Costa 91
4200-450 Porto
Portugal
Tel.: +351/22/5074 771
Fax: +351/22/5500 689
anatal@fade.up.pt

Introduction

The monitoring of training load is a key factor for the control of the training process in sport. An accurate evaluation of training load is paramount for the planning and periodization of training, especially in the prevention of undertraining or overtraining and ensuring that athletes are in an optimal condition for competition [24]. This is particularly difficult to achieve in team sports, since many specific conditioning drills vary considerably in the number of players involved, and the specific tactical roles performed by players. Indeed, different exercise designs and the diversity of tactical roles among players will lead to different physiological demands as well as to inter-individual variations in the imposed training load [6].

Banister [4] and Edwards [14] proposed two heart rate-based methods for training load monitoring. The rationale of heart rate based methods to quantify the training load is the observation that heart rate presents an almost linear relationship with oxygen consumption (VO_2), both at steady-state submaximal exercise intensities [3] and during soccer-specific intermittent exercise [12]. However, heart rate based-methods for quantifying training load are not accurate in the differentiation of high intensity (and/or short duration) exercise above maximal VO_2 (VO_{2max}), like in several interval-training methods, or in training modes such as resistance or plyometric training. Additionally, these methods require the use of heart rate monitors during soccer training, which is not easily feasible since a large number of devices are required, and not all the players feel comfortable in wearing the device during soccer practice. Moreover, heart rate transmitters are not permitted during official competitive matches, which is also a limitation, because the match represents a high percentage of the total week loading [1,20]. Finally, the calculations when using heart rate for training load requires technical expertise and is a time consuming process.

Beyond heart rate-based methods, rate of perceived exertion (RPE) could be another option for training load monitoring, because it is a simple, versatile and cheap method, and correlates with heart rate, blood lactate concentrations and

VO_2[11]. Furthermore, compared to heart rate-based methods, RPE gives a more holistic indication of the global internal load, because it is indicative of both psychological and physiological stress [28]. That said, Foster and colleagues [18] proposed a method to quantify internal training load (session-RPE) based on a category ratio scale (CR10-scale; [8]). These authors multiplied the whole training session-RPE score by the duration of the training session. However, it was emphasized that session-RPE is not a valid substitute of heart rate methods, since only about 50% of variance in heart rate was explained by the session-RPE score [20]. Therefore, to assess and monitor the acute individual's training load response, a simple system is needed.

Visual analogue scale (VAS) questionnaires have been considered an alternative tool to monitor exercise exertion. Visual analogue scales are presented in a graphic scale, and provide a continuous outcome variable [21], which allows the use of parametric statistics for research purposes. Moreover, a strong correlation ($r=0.99$; $p<0.05$) was found between VAS and the CR10 Borg's scale in arm-cranking exercise [9], and VAS has been used both in recreational exercisers [7,22] and elite soccer players [2]. Therefore, this systematic assessment of the internal load could be useful to guide the training process [25]. For this purpose, VAS questionnaires could be a simple method to routinely collect indirect qualitative-quantitative data for training load monitoring. VAS has shown good reproducibility and sensitivity for subjective ratings of perceived exertion during steady-state exercise [22]. However, the validity of VAS questionnaires as a training load monitoring tool has not been investigated. Moreover, the relationship between VAS scores and heart rate-based methods of training load quantification across the different weekly training sessions, as well as during official matches, has not been assessed in soccer players. Therefore, the purpose of this study was to evaluate the convergent validity of a new method of training load monitoring based on VAS scores, and two standard heart rate-based methods during soccer practice and competition.

Materials and Methods

Design

We collected the data for this study during a 4-week period in the middle of a 9-month competitive season. The first two weeks of the study comprised anthropometric measurements, and laboratory and field tests. In order to determine the maximal heart rate and the physical capacity of the players, they performed an incremental laboratory VO_{2max} treadmill test and two field tests: the Yo-Yo intermittent endurance test – level 2 (Yo-Yo IE2), and the Yo-Yo intermittent recovery test – level 1 (Yo-Yo IR1). The laboratory and field tests were conducted in a random order, and were completed within a 2-week period without competitive games. The following 2-week period was devoted to training and match assessments. We monitored heart rate and RPE in each of the 3-weekly training sessions and in 2 official home matches, played two weeks apart. We performed time-motion analysis for the 10 outfield players of each of the three analysed teams. We used the relationships between the VAS training load (VAS-TL) and the commonly used heart rate based training load quantification methods to examine the usefulness of the VAS-TL as a method of assessing training load. We collected VAS and heart rate data for 495 individual training sessions and 64 individual matches. We used for each player, a minimum of 6 training sessions for collecting VAS and heart rate data. We totalled the training loads for each day of the week to provide a weekly training load.

Participants

We analysed 51 regional level youth soccer players from 3 teams competing in the first division of the Portuguese soccer league. Their age, height, weight, and percentage of body fat were (mean±SEM) 15.6±0.3 years, 168.7±1.5 cm, 61.5±2.2 kg, and 14.9±0.8%, respectively. We classified players according to their field position: fullbacks (n=13), central defenders (n=10), midfielders (n=14) and forwards (n=14). Goalkeepers were excluded from the analysis. We interviewed all players in order to provide information concerning the number of years of soccer practice and hours of regular training per week. Players had been regularly involved in soccer for 4.0±0.6 years. The study was conducted in accordance with recognised ethical standards [19], and was approved by the Scientific Committee of the Faculty of Sport of the University of Porto and by the club officials. Players and their parents provided informed consent.

Laboratory tests

The laboratory treadmill test started with a warm-up at 6 and 8 $km \cdot h^{-1}$ in 2.5-min stages, followed by a 2-min rest period and an incremental maximal test. The maximal test began at a speed of 10 $km \cdot h^{-1}$ for 60 s, with a stepwise increase in speed of 1 $km \cdot h^{-1}$ every 60 s until exhaustion. Time to exhaustion, as well as speed at exhaustion, were noted. After the maximal test, subjects ran at 5 $km \cdot h^{-1}$ for 5 min. We recorded heart rate at 5-s intervals throughout the entire protocol using a Polar Vantage NV heart rate monitor (Polar Electro Oy, Kempele, Finland). We measured pulmonary oxygen uptake during all tests using a portable breath-by-breath gas analysis system ($K4b^2$, Cosmed, Rome, Italy). The validity, reliability, and accuracy of the $K4b^2$ portable gas analyser have been reported elsewhere [13,26]. Before each testing session, we calibrated the $K4b^2$ according to the manufacturer's guidelines. Three criteria were considered for VO_{2max} determination: a) plateau in VO_2 (an increase less than 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$ despite an increase in running speed); b) respiratory exchange ratio (RER) greater than 1.10; or (c) heart rate ±5% of age predicted maximal heart rate. We considered individual values of maximum heart rate (HR_{max}) as the peak values reached in 5-s periods.

Field tests

All the 51 players that participated in the study performed the Yo-Yo IE2 and Yo-Yo IR1. After a 10-min warm-up consisting of the first four running bouts of the tests, the players carried out 2×20 m runs back and forth between the start and finish line at a progressively increased speed controlled by audio bleeps from a CD player, according to Bangsbo [5]. After each 2×20 m running bout, the players had a 5-s (Yo-Yo IE2, 2×2.5 m) or 10-s (Yo-Yo IR1, 2×5 m) active recovery periods. We considered the tests ended when the subjects failed twice to reach the starting line (objective evaluation) or the participant felt unable to complete another shuttle at dictated speed (subjective evaluation). We considered the total distance covered during the Yo-Yo IE2 and Yo-Yo IR1 as the testing score. We recorded heart rate in 5-s intervals by short-range radio telemetry (Team System, Polar Electro OY, Kempele, Finland). We administered the Yo-Yo tests outdoors on artificial turf.

Training schedule

We obtained the content of individual training sessions from the coaches. A description and duration of the content of a typical weekly schedule is shown in **Table 1**. Each player completed three training sessions (234±3 min) and one competitive match (80 min) per week during the period of training load monitoring.

The intermittent high-intensity running usually involved 4–5 repetitions of 60-s runs at 80–90 %HR_{max} with 60-s rest periods. The official matches lasted 80 min, and were played according to the rules of the Fédération Internationale de Football Association (FIFA).

Determination of internal training load

We determined the internal training load for each player during each training session and match by three different methods: VAS-TL method, and two heart rate-based methods: Edward's TL and TRIMP.

VAS-TL

All players had been familiarized with VAS questionnaires for rating perceived exertion before the commencement of the study. Each player's VAS-TL was collected about 30 min after each training session or match, to ensure that the perceived effort referred to the whole session rather than the most recent exercise intensity [20].

The VAS consisted of a 100-mm horizontal line. The questionnaire included two questions. The words "no effort at all" or "not demanding at all" were placed at the left end of the scale, and "maximal effort" or "maximally demanding" were placed at the right end of the scale, for questions 1 and 2, respectively (**Fig. 1**). The VAS was scored from 0 to 10, but the subjects were unaware of the numbers. To design which questions to use, the players were asked questions about their training load in training sessions and matches. Based on their comments, the questions used in the study were worded to address the aim of the study. We designed the questions to evaluate the perceived exertion during the training sessions or match. The questions were: "How do you classify the effort made during the training session (or match) today?" (VAS1) "How physically demanding did you perceive the training session (or match) today?" (VAS2). VAS-TL is an RPE-based method proposed in this study, and was calculated by multiplying the scores obtained in the VAS questionnaire in one training session or match by its duration in min.

Table 1 Contents of the training sessions of a typical weekly program. Values represent the average time (min) spent in each type of training.

	T1	T2	T3	Match
jogging	10	10	5	5
stretching	7	7	7	3
skipping and short sprints	3	3	3	2
intermittent high intensity running	–	10	–	–
technical drills	25	20	25	5
small-sided games	25	20	15	–
11*v*11 game	–	20	–	80
set pieces[a]	–	–	15	–
total	70	90	70	95

[T1] training session 1, [T2] training session 2; [T3] training session 3; [a] free kicks, and corners

Heart rate based methods to determine training load

We used two heart rate-based methods for quantifying training load as the criteria of internal training load: the Edwards' training load method [14], and the TRIMP method [4].

The heart rate-based method proposed by Edwards [14] to determine internal training load involved integrating the total volume of the training session with the total intensity of the exercise session, relative to five intensity phases. An exercise score for each training bout was calculated by multiplying the accumulated duration in each heart rate zone by a multiplier allocated to each zone (50–60 % $HR_{max}=1$, 60–70 % $HR_{max}=2$, 70–80 % $HR_{max}=3$, 80–90 % $HR_{max}=4$, and 90–100 % $HR_{max}=5$), and then adding up the results.

The TRIMP method proposed by Banister [4] assumes that each exercise bout elicits a training impulse. The TRIMP was determined using the following formula:

$$TRIMP = D \cdot (\Delta HR_{ratio}) \cdot e^{b \cdot (\Delta HR_{ratio})}$$

where D = duration of training session; and b = 1.92

$$\Delta HR_{ratio} = (HR_{ex} - HR_{rest}) - (HR_{max} - HR_{rest})$$

where HR_{rest} = the average heart rate during rest; and HR_{ex} = the average heart rate during exercise.

To reduce heart rate recording errors, we asked the players to check their heart rate monitors before each session, and before and at the half-time break of the match. Following each training session and match, we downloaded heart rate to a computer using Polar Software. We measured the players' resting heart rate during 5 min of seated rest in three different mornings during the study period after an overnight fast. We considered the individual HR_{max} as the highest value reached during either an incremental treadmill test, the Yo-Yo IE2, the Yo-Yo IR1, or during training.

Match time-motion analysis

We filmed and analysed each player in two consecutive matches separated by 15 days. In order to avoid interferences of pitch dimensions, we restricted all the videotaped games to home-matches, and both were filmed by the same group of researchers.

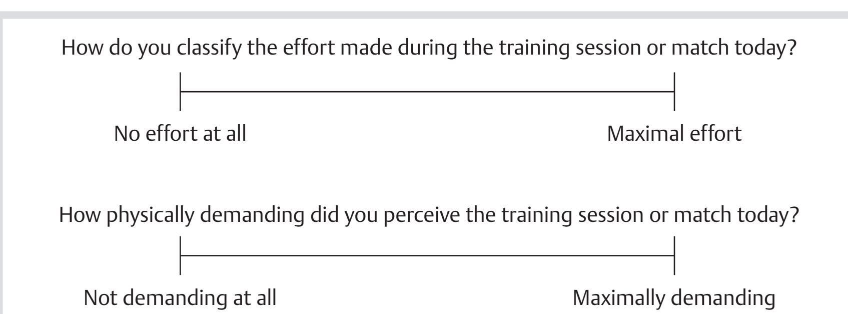

Fig. 1 VAS questionnaire, presenting the two questions proposed in the present study to evaluate training load.

We performed time-motion analysis according to the procedures defined elsewhere [10,27]. We filmed a close up of each player during the entire match using digital video cameras (DCR-HC53E, Sony, JAPAN) positioned at the side of the field, at a height of about 15 m and at a distance of 30–40 m from the touchline. We later replayed the videotapes on a monitor for computerizing coding of the activity pattern. We determined match activities as previously reported [10]: standing (ST, speed from 0–0.4 $km \cdot h^{-1}$); walking (W, 0.4–3.0 $km \cdot h^{-1}$); jogging (J, 3.0–8.0 $km \cdot h^{-1}$); medium-intensity running (MIR, 8.0–13.0 $km \cdot h^{-1}$); high-intensity running (HIR, 13.0–18.0 $km \cdot h^{-1}$); sprinting (SPR, >18.0 $km \cdot h^{-1}$); high-intensity activity (HIA; HIR + SPR).
We recorded the frequency and duration of each activity throughout the game. We determined the distance covered for each locomotor activity as the product of the total time and mean speed for that activity. These categories and the corresponding mean speeds were determined after detailed analysis of the videotapes using glass pre-markers previously established as reference [27]. We calculated the total distance covered during a match as the sum of the distances covered during each type of activity. An experienced observer analysed all the match recordings.

Measurement variability

We estimated reliability statistical analyses of all variables using a test-retest procedure with a random sub-sample of 10 subjects. The intraclass correlation coefficients (ICC) of field (distance covered in Yo-Yo tests) and laboratory (VO_{2max}) measurements ranged between $0.80 \leq ICC \leq 0.97$, and $0.75 \leq ICC \leq 0.82$, respectively.
Reproducibility of the results obtained by the time–motion analysis was determined in a pilot study, in which five matches were analysed twice by the same observer. The two analyses were separated by one month. No differences were observed in the test-retest analysis, and the intra-individual differences in total distance covered were less than 0.3 km (coefficient of variation = 1 %). We observed that the coefficient of variation for test-retest analysis was 2 % for walking, jogging and low-intensity running, 5 % for medium-intensity running, 3 % for high-intensity running, and 7 % for sprinting and backwards running. In addition, we used Kappa of Cohen coefficient to check the reliability of the time-motion variables. The results showed a good inter-observer agreement coefficient for movement type, standing ($\kappa = 0.87$), walking ($\kappa = 0.86$), jogging ($\kappa = 0.91$), medium-intensity running ($\kappa = 0.90$), high-intensity running ($\kappa = 0.89$), sprinting ($\kappa = 0.90$), and high-intensity activity ($\kappa = 0.83$). Intra-observer agreement coefficients ranged between 0.90 and 0.94.

Statistical analysis

A statistical power analysis was performed prior to the start of the study, to ensure adequate statistical power with the correlation analysis, and with comparisons between training sessions and matches on each dependent variable. Results reported by Impellizzeri et al. [20] were used to guide the determination of the required sample size for the correlation analysis. In this case, for a significance level of 0.05, the sample size required for a statistical power of 0.95 was 21 subjects. Regarding the comparisons between training sessions and matches on each dependent variable, for a significance level of 0.05 and a medium-expected effect size (>0.25), the sample size required for a statistical power of 0.95 was 36 subjects. Statistical power analysis was carried out using G*Power version 3.1.2 for Mac [16].

Results are presented as means ± standard errors of mean (SEM). To estimate the reliability of the variables analysed coefficients of variation and intraclass correlation coefficients were calculated. Differences between training sessions and matches on each dependent variable, including heart rate values, VAS-TL, TRIMP and Edwards's training load (Edwards' TL), were analysed using a one-way ANOVA for repeated measures, followed by Bonferroni's post hoc test. The relationships between VAS-TL scores and the 2 heart rate-based methods of training load measurement were assessed using Pearson's product moment correlation and multiple regression models. Statistical significance was set at $p < 0.05$ and SPSS Statistics version 19 was used for all inferential analyses.

Results

Training load in training sessions and official matches

Training load calculated with VAS-TL, TRIMP and Edwards' TL methods varied significantly ($p < 0.05$) between training sessions and matches, with exception of the TRIMP of the second training of the week (▸ **Table 2**). The second training (T2) presented the highest training load of the three training sessions of the week, while the matches showed the peak training load. Significant moderate and large correlations were found between VAS-TL, and TRIMP and Edwards' TL in the first ($r = 0.33$–0.56; $p < 0.001$) and second ($r = 0.56$–0.61; $p < 0.05$) training sessions of the week, with large and very large correlations reached in the match ($r = 0.60$–0.72; $p < 0.05$; ▸ **Fig. 2**).

Correlations between training load and match time-motion variables

The distance covered in the match showed large correlations with match VAS1-TL, VAS2-TL, and Edwards' TL ($r = 0.53$, $p = 0.034$; $r = 0.68$, $p = 0.004$; $r = 0.67$, $p = 0.005$; respectively) and a very large correlation with TRIMP ($r = 0.78$; $p < 0.001$), but only VAS-TL correlated with high-intensity activities. HIA during the match showed large correlation with VAS1-TL ($r = 0.54$; $p = 0.010$; ▸ **Fig. 3a**) and moderate correlation with VAS2-TL ($r = 0.43$; $p = 0.044$, respectively), while the percentage of total time spent in sprint activities presented moderate correlation with VAS1-TL ($r = 0.44$; $p = 0.043$; ▸ **Fig. 3b**).

Influence of field position in training load

The absolute and relative values of heart rate during training sessions and matches are presented in ▸ **Table 3**. With exception of central defenders, mean heart rate values during the match were higher than in training sessions ($p < 0.05$). No differences between positions were found in heart rate during training sessions and match.
Players from all field positions showed higher values of training load in the match than in training sessions, when training load was calculated with VAS-TL and Edwards' TL methods, but not with TRIMP (▸ **Fig. 4**). However, given the low number of subjects of the analysis by field position, it was not possible to confirm statistically these differences. VAS1-TL in the week was higher in central defenders than in fullbacks ($p = 0.038$). As depicted in ▸ **Fig. 4c**, although not statistically different, the players who presented the highest VAS1-TL values in the week (central defenders and midfielders), showed the lowest VAS1-TL values in the match.

Table 2 Training load in all training sessions, total week and match, presented in arbitrary units. Values are mean ± SEM. Values within brackets show % of the weekly TL.

	TL-T1	TL-T2	TL-T3	TL-Week	TL-Match
VAS1-TL*	955 ± 83 (31)	1499 ± 106 (48)	656 ± 70 (21)	3103 ± 172	2127 ± 143
VAS2-TL*	764 ± 73 (29)	1315 ± 101 (49)	582 ± 55 (22)	2661 ± 151	2177 ± 115
TRIMP**	23.6 ± 0.4 (29)	30.8 ± 0.6 (39)	25.5 ± 0.9 (32)	79.8 ± 1.3	31.5 ± 1.0
Edward's TL*	189.2 ± 6.3 (30)	241.2 ± 8.0 (39)	196.6 ± 9.6 (31)	627.1 ± 18.8	339.9 ± 9.0

[TL] training load; [T1] 1st training session; [T2] 2nd training session; [T3] 3rd training session

*Significant differences between training sessions and match ($p<0.05$)

**Significant differences between training sessions and match ($p<0.05$), with exception to T2 *vs.* Match

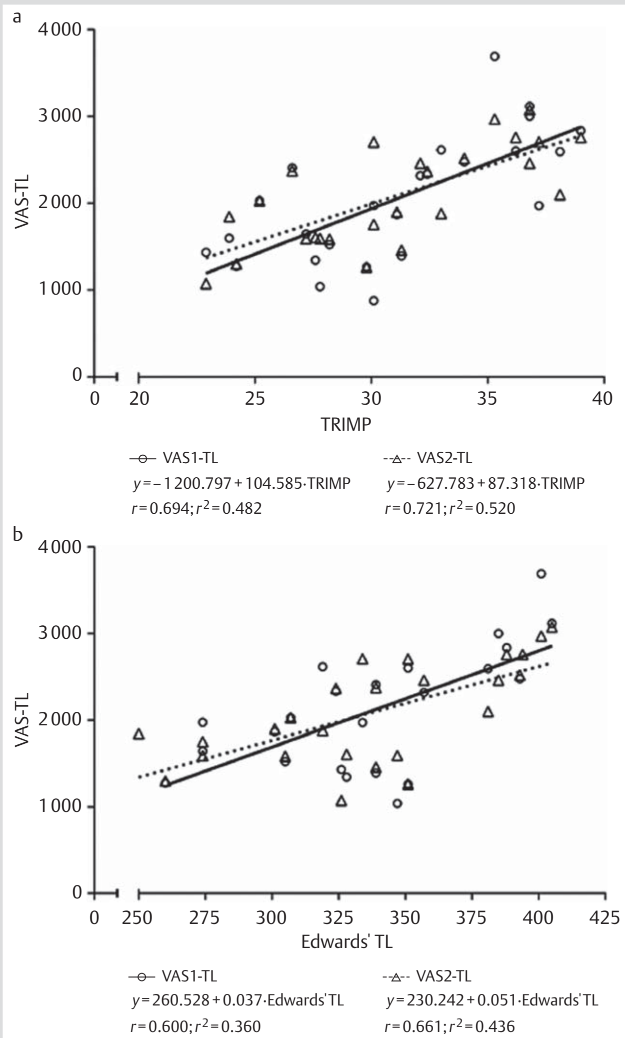

Fig. 2 Correlations between VAS-TL and TRIMP **a**, and between VAS-TL and Edwards' TL **b**, during the match.

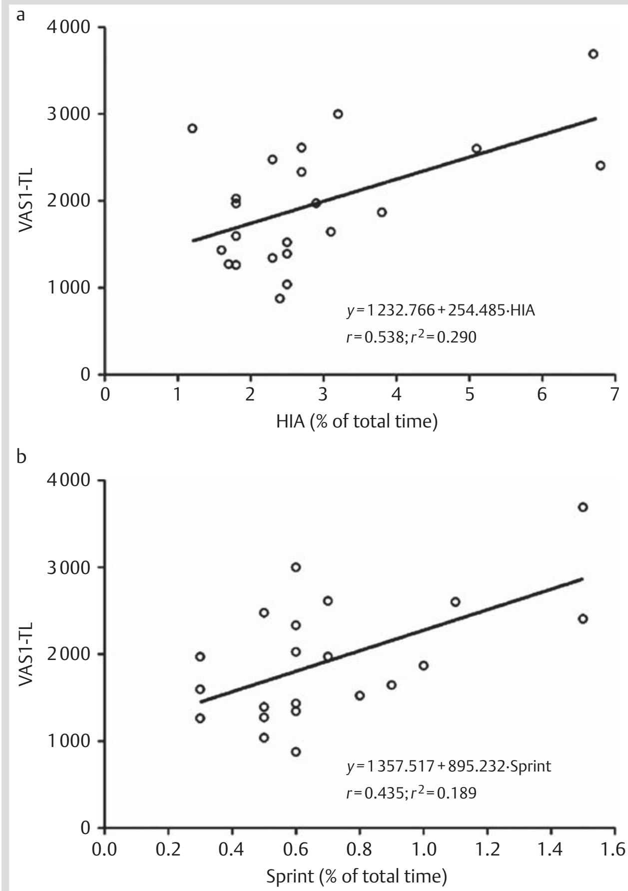

Fig. 3 Correlations between VAS1-TL and HIA **a**, and the percentage of total time spent with sprinting **b**, during the match.

Influence of endurance capacity in VAS-TL

Distance covered in the Yo-Yo tests and VO_{2max} of the players are presented in ▶ **Table 4**. Midfield players presented higher values in the Yo-Yo IE2 than central defenders and forwards ($p<0.05$). The mean value of VO_{2max} was 61.8 (range: 45.7–72.3) $ml \cdot kg^{-1} \cdot min^{-1}$. No associations were found between VO_{2max} and VAS-TL. Interestingly, the performance in the Yo-Yo IR1 was inversely correlated with the match VAS2-TL ($r=-0.47$, $p=0.024$).

Discussion

The results of this study showed that VAS-TL could be a surrogate of TRIMP and Edwards' TL methods in quantifying exercise training in soccer, and thus a good tool to monitor internal training load during the season. Training load calculated with VAS-TL, TRIMP and Edwards' TL methods varied significantly between training sessions and matches. Matches showed the highest training load. We found significant correlations between VAS-TL, and TRIMP and Edwards' TL in training, but the higher correlations were reached in the matches. The distance covered in the match correlated with match VAS-TL, TRIMP and Edwards' TL. However, only VAS-TL correlated with high-intensity activities. Moreover, the performance in the Yo-Yo IR1 was inversely correlated with VAS2-TL in the match.

Table 3 Average heart rate values (b.p.m.) during all training sessions, the week, and match. Values are means ± SEM. Values within brackets show the percentage of HR_{max}.

	T1	T2	T3	Week	Match
CD	148 ± 5 (75)	139 ± 4 (71)	143 ± 5 (73)	144 ± 5 (73)	167 ± 5 (85)
FB	147 ± 4 (74)	142 ± 3 (72)	139 ± 4 (70)	143 ± 3 (72)	172 ± 1 (87)*
MF	139 ± 2 (72)	140 ± 3 (73)	131 ± 4 (68)	137 ± 2 (71)	163 ± 4 (83)*
FW	144 ± 2 (74)	140 ± 5 (72)	133 ± 3 (68)	139 ± 2 (71)	174 ± 4 (87)*
total	143 ± 2 (73)	140 ± 2 (72)	136 ± 2 (69)	140 ± 1 (71)	168 ± 2 (85)*

CD central defender; FB fullback; MF midfielder; FW forward

T1 1st training session; T2 2nd training session; T3 3rd training session

*Significantly different from all training sessions and week (p < 0.05)

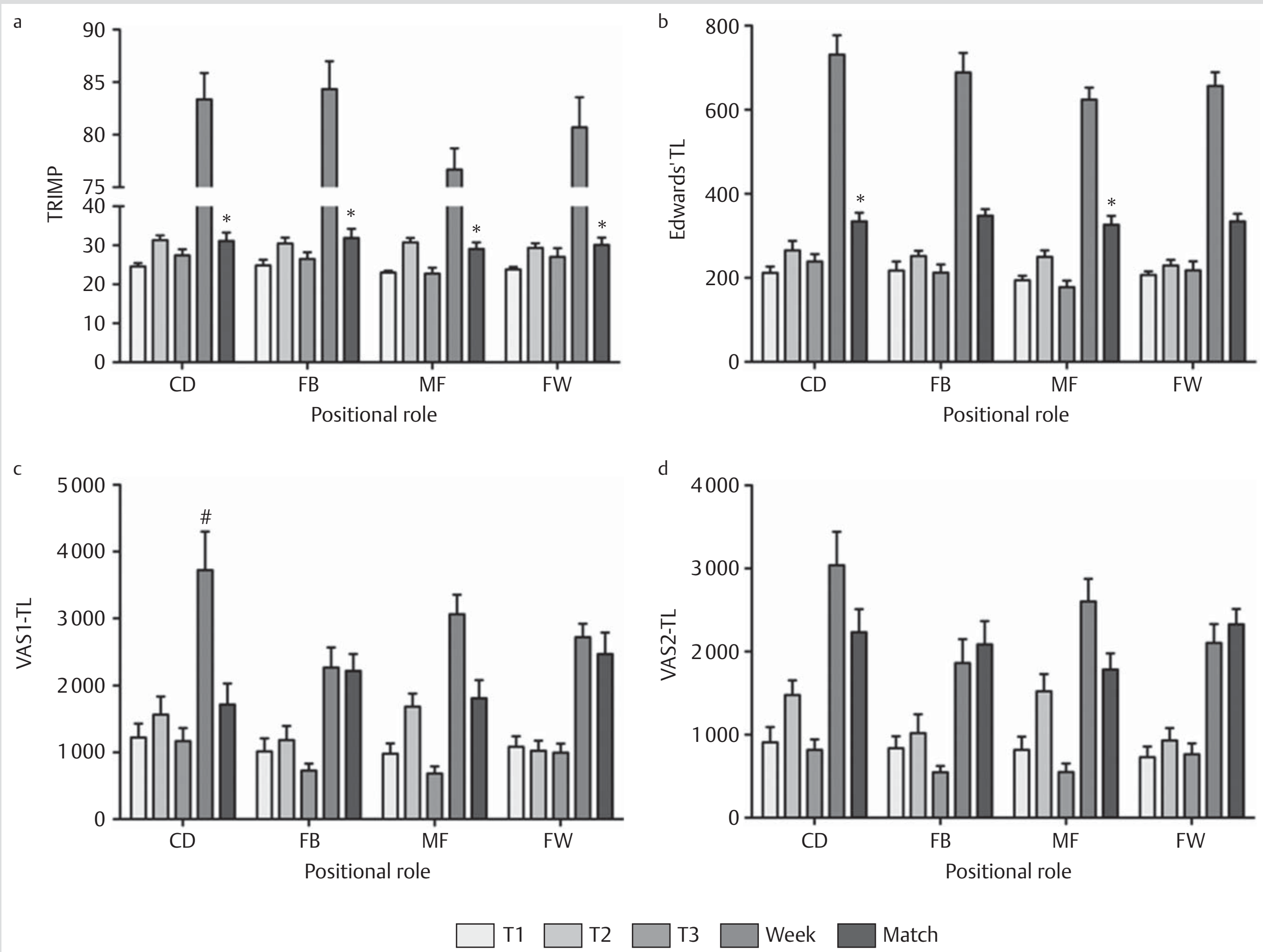

Fig. 4 TRIMP **a**, Edwards' TL **b**, VAS1-TL **c**, and VAS2-TL **d** scores in all training sessions, in the week, and in the match, by positional role (CD: central defender; FB: fullback; MF: midfielder; FW: forward). Values are means ± SEM. *Significantly different from the total week scores (p < 0.05). # Significantly different from FB (p = 0.038).

Table 4 Distance covered (m) in the Yo-Yo IR1 and Yo-Yo IE2 tests, and maximal oxygen consumption (VO_{2max}; ml·kg^{-1}·min^{-1}) of players from different positions. Values are means ± SEM.

	Yo-Yo IR1	Yo-Yo IE2	VO_{2max}
CD	1253 ± 94	980 ± 127	60.3 ± 4.2
FB	1496 ± 106	1131 ± 91	63.0 ± 1.1
MF	1483 ± 119	1444 ± 83*	59.7 ± 3.4
FW	1540 ± 95	1013 ± 86	60.7 ± 1.0

CD central defender; FB fullback; MF midfielder; FW forward

*Significantly different from central defenders and forwards (p < 0.05)

Independent of the method used for the analyses, this study showed that the training load varied between the different training sessions of the week and the match. The second training presented the highest training load of the three weekly training sessions, while match showed the peak training load. These results showed that, when planning the weekly training schedule, coaches tend to include the training sessions with the highest training load in the middle of the week [29]. This strategy might be linked to the need of providing adequate time to recover after the last match and before the next one. A periodization of the training during the week is required in order to avoid training and match-related fatigue, and prevent overreaching and overtraining [23]. Moreover, as previously described for adult male [15] and female players [1], the present study demonstrated that the match training load represents the main training load of the week for youth soccer players. However, it is not possible to state if this is a rational option of the coach, or if it represents the difficulty the coaches have to create training sessions as demanding as competitive matches. Matches are usually accompanied by high levels of psychological stress that could inflate the perceived effort of soccer players after the match, in comparison with training. In fact, perceived exertion has been conceptualized as a psychophysiological phenomenon, since exercise-induced alteration in perception covaries with affective changes [28]. This point needs to be investigated in future studies, since it would be expected that training should mimic the competition's training load.

In the present study, there were significant correlations between VAS-TL, TRIMP and Edwards' TL, in the first and second training sessions of the week, with the higher correlations observed in the match. However, we observed lower correlations between both TRIMP and Edwards' TL methods, and VAS-TL than those reported in previous studies performed with session-RPE in male [20] and female soccer players [1]. As the players analysed in this study were younger than the subjects from the aforementioned studies, it could be suggested that youth players might have underestimated the effort spent in training or matches. In fact, previous studies performed in children concerning age-related preferences in the use of information to form judgements of physical competence showed that, as age increases, greater emphasis is placed on self-referenced information, such as degree of exerted effort [30].

A relationship between TRIMP and Edwards' TL methods was expected, since both methods use heart rate response to exercise for the calculation of training load. Interestingly, as previously observed for session-RPE [20], VAS-TL correlated significantly with TRIMP and Edwards' TL. Thus VAS-TL could be a valid surrogate of heart rate-based methods for training load monitoring in soccer. It might be questioned as to why VAS-TL and the two methods of training load quantification did not show any significant correlation in the third training session of the week. However, the third training session included set pieces (**Table 1**), which might have been felt by players as low-effort and high motivational tasks, which could result in a decrease in the training perceived effort. In opposition, the heart rate based methods would not have been as sensitive as VAS-TL to evaluate the specific characteristics of the third training session. This possibility should not be underestimated, as previous studies referred to the importance of psychological factors in perceived effort and overtraining [28]. Thus, in a quite speculative way, it could be hypothesised that using VAS-TL players could give a more global picture of the training session than with heart rate based training load methods. This could be linked to the fact that the RPE measures the "whole", while heart rate measures only a part of the "whole" [28].

The three methods investigated seem to be valid options to calculate the global training load of the match. However, heart rate-based methods might not be as accurate as VAS-TL when training involves high-intensity activities. In fact, although the distance covered in the match correlated with VAS1-TL, VAS2-TL, TRIMP and Edwards' TL, only the VAS-TL correlated with the percentage of time spent in HIA during the match. Heart rate is not a good indicator of very high-intensity exercise, such as weight training, high-intensity interval training, and plyometric training [11], as well as in match-related small-sided soccer games [24]. In contrast, VAS-TL is not dependent on heart rate responses to exercise, but on the rate of perceived effort. Thus, as fatigue in a soccer match is strongly related with the ability to perform high intensity exercise, the use of perceived exertion-based methods – such as VAS-TL – are preferred when the analysis of soccer-related fatigue is required. This notion is supported by the findings of the present study that HIA and the percentage of time spent with sprint activities correlated with VAS-TL.

Interestingly, the performance in the Yo-Yo IR1 inversely correlated with VAS2-TL in the match. This inverse relationship suggests that players with higher ability to perform high-intensity intermittent exercise show a lower perception of the match demands. In fact, it has been previously described that higher values of physical fitness are related with lower scores of perceived exertion, for a given exercise intensity [14,17,25].

There were some issues that were not sufficiently analysed in the present study that should be fully elucidated in the future. In order to improve the reliability of the preliminary conclusions of the present study, we recommend analysis of a larger sample of soccer players in a higher number of training sessions and matches. Moreover, as the workload during soccer match presents a high inter-individual variability, the calculations of the coefficients of association between the Yo-Yo IR1 performance and VAS-TL should consider the effect of the external load in VAS-TL scores. This can be accomplished by investigating the validity of VAS-TL scores in matches in contrast to standardised protocols that simulate the activity pattern characteristic of the game of soccer. It is also of interest to investigate the influence of competitive level and age on the effectiveness of VAS-TL as a tool for training load monitoring.

In summary, the results of this study showed that VAS-TL could be a surrogate of TRIMP and Edwards' TL methods in quantifying exercise training in soccer, and thus a good tool to monitor internal training load during the season. Since VAS-TL consists of a simple and low-time consuming questionnaire, this tool might be used in the routine training periodization plans in soccer. However, more studies are required to fully validate the VAS-TL method proposed in the present study.

Acknowledgements

João Brito acknowledges the Fundação para a Ciência e a Tecnologia regarding the grant SFRH/BD/44702/2008

Affiliations

[1] University of Porto – Faculty of Sport, Centre of Research, Education, Innovation and Intervention in Sport, Porto, Portugal
[2] University of Porto – Faculty of Sport, Research Centre for Physycal Activity, Health and Leisure, Porto, Portugal
[3] LJMU, Sport and Exercise Sciences, Liverpool, United Kingdom
[4] University of Copenhagen, Department of Exercise and Sport Sciences, Copenhagen, Denmark
[5] University of Exeter, Sport and Health Sciences, Exeter, United Kingdom

References

1 *Alexiou H, Coutts A.* A comparison of methods used for quantifying internal training load in women soccer players. Int J Sports Physiol Perform 2008; 3: 320–330

2 *Andersson H, Ekblom B, Krustrup P.* Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. J Sports Sci 2008; 26: 113–122

3 *Astrand P*, *Rodahl K*. (eds.). Textbook of Work Physiology. New York: McGraw Hill, 1986; 486–522
4 *Banister E*. Modeling elite athletic performance. In: Wenger D, Green H (eds.). Physiological testing of the high-performance athlete. Illinois: Human Kinetics Books, 1991; 403–424
5 *Bangsbo J*. Yo-Yo Tests. Copenhagen: HO+STORM, 1996
6 *Bangsbo J*, *Mohr M*, *Poulsen A*, *Perez-Gomez J*, *Krustrup P*. Training and testing the elite athlete. J Exerc Sci Fitness 2006; 4: 1–14
7 *Bangsbo J*, *Nielsen J*, *Mohr M*, *Randers M*, *Krustrup B*, *Brito J*, *Nybo L*, *Krustrup P*. Performance enhancements and muscular adaptations of a 16-week recreational football intervention for untrained women. Scand J Med Sci Sports 2010; 20: 24–30
8 *Borg G*. Borg Scale. Eur J Appl Physiol 1985; 54: 343–349
9 *Capodaglio M*. Comparison between the CR10 Borg's scale and the VAS (visual analogue scale) during an arm-cranking exercise. J Occup Rehabil 2001; 11: 69–74
10 *Castagna C*, *D'Ottavio S*, *Abt G*. Activity profile of young soccer players during actual match play. J Strength Cond Res 2003; 17: 775–780
11 *Chen M*, *Fan X*, *Moe S*. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: a meta-analysis. J Sports Sci 2002; 20: 873–899
12 *Drust B*, *Reilly T*, *Cable N*. Physiological responses to laboratory-based soccer-specific intermittent and continuous exercise. J Sports Sci 2000; 18: 885–892
13 *Duffield R*, *Dawson B*, *Pinnington C*, *Wong P*. Accuracy and reliability of a Cosmed K4b2 portable gas analysis system. J Sci Med Sport 2004; 7: 11–22
14 *Edwards S*. High performance training and racing. In: Edwards S (ed.). The Heart Rate Monitor Book. Sacramento: Feet Fleet Press, 1993; 113–123
15 *Eniseler N*. Heart rate and blood lactate concentrations as predictors of physiological load on elite soccer players during various soccer training activities. J Strength Cond Res 2005; 19: 799–804
16 *Faul F*, *Erdfelder E*, *Lang AG*, *Buchner A*. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods 2007; 39: 175–191
17 *Foster C*, *Hector L*, *Schrager M*, *Green M*, *Snyder A*. Effects of specific versus cross-training on running performance. Eur J Appl Physiol 1995; 70: 367–372
18 *Foster C*, *Florhaug J*, *Franklin J*, *Gottschall L*, *Hrovatin A*, *Parker S*, *Doleshal P*, *Dodge C*. A new approach to monitoring exercise training. J Strength Cond Res 2001; 15: 109–115
19 *Harriss DJ*, *Atkinson G*. Update – Ethical Standards in Sport and Exercise Science Research. Int J Sports Med 2011; 32: 819–821
20 *Impellizzeri F*, *Rampinini E*, *Coutts A*, *Sassi A*, *Marcora M*. Use of RPE-based training load in soccer. Med Sci Sports Exerc 2004; 36: 1042–1047
21 *Gould D*, *Kelly D*, *Goldstone L*, *Gammon J*. Examining the validity of pressure ulcer risk assessment scales: developing and using illustrated patient simulations to collect the data. J Clin Nurs 2001; 10: 697–706
22 *Grant S*, *Aitchison T*, *Henderson E*, *Christie J*, *Zare S*, *McMurray J*, *Dargie H*. A comparison of the reproducibility and the sensitivity to change of visual analogue scales, Borg scales, and Likert scales in normal subjects during submaximal exercise. Chest 1999; 116: 1208–1217
23 *Kentta G*, *Hassmen P*. Overtraining and recovery. A conceptual model. Sports Med 1998; 26: 1–16
24 *Little T*, *Williams A*. Measures of exercise intensity during soccer training drills with professional soccer players. J Strength Cond Res 2007; 2: 367–371
25 *Manzi V*, *D'Ottavio S*, *Impellizzeri F*, *Chaouachi A*, *Chamari K*, *Castagna C*. Profile of weekly training load in elite male professional basketball players. J Strength Cond Res 2010; 24: 1399–1406
26 *McLaughlin J*, *King G*, *Howlei E*, *Basset D*, *Ainsworth B*. Validation of the COSMED K4 b2 portable metabolic system. Int J Sports Med 2001; 22: 280–284
27 *Mohr M*, *Krustrup P*, *Bangsbo J*. Match performance of high-standard soccer players with special reference to development of fatigue. J Sports Sci 2003; 21: 519–528
28 *Morgan W*. Psychological components of effort sense. Med Sci Sports Exerc 1994; 26: 1071–1077
29 *Rowbottom D*. Periodization of training. In: Kirkendall J (ed.). Exercise and Sport Science. Philadelphia: Lippincott Williams & Wilkins, 2000; 499–514
30 *Weiss M*, *Ebbeck V*. Self-esteem and perceptions of competence in youth sports: Theory, research and enhancement. In: Bar-Or O (ed.). The Child and Adolescent Athlete. Oxford: Blackwell Science, 1996; 364–382