

TOM-Scale: a new method to programme training sessions loads in football

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Summary

There are several methods to control both the training and match load in football. However, most of these methods do not specify a clear methodology to pre-quantify this training or match load. The aim of this study was to develop a football specific training load monitoring scale (TOM-scale) to programme the session training load. 18 professional football players from the Latvian National Football Team were tracked throughout 466 football sessions, with individual sessions ranging from 13 to 24 for each player. Players were tracked using a multisensor device including a 5 Hz Global Positioning System, a 1000 Hz triaxial accelerometer and a heart rate monitor band. A football specific scale was developed to establish session training load prior to it. This scale is based on commonly football training tasks categories, with specific set parameters for each one. External training load variables involved total running distance, % of high intensity actions ($> 14.4 \text{ km}\cdot\text{h}^{-1}$), number of accelerations and decelerations, sprints ($> 21 \text{ km}\cdot\text{h}^{-1}$) and impacts. Internal training load variables were % heart rate maximum, Banister TRIMP and Edwards TRIMP. The results showed positive significant correlations ($p < 0.05$) from moderate ($r > 0.40$) to very large ($r < 0.90$) between TOM-scale training load and all the external and internal training load variables studied. In conclusion, although this new method does not avoid of controlling the real training load to assess the way the football players cope with the individual training loads, TOM-scale may be useful to programme football sessions and adopt a periodization strategy over the season to, in example, avoid non-functional overreaching phases and/or undesirable high isolated performance peaks.

Key words:

Quantification.
Periodization. GPS.
Performance.

TOM-Scale: un nuevo método para programar las cargas de sesiones de entrenamiento en el fútbol

Resumen

En la actualidad, existen diferentes métodos para controlar la carga de entrenamiento y partido en fútbol. Sin embargo, la mayoría de estos métodos no proponen una metodología de programación de dicha carga de entrenamiento o partido. El objetivo de este estudio fue desarrollar una escala específica para programar la carga de entrenamiento en fútbol (TOM-Scale). 18 jugadores profesionales pertenecientes a una selección profesional de jugadores de fútbol europea fueron monitorizados durante un total de 466 sesiones individuales, con una participación individual de 13 a 24 sesiones por jugador. La carga de entrenamiento fue registrada con un dispositivo multisensor el cual incluía un GPS de 5Hz, un acelerómetro de 1000 Hz y una banda de frecuencia cardíaca. Se desarrolló una escala específica en fútbol para establecer la carga de entrenamiento previo a la realización del mismo. Esta escala está basada en la categorización de tareas comunes en los entrenamientos en fútbol, donde posteriormente se especifican en base a parámetros específicos. Las variables de carga externa de entrenamiento contrastadas fueron la distancia total recorrida, el % de acciones de alta intensidad ($> 14.4 \text{ km}\cdot\text{h}^{-1}$), el número de aceleraciones y desaceleraciones, el número de sprints ($> 21 \text{ km}\cdot\text{h}^{-1}$) y los impactos. Las variables de carga interna utilizadas fueron el % de la frecuencia cardíaca máxima, Banister TRIMP y Edward TRIMP. Los resultados mostraron correlaciones positivas significativas ($p < 0,05$) desde moderadas ($r > 0,40$) a muy grandes ($r < 0,90$) entre TOM-Scale y todas las variables de carga interna y externa estudiadas. En conclusión, aunque este nuevo método no exige de controlar las cargas de entrenamiento para contrastar las diferentes asimilaciones individuales de la carga de entrenamiento, es útil para programar sesiones de entrenamiento en fútbol y adoptar estrategias de periodización para, por ejemplo, evitar fases de sobre-entrenamientos no funcionales y/o picos altos de forma aislados no deseados.

Palabras clave:

Cuantificación.
Periodización. GPS.
Rendimiento.

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Introduction

In recent years, several training load (TL) quantification (TL-Q) methods have been widely used with the aim of creating positive adaptations through different kind of stimuli¹. After a fatiguing stimulus, the body falls into a supercompensation phase, turning into an overtraining phase if the stimulus is too fatiguing². Thus, a functional overtraining status may be required to induce positive adaptations²; hence, the TL during the programming phase is important and necessary.

TL has been defined as the product of volume x intensity³, and its quantification has been proposed as an effective strategy to prevent possible injuries⁴. In intermittent sports such as football, TL-Q is complicated since the energy system provides both aerobic and anaerobic energy at different ranges and intensities, and performance depends on different factors such as technique, tactics, physical and psychological team and individual conditions⁵.

TL can be divided into external TL (ETL) and internal TL (ITL). The most common and widely studied methods of ITL are based on derived heart rate (HR) such as Banister Training Impulse (TRIMP-B)⁶ and summated heart rate zone TRIMP, also known as Edwards TRIMP (TRIMP-E), as well as those derived from rates of subjective perception of the session rate of perceived exertion (s-RPE)^{3,7}. Nowadays, Global Positioning System (GPS) and accelerometers are more accurate commonly used to monitor and quantify ETL in football⁸, showing significant positive correlations with ITL variables such as TRIMP-B⁹, TRIMP-E¹⁰ and s-RPE¹¹.

s-RPE is probably the most widely accepted and studied subjective method for TL-Q in team sports such as football⁹. The original method proposed by Foster⁷ used a Borg CR10 adapted scale to obtain the intensity at the end of training from each football player. TL was finally calculated by multiplying this factor by the training volume (i.e., minutes). Despite this method displayed important and significant correlations with different ETL and ITL variables^{3,12}, it is used at the end of the training, once the efforts are performed.

Even though some methods have been described to quantify the global TL in football, to our knowledge, there is no method to determine the TL prior to a training session by the technical staff. Thus, the purpose of this study was to propose and validate a simple and practical method to programme the session TL in football.

Material and method

Participants

21 outfield professional football players from the same First Team of the Latvian National Football Association participated in this study (age 26.00 ± 3.35 years, body mass 76.54 ± 4.99 kg, height 181 ± 6.09 cm). The sample consisted on 4 centre defenders (n = 102), 5 fullbacks (n = 111), 4 wingers (n = 89), 5 midfielders (n = 102) and 3 strikers (n = 62). Players provided written informed consent to participate in the study, which was approved by an institutional ethics committee following the Helsinki Declaration guidelines.

Measures

Players were tracked using a multisensor device (details below) throughout different kind of football sessions' (including friendly matches) between May 2014 and March 2015 during the preparation and qualification stages of Euro France 2016. This tracking provided information from a total of 31 team sessions, with individual sessions ranging from 13 to 29 for each player, resulting finally on a total of 466 individual sessions observations. Football sessions were categorized as conditioning training (COND) (n = 6), tactical training (TAC) (n = 13), pre-match training (PR-M) (n = 4), training match (TR-M) (n = 4) or friendly match (FR-M) (n = 4).

Procedures

A football specific scale was developed to establish the intensity of the drills. First, the original Borg Scale 6-20 was transformed into an exponential curve according to some other authors who have proposed similar approaches using other scales, suggesting that the more intensive the exercise, the greater the difference must be between those intensities^{6,12-14}. Given that previous researches found associations between the first and second thresholds and the values 12 and 14 respectively on the Borg Scale 6-20^{15,16}, we factorized as 1 those values from 6 to 11, as 2 from 12 to 14 and as 3 for 15 and above. The initial values of the scale from 6 to 20 were plotted with the factors and the following prediction equation obtained for the model was finally used to adjust the individual factors:

$$y = 0.4497 * e^{\Lambda(0.1059x)}$$

Session training load calculation instructions

To calculate each session training load (s-TL), prior to each football session, a group of experts formed by three UEFA PRO coaches and one Sports Science fitness coach with large experience at an international level coach followed several steps. First, the intensity of each session drill was calculated, following the next steps (Figure 1): 1) Select a drill category, 2) Set the drill category specifications depending on the drill specific rules, 3) Exchange obtained intensity value by final factorized value. Second, the drill training load (d-TL) was calculated by multiplying the drill intensity by the total drill volume in minutes. Last, the session training load (s-TL) was calculated by summing each d-TL. The following is a more detailed description of the process:

Step 1: A drill was assigned to one of the possible 13 categories as described below:

Recovery: recovery drill with the main aim of recovering after a high intensity training session or day; *Compensatory:* exercises focusing on improving imbalances with low relative weights, core exercises, range of motion exercises and/or balance exercises on the pitch; *Warm up (WU):* drills designed to prepare the body for the subsequent physical activity; *Set pieces (StP):* set piece situations, including crossing and shooting drills; *Resistance drills:* exercises using external weights or body weight to improve strength on the pitch; *Passing drills (PD):* passing situations where usually many different technical abilities are involved, as well as individual tactical situations; *Tactical work (TW):* drills to improve collective tactical situations usually involving the whole group such

as attack-defence situations, game play etc.; *Conditioning circuit* (CC): traditional conditioning circuit with different posts where the objective is to combine different conditional factors with technical and/or tactical abilities; *Small sided game* (SSG): classic small sided game in any format; *Training match* (TM); *Official match* (OM); *1vs1*: situations where 2 players compete each other; and *All out*: situations where the player is running at his/her maximum capacity. Those categories were established by the same group of experts as the most commonly categories during the daily trainings in football. Thus, the first step is to choose a drill category to be set during step 2.

Step 2: The drill was set depending on the category selected during Step 1 and the drill own specific rules. The factors used on each of the Step 2 sections were arbitrary decided by the group of experts, similarly to previous¹⁶. Two points are important at this step: 1) about the relative area per player (Setup D, Figure 1), it was considered that if situated on any limit zone, the higher zone was considered. 2) if the drill category is a training match, it was considered to rest again at the end - 1 if usually pauses or -2 if frequently pauses to the final intensity value

Step 3: the re-converted intensity value obtained after step 2 was exchanged by the corresponding factorized value showed on Figure 1³.

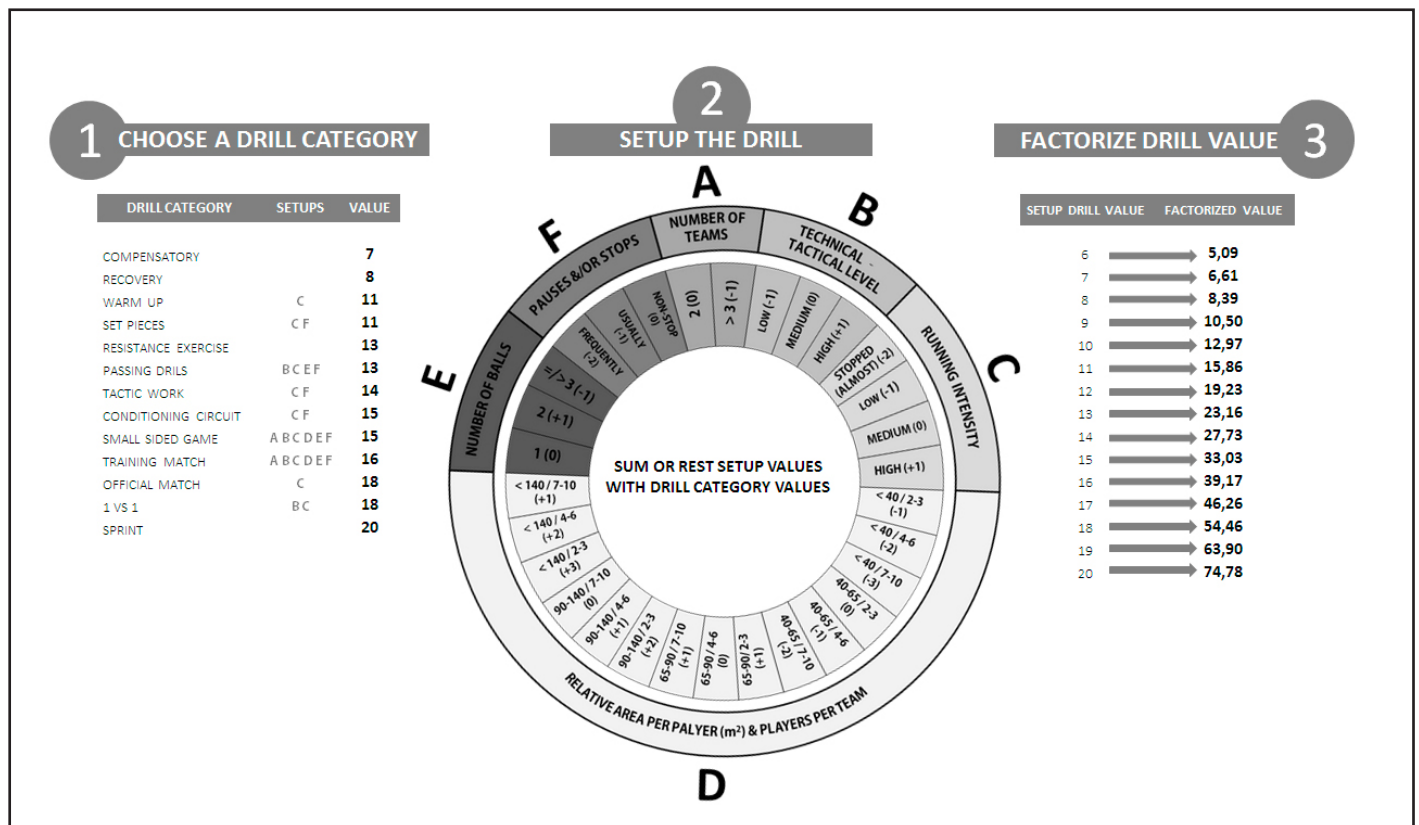
For drills where resting time is an important factor within the drills themselves, this intensity was also considered into the total load. Rest intensity was calculated following the proposal of Scherr *et al.* (2013)¹⁶, identifying every percentage of maximum heart rate with a given value on the Borg Scale 6-20.

Step 4: The fourth step was to establish the total drill volume. Again, if rest was considered, two different volumes were used. Finally, d-TL was calculated by multiplying the factorized intensity for each volume, also summing each individual effort and rest TL if considering rest.

Step 5: the last step was to calculate the s-TL by summing all the d-TL which would be used during the session. This method will be referred to hereinafter as the "training output monitoring scale" or "TOM-Scale".

During each football session, each player wore a special t-shirt with a multisensor device (*WIMU, Realtrack Systems, Spain*) situated between their two scapulae. This device included a 5Hz GPS, a 1000 Hz triaxial accelerometer and ANT+ that was used to connect with a heart rate monitor band (*Garmin HRM, Garmin, USA*). Similar devices with same hardware characteristics have been used on previous studies^{8,10,18,19}. To test the validity and reliability of the 5Hz GPS device a pilot study was conducted. 2 subjects performed 8 laps (16 laps in total) over

Figure 1. Steps to calculate the drill intensity value. Step 1: choose a drill category for the programmed drill. Step 2: for each drill category, choose its own setup zones (from A to F). Step 3: Exchange the value obtained after step 2, and factorize with the values from the step 3. Finally, this value (drill intensity) must be multiplied by the total effort time (total drill volume, in minutes). In case of considering the resting, see methods to add the resting drill load.. Practical example: in case of 10 minutes of a passing drill exercise (Step 1= 13), with a medium technical-tactical level for this drill (Step 2, B = +0), high running intensity during the exercise (Step 2, C = +1), 1 ball used at the same time (Step 2, E = +0) and usually stops (Step 2, F = -1), the d-TL = effort intensity (13 + 0 + 1 + 0 - 1 = 13; step 3 = 23.16) * drill volume (10) = 231.40 a.u. Total s-TL is the result of the summated d-TL from the session.



a team sports circuit²⁰. Gold standards used were real distance and speed, measured with a dual-beam electronic timing gate *OptoJump System (Polifemo Radio Light, Microgate, Bolzano, Italy)* placed at the start position, 10m and 30m. The mean BIAS for total distance during the circuit, 10m sprint and 30m sprint were -2.73 ± 1.64 m ($p < 0.001$), -0.80 ± 0.58 m ($p < 0.001$) and 0.42 ± 2.50 m ($p = 0.515$) respectively. The intra-unit reliability was assessed using Bland-Altman plots and coefficient of variation (CV, in %) comparing the results from each lap for all the subjects. The average BIAS compared with each unit mean laps results for total distance, peak speed and average speed were 0.00 ± 1.68 , 0.00 ± 1.73 and 0.00 ± 0.33 for the circuit, 0.00 ± 0.49 , 0.00 ± 0.53 and 0.00 ± 0.77 for 10m sprints and 0.00 ± 2.34 , 0.00 ± 0.76 and 0.00 ± 0.74 for 30m sprints, non-significant differences in all cases. The CV for total distance, peak speed and average speed were 1.25%, 2.61% and 3.33% for the circuit, 6.34%, 4.31% and 7.45% for 10m sprints and 8.22%, 2.68% and 4.13% for the 30m sprints.

Data were analyzed after each training session using the manufacturer's analysis software (*Qüiko v. 2.0, Realtrack Systems, Spain*). If any kind of interference or signal loss were observed on each file, data were removed from the analysis. Different ETL and ITL variables were calculated for the analysis. ETL involved total running distance (TOT-DIST, in meters), % of high intensity actions (% HIA), total number of accelerations (ACC, in $m \cdot s^{-2}$) and decelerations (DCC, in $m \cdot s^{-2}$) calculated from the GPS, total SPRINTS number and total impacts number (IMPACTS).

HIA speed threshold was considered at speeds $> 14.4 \text{ km} \cdot \text{h}^{-1}$ ^[18], whereas the SPRINTS speed threshold was $> 21 \text{ km} \cdot \text{h}^{-1}$ ^[18]. For the ACC and DCC, the minimum value considered was $0.55 \text{ m} \cdot \text{s}^{-2}$ ^[21], whereas for the IMPACTS it was 5G¹⁸. ITL variables were %HRmax, TRIMP-B⁶ and TRIMP-E¹⁷.

Statistical methods

The Statistical Package for the Social Sciences (SPSS, version 20.0 for Windows, SPSS Inc, Chicago, IL) was used to conduct the analysis. Data are shown as mean \pm SD. To estimate the minimum sample size for the correlation analysis, G*power software (v. 3.1.7) was used, setting a 0.70 effect size, 80% power and $\alpha = 0.05$. The minimum number of sessions per player determined was 13, in accordance with the minimum number of sessions selected for the analysis.

Correlation analysis was used between each player session ETL or ITL variables and each player s-TL using the Pearson correlation coefficient (r) to analyse each player individual responses against each kind of exercise. Prior to correlation analysis, data were log-transformed to reduce the bias from non-uniform distributions. According to Hopkins, correlation magnitudes were classed as trivial (< 0.10), small (0.10 to 0.29), moderate (0.30 to 0.49), large (0.50 to 0.69), very large (0.70 to 0.89) and extremely large (> 0.90)²². The confidence limits (CL) were also calculated at 95%.

Results

Figure 2 shows the correlations between s-TL and ITL and ETL variables. Moderate to very large positive significant correlations were observed between ETL and s-TL. The higher correlation was found bet-

ween s-TL and TOT-DIST (0.87, $p = .00$, 95% CI = 0.84 - 0.90), while the smallest was found between s-TL and HIA ($r = 0.44$, $p < 0.001$, 95% CI = 0.38 - 0.50). Moderate to very large positive significant correlations were also observed between ITL and s-TL. The higher correlation was found between s-TL and TRIMP-B ($r = 0.81$, $p < 0.001$, 95% CI = 0.76 - 0.85), with very similar correlations found between s-TL and TRIMP-E ($r = 0.79$, $p < 0.001$, 95% CI = 0.72 - 0.84). The lowest correlation was found between s-TL and %HRmax (0.46, $p < 0.001$, 95% CI = 0.32 - 0.60).

Line-dot-line shows the prediction intervals. Short-lines shows the confidence intervals (CI = 95%) for the regression line. Black line shows the fitted linear regression line. R represents the Pearson moment product correlation and r^2 the percentage of variance that each variable represents the s-TL variance.

Figure 3 shows a representative load distribution through all football sessions analysed. The higher s-TL were found during Friendly Matches sessions. Accordingly to the correlations values, most of ITL and ETL showed a similar distribution of the load compared to the s-TL. Higher s-TL, ITL and ETL were related to friendly matches, while the lowest loads were found with pre-match training sessions. Distance and %HRmax showed to be the ETL and ITL variables with less variability among the football players (Figure 3, lower SD).

Bars represent each ITL or ETL variables (mean). Black points represent the s-TL for each football session. Error bars represents the standard deviation for each football session (SD) for either the ITL or ETL (bars) and the s-TL (black points). COND = conditioning training. TAC = tactical training. PR-M = pre-match training. FR-M = friendly match. TR-M = training match.

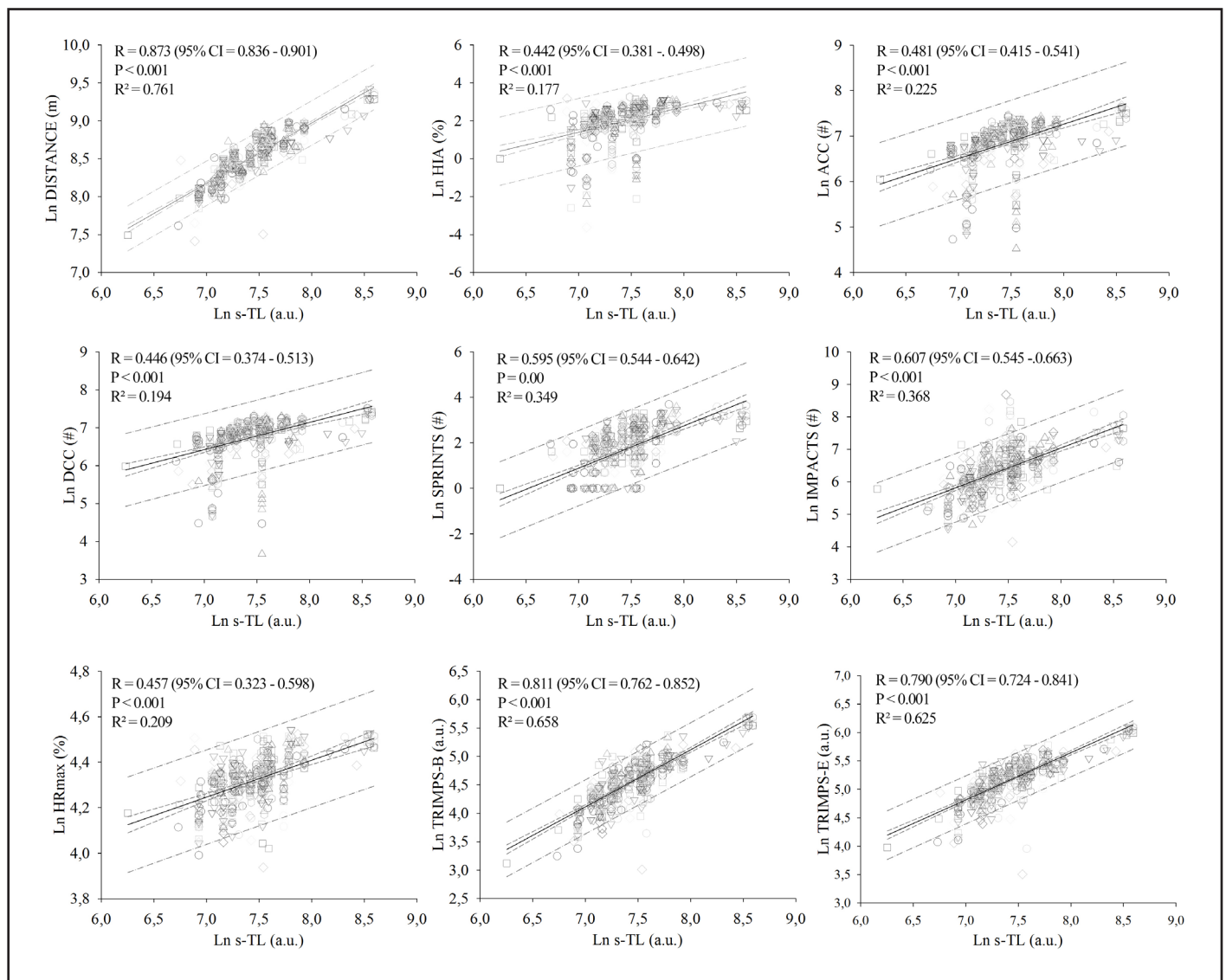
Discussion

The purpose of this study was to propose and validate a simple and practical method to programme the session TL in football. The results showed that TOM-Scale is a valid method to programme the s-TL prior to football training and match sessions.

To our knowledge, this is the first study that observes the relationships between a subjective coach's TL programmed prior to training with ITL and ETL variables among elite football players. The results suggest that the TOM-Scale is a useful method to programme s-TL prior to training. A similar method has been proposed in rowing²³ to predict s-TL in rowing using different factorized values depending on the drill category, together with exponential increment of intensity. In our study, each exercise setup factor was determined arbitrarily (Figure 1, Step 2) by a group of experts (see methods). This approach is supported by some recently research²⁴.

Several studies have shown positive significant correlations between subjective s-TL (calculated as the TL perceived by the players at the end of training) and similar ITL and ETL variables^{9,23}. Previous studies showed that coach's perception of TL after training is not the same as the players²⁵. However, our results suggest that using the TOM-Scale, the coach can programme with good relation to some ETL and ITL the s-TL. ITL such as TRIMP-B or TRIMP-E have shown significant correlations with the s-RPE method in football^{9,10}. ETL also yielded significant correlations with subjective s-TL perceived by players in football (HIA, r

Figure 2. Scatter plots for ITL/ETL against s-TL. Data are represented as the natural logarithm (ln) for each variable.



R: pearson moment product; 95% CI: confidence intervals at 95%; HIA: % high intensity actions; ACC: accelerations; DCC: decelerations; HRMAX: % heart rate maximum; TRIMP-B: TRIMP Banister; TRIMP-E: TRIMP Edward.

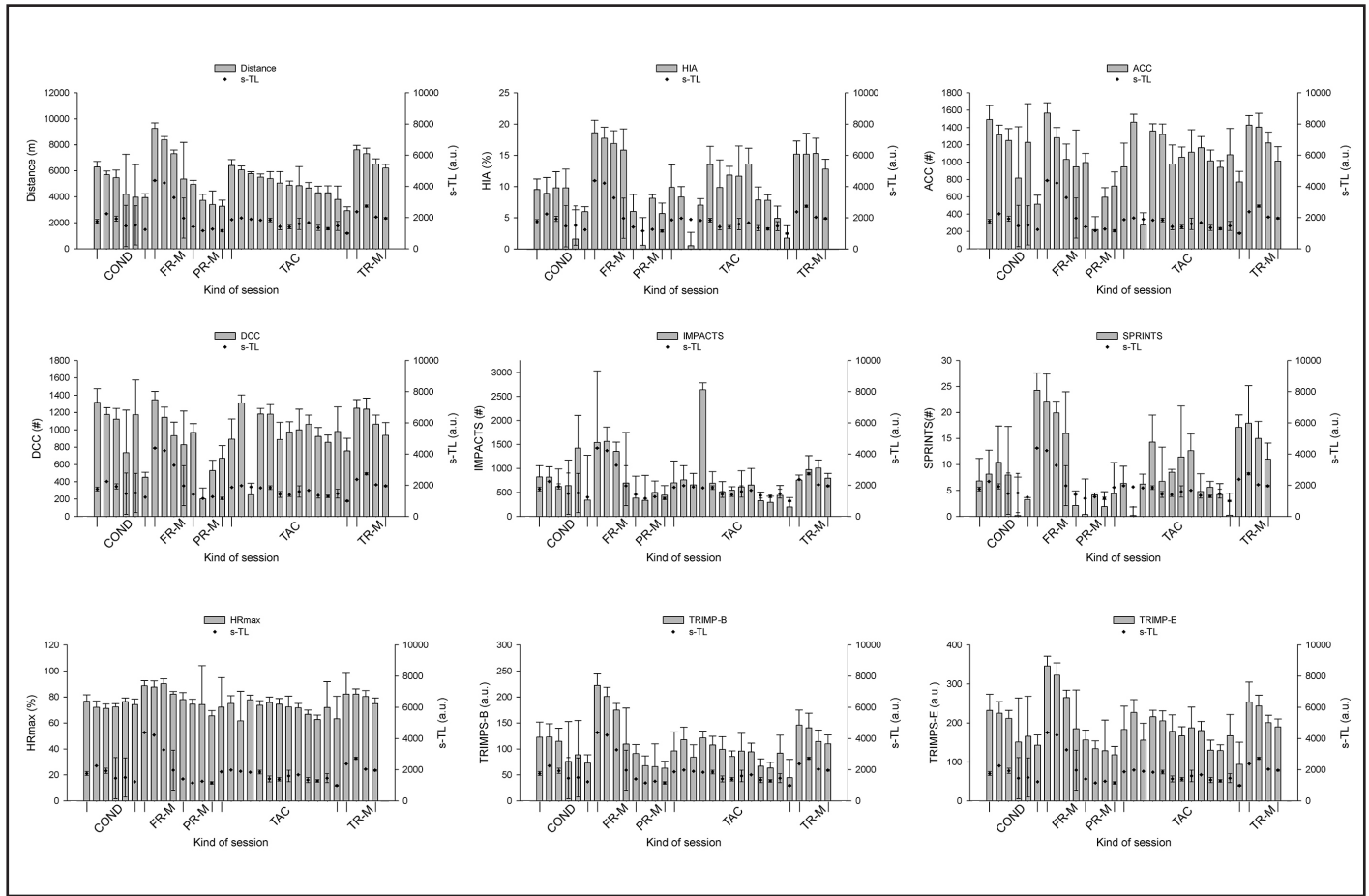
= 0.54 and SPRINTS distance, $r = 0.44$), similar to the results presented here²⁶. In other similar sports such as Australian football, ETL such as TOT-DIST and HIA showed similar correlations with s-RPE compared to the results of this study ($r \approx 0.80$ and $r \approx 0.70$, $p < 0.05$)⁹. As in the study carried out by Scott *et al.*⁹, the correlations found here with TOT-DIST were higher than HIA, SPRINTS, ACC or DCC, and this could be due to a greater dispersion of these variables between different positions on the field¹⁹. Another probable reason for these lower correlations could be related with the low validity of GPS at higher speeds (over $20 \text{ km}\cdot\text{h}^{-1}$)²⁷ or sudden changes of speed²⁷. For this reason, HIA, SPRINTS, ACC and DCC correlations must be interpreted with caution.

To date, no information has been located regarding the relationship between impacts obtained by accelerometers and any subjective s-TL.

However, some research has examined the relationship with player body load (calculated directly from the accelerometer, as impacts) and s-RPE, with similar results to the correlation with IMPACTS in this study ($r \approx 0.75$)^{8,9}. Therefore, this is the first paper to study the relationship between the impacts obtained directly from the accelerometer and a subjective s-TL. In our opinion, IMPACTS is an interesting variable to be controlled since it is directly derived from accelerometers, incorporating information regarding the neuromuscular load. The high correlation found in our study with the TOM-Scale TL suggests that the higher s-TL, higher neuromuscular load will the player present.

In relation to the ITL, the results suggest TRIMP-B or TRIMP-E may be used indistinctly, given that the correlation with TOM-Scale TL was similar. %HRmax, however, resulted on a lower correlation. This could

Figure 3. Representative load distribution of ITL/ETL with s-TL. Data are represented as mean ±SD.



COND: conditioning sessions; FR-M: friendly matches sessions; PR-M: pre-match sessions; TAC: tactical sessions; TR-M: training match; s-TL: session training load; HIA: % high intensity actions; ACC: accelerations; DCC: decelerations; HRMAX: % heart rate maximum; TRIMP-B: TRIMP Banister; TRIMP-E: TRIMP Edward.

be explained by the use of volume to calculate either TRIMP-B or TRIMP-E, whereas %HRmax is just an intensity marker. Some studies have suggested that the use of %HRmax is not valid to quantify TL²⁹ and has the limitation that it cannot distinguish between high and low intensity exercises when they are performed for just few seconds with enough recovery time between them^{30,31}.

A limitation of this study is that the GPS device used for the ETL measures was not validated yet in the scientific literature. A recent review³² has addressed the validity and reliability of similar GPS devices with 5Hz frequency sample, the same of the GPS device used in this study with very comparable results to those found in our GPS validity and reliability test. The evidence largely suggests that 5Hz GPS devices can accurately quantify players' distances during team sports³². However, 5Hz GPS devices tends to differ from reality at moderate to high speeds (i.e. >14 km·h⁻¹). Despite of this, the reliability of these devices when changing of direction, curvilinear movements and even high-speed running or sprints from 10 to 40m³². has been shown to be moderate and replicable. In addition, 5Hz GPS devices have been shown to be acceptable valid and reliable measuring high-speeds (i.e. >8m·s⁻¹)³².

Finally, to accommodate the potential problems of 5Hz GPS devices when assessing high-speeds, authors propose to group distances based on velocity bands³², as it has been done in this study. Another limitation is the reproducibility and reliability of the TOM-Scale TL by different coaches and levels. Future research must focus on this aspect, even to analyse more deeply the validity relationships separately across different kind of soccer sessions.

In conclusion, TOM-Scale may be a useful tool to programme and design football field sessions. The TL calculated with TOM-Scale can be managed over a season to avoid non-functional overreaching phases, avoid injuries and/or keep a high level of fitness during all the season. It can help coaches and staffs in general to understand better what kind of stimulus they are going to achieve with the team. Anticipating the session TL may be also interesting to decide which kind of drill suits better to the expected TL. One limitation of this study is that, although the sample comprised elite football players, the data were obtained and the TOM-scale was applied within the context of a 24-h controlled situation (training camps); hence further study is needed to verify whether this method is valid in other kinds of environments.

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