Original Article

External and internal training load relationships in soccer players

UTKU ALEMDAROĞLU

Faculty of Sport Sciences, Pamukkale University, Denizli, Turkey

ABSTRACT

The aim of the present study was to examine the relationships between internal training loads (TL) (Polar (PLR), Edwards (EDW) Training-Impulse (TRIMP) session RPE (s-RPE) external TL (Total distance (TD), covered distance in five different zone, number of acceleration (ACC) and deceleration actions (DEC) in professional soccer players. Twenty male professional soccer players (age = 27.6 years; height = 177.6 ± 7.1 cm; body mass = 69 ± 8.3 kg) from a professional soccer team voluntarily participated in the study. The correlations between the values were examined individually for each athlete by Pearson correlation test. According to the results of this study showed that there were very large and nearly perfect relations between s-RPE and both HR-based methods (EDW and PLR TRIMP) (respectively, r = .51 - .91; r = .44 -. 90). Additionally, from moderate to large correlations were observed between internal TL methods and external TL methods (walking, number of ACC-DEC actions) (between r = .56 - .82). Moreover, the relations between internal load and external load parameters were weakened in high-speed zones. According to the results of the current study, meanwhile s-RPE may be evaluated in practice as a useful and inexpensive for monitoring the internal TL method, the number of ACC and DEC actions could be appropriate for external TL.

Keywords: Sports performance; Total distance; Acceleration; Deceleration; Rating of perceived exertion; Heart rate.

Cite this article as:
Alemdaroğlu, U. (2021). External and internal training load relationships in soccer players. *Journal of Human Sport and Exercise*, *16*(2), 304-316. https://doi.org/10.14198/jhse.2021.162.07

Corresponding author. *Faculty of Sport Sciences, Pamukkale University, Denizli, Turkey. https://orcid.org/0000-0002-1025-0965*
E-mail: ualemdaroglu@pau.edu.tr
Submitted for publication December 09, 2019.
Accepted for publication February 07, 2020.
Published April 01, 2021 *(in press* February 24, 2020).
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2021.162.07

INTRODUCTION

Nowadays, training and competition loads on elite athletes have dramatically increased because of an ever more congested sports calendar (Schwellnus et al., 2016). Therefore, training monitoring has become an essential process for coaches and sports science practitioners to examine the individual response of players. Training monitoring allows coaches to adapt their programs, help manage illness/injury risk, assess fatigue and the associated need for recovery and avoid the risk of non-functional overreaching (Bourdon et al., 2017; Halson, 2014; B. R. Scott, Lockie, Knight, Clark, & Janse De Jonge, 2013; Soligard et al., 2016). Training load monitoring systems can be categorized into two main types. The first one, internal loads covers both physiological and psychological stressors (heart rate, blood lactate, oxygen consumption, and ratings of perceived exertion (RPE) etc.) imposed on the athlete during training and competition (Bourdon et al., 2017; Ian Lambert & Borresen, 2010; B. R. Scott et al., 2013; T. J. Scott, Black, Quinn, & Coutts, 2013; Soligard et al., 2016). Researchers advise that using internal TL may be most appropriate for monitoring training (Bourdon et al., 2017; B. R. Scott et al., 2013; T. J. Scott et al., 2013). The second, external loads, includes objective measures of the work (power output, speed, acceleration (ACC), deceleration (DEC) etc.) performed by the athlete during training or competition (Bourdon et al., 2017; Ian Lambert & Borresen, 2010; Soligard et al., 2016). External TL seems to be more suitable in the prescription and planning of the training process (Bourdon et al., 2017; B. R. Scott et al., 2013; T. J. Scott et al., 2013).

Especially in team sports, a wide range of internal load parameters have been monitored by coaches (McLaren, Smith, Spears, & Weston, 2017) to ensure that each athlete receives adequate training stimulus (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). The most common internal load parameters are heart rate (HR) based methods, made possible by wireless cardio monitoring technology which allows coaches to transfer of HR data from a transmitter belt worn on the chest to a receiver worn as a wristwatch (Alexandre et al., 2012). Different Training-Impulse (TRIMP) methods have been used by coaches for training monitoring such as Edwards' TRIMP (EDW), which is calculated by multiplying the time spent in five arbitrary pre-defined HR zones by arbitrary coefficients (Manzi et al., 2010; Paulson, Mason, Rhodes, & Goosey-Tolfrey, 2015; B. R. Scott et al., 2013) and Banister's TRIMP, which is calculated by using anaerobic threshold heart rate values and the time spent in arbitrary pre-defined zones (Clarke, Farthing, Norris, Arnold, & Lanovaz, 2013; Manzi et al., 2010; Paulson et al., 2015; B. R. Scott et al., 2013).

However, there are some problems using HR based methods in soccer training such as environmental conditions and medications, affecting heart responses of players (Alexandre et al., 2012), and the cost of systems and technical staff requirements. It should also be mentioned that restrictions on the use of HR transmitter belts during official competitive matches (Impellizzeri et al., 2004)mean that coaches lack match data that may represent a relatively high percentage of the weekly training load (Impellizzeri et al., 2004). For these reasons, many studies examine the s-RPE methods instead of HR-based methods in soccer players, they represent valid alternative and they showed large to very large correlation between s-RPE and EDW TRIMP ($r = .54 – .78$) (Casamichana, Castellano, Calleja-Gonzalez, Roman, & Castagna, 2013; Impellizzeri et al., 2004; Scott, et al., 2013). Research in the other team sports shows similar results (Lupo, Tessitore, Gasperi, & Gomez, 2017; Manzi et al., 2010; Paulson et al., 2015; Scanlan, Wen, Tucker, Borges, & Dalbo, 2014; Scott, et al., 2013). According to the results of previous studies, s-RPE is valid, reliable, inexpensive and very simple method and could be used as an alternative instead of HR-based methods for monitoring training load (Foster et al., 2001; Singh, Foster, Tod, & McGuigan, 2007; Wallace, Slattery, & Coutts, 2014).

The best way for monitoring training is to use internal load and external load together (Paulson et al., 2015). Thus, especially in the last two decades, measuring and evaluating external load parameters (distance covered in various speed zones, distance covered at high intensity, metabolic power, player load (ACC-based method), number of ACC and DEC actions in different zones etc.) of players has been commonly used thanks to the development of technological equipment such as GPS, high-speed video analysis systems and accelerometers (Barris & Button, 2008; McLaren et al., 2017). The most common and valid methods for determining external TL and the performance of soccer players are high-speed running distance (HSR) and sprint distance (above a given high-speed threshold close to maximal running velocity) (Varley & Aughey, 2013). Mohr et al. (2003) compared the HSR performance of elite level players and moderate level players and reported that elite level players covered a 28% greater HSR distance in a soccer game than their moderate level counterparts. However, using distance covered at high intensity has some drawbacks for training monitoring, such as underestimation of training load. The main reason of this underestimation is that some high-intensity actions are classified as low-speed activity according to speed zones in monitoring systems, because many high-intensity actions happen in short duration without a change in location on the pitch (Dalen, JØrgen, Gertjan, Havard, & Ulrik, 2016; Scott, et al., 2013). Moreover, Varley and Aughey (2013) reported that during soccer matches the number of maximal ACC actions is 8-fold higher than sprints in soccer players. At the same time, DEC actions includes eccentric contraction and the metabolic demands of DEC actions could be relatively lower, but many external loads consist of DEC actions (Dalen et al., 2016). Besides, it should be remembered that ACC and DEC actions are more energetically demanding than constant-speed movement (Osgnach, Poser, Bernardini, Rinaldo, & Di Prampero, 2010).

For all these reasons, determining the individual responses of players to ACC and DEC actions in competition and training and the relations between ACC and DEC actions and internal load parameters would add great value to the existing body of knowledge since using these values could allow coaches and sports science practitioners to develop and manage their players' physical attributes in a more detailed way, taking account of game demands and avoiding injuries (Varley & Aughey, 2013). Moreover, the use of ACC-based methods to quantify external TL and the relationship between this and other TL methods in professional soccer is yet to be comprehensively examined (Scott, et al., 2013). To our knowledge, this is the first study to use the number of ACC and DEC n different speed zones in a team sport. Thus, the present study aimed to examine the relationships among Polar (PLR) TRIMP, EDW TRIMP, s-RPE, TD, distance covered in different speed zones, and the number of ACC and DEC actions in professional soccer players.

MATERIAL AND METHOD

Participants

The data was collected over a 10-week soccer season. Twenty professional male soccer players (age = 27.6 years; height = 177.6 ± 7.1 cm; body mass = 69 ± 8.3 kg) from a professional soccer team participated the study voluntarily. Before the data collection procedure, the players performed the modified shuttle run test (MSRT) to determine maximal HR (HRmax) and HR training zones. The Polar Pro (Polar Electro, Kempele, Finland) device was used for 10 weeks (6 weeks pre-competition and 4 weeks in-competition period) in all field workouts (with the exception of strength and regeneration training). The EDW and (PLR) TRIMP, distance covered at various speeds, the number of ACC and DEC actions in three different zones and s-RPE were determined. Data were collected across 761 individual field-based training. The relationships between external and internal training loads were examined and the strength of the relationship was calculated for each player.

Design and procedures

Modified shuttle run test (MSRT)

The MSRT was used on a 100m circular track to determine the maximum heart rate responses of players. Güvenç et al. (2011) reported that the MSRT is a reliable test to determine HRmax (ICC: .90). The MSRT was performed on a natural grass soccer pitch with cones placed every 20m in a circle. The pace was set with a computer throughout the test. The initial speed was set at 10 km·h-1 and was increased by 1 km·h-1 every 3 minutes until exhaustion or two failures to reach the next cone before the signal. Between the stage, players sat and rested for one minute, during which a blood sample was taken from an ear lobe and immediately analysed using a Lactate Plus analyser (Nova Biomedical, USA) which had been previously validated. A Polar Pro (Polar Electro, Kempele, Finland) device was used to determine the players' HR values.

Internal training load

The s-RPE method is very common training monitoring tool and many researchers have reported that this method is a valid, reliable, inexpensive and very simple in various exercise activities (Foster et al., 2001; Singh et al., 2007). This method is also useful for team sports (Ian Lambert & Borresen, 2010; Impellizzeri et al., 2004). The training load was calculated using the s-RPE (CR-10 scale, table 1) by multiplying the training duration (in minutes) by the RPE for the session as described by Foster et al. (Foster et al., 2001). Players were asked how hard you're their workout was; each athlete's session-RPE was collected about 30 min after the training session to ensure that each subject reported a global RPE for the entire session rather than the most recent exercise (Singh et al., 2007). The data were collected by the coach of the team. Each player was confidentially interviewed and not allowed to see the values given by other players. Before the study, the CR-10 scale was explained to players verbally and used for two weeks to ensure that they were familiarized with it.

Table 1. The modified Borg Category Ratio-10 Rating of Perceived Exertion Scale.

Rating	Descriptor
0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very hard
8	
9	
10	Maximal

Two HR-based methods of determining internal load were used in this study. PLR TRIMP was obtained automatically by using the Polar Team Pro system. The other method used was the EDW TRIMP method, which determines TL by calculating the product of the accumulated training duration (minutes) in 5 HR zones applying a coefficient relative to each zone (50 – 60% of HRmax =1; 60 –70% of HRmax = 2; 70 – 80% of HRmax = 3; 80 –90% of HRmax =4; 90 –100% of HRmax = 5) and then summing the result (Manzi et al., 2010; Paulson et al., 2015; Scott, et al., 2013).

External training load

Players' movements during the training were recorded using a portable global positioning system (Polar electro, Kemple, Finland). A Polar Team Pro device was placed into a harness attached to specifically designed chest belts worn according to the manufacturer's instructions on the centre of the chest at the level of the xiphoid process (chest-mounted). All data were downloaded using the Team Pro web page (teampro.polar.com). During each session total distance (TD) was measured, with the players' activities divided into five speed thresholds: walking (.1–7.1 $km \cdot h^{-1}$); jogging (jog) (7.2–14.3 $km \cdot h^{-1}$); running (run) (14.4–19.7 $km \cdot h^{-1}$); high-speed running (HSR) (19.8–25.1 $km \cdot h^{-1}$); sprinting (> 25.1 $km \cdot h^{-1}$) (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010). Deceleration and acceleration actions thresholds were set for low-intensity, moderate-intensity and high-intensity ACC actions at 1–2, 2–3, and > 3 $m \cdot sn^{-2}$; DEC actions at -1–2, -2–3, and > -3 $m \cdot sn^{-2}$, respectively (Abbott, Brickley, Smeeton, & Mills, 2018).

Statistical Analysis

A total of 761 individual training sessions were monitored for the twenty soccer players. Individual correlations were determined based on data from a minimum of 18 training sessions to a maximum of 46. All data were analysed using the Statistical Package for the Social Sciences (SPSS version 21.0, Chicago, Illinois, USA). The mean and SD for each variable were determined to quantify the demands of each training session. Individual Pearson's product-moment correlations between s-RPE, HR-based measures, and external TL were computed using the number of practice sessions for each player according to the methods of Clarke et al. (Clarke et al., 2013). Before Pearson's calculations, product-moment correlations testing skewness and kurtosis were undertaken to determine the normality of the values (-2 – +2). The magnitude of all correlations were categorized according to the following scale: trivial (r < .1), small (r = .1 – .3), moderate (r = .3 – .5), large (.5 – .7), very large (r = .7 – .9), nearly perfect (r > .9), and perfect (r = 1) (Hopkins, Marshall, Batterham, & Hanin, 2009).

RESULTS

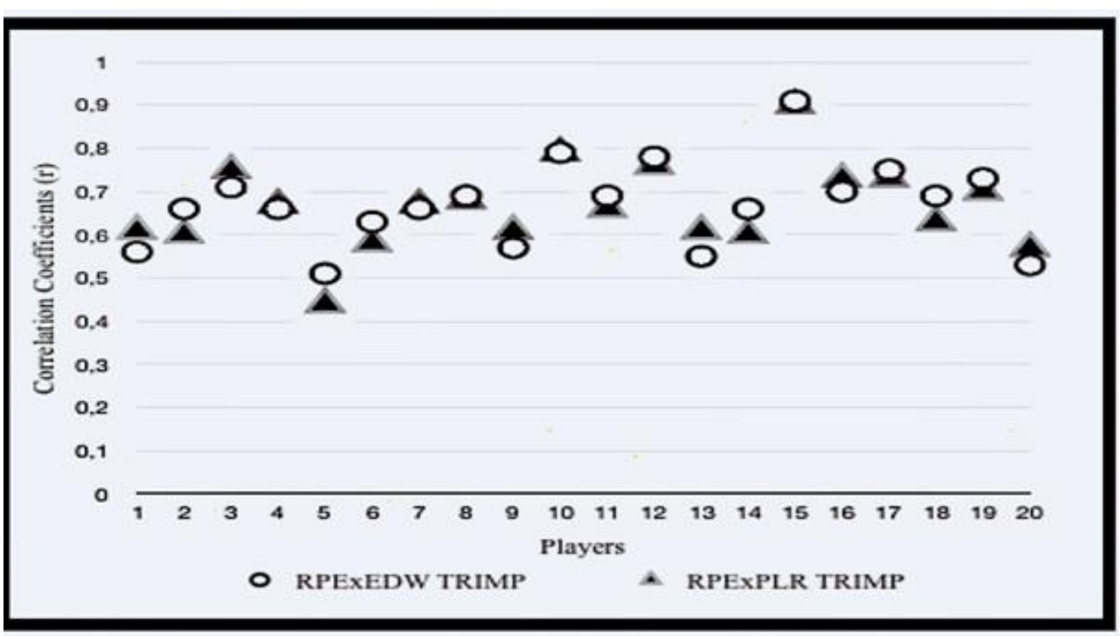

Figure 1. Individual correlations between s-RPE and Edwards (EDW) and Polar (PLR) training impulse (TRIMP).

A large to nearly perfect individual correlation was found between s-RPE and EDW TRIMP (r = .51 – .91). The correlations of s-RPE and PLR TRIMP were from moderate to nearly perfect (r = .44 – .90) (Figure 1). There was also a nearly perfect correlation between two HR-based TL methods (r = .84 – .99), as outlined in Figure 1. All correlations between internal load parameters were significant (p < .01).

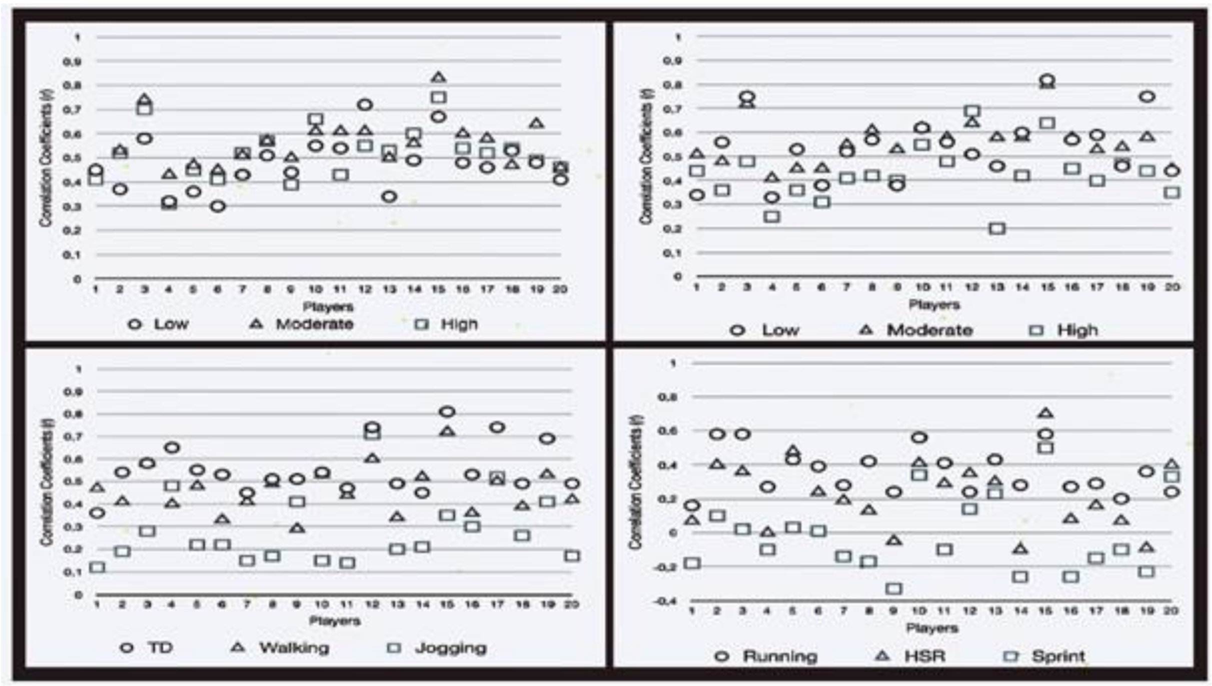

Figure 2. Individual correlations between s-RPE and (a) number of accelerations in the three different zones, (b) number of decelerations in the three different zones and (c) total distance (TD), walking distance and jogging distance and (d) running, high intensity running (HSR) and sprint distances.

As can be seen in Figure 2, there were small to very large correlations between s-RPE and number of ACC actions (between s-RPE and low r = .29 – .72; between s-RPE and moderate r = .42 – .82; between s-RPE and high r = .31 – .75) (Figure 2a). The correlations between s-RPE and number of ACC actions were statistically significant (p < .05) in almost all cases, the exceptions being player 6 in low-intensity zone and player 4 in low and high intensity zones.

Similarly, a small to very large individual correlation was found between s-RPE and the number of DEC actions (between s-RPE and low intensity r = .32 – .81; s-RPE and moderate intensity r = .40 –. 79; s-RPE and high intensity r = .19 – .68) (p < .05; all correlations were found to be significant except for those relating to players 13 and 6 in the high intensity zone) (see Figure 2b).

As shown in Figure 2c, moderate to very large relationships were found between s-RPE and TD and between s-RPE and distance covered at walking pace (r = .36 – .81; r = .29 – .7, respectively; p > .1); these were statistically significant for all players except player 1 for TD and player 9 for distance covered at walking pace were not significant).

According to our results, the correlation between s-RPE and distances covered became weaker in the higher intensity zones. While the relationships between s-RPE and Jogging (see Figure 2c) and between s-RPE and running were positive (small to very large: r = .12 – .71; r = .16 – .58, respectively), there were both negative and positive relations between s-RPE and HSR and between s-RPE and sprint distance covered (trivial to large: r = .001 – .69 - r = .009 – .501, respectively), as shown in Figure 2d. These correlations were significant for only 7 players in distance covered jogging, 9 players in running distance, 6 players in HSR distance, and 3 players in sprint distance, p < .05).

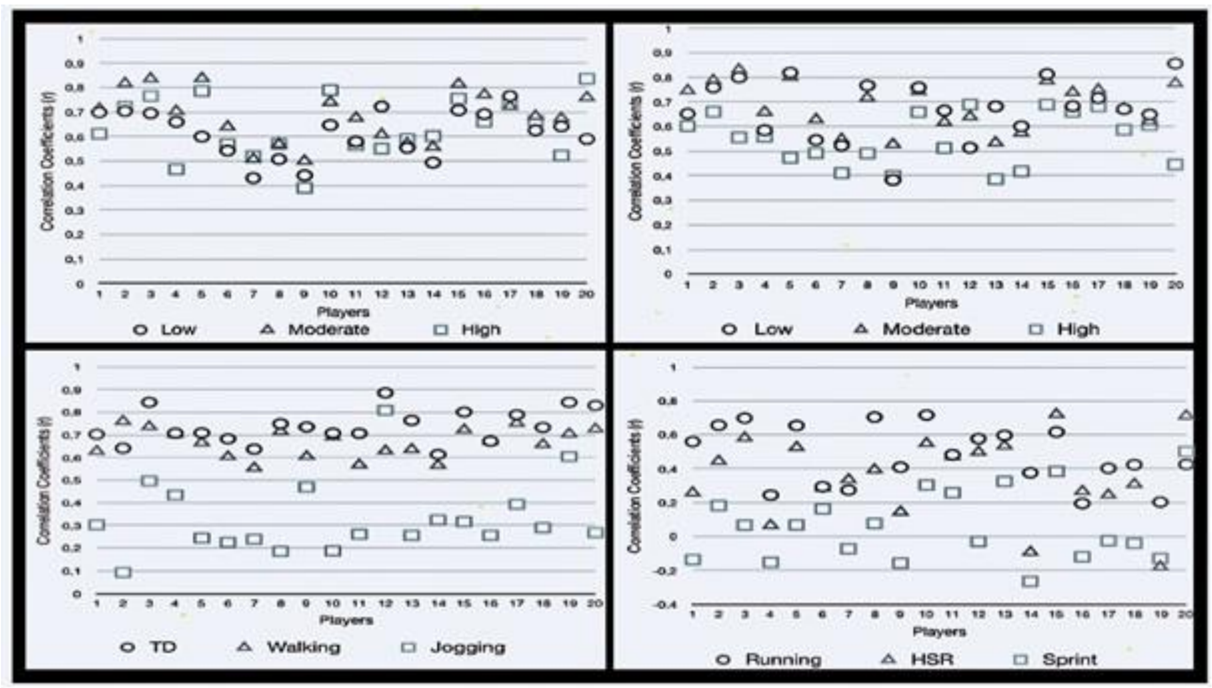

Figure 3. Correlations between Edwards TRIMP and (a) number of accelerations in the three zones, (b) number of decelerations in the three different zones and (c) total distance (TD), walking distance and jogging distance and (d) running, high intensity running (HSR) and sprint distance.

As shown in Figure 3a, significant moderate to very large relationships were found between EDW TRIMP and number of ACC actions (EDW TRIMP and low intensity r = .43 – .76; EDW TRIMP and moderate intensity r = .50 – .83; EDW TRIMP and high intensity r = .39 – .83, p > .01).

There were moderate to very large correlations between EDW TRIMP and number of DEC actions (EDW TRIMP and low intensity r = .38 – .85; EDW TRIMP and moderate intensity r = .52 –.83; EDW TRIMP and high intensity r = .38 –.68, p > .01) (see Figure 3b).

The correlations between EDW TRIMP and distance covered at high intensity were similar to those between s-RPE and these values. As shown in Figure 3, the correlations EDW TRIMP and jogging, running, HSR and sprint distances ranged from trivial to very large (EDW TRIMP and jogging distance r = .09 – .80; EDW TRIMP and running distance r = .19 – .71; EDW TRIMP and HSR distance r = .06 – .72; EDW TRIMP and sprint distance r = -.03 – .50). These correlations were found to be statistically significant for 7 players in jogging, 15 players in running, 12 players in HSR and 3 players in sprint, p > .05).

DISCUSSION

The present study aimed to examine the relationships between internal and external TL in professional soccer players. The main findings are related to the measures of HR based TLs (PLR TRIMP, EDW TRIMP) and s-RPE measures, which demonstrated large to nearly perfect correlations with each other, as shown in Figure 1. Our results are in line with previous studies that have examined the relationships between EDW TRIMP and s-RPE for quantifying training load in team sports such as Australian rules football (Scott, et al., 2013), soccer (Casamichana et al., 2013; Impellizzeri et al., 2004; Scott, et al., 2013), Canadian football (Clarke et al., 2013), basketball (Lupo et al., 2017; Manzi et al., 2010; Scanlan, Wen, Tucker, Borges, et al., 2014; Scanlan, Wen, Tucker, & Dalbo, 2014) and wheelchair rugby (Paulson et al., 2015). Impellizzeri et al. (2004) were the first researchers to report that s-RPE is a valid method to quantify internal TL in soccer players; large to very large correlations were reported between EDW TRIMP and s-RPE TL methods for player's reactions to training sessions in their study ($r = .54 – .78$, $p < .001$). Casamichana et al. (2013) and Scott et al. (2013) reported similar results, finding large and very large correlations between s-RPE and EDW TRIMP in soccer players ($r = .57$, $.77$, respectively). Parallel results have been obtained in studies conducted in basketball, which reported significant relationships from very large to nearly perfect between individual s-RPE and EDW TRIMP (between $r = .75$- $.95$) (Lupo et al., 2017; Manzi et al., 2010; Scanlan, Wen, Tucker, & Dalbo, 2014). Besides, Scott et. al. (2013) and Paulson et al. (2015) found very large ($r = > .80$) and large ($r = .64$) correlations between s-RPE and EDW TRIMP methods in their studies. EDW TRIMP is the most common HR-based method, thus many studies have examined the relationship between EDW TRIMP and s-RPE. However, to our knowledge only one study has compared the relationship between s-RPE and PLR TRIMP. Clarke et al. (2013) found significant correlations between s-RPE with PLR TRIMP in Canadian football players ($r = .65 – .91$). Our study is therefore in line with previous studies in showing that s-RPE is a valid, reliable, inexpensive and straightforward method for monitoring TL in team sports (Foster et al., 2001; Singh et al., 2007; Wallace et al., 2014). On the other hand, coaches should consider that the individual psychological states of players could lead them to perceive the same physiological stimuli differently (Morgan, 1973), which can cause intra-individual variations while using s-RPE. Moreover, the correlations between s-RPE and heart rate-based methods are lower in interval-based training than in endurance-based training (Foster, 1998). A possible explanation for this difference could be the energy demands of soccer training, which involves intermittent actions requiring both aerobic and anaerobic sources for energy provision in the same training session (Bangsbo, 1994; Halson, 2014). In the light of this information, it is recommended that both s-RPE and HR based TL measures are employed to monitor internal TL in soccer players.

One of the important findings of our study is that, while the correlation between s-RPE and TD ranged from moderate to nearly perfect (mean $r = .55$), the correlations between s-RPE and distance covered in the five different speed zones fluctuated greatly across the training sessions assessed (see Figures 2c and 2d). Similarly, previous studies have showed that, while distance covered each session is strongly associated with s-RPE (Bartlett, O'Connor, Pitchford, Torres-Ronda, & Robertson, 2017; Casamichana et al., 2013; Paulson et al., 2015; Scott, et al., 2013), as the speed of external TL increases, the correlations with s-RPE become weaker (Scott, et al., 2013). Decreasing GPS validity in high-intensity exercises can be an important factor in the emergence of this finding (Scott, et al., 2013). Another possible explanation for lower RPE responses after high-intensity activities could be the structure of high-intensity training, with long rest periods between high-speed activities such as sprint training (Paulson, et al., 2015). Coaches should still take into account HSR and sprint data, which may provide important information pertaining to the external TL of soccer players, because, while TD is the most important descriptor of internal load for one player, HSR or sprint distance covered could be for another (Bartlett et al., 2017; Scott, et al., 2013). EDW and PLR TRIMP also were used as internal load training monitoring methods in the current study. The correlations between HR-based methods and TD, and between HR-based methods and distances covered in the five speed zones were similar to the correlations between s-RPE and those external TL methods. Scott et. al. (2013) reported a strong correlation between HR-based methods and distance covered at low speeds but the correlations became weaker with distances covered at higher speeds. The reason HR-based internal-TL measures may be underestimated is that due to the contribution of anaerobic metabolism to high-intensity activities, HR responses of players change slowly because of the short duration of high-intensity exercise (Scott, et al., 2013).

Another important finding of this study was the large and very large correlations between both s-RPE and HR based methods and numbers of ACC and DEC actions independent of zones. Acceleration capabilities of players are vital in decisive activities and may be more important than a player's maximal running speed in team sports (Vázquez-Guerrero, Suarez-Arrones, Gómez, & Rodas, 2018). Dalen et al. (2016) reported that DEC and ACC contributed to up to 10% of the total player load (PL) in soccer. Thus, calculating the number of ACC and DEC actions and PL using the sum of accelerations recorded in the three principal axes of movement (anteroposterior, mediolateral, and craniocaudal) are very common external load monitoring methods over recent decades (Boyd, Ball, & Aughey, 2013; Castillo, Weston, McLaren, Cámara, & Yanci, 2017; Scanlan, Wen, Tucker, Borges, et al., 2014; Soligard et al., 2016). Although accelerometers and GPS devices that enable ACC parameters to be measured have been used for individualization and optimization of exercise and recovery programs by coaches and sports scientists there are few studies in team sports which have made use of those values. One of these studies reported large to very large correlations between PL and EDW TRIMP and s-RPE in soccer players ($r = .70$ and $.74$, respectively) (Casamichana et al., 2013). In a similar study, Scott et. al. (Scott, et al., 2013)reported a strong correlation between s-RPE and PL in Austrian football players; they stated that PL is a valid tool for examining the training load in team sports. Some soccer-specific very high-intensity activities such as dribbling, heading, tackling and kicking which include jumps and turns could be classified under a low-speed locomotor category because players are not able to reach high-speed zones, even though these movements impose a high physiological load on the player (Dalen et al., 2016; Scott, et al., 2013). Therefore, the use of ACC and DEC actions as well as speed and displacement data could be vital in order to measure external load responses (Gaudino, Alberti, & Iaia, 2014; Scott, et al., 2013).

However, some studies questioned the value of measuring ACC and DEC actions by comparing relationships between internal TL and ACC-based methods. Gomez-Piriz et al. (2011) reported that s-RPE was a significant predictor of TL according to results of a linear regression analysis ($\beta = .23$, $p < .05$), but found that s-RPE only accounted for 5% of the variance in PL values in soccer players. They argued that the ACC-based training load may not be a valid tool for coaches to quantify exercise load during soccer- specific training. Moreover, Scanlan et al. (2014) reported only a moderate relationship ($r = .49$) between s-RPE and PL in basketball players. A possible explanation for different results of the aforementioned studies compared to our results is that while all field training was included in our study, just small-sided games and basketball drills were monitored in these two studies. The small pitch where players performed more ACC and DEC actions could have had a negative effect on correlation between s-RPE and heart rate-based methods and ACC-based training load because of the intermittent nature of these training methods, where players meet their energy demands predominantly through anaerobic sources (Bangsbo, 1994; Foster, 1998; Impellizzeri et al., 2004). Therefore, coaches and sports science practitioners should take account of all external TL together for comprehensive perspective on monitoring, especially in training performed on relatively small pitches.

CONCLUSION

According to our results, while s-RPE and both HR-based training load models show strong correlations with the number of ACC and DEC actions and with TD, correlations with distances covered in high-speed zones are less convincing. In any case, with the prevalence of the use of small-sided games in soccer training, distance covered in different speed zones may not be a particularly relevant, since small pitches may not allow players to reach high speeds for extended periods. In these circumstances, ACC-based methods could be a good alternative for monitoring external training load. The most common ACC-based method is the player load method that has been already validated, but this method requires a sophisticated equation in the calculation process. Thus, measuring the number of ACC and DEC actions could be a good alternative to this in monitoring soccer training. We argue that a combination of the internal and external load methods seems to be the best way for monitoring training load in soccer players.

SUPPORTING AGENCIES

No funding agencies were reported by the author.

DISCLOSURE STATEMENT

The author declares no conflicts of interest.

REFERENCES

Abbott, W., Brickley, G., Smeeton, N. J., & Mills, S. (2018). Individualizing acceleration in english premier league academy soccer players. Journal of Strength and Conditioning Research, 32(12), 3503–3510. https://doi.org/10.1519/jsc.0000000000002875

Alexandre, D., Silva, C. D. Da, Hill-Haas, S., Wong, D. P., Natali, A. J., De Lima, J. R. P., … Karim, C. (2012, October). Heart ratemonitoring in soccer: Interest and limits during competitive match play and training, practical application. Journal of Strength and Conditioning Research, Vol. 26, pp. 2890–2906. https://doi.org/10.1519/JSC.0b013e3182429ac7

Bangsbo, J. (1994). The physiology of soccer - With special reference to intense intermittent exercise. Acta Physiologica Scandinavica, Supplement, 151(619), 1–155.

Barris, S., & Button, C. (2008). A review of vision-based motion analysis in sport. Sports Medicine, Vol. 38, pp. 1025–1043. https://doi.org/10.2165/00007256-200838120-00006

Bartlett, J. D., O'Connor, F., Pitchford, N., Torres-Ronda, L., & Robertson, S. J. (2017). Relationships between internal and external training load in team-sport athletes: Evidence for an individualized approach. International Journal of Sports Physiology and Performance, 12(2), 230–234. https://doi.org/10.1123/ijspp.2015-0791

Bourdon, P. C., Cardinale, M., Murray, A., Gastin, P., Kellmann, M., Varley, M. C., … Cable, N. T. (2017). S2-161 Monitoring Athlete Training Loads: Consensus Statement. International Journal of Sports Physiology and Performance, 12. https://doi.org/10.1123/IJSPP.2017-0208

Boyd, L. J., Ball, K., & Aughey, R. J. (2013). Quantifying external load in australian football matches and training using accelerometers. International Journal of Sports Physiology and Performance, 8(1), 44–51. https://doi.org/10.1123/ijspp.8.1.44

Bradley, P. S., Di Mascio, M., Peart, D., Olsen, P., & Sheldon, B. (2010). High-intensity activity profiles of elite soccer players at different performance levels. Journal of Strength and Conditioning Research, 24(9), 2343–2351. https://doi.org/10.1519/JSC.0b013e3181aeb1b3

Casamichana, D., Castellano, J., Calleja-Gonzalez, J., RomaN, J. S., & Castagna, C. (2013). Relationship between indicators of training load in soccer players. Journal of Strength and Conditioning Research, 27(2), 369–374. https://doi.org/10.1519/JSC.0b013e3182548af1

Castillo, D., Weston, M., McLaren, S. J., Cámara, J., & Yanci, J. (2017). Relationships between internal and external match-load indicators in soccer match officials. International Journal of Sports Physiology and Performance, 12(7), 922–927. https://doi.org/10.1123/ijspp.2016-0392

Clarke, N., Farthing, J. P., Norris, S. R., Arnold, B. E., & Lanovaz, J. L. (2013). Quantification of training load in Canadian football: Application of session-RPE in collision-based team sports. Journal of Strength and Conditioning Research, 27(8), 2198–2205. https://doi.org/10.1519/JSC.0b013e31827e1334

Dalen, T., JØrgen, I., Gertjan, E., Havard, H. G., & Ulrik, W. (2016). Player load, acceleration, and deceleration during forty-five competitive matches of elite soccer. Journal of Strength and Conditioning Research, 30(2), 351–359. https://doi.org/10.1519/JSC.0000000000001063

Foster, C. (1998). Monitoring training in athletes with reference to overtraining syndrome. In Med. Sci. Sports Exerc (Vol. 30).

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A New Approach to Monitoring Exercise Training. In Journal of Strength and Conditioning Research (Vol. 15). https://doi.org/10.1519/00124278-200102000-00019

Gaudino, P., Alberti, G., & Iaia, F. M. (2014). Estimated metabolic and mechanical demands during different small-sided games in elite soccer players. Human Movement Science, 36, 123–133. https://doi.org/10.1016/j.humov.2014.05.006

Gomez-Piriz, P. T., JiméNez-Reyes, P., & Ruiz-Ruiz, C. (2011). Relation between total body load and session rating of perceived exertion in professional soccer players. Journal of Strength and Conditioning Research, 25(8), 2100–2103. https://doi.org/10.1519/JSC.0b013e3181fb4587

Güvenç, A., Açikada, C., Aslan, A., & Özer, K. (2011). Daily physical activity and physical fitness in 11- to 15-year-old trained and untrained Turkish boys. Journal of Sports Science and Medicine, 10(3), 502–514.

Halson, S. L. (2014, November 1). Monitoring Training Load to Understand Fatigue in Athletes. Sports Medicine, Vol. 44, pp. 139–147. https://doi.org/10.1007/s40279-014-0253-z

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009, January). Progressive statistics for studies in sports medicine and exercise science. Medicine and Science in Sports and Exercise, Vol. 41, pp. 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Ian Lambert, M., & Borresen, J. (2010, September). Measuring training load in sports. International Journal of Sports Physiology and Performance, Vol. 5, pp. 406–411. https://doi.org/10.1123/ijspp.5.3.406

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. Medicine and Science in Sports and Exercise, 36(6), 1042–1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Lupo, C., Tessitore, A., Gasperi, L., & Gomez, M. A. R. (2017). Session-RPE for quantifying the load of different youth basketball training sessions. Biology of Sport, 34(1), 11–17. https://doi.org/10.5114/biolsport.2017.63381

Manzi, V., D'ottavio, S., Impellizzeri, F. M., Chaouachi, A., Chamari, K., & Castagna, C. (2010). Profile of weekly training load in elite male professional basketball players. Journal of Strength and Conditioning Research, 24(5), 1399–1406. https://doi.org/10.1519/JSC.0b013e3181d7552a

McLaren, S. J., Smith, A., Spears, I. R., & Weston, M. (2017). A detailed quantification of differential ratings of perceived exertion during team-sport training. Journal of Science and Medicine in Sport, 20(3), 290–295. https://doi.org/10.1016/j.jsams.2016.06.011

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. Journal of Sports Sciences, 21(7), 519–528. https://doi.org/10.1080/0264041031000071182

Morgan, W. P. (1973). Psychological factors influencing perceived exertion. Medicine and Science in Sports, 5(2), 97–103. https://doi.org/10.1249/00005768-197300520-00019

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & Di Prampero, P. E. (2010). Energy cost and metabolic power in elite soccer: A new match analysis approach. Medicine and Science in Sports and Exercise, 42(1), 170–178. https://doi.org/10.1249/MSS.0b013e3181ae5cfd

Paulson, T. A. W., Mason, B., Rhodes, J., & Goosey-Tolfrey, V. L. (2015). Individualized Internal and External Training Load Relationships in Elite Wheelchair Rugby Players. Frontiers in Physiology, 6. https://doi.org/10.3389/fphys.2015.00388

Scanlan, A. T., Wen, N., Tucker, P. S., Borges, N. R., & Dalbo, V. J. (2014). Training mode's influence on the relationships between training-load models during basketball conditioning. International Journal of Sports Physiology and Performance, 9(5), 851–856. https://doi.org/10.1123/ijspp.2013-0410

Scanlan, A. T., Wen, N., Tucker, P. S., & Dalbo, V. J. (2014). The relationships between internal and external training load models during basketball training. Journal of Strength and Conditioning Research, 28(9), 2397–2405. https://doi.org/10.1519/JSC.0000000000000458

Schwellnus, M., Soligard, T., Alonso, J. M., Bahr, R., Clarsen, B., Dijkstra, H. P., … Engebretsen, L. (2016). How much is too much? (Part 2) International Olympic Committee consensus statement on load in sport and risk of illness. British Journal of Sports Medicine, 50(17), 1043–1052. https://doi.org/10.1136/bjsports-2016-096572

Scott, B. R., Lockie, R. G., Knight, T. J., Clark, A. C., & Janse De Jonge, X. A. K. (2013). A Comparison of Methods to Quantify the In-Season Training Load of Professional Soccer Players. In International Journal of Sports Physiology and Performance. https://doi.org/10.1123/ijspp.8.2.195

Scott, T. J., Black, C. R., Quinn, J., & Coutts, A. J. (2013). Validity and reliability of the session-rpe method forquantifying training in australian football: A comparison of the cr10 and cr100 scales. Journal of Strength and Conditioning Research, 27(1), 270–276. https://doi.org/10.1519/JSC.0b013e3182541d2e

Singh, F., Foster, C., Tod, D., & McGuigan, M. R. (2007). Monitoring different types of resistance training using session rating of perceived exertion. International Journal of Sports Physiology and Performance, 2(1), 34–45. https://doi.org/10.1123/ijspp.2.1.34

Soligard, T., Schwellnus, M., Alonso, J. M., Bahr, R., Clarsen, B., Dijkstra, H. P., … Engebretsen, L. (2016). How much is too much? (Part 1) International Olympic Committee consensus statement on load in sport and risk of injury. British Journal of Sports Medicine, 50(17), 1030–1041. https://doi.org/10.1136/bjsports-2016-096581

Varley, M. C., & Aughey, R. J. (2013). Acceleration profiles in elite Australian soccer. International Journal of Sports Medicine, 34(1), 34–39. https://doi.org/10.1055/s-0032-1316315

Vázquez-Guerrero, J., Suarez-Arrones, L., Gómez, D. C., & Rodas, G. (2018). Comparing external total load, acceleration and deceleration outputs in elite basketball players across positions during match play. Kinesiology, 50(2), 228–234. https://doi.org/10.26582/K.50.2.11

Wallace, L. K., Slattery, K. M., & Coutts, A. J. (2014). A comparison of methods for quantifying training load: Relationships between modelled and actual training responses. European Journal of Applied Physiology, 114(1), 11–20. https://doi.org/10.1007/s00421-013-2745-1