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Research article

The Ratio between Weekly Training and Match External Physical Loads in U17 Elite Youth Soccer Players: Implications for the Training Process

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Abstract
Research on the external physical load on elite youth soccer players during the weekly training microcycle in competitive periods and official matches is limited. The aims of this study were two-fold: a) investigate possible differences in external physical load (PL) across player positions in U17 elite youth soccer players during official matches; b) determine the weekly training to match physical load ratio (WTMLr) across player positions. The sample included 20 outfield players from an elite soccer academy (mean age 15.94 ± 0.25 years) playing in four positions: central defender (CD), full-back (FB), central midfielder (CM) and Striker (S). Data were collected during the spring in-season period for 17 official matches played in a 4-3-3 game format. Indicators of external physical load monitored were: total distance (TD); total distance in high-speed running (HSR; > 16.1 km.h^{-1}); total distance in sprint running (SPR; > 21.6 km.h^{-1}); and relative physical load intensity (%HSR). The WTMLr was calculated for TD, HSR, SPR and %HSR as the ratio of the average weekly sum of training PL to the average sum of PL in an official match for a given players' position. Collectively, the training intensity during a one-week microcycle (%HSR in WTMLr) achieved only 76 % of match demands. CD performed significantly lower in all measured indicators of external PL during the official match than all other positions ($p < 0.05$; $g > 0.80$) except for TD in S. S achieved significantly higher SPR during official matches compared to CD ($p < 0.05$; $g > 0.80$), CM, and FB ($g > 0.80$). In contrast, CD reported higher WTMLr (medium-large effect size) in HSR and SPR indicators than all other positions. CM performed significantly higher %HSR in WTMLr than S and FB ($p < 0.05$; $g > 0.80$). Results revealed insufficient training intensity relative to match demands and, at the same time, weekly training PL did not meet match demands (especially in HSR and SPR) for players across the different positions. Therefore, practitioners should select appropriate training methods (drills and games) to ensure sufficient training intensity (HSR and SR metrics) and consider using the WTMLr, which can be used to help optimise and individualise training PL for different player positions.

Key words: GPS monitoring, physical workload, individualisation, training, performance, youth.

Introduction

In the last decade and a half, there has been a rapid increase in the number of research studies dedicated to using GPS technology in monitoring external physical load (PL) in soccer. The primary goals are to optimise player physical performance and reduce the risk of injury (Miguel et al., 2021; Ravé et al., 2020; Palucci Vieira et al., 2019; Cummins et al., 2013). Coaches and other practitioners typically use the information from GPS technology to monitor changes in a player's physical performance over time, quantify training PL, and inform injury prevention via the design of specific exercises/games to better replicate the demands of a match (Buchheit and Simpson, 2017).

To optimise match physical performance over time, it is necessary to analyse each player's specific physical activity profile during the game (Lechner et al., 2023; Martín-García et al., 2018). These profiles are then used to plan monthly, weekly, and daily training PL, both for the whole team, and for each player individually (Martín-García et al., 2018). Planning external training PL every week is necessary whilst accounting for each player's performance level (Ravé et al., 2020). As part of this planning, the ratio of weekly training to match PL (WTMLr) can help prepare players notably for worst-case scenarios or the most physically demanding short periods during the match (McCall et al., 2020).

However, research on the WTMLr in the framework of weekly training microcycles seems fundamentally limited. Teixeira et al. (2021) reported only two studies (Clemente et al., 2019; Anderson et al., 2016) on this in a recent systematic review with significant differences in findings observed across studies. Anderson et al. (2016) reported a WTMLr of 0.56 for total distance (TD), 0.22 for high-speed runs (HSR) and only 0.03 for sprints (SPR) which means that the cumulative weekly training PL was far below the match demands. In contrast, Clemente et al. (2019) observed a significant greater weekly training PL compared to match PL (2.8 times for TD; 2.0 times for HIR and 3.5 times for accelerations). Variables such as the number of training sessions and games within a weekly microcycle may cause different WTMLr across these microcycles and, thus, must be considered when analysing players' PL (Teixeira et al., 2021). Since the WTMLr is recommended to stabilise and optimise player performance growth in the long term, it is necessary to monitor this ratio in young elite soccer players (Ravé et al., 2020). However, results mapping the WTMLr are substantially limited for young elite youth soccer categories (e.g. U15 - U17).

As information about players' physical performance during a match primarily serves to plan PL in the weekly training cycles (Ravé et al., 2020), it is necessary to point out that the match PL differs significantly in relation to playing position in elite youth soccer (Maughan et al., 2021; Pettersen and Brenn, 2019; Saward et al., 2016). For instance, Maughan et al. (2021) found in a study in twenty Scottish elite youth players that Wide Midfielders (WM)

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achieved greater HSR than Central Defenders (CD), had greater SPR compared to CD and Central Midfielders (CM) and reported more accelerations than CM. Similarly, the performance of CD in TD and HSR indicators was the lowest in comparison to other players' positions while the performance of CM in TD was the highest (Pettersen and Brenn, 2019). On the other hand, some studies found only limited differences in training and match PL between players' positions, with only a small effect size for the differences (Maughan et al., 2021; Nobari et al., 2021). Moreover, Nobari et al. (2021) pointed out that current research on the assessment of training and match PL with respect to players' positions is very limited. Therefore, a fundamental question posed by Palucci Vieira et al. (2019) is whether there are meaningful differences between players' positions, and if these differences are uniform across youth categories.

The above results confirmed differences in PL depending on players' positions during official matches of youth elite soccer players. However, research mapping the PL patterns in youth soccer using the WTMLr and its magnitude for traditionally used PL metrics (TD, HSR, SPR) with respect to different players' positions seems substantially limited. Recent studies emphasize the need for information on WTMLr in elite youth soccer for individual player positions to ensure maximal optimisation of long-term PL distribution in young prospective players and, therefore, help their successful transition to adult categories (Maughan et al., 2021; Nobari et al., 2021). This study aims to: a) investigate possible differences in PL among U17 elite soccer players during official matches for different player positions; b) determine the WTMLr, with subsequent analysis of differences between player positions. Based upon previous findings, we hypothesize that significant differences will exist between players positions during an official match and in the WTMLr.

Methods

Participants

Twenty soccer players from an elite Czech soccer academy (mean age 15.94 ± 0.25 years) were part of the study. All players had to meet the following criteria: (i) at least 5 years of playing experience in soccer; (ii) no physical limitations or injuries during the in-season period which would limit their health or affect the study findings. Player positions included central defenders (CD, n = 3); full backs (FB, n = 4); central midfielders (CM, n = 5); and strikers (S, n = 8). Goalkeepers were not included. The research did not place any additional burden on the players, as the club collected this data as part of its routine monitoring system. Players signed an informed consent form about the usage of the data for the purpose of this study. The research was conducted in accordance with the Declaration of Helsinki, and was approved by the Ethics Committee of the Charles University Faculty of Physical Education and Sport.

Research design

Training and match data were collected over 17 weeks during the spring in-season part of the year-round season. During this period, a total of 68 soccer training sessions and 17 official matches were held. Only data where the player completed a full match (≥ 90 min) were included (CD = 15, FB = 12, CM = 12, S = 12) to investigate differences in PL during official matches for different player positions. Regarding the WTMLr evaluation, only data where the player participated in all four soccer training sessions and an official match (CD = 5, FB = 10, CM = 11, S = 18) during the weekly microcycle were included. Additionally, to analyse PL in different training sessions during a training week, we used a categorisation system described by Malone et al. (2015), where days which included training sessions before match day (MD), were designated as MD -1 (one day before match day) to MD -5 (five days before match day). MD -6 (six days before match day) was usually a day without training. For this and for WTMLr analysis, training data were used only from weeks with only one official match (13 weeks; 77 %). Regular week microcycles always consisted of four soccer training sessions (/i/ specific technical-tactical players' positions training, /ii/ speed, agility, medium/large-sided games, /iii/ small-sided games focused on anaerobic performance, /iv/ explosive strength, middle medium-sided games) of ninety minutes, one Tabata session (high-intensity non-specific exercises), and one gym-session (strength weight training). Tabata and gym sessions were not included. Exclusion criteria were a) the player did not play the entire match; b) the player did not participate in all four soccer training sessions per week (only regarding WTMLr analysis); c) the player did not complete the entire training session; d) the player did not train at their maximum owing to recovering, or was injured during a training session. All official matches were played with 11 players on each side, in a basic 4:3:3 formation, with a playing time of 2x45 minutes.

Data collection

Data were collected using GPS (Global Positional System) monitoring devices, which are certified for competitive matches by FIFA (SPT Group Pty Ltd., Perth, Australia). The devices have a 10Hz scan rate (10 records per second), 10Hz tri-axial magnetometer, 400Hz tri-axial accelerometer, and gyroscope. Players were familiar with the devices. Players wore tight-fitting vests during training where the chip was placed on the back in the area between the shoulder blades. After each training/match, data from the chip was uploaded to online software.

External PL indicators

The variables measured in this study were: Total distance covered (TD); distance covered by running at high speed > 16.1 km.h^{-1} (HSR); distance covered by running at sprint speed > 21.6 km.h^{-1} (SPR); and relative load intensity as percentages of HSR from TD (%HSR). These indicators were measured and collected as sums of weekly training loads and during official matches. Following commonly accepted recommendations for modified or lower speed thresholds in youth categories compared to adults (Harkness-Armstrong et al., 2022; Atan et al., 2014), lower speed thresholds were used in our study. These were chosen arbitrarily since there is not yet any universally designated standard values.

Data from each player's training process for the entire week were tallied as weekly totals. From the match

data, averages were calculated for each player's position from only matches where that player played a full match (≥ 90 min) at that position. The weekly training to match physical load ratio (WTMLr) was then calculated for players who participated in all four training sessions during a week. The calculation was performed as follows: WTMLr = average weekly sum of training PL to average sum of PL in an official match for a given players' position. WTMLr was calculated for all external PL variables: TD, HSR, SPR and %HSR.

Statistical analysis

The Kolmogorov-Smirnov and Shapiro-Wilks tests were used to test for the normality of the data ($p < 0.05$ to reject the normality of the data). Due to the partially violated normality of the data and the relatively small number of observations, we used the non-parametric Kruskal-Wallis test ($p < 0.05$) to assess the statistical significance of differences in physical load indicators between players' positions: a) during official matches; and, b) when evaluating WTMLr. The Effect Size (ES) of differences between players' positions was assessed using Hedges' g coefficient, with the following interpretation of the magnitude of effects: < 0.50 small effect, 0.50 - 0.80 medium effect, > 0.80 large effect (Brydges, 2019). Hedges' g was used because it is appropriate for groups with different sample sizes. Statistical analyses were performed using IBM SPSS statistical software (SPSS version 24, Chicago, USA).

Results

Table 1 presents the differences between player positions during official matches in TD, HSR, SPR and %HSR. Significantly lower values for TD were observed for CD compared to FB ($p < 0.05$; $g = 2.80$), and CM ($p < 0.05$; $g = 0.95$), respectively. In the HSR indicator, CD again reported significantly lower values in matches compared to CM ($p < 0.01$; $g = 2.07$), FB ($p < 0.05$; $g = 2.48$), and S ($p < 0.05$; $g = 2.30$). Significantly lower values were observed in CD for SPR ($p < 0.05$; $g = 1.08$ - 4.19), and %HSR ($p < 0.05$; $g = 1.85$ - 2.52) compared to all other player positions. Concerning SPR, S demonstrated higher values than all other player positions ($g = 0.81$ - 4.19).

Figure 1 compares the cumulative weekly training load with the load reported during the match (WTMr). CM achieved the greatest values in the weekly training load of all four indicators of PL compared to all other players' positions, but these differences were not statistically significant. CD achieved the highest multiplier values in HSR and SPR compared to all other positions; however, these differences also were not statistically significant. The highest multiplier value in %HSR was reported in CM, which was significantly different to FB ($p < 0.05$) and S ($p < 0.01$), but not to CD.

Figure 2 only reports the effect size values using Hedges' g coefficient for each indicator of PL concerning each pair of player positions. The first four columns show the weekly training PL, while the remaining four describe WTMr. Regarding WTMr, greater values for HSR ($g = 0.55$ - 0.73) and SPR ($g = 0.61$ - 1.60) were observed in CD compared to all other players' positions. The highest values for %HSR were achieved by CM ($g = 0.72$ - 1.80) compared to all other players' positions. Also, CD showed greater values in %HSR compared to FB ($g = 0.71$) and S ($g = 0.92$).

PL in the match was significantly higher ($p < 0.01$) in all monitored indicators compared to all training days except %HSR between MD and MD-2 (Table 2). The TD, HSR, and SPR volume was significantly higher ($p < 0.01$) in MD-3 compared to MD-1 and MD-2. The highest %HSR values were achieved by players in MD-2, which was significantly different from MD-1 ($p < 0.01$) but not significantly different to the other training days of the week.

Table 1. Comparison of external physical load indicators between different players' positions during official match.

	All players	CD	FB	CM	S	P value	Hedges' g
TD (m)	8906.7±1085.8	8361.3±466.7	9608.4±434.1	9405.2±1322.5	8391.9±1281.1	CD vs. FB** CD vs. CM*	CD vs. FB†† CD vs. CM†† FB vs. S†† CM vs. S†
HSR (m)	933.0±275.4	634.1±122.7	1017.6±168.1	1136.4±288.7	1018.7±176.7	CD vs. FB** CD vs. CM** CD vs. S**	CD vs. FB†† CD vs. CM†† CD vs. S†† FB vs. CM†
SPR (m)	209.6±93.5	122.3±39.5	220.3±65.2	227.9±118.6	289.6±40.1	CD vs. FB* CD vs. CM* CD vs. S**	CD vs. FB†† CD vs. CM†† CD vs. S†† FB vs. S†† CM vs. S†
%HSR	10.4±2.6	7.6±1.2	10.6±1.8	12.0±2.1	12.3±2.0	CD vs. FB* CD vs. CM** CD vs. ST**	CD vs. FB†† CD vs. CM†† CD vs. S†† FB vs. CM† FB vs. S††

TD: total distance covered; HSR: distance covered by high-speed runs > 16.1 km.h^{-1}; SPR: distance covered by sprint runs > 21.6 km.h^{-1}; % HSR: relative load intensity, percentages of HSR from TD; CD: central defender; FB: full back; CM: central midfielder; S: striker; * p <0.05; ** p <0.01; † g = 0.5-0.8; †† g > 0.8.

Discussion

The aim of this study was to evaluate selected external variables of physical load (PL) in elite youth soccer players with respect to player positions: a) during official matches; and b) in WTMLr. The results showed significant PL

differences across players' positions during official matches. Furthermore, significant differences were observed in WTMLr.

During official matches, the U17 players in our study covered TD 9000 meters on average, which is less than that reported in U17 players in other studies (Pettersen and Brenn, 2019; Goto and Saward, 2020) where they covered more than 11000 meters. A possible explanation for this difference could be the different mean age across cohorts, even if players were in the same age category. On the other hand, some studies have revealed higher PL in younger age categories compared to older players (Ammann et al., 2023; Morgans et al., 2022; Vigh-Larsen et al., 2018). These findings have often been attributed to differences in style of play, tactical strategies regarding opponents, or lower technical-tactical game understanding among younger players (Ammann et al., 2023; Vigh-Larsen et al., 2018).

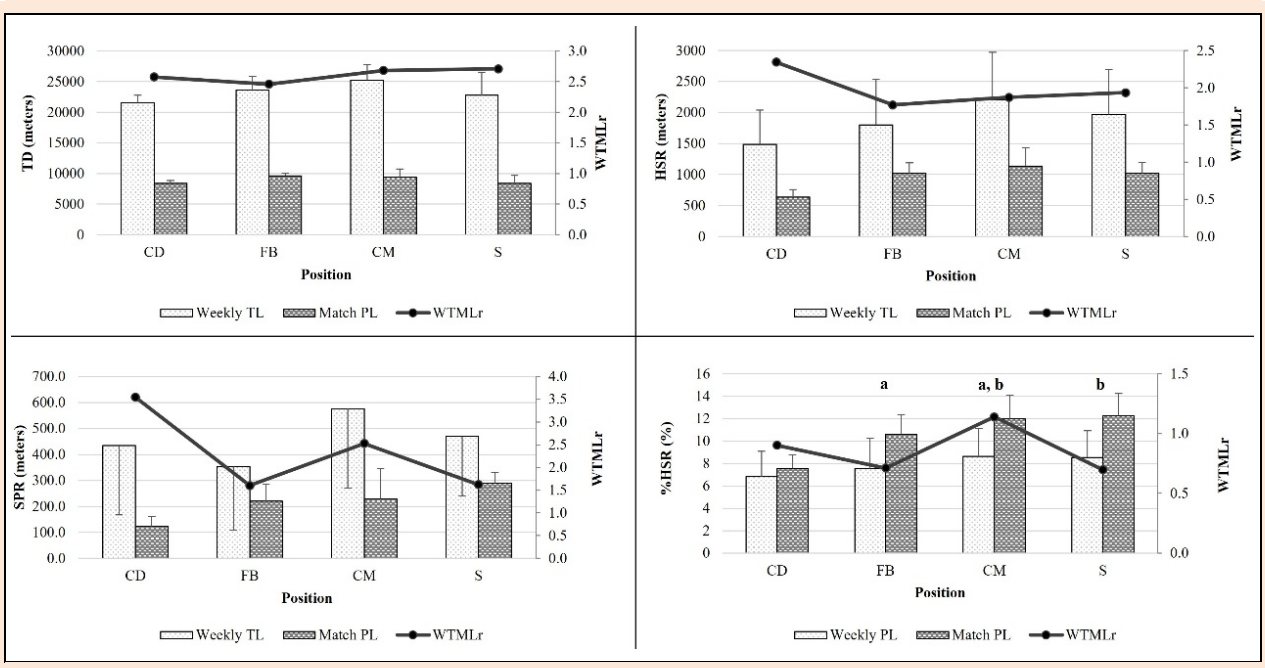

Figure 1. WTMr between different players' positions. TD: total distance covered; HSR: distance covered by high-speed runs > 16.1 km.h^{-1}; SPR: distance covered by sprint runs > 21.6 km.h^{-1}; % HSR: relative load intensity, percentages of HSR from TD; CD: central defender; FB: full back; CM: central midfielder; S: striker; a: $p < 0.05$ in WTMLr; b: $p < 0.01$ in WTMLr.

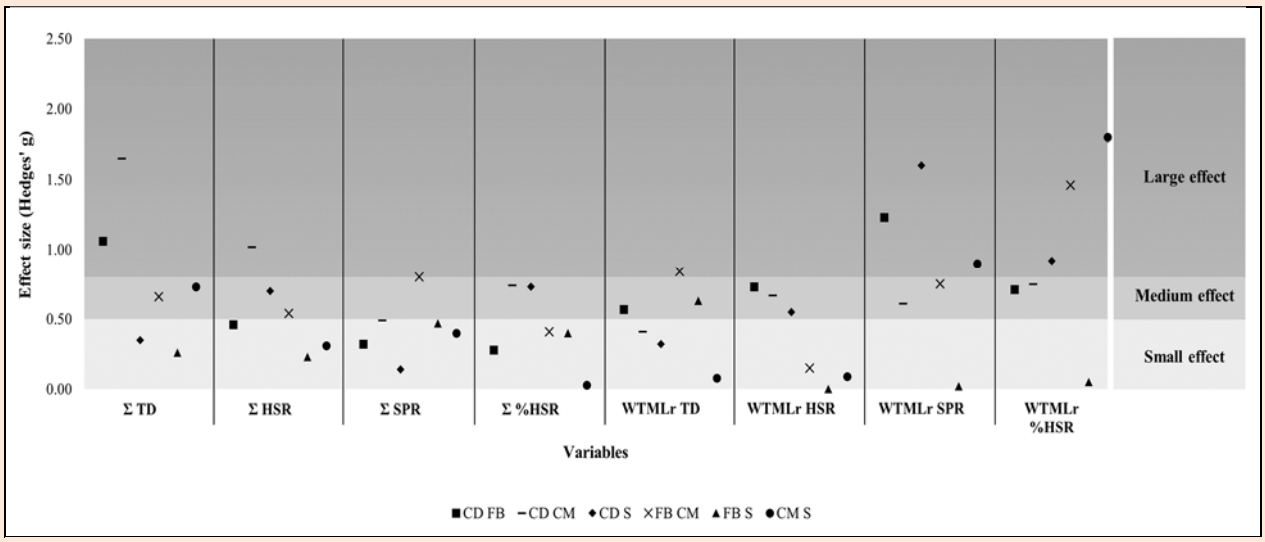

Figure 2. Effect size comparison of physical load between different players' positions a) in the cumulative weekly training load; b) in WTMLr. Σ: sum of weekly training load in the particular indicator; TD: total distance covered; HSR: distance covered by high-speed runs > 16.1 km.h^{-1}; SPR: distance covered by sprint runs > 21.6 km.h^{-1}; % HSR: relative load intensity, percentages of HSR from TD; WTMLr: Weekly Training vs Match Load ratio; CD: central defender; FB: full back; CM: central midfielder; S: striker

Table 2. Means and standard deviations of external PL in the match and single training days during week training microcycle

	MD	MD-1	MD-2	MD-3	MD-4	MD-5
TD (m)	9112.3±998.8 a,b,c,d,e	4938.5±879.3	4293.4±1619.9	6807.6±1728.0 a,b,d	5597.2±1454.0 b	6144.8±965.2 a,b
HSR (m)	969.1±282.5 a,b,c,d,e	289±94.2	353.3±122.9	522.3±235.3 a,b	450.5±213.2 a	557.2±419.9
SPR (m)	217.5±99.6 a,b,c,d,e	54.8±32.1	94.9±85.7	148.1±103.1 a,b,d	99.9±96.3	126.7±180.2
%HSR	10.6±2.6 a,c,d,e	5.9±1.9	9.3±3.9 a	7.7±3.2	8.5±4.5	8.7±5.8

MD: match day; MD-1: one day before match; MD-2: two days before match; MD-3: three days before match; MD-4: four days before match; MD-5: five days before match; TD: total distance covered; HSR: distance covered by high-speed runs > 16.1 km.h^{-1}; SPR: distance covered by sprint runs > 21.6 km.h^{-1}; % HSR: relative load intensity, percentages of HSR from TD; a > MD-1; b > MD-2; c > MD-3; d > MD-4; e > MD-5; ($p < 0.01$).

The average HSR of the U17 players in our study was 10.4% of the TD, which is similar to values previously observed, for example 11 % (Buchheit et al. 2010), and 12 % (Rebelo et al. 2014) in U17 players. However, the match time in both of those studies was only 80 minutes, compared to 90 minutes in our study. The values for HSR 6-7 % reported in U17 players by Pettersen and Brenn (2019) and Goto and Saward (2020) are significantly lower than in our players, but the threshold used for HSR in both studies was 19.8 km/h versus >16.1 km.h^{-1} here. As such, interpretation of HSR values across studies is problematic as a standard threshold has not been agreed upon and values subsequently vary (Miguel et al., 2021; Atan et al., 2014).

In the present U17 players, overall match PL was significantly influenced by playing position. CD achieved the lowest values in TD and significantly lower values in HSR, SPR and %HSR values compared to all other positions, which is similar to previous research (Pettersen and Brenn, 2019; Saward et al., 2016; Buchheit et al., 2010; Douchet et al., 2023). The highest TD values were similarly achieved by FB and CM, who also reported the highest HSR. Similar to our results, Morgans et al. (2022) and Buchheit et al. (2010) found that S performed the highest SPR. However, in several studies, the highest SPR values were achieved by wide midfielders (Pettersen and Brenn, 2019; Saward et al., 2016; Vigh-Larsen et al., 2018) or by FB (Douchet et al., 2023; Modric et al., 2022; Modric et al., 2020). One of the possible reasons for these discrepencies across studies could be linked to different playing formations. For example, the presence of wide midfielders in some formations (Modric et al., 2020) significantly reduces the attacking activity of S or FB.

With regard to WTMLr, our results showed that TD (2.5 - 2.7), HSR (1.8 - 2.3), and SPR (1.6 - 3.5), as a sum of four training sessions per week, exceeded match values several times during the weekly training process, with significant differences across player positions. The present WTMLr values are higher than those of de Dios-Álvarez et al. (2021), whose study was the only one to our knowledge to assess WTMLr in elite youth soccer. The 16 to 18-year-old players in this study, irrespective of player position, achieved values of 2.1 (TD), 1.5 (running speed 14 - 21 km.h^{-1}, almost identical to our HSR) and 1.2 (running speed >21 km.h^{-1}, almost identical to our SPR). The WTMLr should be considered and interpreted cautiously since this ratio often includes average team values with a large inter-subject variability observed for the same external load metric (Gualtieri et al., 2023). In our study, we found the highest variability in WTMLr in SPR, as CD reported the highest value (3.5) compared to CM (2.5), FB, and S (1.6). However, despite the highest WTMLr for CD in SPR, S and CM performed higher distances in SPR than CD during weekly training microcycles. These findings suggest that training was not, in any way, individualised with regard to PL for the different positions, relative to their match PL.

The present results report a WTMLr for %HSR ranging from 0.7 in FB and S to 1.1 in CM, which means the average training intensity across all players was 76 % of the match intensity. When looking at the individual training days during the weekly cycle, the training intensity reached values of 56% (MD - 1), 88% (MD - 2), 73% (MD - 3), 80% (MD - 4) and 82% (MD - 5). Similarly, de Dios-Álvarez et al. (2021) found a value of 0.7 for WTMLr for %HSR, corresponding to 73 % match intensity during training in U18 elite soccer players. In another study in elite U19 players by Douchet et al. (2023), the authors revealed relative values of PL (HSR and SPR) during weekly training microcycles far below 100 % of match demands. Thus, our findings suggest that the intensity of training sessions in young elite players aged 15 - 16 did not fully reflect match-play PL demands. We are convinced that this deficit can negatively affect the long-term development of players' fitness performance and their ability to produce the desired amount of HSR and SPR during the game. Douchet et al. (2023) suggest that the players should achieve 100 % of the relative training load (HSR and SPR) derived from match demands in each training session to ensure an increase in HSR as players mature and thereby facilitate the transition from academy to professional soccer environments. Coaches should, therefore, choose training sessions (drills and games) that ensure training intensity is comparable to match demands. For example, a game profile-based training approach seems to be an optimal training instrument, which has been proposed to induce relative HSR and SPR running distances equal to, or greater than, match outcomes in elite male soccer players (Iacono et al., 2017). We did not have exact information on the ratio of small, medium, and large-sided games in training sessions of the players in our study. However, according to Gualtieri et al. (2023), it is essential to consider not only the choice of game format, but also the relative area per player, which significantly affects the values for HSR and SPR during training sessions.

Our study is not without limitations. First, since we included only players who played the whole match or participated in all training sessions during a week, the sample

size is somewhat small. It was not unusual for the coach to change five players during each match, and not all players participated in all the training sessions in individual weeks. Second, although we described the general training regime of the players, more specific information about training (e.g., different game formats; relative area per player) used during the individual training days would have enabled better interpretation of the results of the WTMLr. Future research should address these limitations and study younger (e.g., U14 - U16) and older (U18 - U19) age categories to provide information leading to a better understanding of the management of WTMLr. Furthermore, it would be helpful to consider so-called contextual factors in the long-term monitoring of physical load during the match (e.g., different styles of play and different playing formations).

Conclusion

When analysing the match demands in young elite soccer players aged 15 to 16 years, performance in TD, HSR, SPR, and %HSR was position-dependent, with CD achieving the lowest values in all the mentioned PL metrics. S performed the highest distance in SPR compared to all other positions. With regard to weekly PL and WTMLr, significant differences were found in SPR and %HSR between player positions, suggesting no adjustment of the WTMLr based on actual match demands. The average collective training intensity (76 % of the match intensity) seems insufficient to build adequate capacity for HIR and SPR and injury risk prevention. As a possible recommendation, the use of more appropriate training methods (e.g., a game profile-based training approach, medium/large-sided games with corresponding relative area per player or running-based drills with linear and non-linear sprints) by club practitioners/specialists could contribute to increasing training intensity and, thus, sufficiently replicate match demands in training sessions.

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Key points

- Using weekly training to match physical load ratio (WTMLr), the weekly training intensity (% high-speed running) achieved only 76 % of the match demands.
- The match demands regarding all measured physical load indicators were position-dependent in young elite soccer players aged 15 to 16.
- Central defenders (CD) performed significantly lower distances than other playing positions in all measured physical load indicators during the match. In contrast, CD reported the highest values for WTMLr in high-speed running and sprints.
- Practitioners need to use appropriate training methodology to replicate match intensity in training sessions during a weekly microcycle and should consider using the WTMLr to help optimise and individualise weekly training.

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