

Match and Training High Intensity Activity-Demands Profile during a Competitive Mesocycle in Youth Elite Soccer Players

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ABSTRACT

The monitoring of the high intensity activity-demands profile during official matches (OMs) and training sessions (TSs) provides a deeper understanding of the relationship between training and competition loads as well as players' fitness characteristics. The aims of this study were to: 1) describe the training and match high intensity activity-demands profile in U-19 soccer players; 2) compare it depending on the type of session (OM or TS) throughout match-weeks; and 3) differentiate between profiles depending on the match location (home or away). Twenty-five U-19 Spanish soccer players were monitored during TSs and OMs for a one-month competitive period using a WIMU PRO™ wearable inertial device. The variables of the study were: high speed running distance (HSRD), total sprints (SPs), maximum speed (MS) and player load (PL). OMs required higher demands than TSs in HSRD (460.99 ± 206.18 vs. 315.45 ± 180.12 m; $p < 0.01$; $d = 0.75$), SPs (10.86 ± 6.64 vs. 7.23 ± 4.82 ; $p < 0.01$; $d = 0.69$), MS (29.99 ± 2.54 vs. 28.50 ± 2.4 km/h; $p < 0.01$; $d = 0.59$) and PL (103.08 ± 24.15 vs. 83.18 ± 17.96 a.u.; $p < 0.01$; $d = 0.94$). The interaction between the type of session and mean week's demands presented differences with medium effect size in MS ($p < 0.01$; $\omega_p^2 = 0.06$) and small effect size in HSRD ($p = 0.04$; $\omega_p^2 = 0.03$), and SP ($p = 0.05$; $\omega_p^2 = 0.03$), but there were no differences in PL ($p = 0.18$; $\omega_p^2 = 0$). Finally, no differences were found in the match location comparison ($p > 0.33$; $d = 0.22-0.33$). Therefore, the profiles presented could be useful for future scientific purposes and serve as valid information for coaches trying to optimize performance.

Key words: workload, competition, team sports, inertial devices, performance.

Introduction

Soccer is an explosive team sport consisting of intermittent repeated periods of high-intensity anaerobic-type activity, interspersed with longer recovery periods of lower intensity (Drust et al., 2000; Varley and Aughey, 2012). In the last decade, several investigations have examined match-play with the aim of identifying competitive demands (Bangsbo et al., 2006; Bloomfield et al., 2007; Dellal et al., 2011; Di Salvo et al., 2007). Recently, the evolution of global positioning systems (GPSs) has provided the opportunity to quantify match demands (Cummins et al., 2013). For instance, soccer players frequently cover an average distance of 10–14 km during a match (Bangsbo et al., 2006; Bloomfield et al., 2007; Dellal et al., 2011; Di Salvo et al., 2007) where 8% of total distance covered is performed at a very high intensity (Bradley et al., 2009).

However, researchers have discovered that youth match performance could be affected by different situational variables such as players' specific positions (Buchheit et al., 2010; Deprez et al., 2015), the type and the level of competition (Buchheit et al., 2010; Palucci-Vieira et al., 2018; Tierney et al., 2016) and playing formation (Tierney et al., 2016). Other contextual variables have been also analyzed in professional soccer such as match status (Castellano et al., 2011; Sampaio et al., 2014), goal occurrence (Miñano-Espin et al., 2017), periods of the season (Mohr et al., 2003) and the match location with a greater demand when playing at home (Castellano et al., 2011; Lago-Peñas and Lago-Ballesteros, 2011).

The identification of the physical demands required in soccer is important to improve planning training programs (Abade et al., 2014). Specifically, to promote an effective transfer to the competitive environment, it is suggested that training should include technical and tactical aspects under similar conditions to those that occur during match-play (Williams and Hodges, 2005). Graded prescription of high workloads should improve players' physical performance, which translates into greater resilience on a match day and more players available on the squad (Gabbett, 2016). Current research in soccer time-motion analysis is mostly focused on the match activity-demands profile and disregards the training profile (Abade et al., 2014). Soccer academies are already incorporating tracking systems (Bowen et al., 2017) since early specialization requires new strategies able to enhance the path to elite performance (Unnithan et al., 2012). In fact, when athletes are being monitored, motivation and sense of belonging to the group increases (Halson, 2014). Moreover, a lot of emphasis has recently been put on identifying and analyzing performance variable characteristic of youth players, which are related to elite players (Unnithan et al., 2012). With regard to physical performance in youth soccer players, issues such as the relationship between training and competitive performance and the influence that the match location may have on performance as it occurs with professional players (Anderson et al., 2016; Aquino et al., 2017), are not well documented yet in youth players. Thus, it would be interesting to study such issues using kinematic variables since to date there is limited research considering the aforementioned aspects due to the difficulty and costs of monitoring at this level (Abade et al., 2014).

Therefore, the aims of this study were to: 1) describe the training and match activity-demands profile in U-19 soccer players; 2) compare the activity-demands profile depending on the type of a session (match or training) throughout match-weeks; 3) differentiate between the activity-demands profiles depending on the match location.

Methods

Participants

Twenty-five U-19 soccer players (age: 18.2 ± 0.87 years; body height: 1.77 ± 0.05 m; body mass: 73.96 ± 4.2 kg; BMI: 21.5 ± 1.1 kg/m²) volunteered to participate in the study. All the players were recruited from one soccer team that played in the U-19 Spanish National League Championship regulated by the Spanish Soccer Federation and had at least 2 years of previous soccer playing experience at the same competitive level.

Every participant was informed about the objectives, protocol and tests of the study. They provided informed consent to take part in the research; the authorization was also obtained from the soccer club. For underage participants, parents or a legal guardian authorized their participation in the study. The University of Almeria Ethics Committee approved the study that complied with the Declaration of Helsinki, and followed the "Ethical Standards in Sport and Exercise Science Research" (Harriss and Atkinson, 2015).

Study design

This work is a cohort study with natural groups (Ato et al., 2013) to describe the high intensity activity-demands of U-19 soccer players during training and matches over a 5-week competitive period, during the 2017-2018 season, and to compare the demands depending on the type of the session and match location (home vs. away). Wireless Inertial Measurement Units (WIMUs) were used to collect data on high intensity demands. Players were excluded from the current analysis if they reported injuries in the previous month, any type of medication for the treatment of pain or musculoskeletal injuries taken at the time of the study, or completed less than 75% of TSs and/or matches. Goalkeepers were not considered for the performance analysis since their position requires different physical, tactical and technical demands in both training and competition (White et al., 2018). TSs and official matches were performed on artificial turf. The team formation in official matches was 4-2-3-1.

The study was carried out during a period of five weeks, from the eighth to the 12th week of competition, which took place from October to November, 2017. The season calendar had total duration of 30 weeks. The temperature ranged from 20 to 24°C. Matches were played between 6 and 8 pm on Sundays. Opposing teams had a high position in the league ranking. The first week there were two familiarization sessions in order to let the players get used to being monitored and ensure that data analysis was performed correctly. During the following five weeks 20 TSs and five official matches within the Spanish League Championship 2017-2018 season were held. Every TS lasted 90 min and matches had two halves of 45 min with a 15-min break in between. Participants met the research team in the locker room 15 min prior to the beginning of the TS and 60 min before matches in order to place the wearable devices in specific chest vests. Participants were instructed to maintain their daily lifestyle and dietary intake before and during the study.

Equipment

Anthropometric characteristics were measured using a stadiometer (SECA, Hamburg, Germany) and a body mass monitor BC 601 (TANITA, Tokyo, Japan).

The locomotive demands of the match and training were quantified using an inertial device (wireless inertial measurement unit, WIMU) called WIMU PRO™ (RealTrack Systems, Almería, Spain) which contained different sensors (four 3D accelerometers; three 3D gyroscopes; one magnetometer; one barometer; UWB, Ultra-wide band; GPS, Global Positioning System). The device recorded data from the accelerometers, gyroscope and magnetometer at a 100 Hz sampling rate, whereas data related to the location (GPS) were recorded at 10 Hz. This device has previously been used in soccer research on activity-demands profiles as well (Gómez-Carmona et al., 2018; Gomez-Carmona and Pino-Ortega, 2016). The validity and reliability for positioning metrics through the GPS (Muñoz-López et al., 2017) and UWB (Bastida-Castillo et al., 2018) have been confirmed obtaining accurate results at 5 Hz (GPS) and 20 Hz (UWB). Data were recorded on the device equipped with an 8 GB memory card.

These devices were first calibrated and synchronized following the instructions from the manufacturing company. The instructions were to: (i) place the device on a flat surface, (ii) turn it on without magnetic devices surrounding it, and (iii) wait for 30 s. Data collected by the devices were transferred to a computer in order to analyze them on SPRO™ (RealTrack Systems, Almería, Spain).

Variables

- a) *Activity-demands profile*: variables for the analysis are shown in Table 1. All the variables have a kinematic background and are common in the scientific literature. They were high speed running distance (HSRD), total sprints (SPs), maximum speed (MS) and player load (PL). Previous studies have also used these high intensity-related variables and classified HSRD, SPs, MS and PL as valid indicators of workload responses in soccer (Casamichana et al., 2013; Miñano-Espín et al., 2017; Palucci-Viera et al., 2018).
- b) Type of a session: the 25 sessions analyzed were classified into two groups (20 training sessions, TSs, $n = 148$; 5 official matches, OMs, $n = 37$).
- c) Match-weeks dynamics: a 5-week mesocycle was analyzed. This mesocycle was divided into five microcycles. Each microcycle consisted of four TSs and one OM. TSs were classified with respect to the Match Day (MD) (MD+1, Monday; MD-4, Wednesday; MD-3, Thursday; MD-2, Friday). The sample size followed this distribution: week 1 (TS: $n = 32$; OM: $n = 8$); week 2 (TS: $n = 28$; OM: $n = 7$); week 3 (TS: $n = 28$; OM: $n = 7$); week 4 (TS: $n = 28$; OM: $n = 7$); and week 5 (TS: $n = 32$; OM: $n = 8$).
- d) Match location: according to OM status, the five OMs were classified into two groups (home

matches, HMs, $n = 23$; away matches, AMs, $n = 14$).

Statistical Analysis

First, a descriptive statistical analysis of four variables (HSRD, SPs, MS, PL) was performed, showing data as mean, standard deviation (mean \pm SD) and typical error (TE) in order to describe the activity-demands profile of TSs and competition. The mean of every variable in TSs and matches was calculated for all field players, excluding goalkeepers. The Shapiro-Wilk test was used to examine normality of variables as well as the Levene's test for homogeneity, which finally resulted in a normal distribution of the variables.

The independent-samples t-test was carried out in order to compare differences between the type of a session (TS vs. OM) and the match location (HM vs. AM). A multivariate analysis of variance (MANOVA) with the Bonferroni post-hoc test was used for the comparison between the interaction of the type of sessions and mean week's demands. The level of significance was set at $p < 0.05$. The magnitude of differences between TSs and match effect size was calculated with Cohen's d . Limit values were: 0-0.2 (low effect), 0.2-0.6 (small effect), 0.6-1.2 (moderate effect), 1.2-2.0 (large effect) and >2.0 (very large effect) (Hopkins et al., 2009). In addition, the magnitude of the differences for MANOVA was calculated using Partial Omega Squared (ω_p^2) that was classified as ≤ 0.01 small, ≤ 0.06 medium, and ≤ 0.14 large following Cohen (1988). The statistical analysis was performed using the *Statistical Package for the Social Sciences* (version 24.0; SPSS Inc., Chicago, IL, USA) in addition to *GraphPad Prism* (version 7; GraphPad Software, La Jolla CA, USA) for the scientific graphing.

Results

Type of a session

Table 2 shows the descriptive and comparative analysis in relation to the type of a session. When comparing the type of a session, official matches recorded higher demands with a moderate effect size in HSRD ($p < 0.01$; $d = 0.75$), SPs ($p < 0.01$; $d = 0.69$), MS ($p < 0.01$; $d = 0.59$) and PL ($p < 0.01$; $d = 0.94$).

Match-weeks dynamics

First, the interaction between the type of a session and mean week's demands presented differences with medium effect size in MS ($p < 0.01$; $\omega_p^2 = 0.06$) and small effect size in HSRD ($p = 0.04$; $\omega_p^2 = 0.03$), and SPs ($p = 0.05$; $\omega_p^2 = 0.03$). There were no differences in PL ($p = 0.18$; $\omega_p^2 = 0$). Then, Figure 1 represents the dynamics of time-motion demands over the match-weeks, analyzed during TSs and official matches. In contrast to week 1, demands recorded in OMs were higher than the ones registered during TSs ($p < 0.05$; $d = 0.23$ -1.28).

Match location

The comparison between the match locations in the time-motion analysis variables is shown in Table 3. In relation to HM, U-19 soccer players recorded 457.21 ± 214.11 (m) in HSRD, 10.73 ± 5.90 SPs, 29.67 ± 2.36 km/h in MS and 105.04 ± 23.82 a.u. in PL. In AM, players recorded 467.70 ± 199.68 m in HSRD, 11.08 ± 5.38 SPs, 30.53 ± 2.82 km/h in MS and 99.61 ± 25.29 a.u. in PL. Finally, no differences were found in the match location comparison ($p = 0.33 - 0.88$; $d = -0.33 - 0.22$).

Discussion

The aims of this study were to describe the training and match activity-demands profile in U-19 soccer players, compare the activity-demands profile depending on the type of a session (OM or TS) through match-weeks, and differentiate activity-demands profiles depending on the match location (HM or AM).

Previous research has shown that there could be differences in training and match performance depending on the level of play (Miñano-Espin et al., 2017). Specifically, training demands for U-19 players were higher in a previous study (Abade et al., 2014) for variables such as SPs (63.2%). Moreover, Iacono et al. (2016) designed a game profile-based training protocol which exposed players to higher HSRD relative demands in three bouts of 24 minutes. According to Abade et al. (2014), the lack of agreement could be due to the fact that more emphasis was placed on specific physical conditioning in the TS. However, players of higher performance levels (professional) experienced similar PL (83.95 ± 23.92 a.u.) (Casamichana et al., 2013). From our perspective, more research is needed on the training activity-demands profile, especially for variables such as PL, MS or HSRD.

Match demands for our U-19 players were close to those of players of a similar age group (Buchheit

et al., 2010) in actions such as MS (28.3 ± 2.2 km/h). In contrast to these results, recent studies found lower HSRD (14%) (Iacono et al., 2017), but higher values in MS than those of our players (18.33%) in Brazilian soccer players (18.2 ± 1.0 years) (Palucci-Vieira et al., 2018). Furthermore, there were less SP actions compared to professional players (84.16%) and HSRD covered (12.42%) (Miñano-Espin et al., 2017), with interesting factors, such as a position description or the quality level of the opponent, making a difference. Difference in the level of competition could be the reason why this variation exists (Mohr et al., 2003). However, research using tracking systems has previously observed that there are differences between GPS and video analysis tracking, commonly used at elite levels, and any comparison of results obtained by different tracking technologies should be done carefully (Linke et al., 2018).

With regard to the comparison between training and match activity-demands profiles, in the present study, a significant increase was observed in matches in all variables when compared to TSs. Nevertheless, the game profile-based protocol developed by Iacono et al. (2017) required higher HSRD demands in TSs than on match days. As a result, this protocol may be considered an advantageous training method capable of stimulating the demands required during a match in U-19 players (Iacono et al., 2017). In addition, another study showed greater HSRD in matches than training for players aged between 17 and 23 (De Silva et al., 2018). Match situational variables mentioned above, especially those related to the player's psychology may explain these differences (Mohr et al., 2003; Sampaio et al., 2014). To the best of the authors' knowledge, no study has analyzed this match-training relationship in soccer players' SP or PL. However, such a comparison has been made with PLs regarding sports such as basketball, where PLs in official matches are substantially more demanding (279 ± 58 a.u.) than scrimmages (171 ± 84 a.u.) with a large effect size ($d = 1.496$) (Montgomery et al., 2010) as in our research. Players tend to maximize their performance in competition (Abbott et al., 2018) and proof of that is how some players triple their values of some variables during matches (Pustina et al., 2017). In addition, friendly matches do not require such high-performance activity-demands compared to official matches (Freitas et al., 2016). Based on these results, future studies should focus on identifying the training and match activity-demands profile in order to optimize performance.

Considering the match-week dynamics, it is interesting to examine how much variability was between training weeks ($p < 0.01$; $d = 0.98$ HSRD, 0.70 SP, 0.91 MS, 0.77 PL) in contrast to the stability of matches (HSRD: $p = 0.42$, $d = 0.35$; SP: $p = 0.30$, $d = 0.39$; MS: $p = 0.57$; $d = 0.30$; PL: $p = 0.88$, $d = 0.19$). Similar studies have found that there were no significant differences ($p > 0.05$) between matches in HSRD (Arruda et al., 2015) or SP (Abade et al., 2014). However, in spite of having differences between weeks, PLs should be taken into account since this is the only accelerometer derived-measurement and there were only significant differences with week 1, but none among any others (Figure 1). This may occur when coaches focus on activities like small-sided games, which increase density (reduced area per player) and thus, players' experience has more impact (Davies et al., 2013). Future studies collecting data on the match-week dynamics could even provide coaches with an insight into where to place the focus in weekly training on explosive movements, agility-training demand or technical and tactical activities.

Finally, when it comes to the match location, there were no statistical differences for any variable in the activity-demands profile of this U-19 team ($p > 0.05$). Similar to our results, Palucci-Vieira et al. (2017) did not find any differences between HM or AM ($p > 0.05$) in the analysis of different variables (HSRD among them, although with different speed thresholds). However, congested match schedules (2 matches per week) may limit this comparison. Instead, there were differences with another research which analyzed similar variables and location conditions in semi-professional players (Aquino et al., 2017), where findings showed that there were statistical differences in performance according to the match location, MS being higher (8.66%) in HM than AM. According to Aquino et al. (2017), a possible explanation for these differences could be related to technical, tactical or behavioral strategies that some teams may implement when playing at home. Unfortunately, it is difficult to compare our results with others due to the fact that there is no research on the role of the match location in kinematic performance from U-19 soccer players to date. Hence, the impact that our descriptive statistics could have on the scientific literature is high. Differences found in other studies could be reduced to minimum values as it occurs in our study depending on other factors such as a congested match schedule. Consequently, further analysis of the influence of training players to compete depending on the match location and match-weeks dynamics should be carried out in order to design specific physical, physiological or psychological TSs before the competition. Such information could be

considered in order to achieve a competitive advantage.

At this point, there may be some discussion about the pros and cons of this research, which presents several limitations since: the description of additional external and internal load variables (e.g. high intensity accelerations or decelerations, changes of direction, high metabolic load distance, energy expenditure) is not provided, the competitive period is relatively short, and only one team from a specific league, country, and level considered as an age group (from 17 to 19 years old) was analyzed, in addition to all the possible differences among participants which may be unknown. However, soccer and performance need to be understood as a multifactorial process, presenting a challenge to researchers (i.e., sport scientists) who continually try to provide key information. Also, that is why this work opens new doors to providing a better understanding and developing further ideas for the future: the relationship between performance and the final score, a study of the differences among different age groups from beginners to professional players, differences among players' positions or linking performance to the game pace in different timestamps during the session (both training and competition).

The multifactorial components of soccer not only in training, but also during matches make its analysis such a complicated process. Our data offer key information for performance analysis, and one of the advantages of this research is the simple description of the activity-demands profile in U-19 soccer players within a random selection from the competitive period, despite the lack of studies comparing training versus competition or the match location influence on performance

Conclusions

In summary, our research aimed to provide data which may be useful for understanding what the U-19 match and training activity-demands profile looks like. Results showed that players facing competition experienced higher demands than in TSs. In addition, there were differences between weeks in training loads, whereas matches showed no significant variability. Finally, no differences in performance between HM or AM were found when analyzing competition related to the match location. Consequently, the presented profiles could be useful for future scientific purposes, enabling researchers to make comparisons and giving access to valid information for coaches trying to lead their teams to optimal performance.

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Table 1 *Description of external load variables recorded in this research.*

Variables	Description
High Speed Running Distance (m) (Miñano-Espin et al., 2017)	Distance covered at a speed of over 21 km/h
Sprints (Miñano-Espin et al., 2017)	Total of actions at a speed of over 24 km/h
Maximum Speed (km/h) (Aquino et al., 2017)	Maximum speed reached by the player in the session
Player Load (a.u.)	Accelerometer-derived measurement of total body load in its 3 axes (vertical, anterior-posterior and medial-lateral).

$$PL_n = \sqrt{\frac{(X_n - X_{n-1})^2 + (Y_n - Y_{n-1})^2 + (Z_n - Z_{n-1})^2}{100}}$$
$$PL_{total} = \sum_{n=0}^m PL_n \times 0,01$$

where:

- PL_n is the player load calculated in the current instant
- n is the current instant in time
- $n-1$ is the previous instant in time
- X_n , Y_n and Z_n are the values of Body Load for each axis of movement in the current instant in time.
- X_{n-1} , Y_{n-1} and Z_{n-1} are the values of Body Load for each axis of movement in the previous instant in time.

Table 2 Descriptive and comparative analysis of external load variables recorded in the present research in relation to the type of a session.

Variable	Training ($n = 140$)		Official matches ($n = 37$)		t	p	d
	$\mu \pm \sigma$	TE	$\mu \pm \sigma$	TE			
HSRD	315.45 \pm 180.12	15.22	460.99 \pm 206.18	34.36	-4.19	<0.01	0.75
SPs	7.23 \pm 4.82	0.407	10.86 \pm 6.64	0.94	-3.89	<0.01	0.69
MS	28.50 \pm 2.47	0.21	29.99 \pm 2.54	0.42	-3.20	<0.01	0.59
PL	83.18 \pm 17.96	1.52	103.08 \pm 24.15	4.02	-5.49	<0.01	0.94

Note. HSRD: High Sprint Running Distance (m); SPs: Total Sprints (n); MS: Maximum Speed (km/h); PL: Player Load; n: number of cases; μ : mean; σ : standard deviation; TE: typical error; t : t-student value; p : p value; d : Cohen's d effect size.

Table 3 Descriptive and comparative analysis of external load variables recorded in the present research in relation to the match location.

Variable	Home ($n = 23$)		Away ($n = 14$)		t	p	d
	$\mu \pm \sigma$	TE	$\mu \pm \sigma$	TE			
HSRD	457.21 \pm 214.11	44.64	467.70 \pm 199.68	55.38	-0.14	0.88	0.05
SPs	10.73 \pm 5.90	1.23	11.08 \pm 5.38	1.49	-0.17	0.86	0.06
MS	29.67 \pm 2.36	0.49	30.53 \pm 2.82	0.78	-0.98	0.33	0.33
PL	105.04 \pm 23.82	4.97	99.61 \pm 25.29	7.01	0.64	0.52	0.22

Note. HSRD: High Sprint Running Distance (m); SPs: Total Sprints (n); MS: Maximum Speed (km/h); PL: Player Load; n: number of cases; μ : mean; σ : standard deviation; TE: typical error; t : t-student value; p : p value; d : Cohen's d effect size.

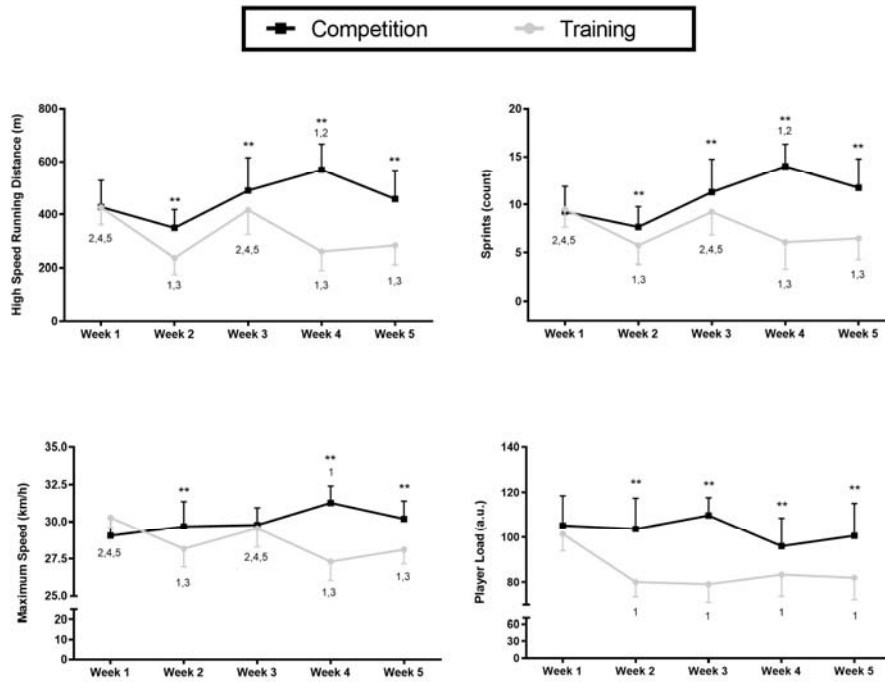


Figure 1 Dots plot \pm SD that represent the dynamics of the dependent variables (A: HSRD, B: SP, C: MS, D: PL) in the present research over the match-weeks analyzed. **Significant differences between training sessions and official match per week; ¹Significant differences with week 1 ($p < .05$); ²Significant differences with week 2 ($p < .05$); ³Significant differences with week 3 ($p < .05$); ⁴Significant differences with week 4 ($p < .05$); ⁵Significant differences with week 5 ($p < .05$)