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How does the workload applied during the training week and the contextual factors affect the physical responses of professional soccer players in the match?

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Abstract

The aim of this study was to examine whether match physical output can be predicted from the workload applied in training by professional soccer players. Training and match load records from two professional soccer teams belonging to the Spanish First and Second Division were collected through GPS technology over a season ($N = 1678$ and $N = 2441$ records, respectively). The factors playing position, season period, quality of opposition, category and playing formation were considered into the analysis. The level of significance was set at $p \leq .05$. The prediction models yielded a conditional R-squared in match of 0.51 in total distance (TD); 0.58 in high-intensity distance (HIRD, from 14 to 24 $km \cdot h^{-1}$); and 0.60 in sprint distance (SPD, $>$24 $km \cdot h^{-1}$). The main finding of this study was that the physical output of players in the match was predicted from the training-load performed during the previous training week. The training-TD negatively affected the match physical output while the training-HIRD showed a positive effect. Moreover, the contextual factors – playing position, season period, division and quality of opposition – affected the players' physical output in the match. Therefore, these results suggest the appropriateness of programming lower training volume but increasing the intensity of the activity throughout the weekly microcycle, and considering contextual factors within the load programming.

Keywords

Association football, global positioning system (GPS), performance analysis, periodisation, training

Introduction

Soccer is a complex sport with a myriad of factors that may affect players' physical performance.[1–4] Competing at a high-level is increasingly challenging and players must attain optimal physical readiness to withstand the competition demands.[5,6] Therefore, monitoring and quantifying the players' workload is paramount to optimising performance and reducing the injury risk.[7,8] Accordingly, the application of global positioning system (GPS) data for external-load monitoring is commonly used in professional soccer, as it allows coaches to evaluate the effectiveness of the training intervention on a daily basis.[9] The analysis of locomotion parameters provides tangible information on physical activity in soccer. However, it is important to note that situational variables significantly affect players' physical responses and must be taken into account for load programming, such as the training-day into the weekly microcycle, the differences responses by playing position or the playing style proposed by the team. In this sense, several authors have found that the greatest training load (TL) is concentrated in the middle days of microcycle (4 and 3 days

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before the match) and progressively decrease until one day before the match,[10,11] in addition the physical demands developed by players vary according to the playing position,[8,10,12] Likewise, the playing style or the different technical skills also affect the physical output of players, either in prompt responses or considering the whole match (e.g., accumulated fatigue).[13,14] For instance, Tierney et al.[14] compared the physical responses across the 5 most common playing formations (4-4-2; 4-3-3; 3-5-2; 3-4-3 and 4-2-3-1) in match play in professional youth soccer players and found large load differences between formations; the 3-5-2 formation showed the greatest total distance and high-intensity distance, and the 4-2-3-1 the greatest number of accelerations and decelerations.

On the other hand, there are also contextual factors that affect the physical responses of players in competition: the quality of opposition,[5,15,16] match location,[5,17] match score[18,19] or the season period[15,17] are some of the most analysed factors. In overall, playing against top-teams elicit higher physical demands, covering greater total distance and high-intensity distance; home teams covered a greater total distance and low intensity distance; teams with an adverse match score-line showed higher physical responses than their opponents; and players showed different performance between periods of the season, although there are currently discrepancies in the literature regarding the most physically demanding period. Moreover, recent studies have analysed how these contextual factors affected the load across the training week.[1–3] Rago et al.[3] found higher total distance and high-intensity distance in the training-week after an away-match and after playing against a weak team. In contrast, Brito et al.[1] showed lower load on the training-week before and after playing against a top team. Recently, Guerrero-Calderón et al.[2] showed higher TL within the training week when the upcoming match was away and against a top opponent. In addition, these authors found a decrease in all TL measures from the start to the middle period of the season, and a further decrease from the middle to the end of the season in high-level players. In accordance with the results, the abovementioned authors argued the need to consider the contextual factors within the TL programming.

Players require an increased physical capacity to cope with the competition demands. In this sense, it is of paramount importance to design specific workload programs for players according to the playing position, quality of opposition, match location or season period, among others. To the authors' knowledge, it would be useful for coaches to determine how the workload realised during the training week will affect the physical output of the upcoming match in order to ascertain the level of 'readiness' of the players for the match load. Based on previous studies, the weekly TL greatly affects the match load.[11,12,20] Our hypothesis is that the load showed by players on match day (MD) can be predicted from the TL realised during the weekly microcycle immediately before the match. In addition, the influence of contextual factors on physical output, the factors season period, quality of opposition, playing style and category will be considered within the predictive models. Therefore, this study aimed to examine whether the match physical output can be predicted from the TL realised during the previous training-week on professional soccer players. Subsequently, it was determined how the match load affects the match-score and, if so, how it can be explained by TL.

Methods

Participants and sample

Training and match load data across two male professional soccer teams belonging to the Spanish First and Second division (D1 and D2, respectively) were analysed in this study: thirty players from D1 during the 2015–2016 season (22.8 ± 0.8 yr; 177.8 ± 6.9 cm; 73.3 ± 5.7 kg) and twenty-six players from D2 during the 2017–2018 season (24.3 ± 0.1 yr; 177.5 ± 2.7 cm; 72.7 ± 8.1 kg). Only the records for single-match weeks with at least 4 team training sessions before an official League match during the competitive period were considered within the analysis. Thus, a total of 29 matches and 33 training weeks (for training data) were collected from D1; and 33 matches and 41 training weeks from D2. The data corresponding to preseason, Christmas period, microcycles with two weekly matches and exclusively tactical training sessions (e.g., set pieces) were excluded from the analysis in order to avoid variability in training records. The records of players who did not complete the full training session and those who participated in less than 80 minutes of match play were neither consider. Each of the 4119 initial records (1678 from D1 and 2441 from D2) correspond to training-sessions or match per player. All records were aggregated per player and per week. Accordingly, one observation corresponded to the training and match load during a single week by player. Only weeks where the respective player was recorded for at least three training sessions and one match were considered within the analysis. This resulted in 141 observations of players in distinct weeks, from which two had to be discarded because of missing data. The remaining 139 observations stemmed from 26 players and 26 distinct training weeks. Therefore, as the number of training records was not the same every week, the TL data per week was aggregated by averaging the TL over the number of training sessions recorded. This data set was used for statistical analysis.

In terms of playing formation, the D1-team used the 4-5-1 formation on 22 matches, 4-4-2 on 8 matches, 4-3-3 in 7 matches and 3-4-3 in 1 match; and the D2-team used the 4-5-1 formation in 35 matches, 4-4-2 in 4 matches and 4-3-3 in 3 matches.

The Club and players were informed about the aim of this study, and both obtained consent. This study was approved by the University of Granada Ethics Committee (Number 471/CEIH/2018). It complied with the ethical standards of the University and followed the guidelines of the Declaration of Helsinki (2013).

Instruments

GPS technology (GPEXE Pro® 18.18 Hz, GPEXE, Udine, Italy) was used to collect data for this study. These devices have proven to be a valid and reliable tool for daily load-monitoring in soccer.[7,8,21] To avoid inter-unit errors, each player used the same GPS unit in all training sessions and matches.[7,8,21]

Variables

Physical responses. The following locomotion metrics were collected for analysis: total distance covered (TD); high-intensity running distance (HIRD), which is the total distance covered at speeds $>14\,\text{km}\cdot\text{h}^{-1}$); and sprint running distance (SPD), considering only the distance covered at speed higher than $24\,\text{km}\cdot\text{h}^{-1}$. Training (t-TD, t-HIRD and t-SPD) and match metrics (m-TD, m-HIRD and m-SPD) were differentiated for analysis. All distances were recorded in meters.

Contextual factors. Both training and match records were classified according to the *season period*; from August to November (Start), December to February (Middle) and March to May (Final);[6,15,17] *quality of opposition*, differentiating the teams according to their League ranking at the end of the previous match-week:[1,2] 'Top-teams' (1^{st} to 6^{th} on D1, and 1^{st} to 7^{th} on D2), 'Medium-teams' (7^{st} to 14^{th} on D1, and 8^{st} to 15^{th} on D2) and 'Weak-teams' (15^{st} to 20^{th} on D1, and 16^{st} to 22^{th} on D2); *playing position*, classified by central defenders (CDs), external defenders (EDs), central midfielders (CMs), wide midfielders (WMs) and forwards (FOs)[7,12,22] (goalkeepers were not considered); *division*, D1 and D2; and *playing formation*, differentiating by 4-5-1 formation, 4-4-2 and 4-3-3. The 3-4-3 formation data was deleted as it was only used in a single match.

Statistical analysis

R Studio (version 3.6.1; R Core Team, 2019) was used for data processing and statistical analyses. In order to examine the relationship between the TL and the match physical output, linear mixed effects models were fit for three different dependent variables: m-TD, m-HIRD and m-SPD. As fixed effects, we entered five contextual factors (division, quality of opposition, playing position, formation used by the team and season period) as well as two TL variables (t-TD and t-HIRD) into the model. Since the SPD is a subset of the HIRD, we only include t-HIRD to avoid collinearity of results. Actually, the correlation between t-HIRD and t-SPD amounted to $r(137) = .35$ ($p < .001$). Similar, m-HIRD and t-SPD were also correlated with $r(137) = .56$ ($p < .001$). By the nature of the collected data, the assumption of independence between observations was violated (players were observed multiple times and multiple players participated in the same matches), so mixed effects models were used and the players were modelled as random effects, using random intercept-only models. However, the inter-dependency of observations cannot be fully overcome. Testing of fixed effects was done using Likelihood Ratio Tests.[23,24] Conditional R^2 (R^2_c) was calculated following the calculations of Nakagawa and Schielzeth.[25] The linear mixed effects analysis was done using the lme4 package.[26]

Results

The parameter estimates for the linear mixed models of the total distance (m-TD), high-intensity running distance (m-HIRD) and sprint distance covered in match (m-SPD) are shown in Table 1.

Total distance

The average TD covered by players per match was 9298 m (±871 m). The distance covered with respect to the contextual factors is shown in Figure 1.

The model of m-TD yielded a R^2_c of .51. The random effects of players accounted for approximately 17.7% of the variance in m-TD. Likelihood ratio tests of predictors indicated significant fixed effects of playing position, $\chi^2(4) = 17.89$, $p = .001$; season period $\chi^2(2) = 13.75$, $p = .001$; t-TD, $\chi^2(1) = 8.29$, $p = .004$; and t-HIRD, $\chi^2(1) = 8.42$, $p = .004$. Therefore, the season period and playing position significantly affected m-TD. In addition, both t-TD and t-HIRD significantly affected m-TD; t-TD showed a slight negative effect, and t-HIRD had a positive effect on m-TD. Figure 2 shows the relationship between m-TD and t–HIRD.

Table 1. Parameters estimates and *p*-values of predictors for linear mixed models of the total distance (m-TD), high-intensity running distance (m-HIRD) and sprint distance covered in match (m-SPD).

	m-TD model		m-HIRD model		m-SPD model	
Fixed effects	Estim.	*p*	Estim.	*p*	Estim.	*p*
(Intercept)	9051.07	–	1314.97	–	18.31	–
Division (2)	437.93	.07	331.48	.002	58.47	.03
Quality of opposition (medium)	−338.08	.07	−167.41	.04	−14.76	.08
Quality of opposition (top)	−60.75	.07	32.00	.04	28.52	.08
Playing position (ED)	33.22	.001	172.34	<.001	53.40	.001
Playing position (CM)	1122.85	.001	769.01	<.001	−8.67	.001
Playing position (WM)	304.26	.001	578.76	<.001	136.78	.001
Playing position (FO)	−288.87	.001	338.26	<.001	102.99	.001
Formation [4-4-2]	235.45	.56	48.60	.56	41.28	.09
Formation [4-5-1]	222.95	.56	126.08	.56	57.46	.09
Season period (middle)	714.12	.001	320.53	.003	38.30	.001
Season period (end)	646.45	.001	337.64	.003	107.50	.001
t-TD	−0.36	.004	−0.18	.003	−0.04	.006
t-HIRD	1.06	.004	0.76	<.001	0.18	<.001
Random effects	Var.	SD	Var.	SD	Var.	SD
Player (intercept)	134,040	366.1	11,617	107.8	1672	40.9
Residual	384,986	620.5	102,656	320.4	4815	69.4

Var.: variable; SD: standard deviation.
p values are obtained from likelihood ratio tests.

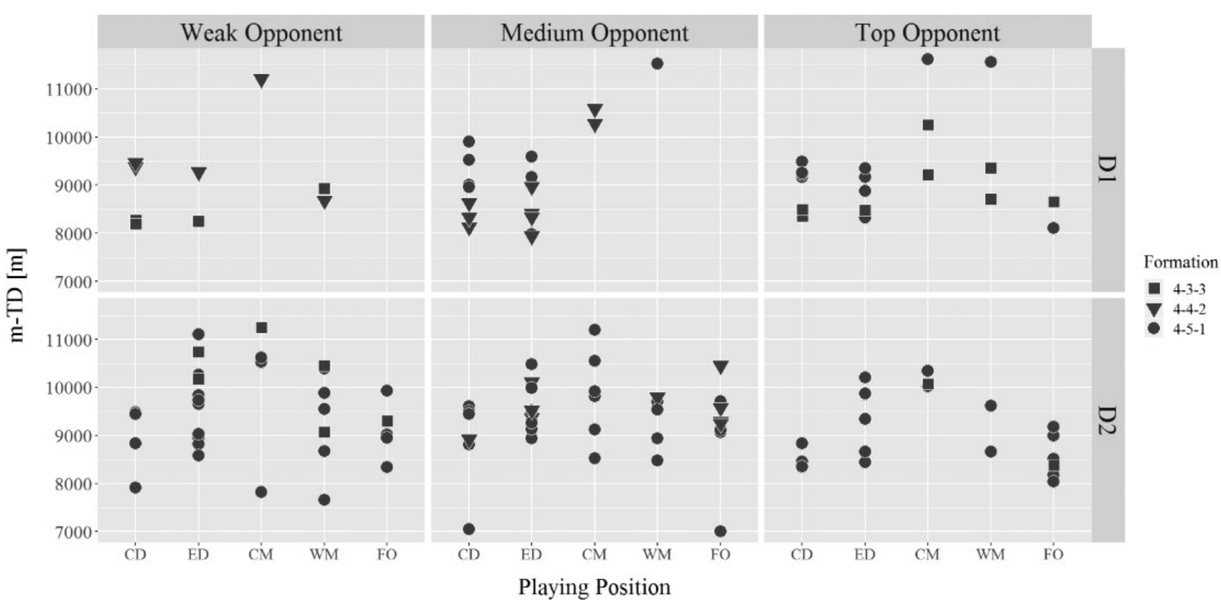

Figure 1. Total distance covered by players during the match considering the contextual factors division, playing position, opponent quality and playing formation.

High-intensity distance

Players in this study covered on average 1880 m (±501 m) of HIRD per match. The effect of the contextual factors on m-HIRD is shown in Figure 3.

The R^2_c of the m-HIRD model was .58. The random effects of players accounted for approximately 4.6% of the variance in m-HIRD. Likelihood Ratio Tests of predictors indicated significant fixed effects of division, $\chi^2(1) = 9.66$, $p = .002$; quality of opposition, $\chi^2(2) = 6.68$, $p = .04$; playing position, $\chi^2(4) = 31.43$, $p < .001$; season period, $\chi^2(2) = 11.36$, $p = .003$; t-TD, $\chi^2(1) = 8.63$, $p = .003$; and t-HIRD, $\chi^2(1) = 16.05$, $p < .001$.

Thus, the contextual factors division, quality of opposition, season period and playing position significantly affected the m-HIRD. On the other hand, t-TD showed a slight negative effect on m-HIRD while the t-HIRD had a positive effect. Figure 4 shows the relationship between the HIRD covered in match and in training.

Sprint distance

Players in this study covered on average 176 m (±109 m) m-SPD per match. The distance covered with respect to the contextual factors is shown in Figure 5.

The R^2_c of the m-SPD model was .60. The random effects of players accounted for approximately 14% of the variance in m-SPD. Likelihood Ratio Tests of predictors indicated significant fixed effects of division, $\chi^2(1) = 4.82$, $p = .03$; playing position, $\chi^2(4) = 18.29$, $p = .001$; season period, $\chi^2(2) = 13.1$, $p = .001$; t-TD, $\chi^2(1) = 7.4$, $p = .007$; and t-HIRD, $\chi^2(1) = 18.57$, $p < .001$. Thus, the contextual factors division, season

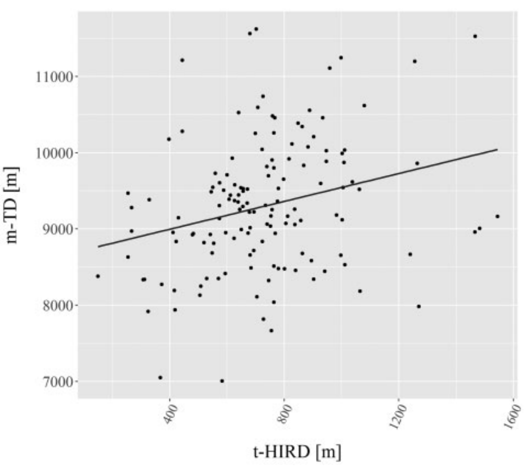

Figure 2. Total distance covered during the match as a function of high-intensity running distance covered during training in the week before the match. Each point represents the record of one player a single week. The linear mixed effects analysis yielded an R^2_C of .51 for the m-TD model.

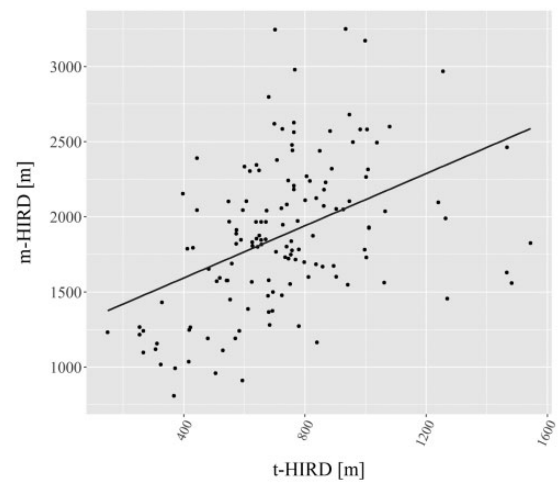

Figure 4. High-intensity running distance covered during the match as a function of high-intensity running distance covered during training in the week before the match. Each point represents the record of one player a single week. The linear mixed effects analysis yielded an R^2_C of .58 for the m-HIRD model.

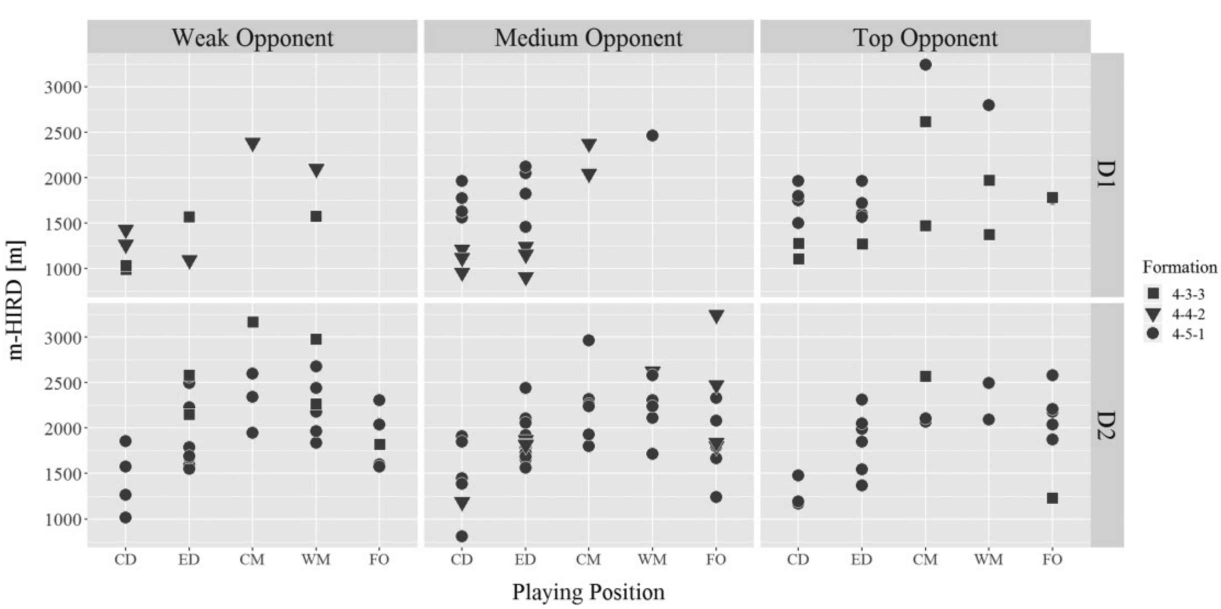

Figure 3. High-intensity running distance covered by players during the match considering the contextual factors division, playing position, opponent quality and playing formation.

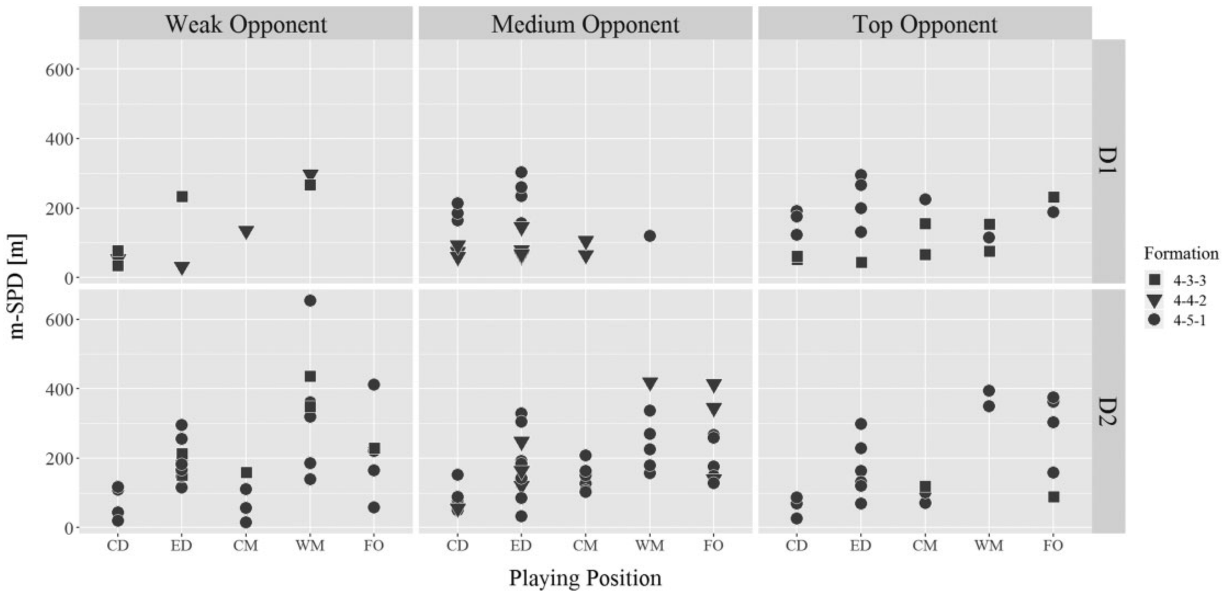

Figure 5. Sprint distance covered by players during the match considering the contextual factors division, playing position, opponent quality and playing formation.

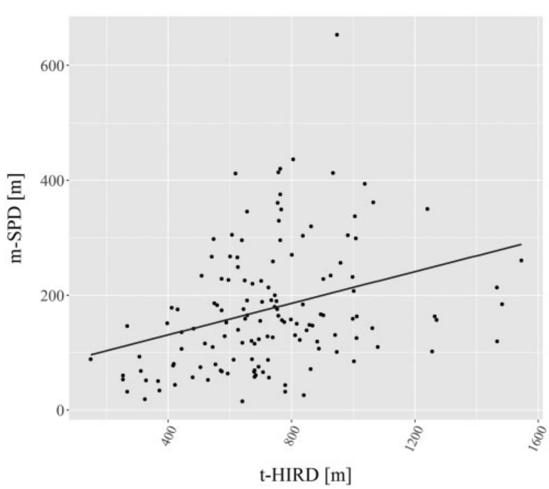

Figure 6. Sprint distance covered during the match as a function of high-intensity running distance covered during training in the week before the match. Each point represents the record of one player a single week. The linear mixed effects analysis yielded an R^2_C of .6 for the m-SPD model.

period and playing position significantly affected m-TD. Besides, the m-SPD was negatively affected by m-TD, and positively affected by t-HIRD. Figure 6 shows the relationship between m-SPD and t-HIRD.

Discussion

The aim of the present study was to examine whether the physical match performance can be predicted from the workload realised by professional soccer platers across the previous training week. The main finding was that both the total distance, high-intensity running distance and sprint distance covered in match by players showed strong relationships to TL realised during the previous week (t-TD and t-HIRD). Accordingly, a common feature of all the metrics was that t-TD negatively affected the physical output of the match, while t-HIRD showed a positive effect. Furthermore, the contextual factors affected on match physical responses: the playing position and season period affected in all match physical variables, the m-HIRD was affected by quality of opposition whereas the m-HIRD and m-SPD differed between divisions.

The monitoring and quantification of TL is of paramount importance in professional soccer to optimize the physical capacity of players and prevent injuries.[9,27] In this regard, the design of individualized training programs based on the specific competition demands represents a good strategy to optimize the training periodization.[11] However, although there is a widespread belief among practitioners that 'players compete as they train', a recent study conducted with semi-professional soccer players questioned the appropriateness of the TL applied across the microcycle due to the high variability of physical and physiological responses found between training sessions and official matches, and finally the authors concluded that players do not train as they compete.[28] Nonetheless, although no appropriate TL has been established at present, the main physical objective of training is to prepare players to withstand the competition demands.[29] Accordingly, the present investigation found that the TD covered by players during the previous training week negatively affected their physical output in the upcoming match: for every meter of TD covered in training, players covered 0.36, 0.18 and 0.04 m less TD, HIRD and SPD respectively, in the match. Contrarily, t-HIRD showed a positive effect: for every meter of HIRD that players showed in the preceding training week, they covered 1.06, 0.76 and 0.18 m more TD, HIRD and SPD respectively, in the match. These results could be interpreted as: players should develop a limited volume of training (i.e., TD), while those training sessions should present a greater activity of high-intensity. Soccer is a high-intensity activity characterized by the alternation of intermittent efforts.[4] Although several authors have argued that players may reduce their match physical output after developing a high load volume (i.e., TD) in the previous training week,[10,11] players should develop a high enough HIRD over the training week to achieve good readiness for competition.[30] However, coaches should be prudent about programming the high-intensity activity of players and avoid excessive TLs and long training sessions the day before the match,[30] as an excessive load may increase the players' fatigue and subsequently damage their physical capacity and increase the injury risk.[10,11] In this sense, a recent systematic review showed that very high-intensity distance caused changes in the muscle-damage markers (e.g., creatine kinase) 24 hours after activity.[31] Furthermore, coaches should also take into account the individual players' accumulated load when programming the workload in order to avoid load spikes, which are considered to be a substantial risk factor.[32,33] Therefore, these results suggest the importance of load periodization over the microcycle and the progressive exposure to higher workloads.

In recent years, an increased number of studies have also highlighted the importance to contextualize the load monitoring.[1–3] This study aimed to determine whether the match physical output can be predicted from the TL considering several contextual factors such as playing position, season period, playing style or quality of opposition within the analysis. The factors playing position and season period affected the physical responses analysed in competition (i.e., m-TD, m-HIRD and m-SPD). The high workload variability existing between playing positions is well established.[11,12] In line with other authors, CM was one of the most physically demanding positions.[7,10] Accordingly, CMs showed the greatest TD and HIRD compared to other positions. However, the CMs also covered the lowest SPD. Thus, special emphasis should be placed on ensuring proper load programming by designing specific tasks with the types of effort and locomotion activities demanded by position in the match.[11,12] Concerning to the workload developed by players in match across the season, this study showed variability between the different metrics analysed: whereas players covered a greater m-TD in the middle period compared to the other periods, the highest m-HIRD and m-SPD were found in the final period of the season. The literature shows controversy about the season period: several authors showed higher total distance and high-intensity distance covered in the final period compared to the first and middle period,[15,17] Guerrero-Calderón et al.[2] found the greatest TL in the middle period, whereas other authors have found no significant TL variations over the season.[7] These discrepancies between authors may be due to the different leagues analysed; Mohr et al.[17] and Rampinini et al.[15] analysed the Italian First Division, J. Malone et al.[7] analysed the English Premier League, Guerrero-Calderón et al.[2] analysed the Spanish First Division and the present study was performed with Spanish First and Second Division teams. Nonetheless, these results also showed the lowest values in the initial period for all metrics (m-TD, m-HIRD and m-SPD). This may be interpreted by the fact that the players just completed the preseason and are still gradually improving their physical capacity.[17] Similarly, the results found that the division-factor affected HIRD and SPD in the match. It therefore suggests the importance of contextualizing the load in order to consider the specific demands of the category concerned. On the other hand, several authors concluded that environmental temperature or humidity may play an important role for exercise performance.[15,34,35] Accordingly, very hot or cold air temperature or high humidity may negatively affect the physical responses of soccer players due to high thermal stress. Although this factor was no considered in the study, the variability found in the physical output between season periods may be also due to environmental factors. Nonetheless, it should be noted that soccer players from different countries and competitions may have different best comfort zones of air temperature and humidity.[15] Within the workload contextualization the playing style is another important factor. Contrary to Tierney et al.,[14] who found significant differences in the physical responses according to playing style, the present study showed that the different formations used by teams during the season did not affect the players' physical responses.[36,37] It should be noted that the analysed teams used the same playing system in almost all matches and only changed the formation a few times during the season. This may be interpreted as occasional variations in formation are not enough to cause changes in players' physical responses, as they might need a longer period of learning and adaptation to new stimuli of the playing system.[38] Finally, the quality of opposition is another factor that greatly affects the players' physical performance in competition.[16,19,39] These results showed that the quality of opposition significantly affected the m-HIRD, although it did not affect the m-TD and m-SPD. Competing against the best teams is more physically demanding and involves covering a longer distance.[2,39] However, some authors have concluded that the effect of this factor on physical performance is due to variations in the technical-tactical aspects.[16,39] For instance, Lago-Peñas et al.[39] showed that best teams normally have greater percentage of ball possession, and consequently playing against them involves covering higher TD without the ball in the attempt to regain the possession. While the previous author found variability in the TD, this study showed no differences in m-TD and m-SPD. The increased HIRD and similar TD showed in matches when competing against top teams may be explained for reasons such as these teams are able to move the ball faster or achieve a better defensive position on the field, so more intense efforts are needed when playing against these teams.[40] Therefore, coaches must consider the quality of opposition together with other contextual factors within the workload programming to attain a good readiness of players to withstand the match demands. However, although these results showed that the contextualized workload developed by players during the training week strongly affected their physical output in the match, further research should attempt to analyse a larger number of teams from different leagues and countries. Furthermore, it would be useful to take into account technical-tactical aspects within the analysis in order to define the specific profiles by position.

Conclusions

The main finding of this study was that the physical responses developed by players in the match (m-TD, m-HIRD and m-SPD) were predicted from the workload performed during the training week before the match. In this sense, the TD covered in training showed a negative effect in the match physical output whereas the t-HIRD showed a positive effect. Therefore, these results suggest the appropriateness of reducing the volume of training sessions in order to cover less TD, but increasing the intensity or speed of the activity, meaning low TD and high HIRD. Accordingly, the HIRD metric was considered the most determinant physical metric. Finally, the contextual factors playing position, season period, division and quality of opposition showed a strong effect on match performance and thus they must consider within workload programming. These contextual factors should not be analysed in isolation as these factors may affect one another.

Practical applications

Gaining knowledge about how the workload developed by professional players during the training week and situational variables affect their physical output in the match is really useful for technical staff to interpret the TL properly. In this regard, the intensity of training should be high while the volume should be kept low in order to achieve an increased physical output in the upcoming match. This means covering an elevated HIRD without covering too much total distance during the training week before the match. Accordingly, if players cover an additional 400 meters of HIRD during the training week, it is estimated to increase 424, 304 and 72 m of TD, HIRD and SPD respectively in the upcoming match. However, these 400 m should not increase the total distance covered by the players. In addition, practitioners must take special consideration of contextual factors. For instance, in those scenarios when a team is facing top teams near to the end of the season, the HIRD requirements are higher compared to playing against lower-ranked opponents or when the match is the initial period of the season. Furthermore, by collecting data from individual players throughout the season, practitioners can predict what the load pattern will be in the match. This information is very useful for coaches as it provides insight into the players' level of 'readiness' to cope with the match demands and how the TL affects match load considering different contextual factors.

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