

Training Load, Official Match Locomotor Demand, and Their Association in Top-Class Soccer Players During a Full Competitive Season

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Abstract

Riboli, A, Nardi, F, Osti, M, Cefis, M, Tesoro, G, and Mazzoni, S. Training load, official match locomotor demand, and their association in top-class soccer players during a full competitive season. *J Strength Cond Res* 39(2): 249–259, 2025—To examine training load and official match locomotor demands of top-class soccer players during a full competitive season and to evaluate their association. Twenty-five top-class soccer players competing in UEFA international competitions were included. The season was divided into 2 different categories: 2 matches (M2) or 3 matches (M3) in 8 days. Starters and nonstarters were classified. Total distance (TD), high-speed running (HSR, 15–20 km·h⁻¹), very high-speed running (VHSR, 20.1–24 km·h⁻¹), sprint (SPR, >24.1 km·h⁻¹), and accelerations/decelerations (Acc + Dec, >3 m·s⁻²) were recorded. *Trivial to moderate* differences ($p < 0.05$) in training load between M2 and M3 were found: HSR, VHSR, and SPR were higher in M2 than M3, whereas TD and Acc + Dec were higher in M3 than M2. Week-by-week variability in training load ranged from ~16 to ~59% depending on metrics. Official match locomotor demands were similar ($p > 0.05$) in M2 and M3 with ~5 to ~29% match-to-match variability depending on metrics. Total load (i.e., training plus match loads) was higher ($p < 0.05$, ES: 0.75/1.61) in starters than nonstarters, because of a higher match load and no difference in the training load. Very high-speed running and SPR accumulated during training sessions were *largely to very largely* ($r = 0.60$ to 0.72) associated with TD, HSR, VHSR, and Acc + Dec covered during official match; VHSR and TD during training were *largely to very largely* ($r = 0.57$ and 0.71) associated with SPR and Acc + Dec during official match. In conclusion, (a) congested periods seemed to not affect official match locomotor performance; (b) practitioners may consider high week-by-week workload variability for individualizing training prescriptions, especially for nonstarters; and (c) the VHSR and SPR accumulated during training were associated with the official match locomotor demands, and it may be considered for maximizing performance.

Key Words: team sport, elite football, elite soccer, high-intensity training, high-speed running

Introduction

In soccer, the quantification of training load and official match locomotor demands are considered crucial for an accurate training prescription (25,32). Various tracking technologies (e.g., global positioning system, semiautomatic video analysis, etc.) are used to quantify locomotor activities, such as total distance (TD), distances covered at different running speeds, and the distance covered accelerating/decelerating (49). The locomotor loads during match and training are used to control and adjust individual workload (29,37) using soccer-specific drills (e.g., small-sided games, positional-drills, etc.) and individual exercises (49,53). However, the optimal use of this information for maximize physical performance is still under discussion and needs to be investigated further to assist practitioner's with the training load management during the on-field practice.

Top-class soccer is characterized by a growing number of matches and congested fixtured periods (40) with 2 or often 3 matches in 7–8 days per week (M2 and M3, respectively). Difference in the number of matches played by each member of a squad may lead to marked differences in the individual between weeks workload (13,40); for example, the distance covered at

a speed >20 km·h⁻¹ during a match may be more than 1,000 m (1,18), whereas during a typical training week, less than 450 m > 20 km·h⁻¹ was previously reported (12,13); therefore, the week-by-week individual workload variability could be very marked within and between M2 and M3 across the in-season period. In addition, the players' selection as starters of a game or nonstarters increases the complexity of controlling the individual load of top-class players (41), especially in team involved in both national and international competitions. These contextual factors may be considered for prescribing the optimal training load at an individual level (29) and to maintain/develop the individual fitness level during the season (25). However, to the best of our knowledge, information about individual variability in workload during M2 and M3 in top-class soccer players is still lacking.

In addition, the congested fixture periods could lead to cumulative fatigue affecting match performance (34,58,59). It has been shown that periods with frequent matches provided alterations in hormonal (58,59), psychological (58,59), tactical (20), and physical variables (20,34,58,59) in professional soccer players. Recent findings in Spanish La Liga (35), French League One (19), English third division (33), and Brazilian first and second division (43) soccer players suggested that congested fixture periods may also lead to reduced volume of low and moderate running during the official match, whereas total distance and high speed running distance have been reported to be

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maintained (34). Therefore, the effect of cumulative fatigue across congested fixed periods may affect the fitness maintenance and/or development, and it should be considered for the individual training load management. However, no information for Italian Serie A soccer players has been previously provided about the locomotor demands across congested matches.

About the relationship between training load and fitness development, an inversely moderate correlation between cumulative total distance covered during training and the relative change in heart rate during submaximal running has been previously observed in Spanish La Liga soccer players (44). In Portuguese elite players, as already observed in other team sports such as handball (22), a higher amount of locomotor demands covered during official match seemed to influence players' fitness during the season because of a high stress level imposed on the neuromuscular system (60). Similarly, associations between match-accumulated locomotor demands and a better score in neuromuscular parameters (i.e., CMJ, drop jump height and contact time) were previously demonstrated (38,61). In addition, it has been shown that high-speed running and sprint covered during practice may improve physical performance (8,36). These findings (38,60,61) seem to suggest that an accumulated higher locomotor demand during training and/or match could positively affect physical fitness. However, it is unclear which variable (e.g., high speed running, sprinting, or acceleration/deceleration) is most important for performance development for each player (42).

Thus, the aims of the present study were (a) to examine the variation in training and match locomotor demands of players in a top-class team during a season and compare periods with 2 of 3 matches during a 8-day period, (b) to assess any difference in official match locomotor demands during congested and non-congested fixed periods, (c) to assess any difference in the total load (i.e., training and match locomotor demands) between starters and nonstarters, and (d) to evaluate whether individual associations between various training load variables and match locomotor demands exist.

Methods

Experimental Approach to the Problem

The present investigation was carried out during a full competition season. The participants undertook their traditional weekly training routine. Only the in-season period was considered for the current study. Training and match data were collected daily by a highly qualified technical-staff. The data were divided into 2 different categories (a) 2 matches within 7–8 days (M2) and (b) 3 matches within 8 days (M3). In M2, the training/match cycle was, for example, with a first national match on Sunday and a second national match on Saturday or Sunday leading to a 7- or 8-day cycle; in M3, the international competitions lead to a more congested schedule within a similar 7- or 8-day cycle with, for example, a first national match on Sunday, a second international match on Wednesday, and a third national match on Saturday or Sunday. For M3, locomotor match demands were classified as first (first), second (second), and third (third) match played during the 8 days. Starters and nonstarters were classified according to different factors: (a) players have to be in the starting line-up, (b) players needed to have a match-time exposure higher or lower than the team average exposure calculated using a median-split approach across a 4-week period, as previously suggested (24); this led to a match-time exposure of ~60% or ~20% of the total

match duration for starters and nonstarters, respectively. To investigate the individual association between training load and official match locomotor demands, a 4-week cumulative workload achieved during training or match sessions (i.e., a sum of daily training and match loads across 4 week) for each metric was associated with the subsequent load during official match (i.e., if the player played at least 65 minutes); the 65-minute playing time was defined accordingly to modern football rules that permit an increased number of substitutions ($n = 5$) affecting the number of players playing 85 minutes or full time (i.e., 90 minutes). Because of this increased number of substitutions and an increased variability in the individual time spent on the pitch across a season, 65-minute playing time helps to increase the sample size and the number of playing positions available for ecological studies. For example, defenders are usually less substitute than forward, wide-forward, etc. possibly affecting the current analysis. However, the official match locomotor demands were normalized in meter covered per minute ($\text{m} \cdot \text{min}^{-1}$) to avoid any possible influence of different playing time. The analysis was performed considering the individual association between training and match demands across the entire in-season period; training load, official match locomotor demands, and their association were investigated in our samples showing overall results and detailed for 3 representative players. The dataset was in long format: in particular, given I players, each row represents the j -th training or match session ($J =$ total number of training and match sessions) of the corresponding i -th player. A specialized and high-qualified physician staff recommended and monitored the diet regime of each player frequently. Training sessions and matches were conducted on grass pitches (105×66 m).

Subjects

Twenty-five top-class soccer players (age: 27 ± 5 years; body mass: 79 ± 7 kg; body height: 1.84 ± 0.06 m) competing in UEFA national and international competitions were included in the current study. These included central defenders ($n = 6$), full backs ($n = 4$), central-midfielders ($n = 5$), external midfielders ($n = 5$), and forwards ($n = 5$). The club's medical staff certified the health status of each player. The present data arose from the daily player monitoring in which players' activities are routinely measured over the course of the season. Signed informed consent documents were obtained for all subjects. Before to be considered for scientific purposes, any information was anonymized and averaged accordingly with the internal policy of the club's sport performance and research department. The Ethics Committee of the University of Milan approved the study. It was performed in accordance with the principles of the Declaration of Helsinki (1975).

Procedures

A GPS unit (GPEXE Pro2, Exelio SRL, Italy, firmware version 0.13) was used to collect data during the training sessions (63). The GPS unit was placed within a dedicated pouch between the player's shoulder blades (upper thoracic-spine) in a sports vest and worn under the playing jersey. Each device was turned on at least 15 minutes before each session to allow for acquisition of the satellite signal. To reduce the interunit differences, each player wore the same unit for every training session over the whole investigation (49). The locomotor activities during the official matches were collected using a computerized

semiautomatic video-based multicamera image system (MCIS, STATS LLC, Chicago, IL). The system has previously been shown to provide valid and reliable measurements of the match activity in soccer (18). The Global Positioning System and the video-based multicamera image system used in the current investigation has been previously compared (18) showing trivial differences (49) and used in several studies (11,49,51,53). In details, the systems used in the current study showed trivial differences for total distance ($-3.0 \pm 1.3\%$, ES = -0.18 , CI: $-0.80/0.44$), high-speed running ($-3.3 \pm 1.6\%$, ES = -0.12 , CI: $-0.74/0.51$), sprint ($-3.9 \pm 10.9\%$, ES = -0.11 , CI: $-0.44/0.22$), and acceleration plus deceleration ($-4.1 \pm 6.3\%$, ES = -0.19 , CI: $-0.80/0.44$); a small TEE was found for total distance (TEE: 0.09, CI: 0.07/0.14), high-speed running (TEE: 0.04, CI: 0.03/0.06), and sprint (TEE: 0.08, CI: 0.07/0.10), whereas a moderate TEE was found for acceleration plus deceleration (TEE: 0.75, CI: 0.56/1.10); a nearly perfect correlation was observed for total distance, high-speed running, and sprint, and a moderate correlation for acceleration plus deceleration measured using GPS and semiautomated video analysis (49). For each match/training comparison, a dedicated calibration equation (49) was used to account these differences for the interchangeability purposes between semiautomated video-tracking data and GPS. After each match, the data collected through video-tracking system were converted using the dedicated calibration equation for reducing the differences than GPS.

After the completion of each training and match, each file was trimmed so that only data recorded when the player was on the field was included for further analysis. During both training sessions and home matches, a customized spreadsheet was used to allow analysis of distance covered in the following categories: total distance (TD), total high-intensity running distance (HSR, $15\text{--}20 \text{ km}\cdot\text{h}^{-1}$), total very high-speed running distance (VHSR, $20\text{--}24 \text{ km}\cdot\text{h}^{-1}$), total sprint distance (SPR, $>24 \text{ km}\cdot\text{h}^{-1}$) (18,23,46), and total distance with variations in running speed $>3 \text{ m}\cdot\text{s}^{-2}$ (accelerations/decelerations, Acc + Dec) (49,57). TD, HSR, VHSR, SPR, and Acc + Dec were accounted as total (m) or relative ($\text{m}\cdot\text{min}^{-1}$) distance covered. The week-to-week and match-to-match variability were calculated for TD, HSR, VHSR, SPR, and Acc + Dec both for training and match load demands, respectively. Match load for each parameter was also expressed per time unit ($\text{m}\cdot\text{min}^{-1}$). TD, HSR, VHSR, SPR, and Acc + Dec were measured during training and match using GPS and MCIS, respectively. The interchangeability of these 2 tracking technologies has been established (49). For each dependent locomotor activity, a calibration equation was calculated to compare GPS and MCIS, as previously proposed (49).

Statistical Analysis

Statistical analysis was performed using a statistical software package (SigmaPlot v-12.5, Systat Software Inc., San Jose, CA). To check the normal distribution of the sampling, a Shapiro-Wilk test was used. Between-week and between-match coefficient of variation (CV) were calculated to determine training and match demands variability in TD, HSR, VHSR, SPR, and Acc + Dec. A linear mixed model analysis was used to calculate the individual relationship between TD, HSRD, VHSRD, sprint, and Acc + Dec covered during the training sessions across a 4-week cumulative load with the locomotor demands covered during the following official match; a maximum likelihood estimation (MLE) model was used. To

determine the differences between M2 and M3 in each locomotor metric, a post-hoc analysis was applied. The residual distribution was checked by a diagnostic analysis to confirm that the residuals were normally distributed ($p > 0.05$ in the Shapiro-Wilk test) (16). The correlation coefficient strength was interpreted as follows: $r = 0.00\text{--}0.09$ *trivial*, $0.10\text{--}0.29$ *small*, $0.30\text{--}0.49$ *moderate*, $0.50\text{--}0.69$ *large*, $0.70\text{--}0.89$ *very large*, and $0.90\text{--}0.99$ *nearly perfect*. The Cohen's d effect size with 95% confidence intervals (CI) was calculated and interpreted as follows: <0.20 : *trivial*, $0.20\text{--}0.59$: *small*, $0.60\text{--}1.19$: *moderate*, $1.20\text{--}1.99$: *large*, and ≥ 2.00 : *very large* (27). Statistical significance was set at $\alpha < 0.05$. Unless otherwise stated, all values are presented as mean \pm SD.

Results

Average Training Loads

A high to very-high week-by-week variability was observed in both M2 and M3 for TD (~ 36 and $\sim 21\%$, respectively), HSR (~ 38 and $\sim 16\%$), VHSR (~ 43 and $\sim 27\%$), SPR (~ 59 and $\sim 34\%$), and Acc + Dec (~ 38 and $\sim 18\%$).

As shown in Figure 1, a *small* [ES: -0.57 (CI: $-1.44/0.29$)] difference with a similar ($p = 0.085$) TD in M2 ($\sim 15,967$ m) than M3 ($\sim 19,222$ m) was found, whereas HSR was *moderately* [ES: 0.73 ($-0.14/1.61$)] higher ($p < 0.001$) in M2 (~ 666 m) than M3 (~ 489 m).

As shown in Figure 2, a *trivial* [ES: 0.12 ($-0.73/0.99$)] difference with a higher ($p = 0.026$) VHSR in M2 (~ 490 m) than M3 (~ 464 m) was found. Sprint showed a *moderately* [ES: 0.63 ($-0.23/1.50$)] higher ($p < 0.001$) distance covered in M2 (~ 197 m) than M3 (~ 126 m), whereas a *moderately* [ES: -0.80 ($-1.68/0.07$)] slightly lower ($p = 0.045$) Acc + Dec in M2 (~ 667 m) than M3 (~ 865 m) was found.

Individual Training Loads

As shown in Figure 1, player 1 showed similar ($p > 0.05$) training load in M2 and M3 with *small* (ES: $0.20/0.42$) differences for TD and HSR; player 2 and player 3 showed similar ($p > 0.05$) training load in M2 and M3 with differences for TD and *moderate* (ES: $0.62/0.85$) differences for HSR.

As shown in Figure 2, player 1 showed similar ($p > 0.05$) training load in M2 and M3 with *small* (ES: $0.21/0.37$) differences for VHSR and Acc + Dec, whereas SPR showed *moderate* [ES: 0.69 ($-0.19/1.56$)] differences; player 2 and player 3 showed similar ($p > 0.05$) training load in M2 and M3 with *trivial* (ES: $-0.12/0.03$) differences for Acc + Dec, *small* (ES: $0.24/0.50$) differences for VHSR, and *moderate* (ES: $0.62/0.85$) differences in SPR. Between-players comparison showed *trivial* to *very large* (ES: $0.07/3.83$) differences within each dependent parameter (Figures 1 and 2).

Official Match Locomotor Demands

As shown in Figures 3 and 4, the match-by-match variability for relative (i.e., $\text{m}\cdot\text{min}^{-1}$) distance was $\sim 5.2\%$ for TD, $\sim 13.4\%$ for HSR, $\sim 19.7\%$ for VHSR, $\sim 28.8\%$ for SPR, and $\sim 15.8\%$ for Acc + Dec; the overall between-matches variability for each player is showed in Table 1. Because of different time exposure, when considering the match-by-match variability using the total distance covered (i.e., meters instead of $\text{m}\cdot\text{min}^{-1}$), it increases for TD ($\sim 25\%$), HSR ($\sim 27\%$), VHSR ($\sim 37\%$), SPR ($\sim 37\%$), and Acc + Dec ($\sim 26\%$).

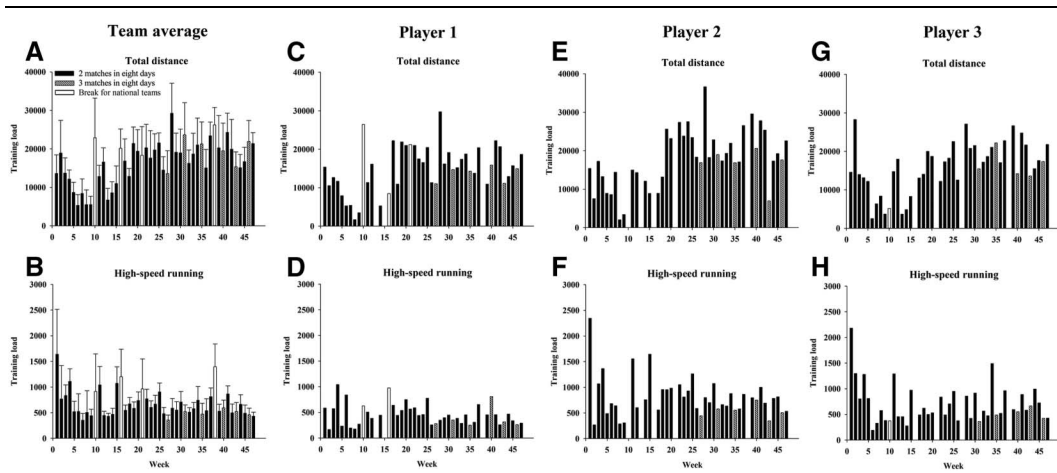


Figure 1. Week-by-week training load variations for total distance and high-speed running distance during the season. Data are reported for team average (panels A–B; mean ± within-players SD) and for 3 representative players: player 1 (C–D), player 2 (E–F), and player 3 (G–H). Black bar, barred bar, and white bar indicate periods with 2 matches within 8 days, 3 matches within 8 days, and breaks for national team, respectively.

Figure 3 shows the total meters covered for TD and HSR across M2 and M3. Normalizing the distance covered in $\text{m}\cdot\text{min}^{-1}$, *trivial* differences between M2 and M3 for TD [$\sim 117.7 \text{ m}\cdot\text{min}^{-1}$ and $\sim 118.0 \text{ m}\cdot\text{min}^{-1}$, $p = 0.949$, ES: $-0.01 (-0.66/0.63)$] and HSR [$\sim 17.1 \text{ m}\cdot\text{min}^{-1}$ and $\sim 17.5 \text{ m}\cdot\text{min}^{-1}$, $p = 0.521$, ES: $-0.18 (-0.83/0.46)$] were found.

Figure 4 shows the total meters covered for VHHR, SPR, and Acc + Dec across M2 and M3. Normalizing the distance covered in $\text{m}\cdot\text{min}^{-1}$, *trivial* to *small* differences were found between M2 and M3 for VHHR [$\sim 6.2 \text{ m}\cdot\text{min}^{-1}$ and $\sim 6.2 \text{ m}\cdot\text{min}^{-1}$, $p = 0.978$, ES: $0.00 (-0.65/0.65)$], SPR [$\sim 3.9 \text{ m}\cdot\text{min}^{-1}$ and $\sim 4.2 \text{ m}\cdot\text{min}^{-1}$, $p = 0.187$, ES: $-0.44 (-1.09/0.22)$], and Acc + Dec [$\sim 5.3 \text{ m}\cdot\text{min}^{-1}$ and $\sim 5.6 \text{ m}\cdot\text{min}^{-1}$, $p = 0.084$, ES: $-0.46 (-1.12/0.19)$].

Each representative player (Figures 3 and 4) showed *trivial* to *small* (ES: -0.03 – -0.54) differences in relative (i.e., $\text{m}\cdot\text{min}^{-1}$) TD, HSR, VHHR, SPR, and Acc + Dec within M2 than M3. Moreover, *trivial* to *very large* (ES: $0.09/3.18$) between-players differences within each dependent parameter (Figures 3 and 4) were found.

Comparison Between Matches Within Congested Periods

Within-M3, relative TD, HSR, VHHR, SPR, and Acc + Dec showed *trivial* to *small* (ES: $0.08/0.55$; $p > 0.05$) differences across the first, second, and third match played for both team average and individual representative players. Moreover, in the

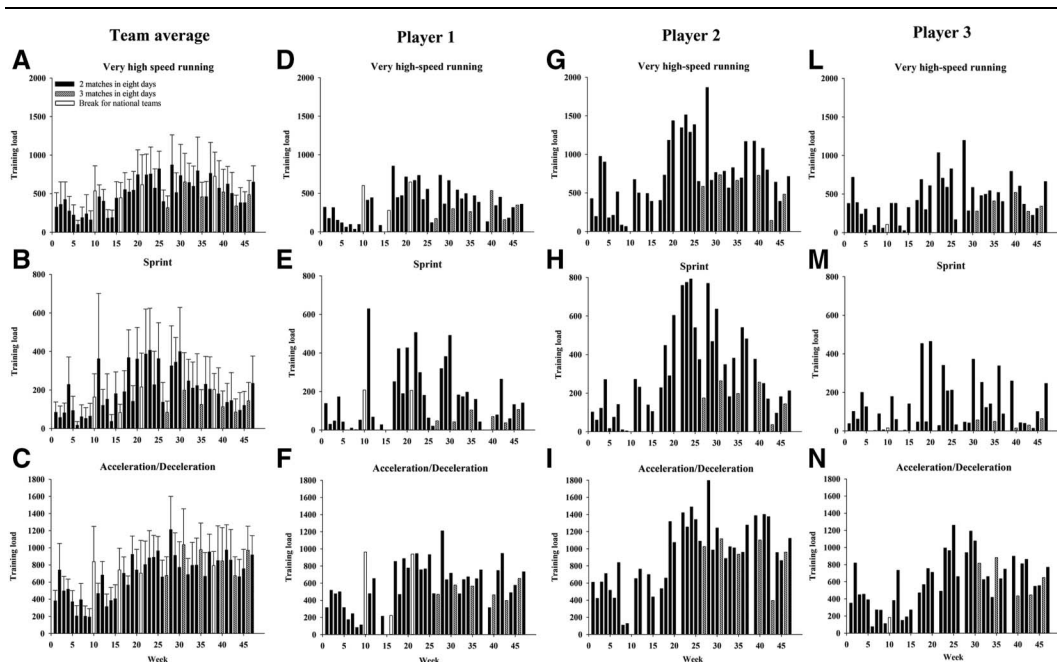


Figure 2. Week-by-week training load variations for very high-speed running distance, sprint distance, and acceleration/deceleration distance during the season. Data are reported for team average (panels A–C; mean ± within-players SD) and for 3 representative players: player 1 (D–F), player 2 (G–I), and player 3 (L–N). Black bar, barred bar, and white bar indicate periods with 2 matches within 8 days, 3 matches within 8 days, and breaks for national team, respectively.

Table 1
The coefficient variation (CV%) between matches is shown for each player.*†

	n°	TD	CV%	HSR	CV%	VHSR	CV%	SPR	CV%	Acc/Dec	CV%
Player 1	28	109.3 (5.0)	4.6	13.1 (1.9)	14.2	5.6 (0.8)	14.9	4.1 (1.1)	27.4	5.7 (0.6)	10.4
Player 2	35	108.4 (7.2)	6.6	14.5 (2.3)	15.6	5.7 (1.0)	18.3	4.0 (1.0)	24.4	4.9 (0.7)	15.1
Player 3	15	109.3 (6.4)	5.8	14.7 (2.2)	15.1	6.2 (1.1)	17.1	4.2 (1.0)	22.9	5.5 (0.7)	12.8
Player 4	34	126.7 (7.2)	5.7	22.6 (3.0)	13.1	6.9 (1.1)	16.1	3.0 (0.8)	25.5	5.2 (0.8)	15.8
Player 5	38	122.5 (5.2)	4.2	19.8 (2.5)	12.6	5.6 (0.9)	16.1	3.4 (1.1)	30.8	5.0 (0.7)	14.4
Player 6	10	122.8 (6.7)	5.5	20.8 (2.3)	11.1	7.5 (1.6)	21.0	3.8 (1.0)	27.3	5.5 (0.9)	15.7
Player 7	39	121.5 (6.1)	5.0	18.9 (2.4)	12.6	7.6 (1.6)	21.3	5.8 (1.5)	26.5	6.5 (1.1)	17.5
Player 8	21	120.2 (6.4)	5.3	19.0 (2.4)	12.8	7.4 (1.8)	23.9	4.8 (1.6)	32.1	6.0 (1.1)	18.4
Player 9	24	125.1 (7.1)	5.6	21.0 (2.7)	12.9	8.0 (1.4)	17.3	5.0 (1.3)	27.1	6.7 (1.2)	18.3
Player 10	26	109.1 (6.1)	5.6	12.7 (1.8)	14.3	4.1 (1.1)	26.3	2.5 (0.9)	35.3	4.0 (0.7)	16.3
Player 11	25	115.1 (4.9)	4.3	14.9 (1.6)	10.8	5.3 (1.1)	20.7	3.1 (0.9)	28.9	4.4 (0.9)	20.3
Player 12	30	112.1 (5.4)	4.8	13.0 (2.1)	16.0	4.6 (0.9)	18.9	3.3 (0.9)	28.2	4.4 (0.8)	18.6
Player 13	22	114.7 (6.6)	5.7	15.5 (2.4)	15.3	5.4 (1.2)	22.6	3.1 (0.8)	25.4	5.1 (0.6)	12.6
Player 14	23	115.9 (4.9)	4.2	15.3 (1.8)	11.6	4.8 (1.0)	21.1	2.8 (1.1)	40.9	5.2 (0.8)	14.4

*TD = total distance; HSR = high-speed running; VHSR = very high-speed running; SPR = sprint distance; Acc/Dec = accelerating and decelerating distance.

†Individual average locomotor load ($m \cdot min^{-1}$) was calculated by the official matches played at least 85 minutes for a minimum of 10 matches per player. Number of considered matches (*n*), mean (*SD*), and CV % are shown for each locomotor parameter.

first, second, and third match, a similar ($p > 0.05$) content for HSR (~14.7% than TD), VHSR (~5.3%), SPR (~3.4%), and Acc + Dec (~4.7%) were retrieved.

Starters vs. Nonstarters

No differences in training load were observed between starters and nonstarters, whereas starters had higher match load than nonstarters for each metric; detailed information about training and match load in starters and nonstarters is reported in Table 2. Therefore, the total load was moderately to largely higher in starters than nonstarters (Table 2).

Individual Associations Between Training Load and Official Match Locomotor Demands

As reported in Table 3, the 4-week cumulative load for VHSR and SPR showed a large to very large positive influence on TD, HSR, VHSR, and Acc + Dec covered during official match; VHSR showed a largely positive influenced on SPR covered during

official match; TD was very largely correlated with higher Acc + Dec retrieved during official match.

In addition, Figure 5 shows the individual association between training load and official match locomotor demands in 4 representative players. Player 1 showed no associations between training load and official match locomotor demands. Player 2 showed large influence of VHSR and SPR on HSR and Acc + Dec accumulated over the match. Player 3 showed a large to very large influence of VHSR and SPR on HSR, VHSR, and SPR retrieved during official match. Player 4 showed large to very large influence of VHSR accounted during trainings on HSR, VHSR, SPR, and Acc + Dec covered during official match; in addition, player 4 showed a very large correlation between training load for SPR and Acc + Dec accumulated during official match.

Discussion

The major findings of the present study were (a) the great variability in training load across the season in top-class soccer players; (b) the large to moderate differences in training load across M2 and M3 with more HSR, VHSR, and SPR performed

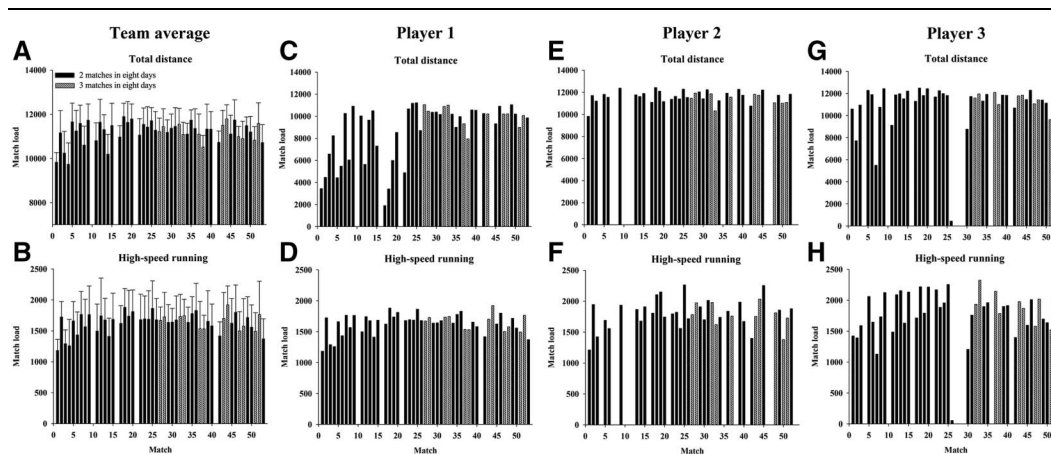


Figure 3. Match-by-match performance variations for total distance and high-speed running distance during the season. Data are reported for team average (panels A–B; mean ± within-players SD) and for 3 representative players: player 1 (C–D), player 2 (E–F), and player 3 (G–H). Black bar and barred bar indicate 2 matches within 8 days, or congested periods with 3 matches within 8 days, respectively.

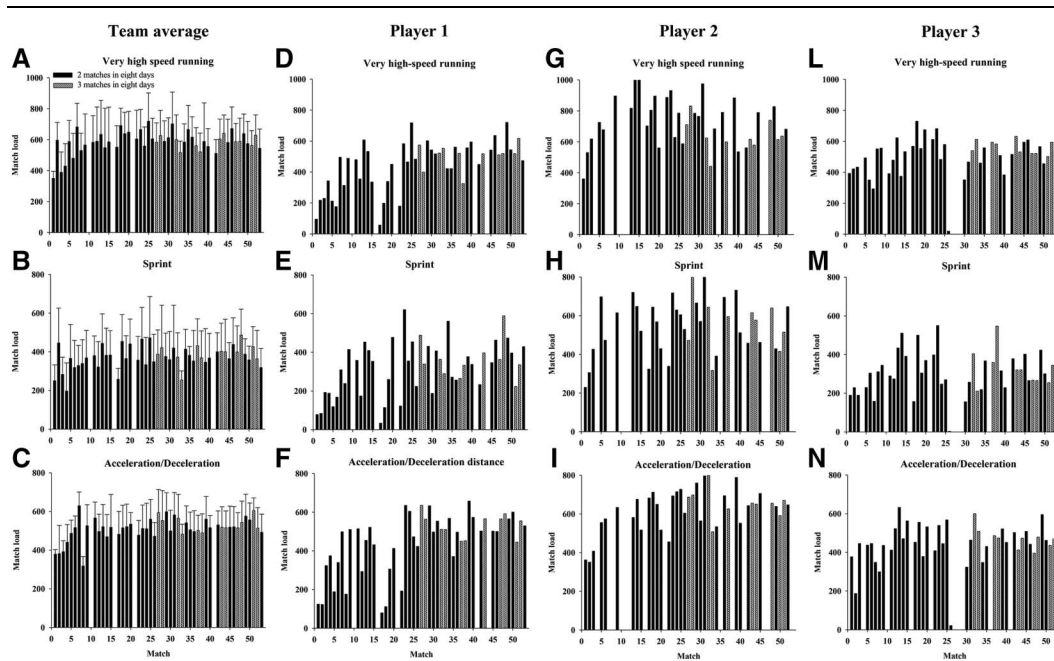


Figure 4. Match-by-match performance variations for very high-speed running distance, sprint distance, and acceleration/deceleration during the season. Data are reported for team average (panels A–C; mean ± within-players SD) and for 3 representative players: player 1 (D–F), player 2 (G–I), and player 3 (L–N). Black bar and barred bar indicate 2 matches within 8 days, or congested periods with 3 matches within 8 days, respectively.

in M2 than in M3 and more TD and Acc + Dec in M3 than M2; and (c) no difference in official match locomotor demands observed whether the top-class players played 2 or 3 official matches during an 8-day period. In addition, despite the compensatory training session for who did not play the match, no significant difference in training load (i.e., that excluded match load) was observed between starters and nonstarters; therefore, total load (i.e., training plus match load) was higher in starters because of a higher locomotor load during the matches. Interestingly, despite a high individual variability, VHSR and SPR during training largely to very largely affected TD, HSR, VHSR, and Acc + Dec during the match, VHSR during training largely affect SPR, whereas TD during training

very largely influenced only Acc + Dec covered during the match.

The present findings come with a great between-weeks training load variability across different metrics in M2 (from ~36 to ~59%). Similarly, a high between-weeks variability was found across each metric in M3 (from ~21 to ~34%). Interestingly, despite M3 was mainly characterized by an even more complex training process than M2, similar variabilities were found. Training load management is affected by several aspects such as individual wellness status (64), physical fitness (49), and technical/tactical behaviors (14) leading to great variability in training load typically intrinsic in soccer-specific real-life contextual factors (17,62). As such, the high between-

Table 2

Summary of training, match, and total load for starters and nonstarters across 4-week periods.*†

		Starters	Nonstarters	p	ES (95% CI)
Training load	TD	63,816 (12,360)	66,639 (14,409)	0.291	-0.21 (-0.76 to 0.35)
	HSR	2,498 (1,004)	2,478 (433)	0.471	0.03 (-0.53 to 0.58)
	VHSR	1836 (561)	1965 (558)	0.271	-0.23 (-0.78 to 0.33)
	SPR	688 (307)	796 (277)	0.164	-0.36 (-0.92 to 0.20)
	Acc/Dec	2,648 (636)	2,771 (670)	0.310	-0.19 (-0.74 to 0.37)
Match load	TD	37,938 (8,977)	17,500 (10,903)‡	<0.001	2.01 (1.33 to 2.70)
	HSR	5,479 (1,454)	2,587 (1813)‡	<0.001	1.73 (1.08 to 2.38)
	VHSR	1943 (512)	991 (746)‡	<0.001	1.47 (0.84 to 2.09)
	SPR	1,227 (424)	636 (521)‡	0.002	1.22 (0.62 to 2.26)
	Acc/Dec	1721 (437)	848 (610)‡	<0.001	1.62 (0.98 to 2.26)
Total load	TD	101,755 (16,045)	83,787 (17,428)‡	0.004	1.06 (0.46 to 1.65)
	HSR	7,977 (1,622)	5,032 (1956)‡	<0.001	1.61 (0.98 to 2.25)
	VHSR	3,779 (632)	2,943 (1,057)‡	0.011	0.94 (0.36 to 1.53)
	SPR	1915 (565)	1,421 (723)‡	0.028	0.75 (0.18 to 1.32)
	Acc/Dec	4,369 (769)	3,605 (1,068)‡	0.021	0.81 (0.23 to 1.39)

*TD = total distance; HSR = high-speed running; VHSR = very high-speed running; SPR = sprint distance; Acc/Dec = accelerating and decelerating distance.

†Data are presented as mean (SD). Effects size and 95% confidence intervals (95% CI) are also reported.

‡p < 0.05 vs. starters.

Table 3
The relationship between training load (4-week cumulative period) and the following match load for each locomotor parameter is shown.*

	Match load									
	TD	<i>p</i>	HSR	<i>p</i>	VHSR	<i>p</i>	SPR	<i>p</i>	Acc/Dec	<i>p</i>
Training load										
TD	0.488	0.128	0.477	0.138	0.525	0.097	0.555	0.076	0.715	0.013†
HSR	0.304	0.364	0.320	0.338	0.277	0.409	0.323	0.332	0.452	0.163
VHSR	0.624	0.040†	0.653	0.032†	0.604	0.048†	0.575	0.043†	0.682	0.020†
SPR	0.722	0.012†	0.719	0.012†	0.670	0.024†	0.521	0.100	0.676	0.022†
Acc/Dec	0.525	0.097	0.502	0.116	0.587	0.057	0.631	0.037†	0.786	0.004†

*TD = total distance; HSR = high-speed running; VHSR = very high-speed running; SPR = sprint distance; Acc/Dec = accelerating and decelerating distance.

†The bold text highlights significant correlations (*p* < 0.05).

week variability is possibly because of continuous adjustments in training prescriptions with the aims to reduce cumulative fatigue for enhancing player readiness across both M2 and, especially, M3. In addition, such differences in between-week training load across M2 and M3 may be because of the intrinsic day-by-day variability in locomotor load during soccer-specific drills (e.g., small- or large-sided games) as previously reported in French League 1 (17), Dutch first Division (62), and Italian Serie B soccer players (45). Therefore, coaches and performance scientists should consider the soccer-specific variability for both actual and cumulative training load prescriptions. Rapid spikes in training loads were found to be possible associated with an increased risk for noncontact injuries in different populations such as youth (6) and adult (5)

English Premier League soccer players, Gaelic footballers (36), Australian Football (15), and Rugby (28) league players. Conversely, a progressive high chronic training load prescription was reported as an effective strategy for a proper individual performance development (21,36). In the training routine, coaches and performance scientists should consider the multifactorial nature of factors affecting both performance development and injury risk (29). No “magic” numbers using dedicated mathematical approach can be nowadays recognized (30,31); however, an accurate analysis of the individual locomotor demands across the training routine may help practitioners to adapt training prescriptions for individual needs (i.e., a progressive exposure to high loads, an increased exposure to high speed running and sprinting for nonstarters,

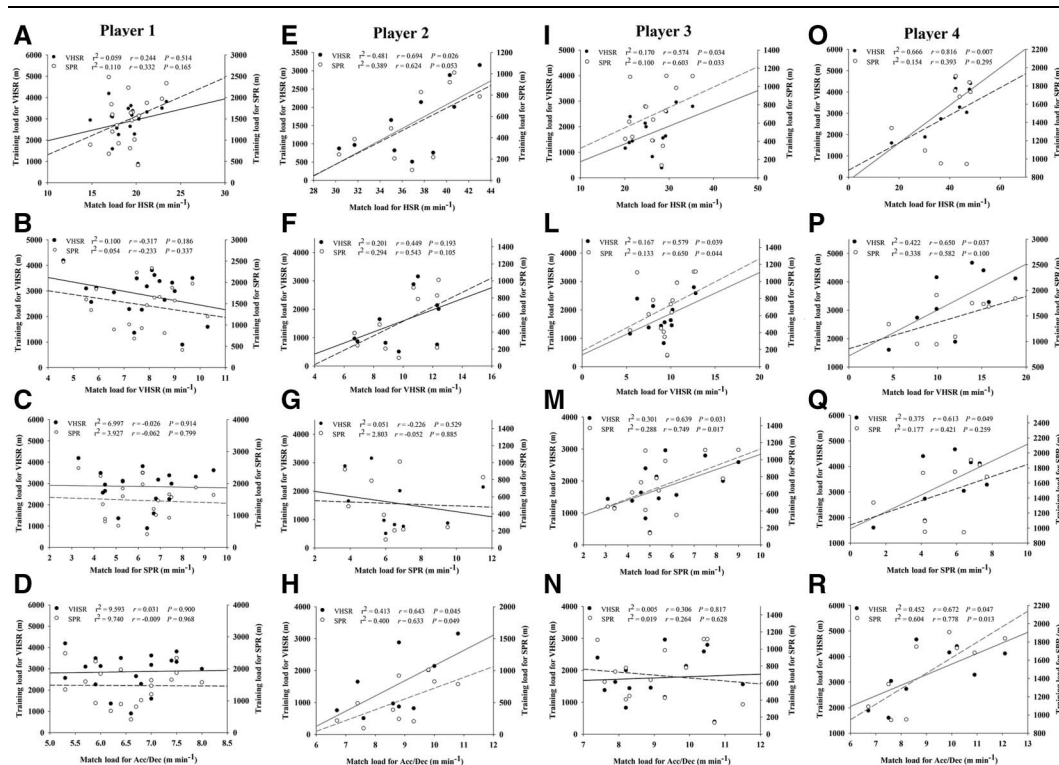


Figure 5. The relationship between training loads and match performance in 4 representative players. The very high-speed running distance (black circles, left y-axes) and the sprint distance (white circles, right y-axes) covered during a 4-week cumulative training periods are related to high-speed running (HSR), very high-speed running (VHSR), sprint distance (SPR), and acceleration + deceleration distance (Acc + Dec) covered during the following official match (x-axis). Data are shown for 4 representative players: player 1 (panels A–D), player 2 (E–H), player 3 (I–N), and player 4 (O–R). The regression analysis with coefficient of determination, coefficient of correlation, and *p*-value are also reported. The continuous bold regression line is for VHSR, and the dashed line is for SPR. The red lines highlight significant between-parameters correlation.

a manipulation in training exposure for starters, etc.). Therefore, practitioners should monitor and properly manage the changes in training loads for both performance and prevention purposes (5,6).

The players performed more HSR, VHSR, and SPR during training in M2 compared with M3, whereas TD and Acc + Dec were higher in M3. It is obvious that low-intensity training sessions are usually performed the day before a game. Soccer-specific drills, such as small-sided games in reduced pitch size, are usually used for preparing the players and team tactical behaviors across consecutive matches. It was shown that when pitch size is reduced or the number of player increased, the prevalence of the locomotor activities is rather characterized by Acc + Dec (49). These led to a higher training load for TD and Acc + Dec in M3, in which a higher number of training sessions (i.e., no day-off) mainly characterized by small pitch size drills were performed to preserve players by fatigue related to HSR, VHSR, and SPR. With this regard, attention should be placed in training load differences between starters and nonstarters, in which a lack of high-intensity running can negatively affect locomotor capacity (4) especially across consecutive congested periods (i.e., M3). In the present study, starters showed a higher total load (i.e., training load plus match load) for each locomotor metric than nonstarters, whereas training load (i.e., match load not included) showed no between groups differences. This implies that nonstarters may perform more supplementary high-intensity trainings to maintain and even develop the physical capacity during the season (i.e., to compensate the lack of match loads), as previously demonstrated in Serie A soccer players (24). However, in real-life context, the congested fixture periods reduce the time between matches affecting the possibilities to conduct high-intensity activities. For example, travel at night after an evening match, a low duration and a bad quality of sleep, and less than 48 hours before next match limit the possibility to do a high volume of high intensity training. Nevertheless, coaches and performance scientists should carefully try to manage individual workload for nonstarters within such contextual limitations especially across congested fixtures periods (i.e., M3)).

To check for variability in the dependent parameters because of different technical and tactical requirements across the matches (23,46), the CV for each metric during both M2 and M3 was calculated. Relative locomotor metrics ranged from ~5 to ~29% for TD and SPR, respectively. Similarly, ~30% match-to-match variations for distance covered $>25.2 \text{ km}\cdot\text{h}^{-1}$ were previously found over the whole match in Premier League (23) and Serie A (46) soccer players. On the contrary, a lower match-to-match variability for SPR (~17%) was reported in the most demanding phases of match play in Serie A soccer players (57). This typical variability may be considered by coaches and performance scientists because of the performance of soccer players is highly variable because of several technical and tactical aspects. Therefore, not just the locomotor demands may help to discriminate between a better or worst performance. As such, it was previously reported that the locomotor demands during official matches does not reflect the individual training status of elite Italian Serie A soccer players (51).

Moreover, the present study compared the locomotor load during both M2 and M3. Interestingly, no differences in TD, HSR, VHSR, SPR, and Acc + Dec were observed between M2 and M3. In addition, no difference in any locomotor metrics was found between first, second, and third match in M3. Similarly to the present results, no differences in the locomotor demands between congested and noncongested fixtures were found in

Spanish La Liga (35), French League One (19), English third division (33), and Brazilian first and second division (43) soccer players. In contrast, studies have observed that a high frequency of match play did impair official match locomotor demands (39,59). Congested periods of match play have been shown to lower physical fitness and, in turn, match performance as a result of reduced training load (59). It was shown that top-class Italian Serie A soccer players increased their physical performance when only conducting 2 matches per 8 days in association with a large amount of high-intensity training loads (39). This suggests that a reduction in high-intensity training activities during congested fixed periods could negatively affect official match locomotor demands, and supplementary training prescriptions are required for maintaining individual physical fitness. Moreover, the effects of congested match period on hematological parameters and physical fitness in elite soccer player were examined, and potentially negative effects on performance were underlined (59). In addition, technical performance was suggested to be maintained when players were exposed to 3 matches in 7 days or less (2), or when 6 consecutive matches were played within 3 days' rest in between (10). However, controversial or inconclusive findings (34) highlight that future studies are required to examine performance impairments integrating physical performance, technical skills, and tactical behaviors together.

The accumulated 4-week VHSR and SPR during training was associated with TD, HSR, VHSR, and Acc + Dec covered during official match. Very high-speed running during training was also related to SPR during match, whereas TD was only associated with Acc + Dec distance covered during the match. Therefore, the present findings suggested VHSR and SPR as main effective training load metrics to properly develop physical performance in top-class soccer players. It has been previously suggested that very high speed to sprint running (29) does lead to increase physical performance and prevent injuries (8,36) by affecting neuromuscular hamstring pattern at a greater extent than different strengthening exercises (65). Moreover, high-intensity activities do improve performance reducing energy expenditure and increase expression of muscle Na⁺, K⁺ pump α subunits, which may preserve muscle cell excitability and delay fatigue development during intense exercise (3). Therefore, the time spent and the distance covered at high-intensity activities during training and matches (52) were suggested as a useful tool for both metabolic and neuromuscular performance development in elite soccer (4). In addition, professional players have become faster over the time, indicating that sprinting skills are becoming more and more a key factor in modern soccer (7,9). Nevertheless, several studies (1,12,37) showed a great difference between training loads and match demands especially for intensities ranging from high-speed running to sprint in elite soccer players (47). These highlighted a gap between training and match locomotor demands (47) suggesting that practitioners should be considered to intensify training, especially for high-intensity activities. In addition, the present findings suggested that an individualized approach to training load management is required. From an individual point of view, no clear associations (i.e., presence of responder and nonresponders) between training load and official match locomotor demands were found. The players' individual physical and physiological characteristics (e.g., cardiovascular and metabolic capacity, etc.) (50) can influence training outcomes and dose-response effects. As such, for replication purposes, possible differences in players' characteristics, coaching' style of training, etc. should be considered because of

possible effects on training outcomes. Therefore, to optimize physical performance development in top-class soccer players, an intensified acute and cumulative training load management for VHSR and SPR seemed required because of their cumulative effects on official match performance. Nevertheless, an individualized approach is recommended.

Some strength and limitations of current study need to be considered. (a) The sample size used is relatively small and limited to just one team. However, this investigation come from real-life context were a large sample size was not feasible because of a limited number of top-class soccer players. Therefore, as previously suggested, researches from real life provide a very high impact on a real-world practice, even with a small sample size (26). (b) Differences in between-periods training status, such as aerobic fitness, neuromuscular characteristics, etc., should be considered. This physiological information is mandatory to determine the individual performance abilities of top-class player; the official match locomotor demands alone may be affected by several technical-tactical factors that could involve players in a higher or lower locomotor demands during official matches independently by a lower or higher fitness status across the season (51). These latter could affect the individual relationship between training loads and official match locomotor demands. In addition, it should be remark that the performance of soccer players is dependent on a great number of factors, only one of these is the locomotor demand; not just the locomotor demands may help to discriminate between a better or worst performance. As mere examples, a player can lose the ball possession, and he must perform a recovery sprint, a player in a wrong position to defend a pass must perform a high acceleration to recover; even on the team level, a team cannot retain possession and thus sits in a low block defensive shape to limit the space in behind and thus limit the distance that needs to be covered at high speed when defending. These latter further highlight the multifactorial nature of soccer performance. Therefore, the current study opens to future perspective and further investigations in the description of the training/locomotor demands during competitive periods and also about player's performance. In addition, future research studies seem required for a clear understanding of the relationship between training load and physical, technical, and tactical performance development in top-class soccer players.

A high variability in locomotor load across different metrics during both trainings and matches was found especially for high-intensity activities, such as VHSR and SPR. During congested fixture periods, official match locomotor demands were maintained across the 3 matches during a week. The total load for nonstarters was lower than starters, and it should be considered for the individual training load management across the season. The VHSR and SPR during training were associated with official match locomotor demands and suggested to intensify the training load for optimizing high performance in top-class soccer players, although an individual approach should be considered.

Practical Applications

The variations across M2, M3, and match should be considered for acute and cumulative training load prescription across competitive season. Total load (i.e., training and match load) should be considered for compensative exercise or tapering prescriptions, especially for nonstarters. For a mere example, at match-day plus 2, individualized interval/

intermittent running-based aerobic exercises (i.e., at \sim maximal aerobic velocity; from $\sim 15 \text{ km}\cdot\text{h}^{-1}$ to $\sim 20 \text{ km}\cdot\text{h}^{-1}$) (48,56), very high-speed to sprint running-based exercise (e.g., from $\sim 20 \text{ km}\cdot\text{h}^{-1}$ to \sim peak speed), and/or high-intensity soccer-specific drills can be prescribed accordingly with previous match exposure (i.e., starters or non-starters) leading to a supplementary amount of high-intensity activities especially in who did not played the game. Similarly, practitioners could manage week-by-week training loads with the aims to develop a progressively increased training load for optimizing individual physical fitness and to reduce between-week variability, which were previously related with a possible injury risk increment (5,6). Interestingly, the association between VHSR and SPR with official match locomotor demands may help practitioners for a better acknowledgement of the most important metrics for training load management. Therefore, high to very high-speed running or sprint activities were found to be the most effective tools to positively affect the locomotor demand during official match in top-class soccer players. In practice, in the middle of the week (i.e., match-day plus 4 or match-day minus 3) in M2 or in the day after the official match for who did not play in M3, soccer-specific drills (49) and/or high-intensity running-based exercises can be proposed to maximize transfer to match physical performance overloading the average (49) and maximal match-play locomotor intensities (52,55,57) for VHSR and SPR. Therefore, as a mere practical example, practitioners could prescribe large-sided games (i.e., $\sim 300 \text{ m}^2$ per player), supplementary individual positional exercises (i.e., when small pitch size are required), and/or running-based exercises to recreate sprint activities similar to official match demands (52), as previously suggested in Serie A soccer players (49,57); conversely, when lower locomotor demands are required, a reduction in the relative pitch sizes (i.e., area per player) may be used to reduce high-intensity activities maintaining or increasing the technical demands (54). Finally, individual dose-response relationships and fitness changes need to be continuously monitored over the season because of a highly variable individual association between training load and official match locomotor demands. Despite VHSR and SPR seems an effective tool for the physical performance enhancement during official matches, coaches and performance scientists should consider individual variability in the dose-response effect. This latter information suggested that an overall individualized approach is mandatory required to properly manage individual physical performance development.

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