Submission Type: Original Research

Variability of external load measures during soccer match play: Influence of player fitness or pacing?

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Abstract word count: 204

Text-only word count: 2454

Number of Tables: 0

Number of Figures: 3

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ABSTRACT

Purpose: The aims of this study were to examine the variability of selected external load metrics within 15-min intervals during soccer match play and examine their relationship with players' high-intensity intermittent fitness. **Methods:** A total of 18 male soccer players were monitored for their external load metrics during 26 matches which included: total distance (TD), high metabolic load distance (HMLD), and mechanical work (MW) (defined as the sum of accelerations and decelerations >3 m^2). Additionally, players completed the 30-15 Intermittent Fitness Test (V_{IFT}). **Results:** TD had lower coefficient of variation (CV) values than HMLD and MW (ES; 5.2 to 6.4; *very large*). Within-players' Δ-15_{min} showed *moderate-to-large* decreases (ES; -0.7 to -1.6) and increases (ES; 0.9 to 1.8) in absolute and CV values, respectively. *Large* relationships (*r*= 0.55 to 0.61) were observed between V_{IFT} and 15-min_{mean} and 15-min_{best} in all selected external load metrics. However, *small*-to-*moderate* (0.27 to 0.41) associations were observed between V_{IFT} and Δ-15_{min} in selected external load metrics. **Conclusion:** These findings suggest that those players with relatively lower intermittent running capacity might show lower variability during the match, as evidenced by smaller reductions in high intensity actions during the final 15 minutes. We attribute these observations to players' possessing better pacing strategies.

Keywords: football; athletic performance; total distance, high metabolic load distance, mechanical work, external load

Introduction

Soccer is an intense intermittent sport requiring players to maintain their physical performance during a match [1]. Players often experience fatigue during the match, which can have an impact on their performance after short periods of intense activity (i.e., transient fatigue), in the end of the first half or towards the end of the match [2].

Monitoring fluctuations of a player's physical performance during a match is often performed using different time intervals (e.g., 15-min intervals) that helps practitioners make informed decisions about a player's fatigue status [3,4]. By analyzing running performance in shorter time intervals, it is possible to identify changes in running intensity and patterns that might be related to specific match events or factors [5]. To detect a real change in physical performance for monitoring purposes, one of the first steps is to understand the 'noise' (i.e., variability or typical error) of the selected metric [6]. Match-to-match variations in external load measures depends on the metric selected, for example total distance possessing lower coefficient of variation (CV= 6.8%) compared to accelerations (CV= 17%) [7].

Several studies report the variability of physical performance in external load metrics during 15-min intervals of soccer matches [3,4,7,8]. Soccer has also evolved such that players are now required to perform more high-intensity actions than reported 20 years ago[9]. Few studies have examined the variability of more explosive movements (e.g., accelerations, decelerations) in professional soccer players [7,10]. Moreover, the variability of metrics such as high metabolic load distance (HMLD) that includes both high-speed running (distance > 19.8 $km \cdot h^{-1}$) and explosive distance (distance covered by accelerations and decelerations) during 15-min intervals have never been examined. Indeed, as the intensity of soccer has evolved, both the number of explosive actions and the distance covered via these actions (i.e., accelerations, decelerations, high-speed running) has become important. HMLD therefore provides a gestalt measure that accounts for these actions.

The difference between first and last 15-min intervals during matches (i.e., Δ-15_{min}) have been used as an indicator of fatigue in match physical performance without examining its variability in professional soccer players [4,8,11]. Although the relationship between high-intensity intermittent running capacity and match performance have been reported before [1,4], no study has yet examined its association with Δ-15_{min}. The understanding of such a relationship can assist practitioners in comprehending whether physical qualities influence players' pacing strategy during the match (i.e., 'fitter' players exhibit a more consistent physical performance during the match). We hypothesized that players with poorer high intensity intermittent running performance adopt different pacing strategies to those players with superior capabilities.

The aims of this study were to examine the variability of selected external load metrics across 15-min intervals during match play in and examine their relationship with high-intensity intermittent running performance.

METHODS

Participants

Data were collected from 18 professional male soccer players (mean ± SD age: 24.2 ± 3.4 years, body mass: 76.1 ± 3.2 kg, and height: 179.2 ± 4.6 cm) during an in-season phase of 2021-2022 in the Greece Super League corresponding to Tier 4 of the Participants Classification Framework [12]. Out of the 18 players, four were categorized as full backs, three as central defenders, four as midfielders, five as wingers, and two as forwards. The data were collected by the club's sport science staff for the monitoring process in which player activities are routinely measured over the course of the competitive season [13]; therefore, ethics committee clearance was not obtained beforehand. However, the the club provided written permission to use the data for the purpose of the study. All players at the club were also aware as part of contractual obligations that data might be used for research purposes and provided consent for their data to be used.

Design

This study used a longitudinal observational design with a non-probabilistic convenience sampling strategy. Eighteen professional soccer players from the same team were systematically monitored for selected external load measures over a series of 26 matches during the in-season period from September 2021 to March 2022 (seven months). The inclusion criteria for match data were at least 60 minutes playing time. Additionally, the players underwent a single testing session to evaluate their high-intensity intermittent fitness using the 30-15 Intermittent Fitness Test ($30\text{-}15_{IFT}$, V_{IFT}) during the preseason phase.

Procedures

The valid and reliable 30-15 Intermittent Fitness Test[14] was used in the end of pre-season before commencing official matches on natural turf at 10:30 A.M (temperature at 24-26 ºC, relative humidity 50-60%). The test consisted of 30 s shuttle runs interspersed with 15 s passive recovery periods. The test started at 8 $km\cdot h^{-1}$ and increased by 0.5 km·h^{-1} for each successive 30 s. The test ended when a player reached exhaustion or could not reach the next 3 m zone on the audio signal on three consecutive occasions. The speed at termination of the 30-15$_{IFT}$ (V_{IFT}) was recorded for analysis.

During all matches selected external load metrics including total distance (TD), HMLD, and mechanical work (MW) (the sum number of accelerations and decelerations >3 m^2) were collected for analyses. Data were collected using STATSport GPS system (Apex 10 Hz; 100 Hz tri-axial accelerometer, and 10 Hz magnetometer). The unit was positioned on the participant's back, midway between the scapulae. The same unit was worn by each player for each match. Validation of this instrument has been previously conducted, and the results confirm its ability to evaluate both linear running and sport-specific activity. Specifically, the Apex units (10 and 18 Hz) demonstrated a high level of accuracy with bias < 5% in the selected external load metrics [15].

All data recorded by the units were downloaded and further analyzed by the STATSports Apex Software (Apex 10 Hz version 2.0.2.4, North Ireland). The data processed were split in 15-min intervals for analyses and computed relative (per minute) to include extra time (>90 min) and standardize comparisons. Therefore, extra time minutes were included in the last 15-min interval of the match.

Statistical Analyses

Data in the text and figures are presented as means with standard deviation (SD) or 90% confidence intervals (CI), where specified. Match-to-match variations in 15-min intervals for different metrics were analyzed using the typical error of measurement (TE) in standardized units (Cohen's d principle) [16] and expressed as a coefficient of variation (CV) [17]. Differences between first and last 15-min intervals for absolute values and CV of TD, HMLD, and MW metrics were standardized as a factor of smallest worthwhile change (SWC) based on a small standardized effect (0.2 x between-athletes' standard deviation SD) [18]. The Hopkins scale was used for interpreting changes: < 0.2: *trivial*; 0.2 – 0.6: *small*; 0.6 – 1.2: *moderate*; > 1.2: *large* [17]. Pearson correlation coefficients were used to measure the relationships between V_{IFT} with mean and best 15-min performed for different metrics during the matches. The magnitude of the correlations (r, 90% confidence limits, CL) was ranked as *trivial* (<0.10), small (>0.10-to-0.30), *moderate* (>0.30-to-0.50), *large* (>0.50-to-0.70), *very large* (>0.70-to-0.90), *nearly perfect* (>0.90-to-0.99), and *perfect* (1) [18].

Results

The mean ± SD V_{IFT} value of players was 20.5 ± 0.6 $km \cdot h^{-1}$. Between-group CV for different metrics are shown in Figure 1 (A). Data regarding absolute values of selected metrics during all 15-min intervals (± SD) are represented in Figure 1 (B, C, and D).

Variations of different metrics during 15-min intervals

Between-metric analyses showed TD has lower CV values compared with HMLD (98.0%, [80.0: 117.7]; ES: 5.20 [4.47: 5.92]; *very large*) and MW (134.3%, [109.1: 162.7]; ES: 6.48 [5.61: 7.35]; *very large*). The CV of HMLD was lower than MW (15.7%, [3.0: 29.9; ES: 1.03 [0.21: 1.85]; *moderate*).

Within-player Δ-15$_{min}$ for absolute and CV values of selected metrics

Within-player mean CV (±SD) for selected metrics during different 15-min intervals are shown in Figure 1 (A). Within-player changes of selected metrics from first to last 15-min intervals (Δ-15_{min}) showed *large* (-11.9.0%, [-14.2: -9.6]; ES: -1.62 [-1.95: -1.29]) changes for TD and *moderate* changes for HMLD (-19.7.0%, [-23.4: -15.8]; ES: -1.04 [-1.27: -0.82] and MW (-17.4.0%, [-20.9: -13.8]; ES: -0.71 [-0.87: -0.55) metrics, respectively (Figure 1).

Figure 1 about here

The CV of all selected metrics increased with *large* changes in TD (45.3%, [23.7: 70.7]; ES: 1.48 [0.84: 2.12]) and HMLD (51.8%, [31.8: 74.8]; ES: 1.81 [1.20: 2.42]) and *moderate* changes (38.5%, [20.4: 59.3]; ES: 0.91 [0.52: 1.30]) in MW (Figure 2).

Figure 2 about here

Relationship between V_{IFT} with Δ-15$_{min}$ and match performance

Trivial associations were observed between V_{IFT} and Δ-15_{min} for TD (r = 0.06, -0.35; 0.45). Small (r = 0.27, -0.15; 0.60) and *moderate* (r = 0.41, 0.00; 0.69) positive associations were observed between V_{IFT} and Δ-15_{min} in MW and HMLD metrics, respectively.

Large relationships were observed between V_{IFT} and 15-min_{mean} and 15-min_{best} performance of all selected metrics among players (Figure 3).

Figure 3 about here

Discussion

The aims of this study were to examine the variability of selected external load metrics of 15-min intervals during match play and examine their relationship with high-intensity intermittent running fitness. The main findings of the present study were that a) TD offers a more stable measure of movement characteristics of soccer players during match play compared to HMLD and MW, b) within-player's Δ-15_{min} showed *moderate-to-large* decreasing (ES; -0.7 to -1.6) and increasing (ES; 0.9 to 1.8) trends in absolute and CV values, respectively, and c) intermittent running capacity measured using the V_{IFT} was related to players' TD, HMLD and MW during both 15-min_{mean} and 15-min_{best}.

Our results revealed that TD was less noisy (i.e., has lower CV values, 9%) than HMLD (17%) and MW (21%). These findings agree with previous studies[7,10,19,20] showing that less intense running activities have lower within-match CV values compared to more intense activities. This presents a dilemma for practitioners seeking to reliably monitor sprinting that is often associated with key events in a match [21] or a higher risk of injury[22].That HMLD is less noisy (17%) compared to sprinting distances reported elsewhere (53%) [7] , suggests that monitoring more complex metrics such as HMLD might provide a more stable assessment of explosive-type movements (i.e., distance covered by accelerations and decelerations) that inform practitioners about the key characteristics of soccer match play. The CV for mechanical work, defined as a combination of the number of accelerations and decelerations, was slightly higher (21 cf. 17%) than a study reporting match-to-match variability for accelerations [7]. While this metric might appear more specific to intermittent sports such as soccer, is remains less reliable than other metrics (e.g., total distance) for monitoring purposes.

Our analyses of within-player Δ-15_{min} revealed a *large* reduction in TD (ES; -1.62) and *moderate* decreases in HMLD and MW (ES: -0.71 to -1.04) (Figure 1). These results confirm previous studies reporting reductions in high-intensity running in the final 15-30 min compared to initial 15-min of a match in both normal [3,4,11,23] and hot environments [8]. Assuming fatigue occurs towards the end of the match and is represented by reductions in movement characteristics, our data suggest that fatigue can be represented by TD and higher intensity actions of HMLD and MW. These data suggest fatigue occurs towards the end of the match for all players independent of competitive standard and team position [4] which might be explained by dehydration [24] and muscle fiber glycogen depletion[25].

The present study revealed greater noise toward the end of the match with Δ-15_{minCV} with *moderate* to *large* magnitudes in selected metrics (~ 31-to-45%) (Figure 2). This result contradicts the finding of Carling et al. (2016) [19] that revealed a lower variability across halves and at the end of play for total high-speed running (ranged from 37 to 142%) and running ≥80% of maximal aerobic speed (ranged from 20 to 53%). These findings highlight difficulties in interpreting movement data during the latter stages of soccer match performance and recommends the need for further research to better understand the performance fluctuations during a match.

Our results indicate *large* positive correlations between V_{IFT} and $15\text{-}min_{mean}$ and $15\text{-}min_{best}$ in all selected metrics (range; r = 0.55-0.61) (Figure 3). These observations differ from the *very large* relationships between YoYo IRT and match performance in soccer reported elsewhere [1,4]. Higher correlations might be explained by the greater specificity of Yo-Yo IRT than V_{IFT} to the intermittent nature of soccer match play[1].

The present study revealed for the first time *trivial* (r = 0.06), *small* (r = 0.27) and *moderate* (r = 0.41) associations between V_{IFT} and $\Delta\text{-}15_{min}$ for TD, MW and HMLD, respectively. These data suggest players with superior intermittent running fitness had larger decrements in the selected movement characteristics in the final quarter of a match. Players with a higher intermittent running capability might well be capable of higher outputs during the initial stages [26] that leads to greater reductions in movement towards the latter stages of a match. Those players with a lower intermittent running capacity adopt appropriate pacing strategies to distribute their efforts and maintain running performance for the entire match [27]. Indeed, players with lower intermittent running capacity might have managed their efforts more efficiently and reserved some energy for the last part of the match to perform more stable and experience less declines in the final 15-minutes of the match. These observations could also be attributed to the homogeneity of players' high intensity running performances and the contextual factors specific to the match that influence players' roles and tactical behavior subsequently effecting players' external load. [25]

This study has several limitations. We adopted a convenience sampling strategy which means the sample size, and thus number of match performances, was relatively small. The data are also drawn from a single team, meaning generalization of the findings should be done cautiously. The $30\text{-}15_{IFT}$ was conducted during the preseason which does not account for in-season fluctuations in players' fitness. Indeed, in-season testing might offer more valid measures of intermittent running fitness. We also acknowledge that reliability and validity of some of the metrics reported using the GPS devices are not reported in the literature. While practically relevant, the associated noise and the underlying movements influencing such measures remains to be elucidated. Furthermore, contextual factors, such as playing position, match venue, match status, and opponent's ranking, were not accounted for. Future research should consider including these contextual factors for more robust analyses. Finally, the study did not include a complementary analysis of tactical behavior, which could have provided additional insights into the underlying processes to explain the external load.

Practical Applications

The results of the present study reveal that total distance provides a more stable metric of player movement during soccer match play compared to more intense measures such as mechanical work and high metabolic load distance. Practitioners should therefore be cautious when tracking more intense activities to monitor players' physical performance fluctuations during matches. Based on the associations between V_{IFT} and physical performance of players during a match, coaches and practitioners might want to think carefully about the implications for tactical decisions for player selection and substitutions. For example, fitter players might require bespoke substitution strategies to maintain intensity in the position. Similarly, those whole-match players who can pace their involvement during a match might perform with less well-developed fitness and can be trained using modified conditioning strategies to those requiring high fitness.

Conclusions

This study suggests that fitness and match-related movement characteristics might not be associated. Some players with inferior high intensity running capability might show lower variability during the match, as evidenced by a less pronounced decline in total distance and high speed movements during the final 15 min of a match. Such observations are probably attributed to players' more adapted psychophysiological systems and pacing strategies.

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Table and Figure Captions

Figure 1. Whitin-player 15-min interval values of selected metrics. A) coefficient of variation on 15-min intervals, B) absolute 15-min intervals of total distance (TD) per min, C) absolute 15-min intervals of high metabolic load distance (HMLD) per min, and D) absolute 15-min intervals of mechanical work (MW, the sum number of accelerations and decelerations > 3 m^2).

** *moderate* decrease from 1st to last 15-min (Δ-15_{min}), *** *large* decrease from 1st to last 15-min (Δ-15_{min})

Figure 2. Within-player coefficient of variations of selected metrics. A) total distance (TD), B) high metabolic load distance (HMLD), and C) MW (the sum number of accelerations and decelerations > 3 m^2).

** *moderate* increase from 1st to last 15-min (Δ-15_{min}), *** *large* increase from 1st to last 15-min (Δ-15_{min})

Figure 3. Relationship between V_{IFT} and $15\text{-min}_{mean/best}$ intervals of total distance (TD) per min, high metabolic load distance (HMLD) per min, and MW (the sum number of accelerations and decelerations > 3 m^2) per min.

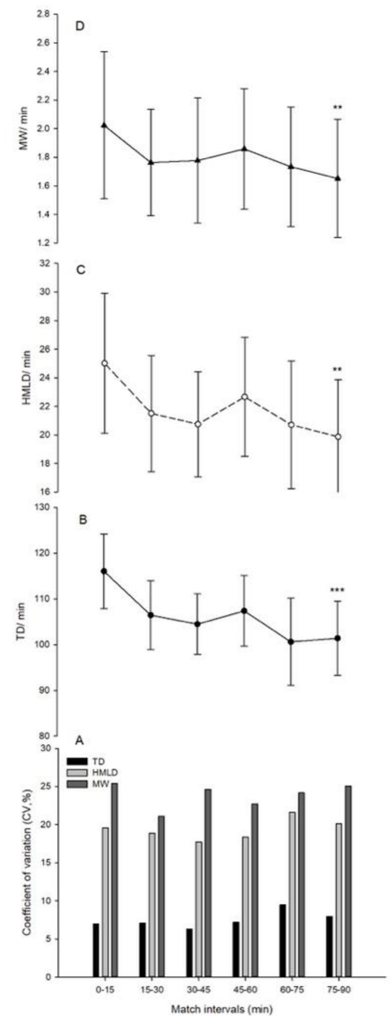

Figure 1. Within-player 15-min interval values of selected metrics. A) coefficient of variation on 15-min intervals, B) absolute 15-min intervals of total distance (TD) per min, C) absolute 15-min intervals of high metabolic load distance (HMLD) per min, and D) absolute 15-min intervals of mechanical work (MW, the sum number of accelerations and decelerations > 3 m^2).

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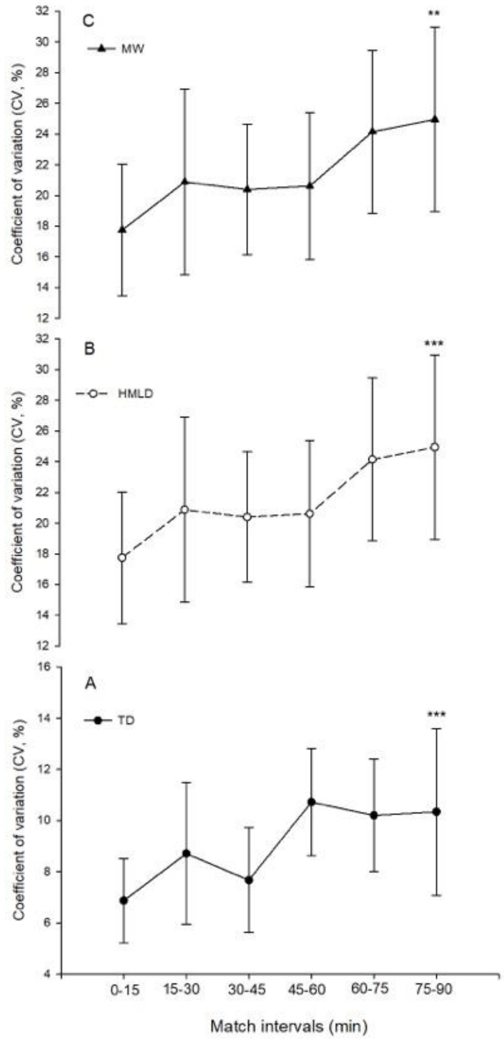

Figure 2. Whitin-player coefficient of variations of selected metrics. A) total distance (TD), B) high metabolic load distance (HMLD), and C) MW (the sum number of accelerations and decelerations > 3 m^2).

** moderate increase from 1^{st} to last 15-min (Δ-15_{min}), *** large increase from 1^{st} to last 15-min (Δ-15_{min})

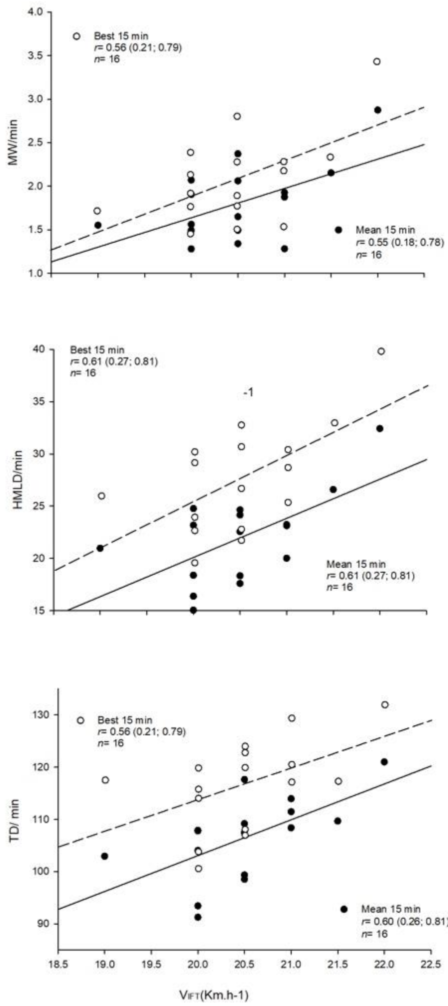

Figure 3. Relationship between V_{IFT} and $15\text{-min}_{mean/best}$ intervals of total distance (TD) per min, high metabolic load distance (HMLD) per min, and MW (the sum number of accelerations and decelerations > 3 m^2) per min.