RESEARCH ARTICLE

Physical load and position characteristics in a 3-4-3 soccer playing system using GPS equipment

Yuefeng Jin*

Department of Sports, Nanjing University of the Arts, Nanjing, Jiangsu, China.

Received: May 27, 2025; **accepted:** September 20, 2025.

Tactical formation in soccer has a significant impact on players' physical demands and overall performance. The 3-4-3 formation is often adopted for its strategic balance between offensive and defensive roles. However, despite its frequent use, the specific physical load and positional characteristics within the 3-4-3 system remain underexplored in the context of collegiate soccer. This research demonstrated the physical load and positional demands of players within the 3-4-3 formation by analyzing GPS data. Twenty matches from the China University Football League (CUFL) were analyzed including ten starting field players and all substituted players. Player positions in the 3-4-3 system were classified into six roles, and metrics such as total distance, high-intensity movements, and sprint distances were examined. The results revealed that defenders experienced a lower physical load, while central midfielders and forwards covered greater total distances but exhibited lower high intensity running and sprint distances. In addition, positions such as central midfielders and forwards showed higher intensity in the second half, contradicting previous studies. This study provided valuable insights into the positional demands of the 3-4-3 formation and contributed to a deeper understanding of tactical efficiency in collegiate soccer. The results held important implications for refined training strategies, improved player performance, and reduced injury risks.

Keywords: soccer; tactical formations; GPS; 3-4-3 system; positional physical load; performance characteristics.

***Corresponding author:** Yuefeng Jin, Department of Sports, Nanjing University of the Arts, Nanjing, Jiangsu 210013, China. Email: jinyuefeng_nua@163.com.

Introduction

Sport performance science now engages digital measurement tools that record motion, mechanical load, and physiological strain in real time [1]. Wireless sensors, optical systems, and algorithmic feedback enable objective evaluation of training interventions. Soccer has drawn special attention from these advances because technical skill, tactical awareness, psychological resilience, and physical capacity interact in complex fashion [2, 3]. Among these components, physical load is most amenable to objective quantification. Time–motion analysis divides play into locomotor categories including walking, jogging, running, and sprinting, and relates each category to metabolic cost [4]. Distance covered, velocity distribution, and sprint frequency reveal work rate, endurance, and spatial engagement over a ninety-minute contest. When large datasets are available, analysts can integrate contextual variables of pitch dimensions, surface type, and environmental stress, thereby constructing training plans that correspond to match reality. Digital instrumentation has superseded

traditional stopwatch observation and nurtured a culture of measurable preparation. Match statistics now appear during broadcast, shaping spectator expectation, and commercial valuation, while open data archives invite cross-disciplinary collaboration among physiologists, engineers, and data scientists. As a result, high-resolution tracking stands at the center of evidence-based soccer practice. Global Positioning System (GPS) tracking constitutes the core of this monitoring effort. Compact receivers fixed between the scapulae sample spatial coordinates at ten hertz, record speed, acceleration, deceleration, and direction change, and may integrate heart-rate transducers to capture internal load. Receiver firmware fuses global navigation satellite data with inertial measurement unit signals to enhance accuracy during rapid directional change. Validation studies report errors below two percent for total distance and below five percent for high intensity running values regarded as acceptable for applied research. Before satellite tracking, analysts relied on hand notation or semi-automatic optical systems, methods that required time-intensive frame coding and offered limited spatial precision. The International Football Association Board authorized wearable sensors in official fixtures in 2015, an act that triggered large-scale deployment across professional, collegiate, and youth competitions [5-8]. Research derived from these databases has outlined the locomotor profile of back-four formations such as 4-3-3 and 4-4-2 [9, 10]. Elite matches yield nine to fourteen kilometers of total running with high intensity actions concentrated in laterals and forwards [11]. Studies confirm that midfielders accumulate the greatest distance, defenders register lower exposure to peak velocity, and forwards execute the highest number of sprints. These observations now inform conditioning drills, tactical periodization, and return-to-play benchmarks.

Knowledge drawn from back-four structures cannot be transferred without caution to three-back systems such as 3-4-3 or 3-5-2, which redistribute defensive coverage and create different transition pathways [9, 10]. Three-back formations assign wide lane maintenance to outside midfielders while releasing an extra forward, adjustments that could alter high-speed exposure and cumulative load. Empirical evidence on these configurations remains scarce. During the 2018 FIFA World Cup, three out of thirty-two squads employed a permanent three-defender arrangement, and peer-reviewed literature mirrors this limited usage. The shortage of detailed data hampers coaches who plan substitution patterns, conditioning cycles, and tactical rehearsal within three-back frameworks. Collegiate competitions provide an ideal setting for evaluation, because roster depth, training volume, and match frequency differ from professional leagues. Changes to substitution law further motivate examination of three-back formations. The shift from two changes before 1994 to three in 1995 and five after 2020 expands tactical latitude and allows staff to relieve positions that endure severe high speed load. Without quantitative evidence, coaches may overuse rotations, disrupt team cohesion, or underuse them, exposing players to fatigue-related injury. Addressing this gap is essential for informed decision-making in both practice and research.

This research targeted this deficit by analyzing GPS output from twenty China University Football League matches contested in a 3-4-3 configuration. Six discrete roles were defined and for each role the study extracted total distance, high intensity running distance, sprint distance, sprint count, and segments data when role change occurred during play. Match environment was documented through temperature, humidity, and Wet Bulb Globe Temperature to account for thermal strain. Statistical evaluation employed one-way analysis of variance for positional comparison and paired testing for half-to-half difference. The research produced a detailed map of physical demands within the three-back structure and clarified how substitution strategy influenced second-half output. The results would support conditioning

staff in designing role-specific programs, inform tactical planners who distributed running resources across phases of play, and provide researchers with a reference dataset for comparative work. By extending evidence to an under-examined formation, the study strengthened the scientific foundation of workload management in soccer.

Materials and methods

Participants

The participants in this study were male soccer players from the top teams that competed in China University Football League (CUFL), a highly competitive collegiate soccer league. A total of 32 players were drawn from two finalist squads representing Nanjing University and Hohai University, both located in Nanjing, Jiangsu, China, with the mean ± standard deviation (SD) values for height, body mass, and age as 180.4 ± 5.7 cm, 68.1 ± 4.5 kg, and 21.2 ± 1.1 years, respectively. These players were selected based on their involvement in official matches, ensuring that the data collected reflected the physical demands of high-level competition. Each player took part in organized soccer for at least eight seasons with average playing experience of 10.3 ± 2.2 years and a weekly schedule of 4 - 5 pitch sessions plus 1 - 2 strength-conditioning sessions during the competitive period. These characteristics were systematically recorded to establish baseline data for each player and ensure that the sample represented a typical cohort of competitive collegiate soccer players. Prior to the commencement of any data collection, all participants were screened for any potential health concerns that could interfere with their participation in the study. Specifically, each player was assessed for the absence of any reported symptoms of illness, the use of any regular medications, or any existing medical conditions that might hinder their ability to engage in the physical demands of the study. This step was essential to ensure the validity of the results and to minimize any confounding variables that could arise from underlying health issues. All experimental procedures were approved by the Institutional Review Board of Nanjing University and Hohai University (Nanjing, Jiangsu, China) (Approval No. 202401). Written informed consent was obtained from each participant before data collection. A total of 20 CUFL fixtures held between March and June in 2024 were monitored. Each squad contested 10 of these matches in accordance with league calendar with a mean interval of 7.1 ± 1.3 days separating consecutive games. A comprehensive overview of the climatic field conditions was recorded including environmental factors of temperature, humidity, and Wet Bulb Globe Temperature (WBGT). The WBGT was a critical metric for evaluating heat stress during physical activity and was often used in sports science to assess the risk of heat-related illness. The calculation of WBGT was as follows.

$$WBGT = 0.7 \times Tnwb + 0.2 \times Tg + 0.1 \times Ta \quad (1)$$

where Tnwb was natural wet-bulb temperature (°C). Tg was globe temperature (°C). Ta was air temperature (°C). Across the 20 monitored matches, ambient temperature, relative humidity, and WBGT on the field averaged 23.6 ± 1.9 °C, 63.7 ± 6.1%, and 25.9 ± 1.7 °C, respectively, which corresponded to low to moderate thermal strain.

Measurement procedure

All field players (FPs), excluding the goalkeeper (GK), from both the starting lineup and all substitutes were equipped with GPS-enabled Polar Vantage V devices (Polar Electro Oy, Kempele, Finland). Each sensing unit was mounted in a low-profile module fixed to an elastic chest strap positioned across the anterior thorax at the level of the xiphoid process, which secured the device in a stable location without restricting breathing or upper-limb movement. These wearable devices were used to record a range of positional data including total distance covered, movement speed, and other relevant metrics such as acceleration, deceleration, and the number of high intensity sprints. The GPS devices also captured the player positional

coordinates in real-time, enabling detailed analysis of player movement across the field throughout the match. Each official match had a total duration of 90 minutes, consisting of two 45-minute halves, excluding halftime but including any scheduled water breaks. To ensure that the data faithfully reflected players' physical efforts during match play, the analysis was restricted to the actual time that players were on the field, excluding any periods of inactivity during substitutions or injury stoppages. This approach allowed for a more exact measurement of physical load during active play, accounting for the varying demands of different match situations. The GPS devices had several key specifications designed to optimize data collection. The sampling rate was set to 1 Hz, meaning the device recorded positional data once per second, yielding a high level of temporal resolution for tracking player movements. The GPS accuracy was approximately 1 meter, ensuring that positional data was precise enough for detailed analysis of movement patterns across the field. Additionally, the devices were capable of continuous recording for up to 4 hours, which was more than sufficient for the duration of a 90-minute match plus any additional recovery periods or post-match activities. Once the match concluded, all data collected during the game, as well as any post-match information, was exported from the GPS devices for further analysis. This data was then stored and processed using specialized software, where it was used to calculate and analyze various performance metrics. These metrics were critical for understanding the physical demands placed on players in different positions and formations, and for assessing the impact of environmental conditions on player performance.

Analyzed parameters

The parameters of total distance (km), high intensity running distance (distance covered at speeds ≥ 18 km/h), sprint distance (distance covered at speeds ≥ 24 km/h), and sprint count (number of efforts in which speed reached ≥ 24 km/h for at least one second) were extracted from the GPS dataset for analysis. These parameters provided insights into the physical demands of players during matches. Total distance measured overall movement, while high intensity running and sprint distances reflected more intense efforts at speeds ≥ 18 km/h and ≥ 24 km/h, respectively. Sprint count tracked the number of high-speed efforts sustained for at least one second. Together, these metrics helped assess the intensity of the match and the physical load on players in different positions.

Data analysis

The teams utilized a 3-4-3 formation, consisting of 1 goalkeeper (GK), 3 defenders (DF), 4 midfielders (MF), and 3 forwards (FW). Based on the tactical roles assigned to each position, players were categorized into six distinct positional roles defined as center defender (CDF), inside defender (IDF), center midfielder (CMF), outside midfielder (OMF), inside forward (IFW), and center forward (CFW). The data for both starting and substitute players in each positional role were combined to represent 90 minutes of match data for analysis. In instances where players changed positions during the match, the data before and after the positional change were separated at the exact moment of the change and then aggregated for each respective position.

Statistical analysis

SPSS, version 28 (IBM, Armonk, New York, USA) was employed for the statistical analysis of this research. All data were presented as the average value ± standard deviation (SD) to provide a clear representation of the central tendency and variability of the measured physical parameters. The mean differences between six positional groups identified in the 3-4-3 formation (CDF, IDF, CMF, OMF, IFW, CFW) were compared using one-way analysis of variance (ANOVA) [12]. When significant differences were observed, post-hoc pairwise comparisons were conducted using the Tukey-Kramer method [13]. Paired t-tests were applied to assess differences between the first and second half of the match. A *P* value less than 0.05 was considered statistically

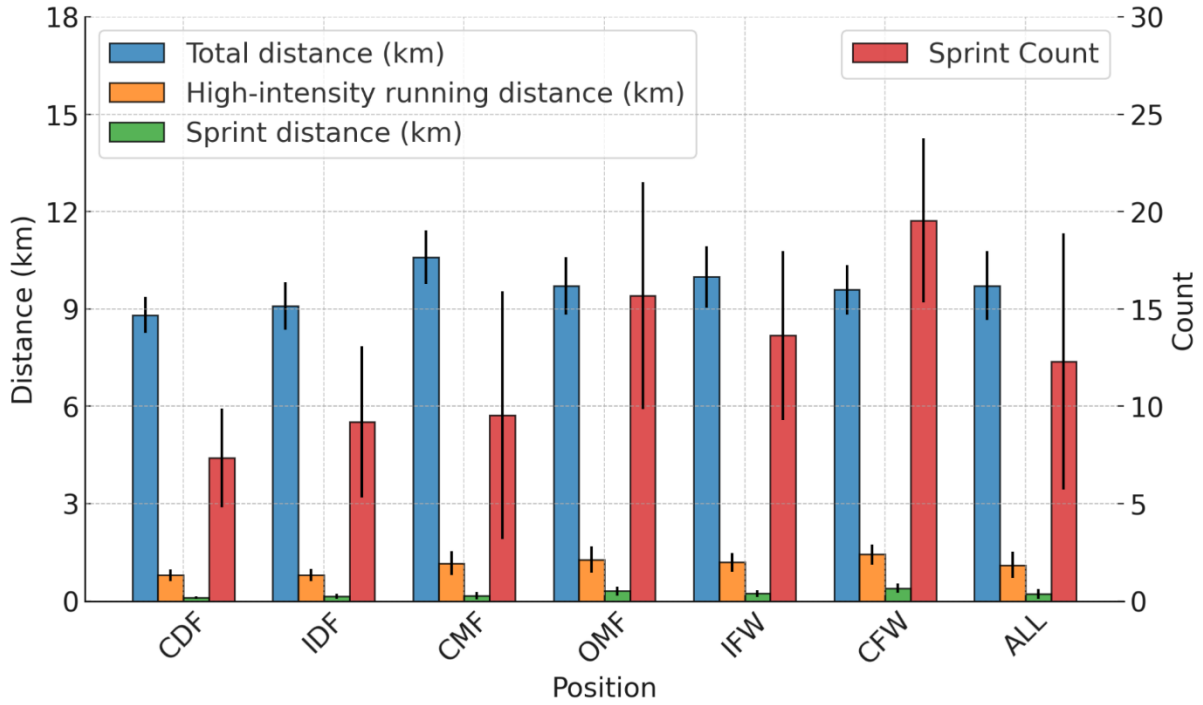

Figure 1. The positional averages for total distance, high intensity running distance, sprint distance, and sprint count.

significant. Assumptions of normal distribution and equal variance were examined with Shapiro–Wilk and Levene tests.

Results and discussion

Total distance

The positional averages for total distance, high intensity running distance, sprint distance, and sprint count of this research were shown in Figure 1. The total distance has long been recognized as a key metric in soccer, even before the widespread adoption of GPS technology. Previous research has repeatedly shown that elite and sub-elite male and female athletes run between 9 and 14 kilometers per game with a significant portion of this distance due to high intensity running [14]. Randers *et al*. measured an average total distance of 10.72 ± 0.70 km in a cohort of elite players [15], while Ogai *et al*. found an average of 11,107.6 meters across nine university-level matches [16]. This study observed that field players in the 3-4-3 formation covered an average total distance of 9,715.5 meters per match, which was in alignment with these previous findings. While the results were lower than that reported for higher level competitions, it was still consistent with the physical demands of university level soccer players. The total distance reflected the overall physical workload placed on players during the match, but it should be interpreted in the context of the team tactical approach and playing style. Although some studies suggested a correlation between total distance covered and match outcomes [17-19], others have pointed out that total distance alone may not serve as a fully reliable indicator of team performance, especially when comparing teams at different competitive levels. Total distance is more often reflective of a team's specific tactical strategies and playing style, rather than directly indicating the success or failure of a team. Regarding positional differences, the three central defenders in the 3-4-3 system comprising one CDF and two IDF covered significantly less distance than players in more dynamic positions such as midfielders and forwards. Specifically, CDF covered a markedly lower total distance than

OMF, CMF, IFW, and CFW. IDF also covered less distances than CMF and IFW, though no significant difference was found between IDF and OMF or CFW, which suggested that, within the 3-4-3 formation, defenders generally experienced lower physical demands in terms of total distance, which was probably due to their more stationary and defensive roles within the tactical setup. Furthermore, no statistical difference was found between CDF and IDF, indicating that the physical demands of these two defender positions were quite similar, both being characterized by lower overall movement compared to attacking players. This pattern further emphasized the defensive and less physically taxing role of defenders in the 3-4-3 system.

High intensity running distance

In terms of high intensity running distance, both CDF and IDF recorded significantly lower values compared to other positional groups (Figure 1). These defensive roles exhibited much lower sprint counts as well, particularly when compared to CFW, OMF, and IFW. This pattern indicated that defenders in general required less physical exertion and intensity, consistent with their more stationary roles within the tactical system. This finding aligned with prior research conducted on the 4-4-2 formation, where center-backs were found to cover significantly less distance than side defenders (SDF), midfielders, and forwards [11, 16]. In the 4-4-2 system, SDFs were shown to exhibit higher total and high intensity running distances, likely due to their increased involvement in attacking plays. Similarly, in the 3-4-3 formation, IDFs tended to have fewer attacking responsibilities compared to the more attacking-oriented OMFs and forwards, which made them more analogous to center-backs in a traditional four-back system, who were often required to maintain defensive solidity and contribute minimally to offensive transitions. When analyzing the midfielders (CMF, OMF) and forwards (IFW, CFW), significant differences in total distance covered were observed. CMF covered the highest average distance, significantly exceeding that of OMF and CFW. IFW also recorded high total distances, ranking second, which suggested that both CMF and IFW played central roles in facilitating transitions between defense and attack, contributing to both offensive and defensive phases of play. Interestingly, the trend for high intensity running distance diverged. Both CFW and OMF exhibited the highest high intensity running values followed by IFW and CMF. Despite no statistical differences being observed in this category, CFW and OMF consistently demonstrated higher physical intensity as evidenced by their higher sprint counts and running speeds. These results suggested that the attacking players in the 3-4-3 formation, particularly the forwards and outside midfielders, were subject to more intense physical demands, both in terms of movement speed and overall physical exertion during match play.

Sprint distance and sprint count

The positional averages for sprint distance and sprint count demonstrated that CFW covered significantly greater sprint distances and executed more sprints compared to IFW and CMF. Additionally, OMF also recorded higher values than CMF (Figure 1). These results suggested that CMF and IFW positions were engaged in more sustained, moderate intensity movements across larger areas of the pitch, focusing on maintaining possession and transitioning between defense and attack. In contrast, CFW and OMF were primarily responsible for more explosive, high intensity actions such as sprinting into space and pressing the opposition. These findings aligned with previous research that showed that side midfielders (SMFs) and forwards (FWs) often displayed higher values for high intensity running and sprinting distance as they were frequently involved in offensive transitions and counterattacks [11, 16, 20]. However, a notable observation in this study was the significant positional differences among the three forwards in the 3-4-3 system. Two IFWs and one CFW exhibited distinct tactical and physical roles with CFW demonstrating greater sprint intensity, reflecting the more attack-oriented

responsibilities of this position compared to the IFWs. This highlighted the varying physical demands within the forward positions in the 3-4-3 system with CFW being required to perform more direct attacking runs, often leading the line and pressing higher up the pitch. The distinct roles and varying levels of intensity between these forwards further emphasized the importance of positional specialization within this formation. It also suggested that the 3-4-3 system required a high level of positional awareness and adaptability with players being required to balance both offensive and defensive tasks depending on their role. CMF, positioned centrally on the field, covered a broad area both offensively and defensively, requiring extensive movement throughout both phases of play. Similarly, IFW operated mainly in central areas and demonstrated movement patterns that were strikingly similar to those of CMF, suggesting that both positions shared comparable physical demands. Both positions were involved in transitions, maintaining possession, and supporting both the defense and attack, which accounted for their relatively high total distances covered. In contrast, CFW and OMF relied more on short bursts of high intensity movement and sprints. CFW was tasked with making aggressive attacking runs, often pressing the opposition and breaking through defensive lines. Notably, CFW was substituted in all matches, indicating that the physical demands of this position necessitated frequent rotation to maintain performance intensity, particularly given the explosiveness and intensity required for attacking plays. On the other hand, OMF was substituted in only 21% of the matches, implying that OMFs required greater individual endurance and running capacity. This higher substitution rate for CFWs and lower substitution rate for OMFs reflected the differences in their roles with OMF being tasked with sustained offensive and defensive duties that required endurance. The resulting data suggested that, while CFWs performed more explosive actions, their high intensity nature of play necessitated more frequent rest, whereas OMFs, despite also engaging in high intensity actions, exhibited stamina to endure longer periods of play without significant drops in performance (Figure 2).

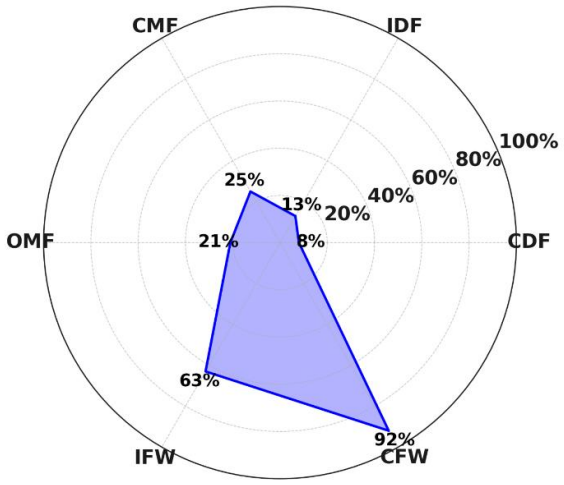

Figure 2. Substitution percentage for each position.

High intensity running and sprinting are critical components of elite level soccer with top players demonstrating significantly higher values in these areas compared to lower levels of competition. Substitution strategies in soccer matches have evolved considerably, particularly with the changes to substitution rules over the years. Prior to 1994, only two substitutions were allowed per match, which was increased to three in 1995. In response to fixture congestion and the increasing physical demands of the sport, a temporary five substitution rule was introduced during the COVID-19 pandemic, which was later permanently adopted by the IFAB. The expansion of substitution allowances has provided greater tactical flexibility, allowing coaches to better manage player workloads during matches. This flexibility has made workload management a key aspect of match strategy [21]. Effectively rotating high intensity players such as CFWs and OMFs is now vital for maintaining peak performance throughout a match. This change in substitution rules has provided teams with more control over player fitness, enabling more precise management of player energy levels during key moments of the game. As soccer continues to evolve, the strategic significance of substitutions

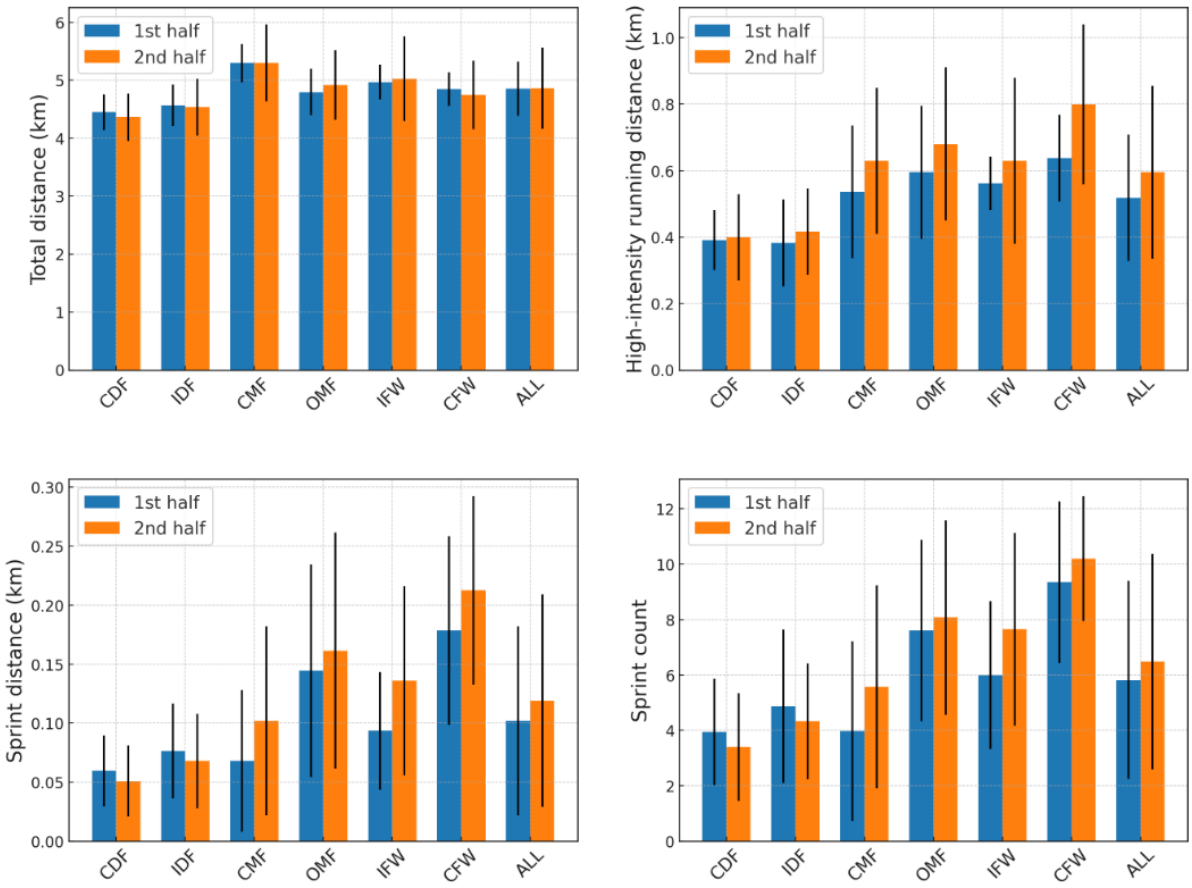

Figure 3. Comparison of the positional performance characteristics between first half and second half.

continues to grow, influencing tactical decisions, match dynamics, and overall team performance.

Comparison between first half and second half

A comparison of performance between the first and second halves revealed significant differences in high intensity running distance, sprint distance, and sprint count. While total distance covered remained consistent across both halves, high intensity running distance, sprint distance, and sprint count were significantly higher in the second half (Figure 3). This increase in physical output in the second half might seem counterintuitive as it contradicted the typical assumption that player physical performance declined as a match progresses. However, positional analysis revealed that the second half demonstrated a significant increase in high intensity running distance for CMF, OMF, and CFW. Similarly, sprint distance showed notable increases for CMF and IFW with CMF also recording a significantly higher sprint count in the second half compared to the first. These findings highlighted that certain positions, particularly midfielders and forwards, demonstrated an increase in physical exertion during the second half, while defenders maintained stable output levels. These results challenged the widely held belief that physical performance tended to decrease in the second half of matches. Previous research has frequently reported a decline in total distance covered, high intensity running, and sprinting as the game progresses with elite teams in various leagues including La Liga in Spain, showing a performance drop in the latter stages of matches [22-24]. In contrast, the data from this study demonstrated a different trend with several positions, particularly those in more

dynamic roles, displaying an increase in physical output after halftime. A potential explanation for these findings was the role of player substitutions. Notably, CFW and IFW had high substitution rates, suggesting that these players were replaced more frequently to manage fatigue and maintain intensity levels throughout the game. This strategic rotation might have contributed to the observed increase in physical performance during the second half. On the other hand, CMF and OMF had significantly lower substitution rates, indicating that their sustained or increased physical workload in the second half was likely influenced by other factors such as individual endurance, tactical responsibilities, and the evolving dynamics of the match. Other contextual factors could also provide insights into these findings. The overall flow of the match, the team position in terms of score, and the relative strength of the opposition could have influenced player's physical demands during the second half. Players on the leading team might have been more inclined to conserve energy, whereas those trailing could need greater effort to recover or press for a goal. Furthermore, tactical decisions such as whether players were making attacking runs or forced into defensive actions could have impacted their physical exertion. As the match evolved, these dynamics could lead to varying degrees of intensity depending on the tactical adjustments made by the coach and the opposition strategy. To provide a more comprehensive understanding of these trends, future studies should integrate GPS data with match footage, player fatigue monitoring, and other performance metrics, offering a more holistic view of the positional demands in the 3-4-3 system, particularly within the context of collegiate soccer.

Conclusion

GPS tracking data collected from 20 official soccer matches played in the CUFL was analyzed to examine positional performance characteristics within the 3-4-3 formation. By categorizing player roles into six positional groups, the analysis focused on key performance metrics including total distance, high intensity running distance, sprint distance, and sprint count with particular attention to the effects of player substitutions. The three defender positions of one CDF and two IDFs recorded significantly lower total distance, high intensity running distance, and sprint distance compared to midfielders and forwards. This result indicated that defenders within the 3-4-3 formation encountered reduced physical demands, especially regarding high intensity actions and sprint efforts. For midfielders (CMF, OMF) and forwards (CFW, IFW), distinct differences in performance metrics emerged. CMF and IFW positions exhibited greater total distances but lower high intensity running distances and fewer sprints compared to CFW and OMF, which demonstrated consistently high intensity efforts and numerous sprints. Additionally, high intensity running distance, sprint distance, and sprint count increased significantly in the second half, contrasting with prevailing beliefs about declining physical performance as matches progress. These findings provided comprehensive insights into positional demands within the 3-4-3 system, facilitating improvements in player development, tactical implementation, and workload management strategies in collegiate soccer contexts.

References

1. Jin Y. 2024. Biomechanical insights into goalkeeper preparatory movements during defensive dives for football shots. Mol Cell Biomech. 21(4):824.
2. Strykalenko Y, Huzar V, Shalar O, Oloshynov S, Homenko V, Svirida V. 2021. Physical fitness assessment of young football players using an integrated approach. J Phys Educ Sport. 21(1):360-366.
3. Qader MA, Zaidan BB, Zaidan AA, Ali SK, Kamaluddin MA, Radzi WB. 2017. A methodology for football players selection problem based on multi-measurements criteria analysis. Measurement. 111:38-50.
4. Hands DE, Janse de Jonge X. 2020. Current time-motion analyses of professional football matches in top-level domestic leagues: A systematic review. Int J Perf Anal Spor. 20(5):747-765.
5. Buchheit M, Allen A, Poon TK, Modonutti M, Gregson W, Di Salvo V. 2014. Integrating different tracking systems in football:

Multiple camera semi-automatic system, local position measurement and GPS technologies. J Sport Sci. 32(20):1844-1857.
6. Bastida-Castillo A, Gómez-Carmona CD, De La Cruz Sánchez E, Pino-Ortega J. 2019. Comparing accuracy between global positioning systems and ultra-wideband-based position tracking systems used for tactical analyses in soccer. Eur J Sport Sci. 19(9):1157-1165.
7. Edgecomb SJ, Norton KI. 2006. Comparison of global positioning and computer-based tracking systems for measuring player movement distance during Australian Football. J Sci Med Sport. 9(1):25-32.
8. Curtis RM, Huggins RA, Looney DP, West CA, Fortunati A, Fontaine GJ, *et al*. 2018. Match demands of national collegiate athletic association division I men's soccer. J Strength Cond Res. 32(10):2907-2917.
9. Paraskevas G, Smilios I, Hadjicharalambous M. 2020. Effect of opposition quality and match location on the positional demands of the 4-2-3-1 formation in elite soccer. J Exerc Sci Fit. 18(1):40-45.
10. Tierney PJ, Young A, Clarke ND, Duncan MJ. 2016. Match play demands of 11 versus 11 professional football using Global Positioning System tracking: Variations across common playing formations. Hum Movement Sci. 49:1-8.
11. Kenichiro N, Haruo O, Toshiki T, Masashi W, Yunosuke K. 2017. A basic study on the position characteristics of college male soccer players using GPS equipment. Sports and Human Studies: Journal of Shizuoka Sangyo University. 2(1):5.
12. Gurvich V, Naumova M. 2021. Logical contradictions in the one-way ANOVA and Tukey–Kramer multiple comparisons tests with more than two groups of observations. Symmetry. 13(8):1387.
13. Migliaccio G, De Blasio A. 2024. The economic performance of Italian olive oil companies: A comparative quantitative approach using the ANOVA and Tukey-Kramer methods. Quant Financ Econ. 8(3):437-465.
14. Bangsbo J, Mohr M, Hasegawa Y, Yasumatsu M. 2012. Fitness testing in football: Fitness training in soccer II. Slangerup: Bangsbosport.
15. Randers MB, Mujika I, Hewitt A, Santisteban J, Bischoff R, Solano R, *et al*. 2010. Application of four different football match analysis systems: A comparative study. J Sport Sci. 28(2):171-182.
16. Ogai T, Ohira M, Nakano Y, Cho Kj, Kawamoto D, Imaizumi T, *et al*. 2021. A study on physical load management by GPS in male university soccer players. Ryutsu Economics University Bulletin of Sports and Health Science. 14:41.
17. Pappalardo L, Cintia P, Ferragina P, Massucco E, Pedreschi D, Giannotti F. 2019. PlayeRank: Data-driven performance evaluation and player ranking in soccer *via* a machine learning approach. ACM Trans Intell Syst Technol. 10(5):1-27.
18. Wright C, Carling C, Lawlor C, Collins D. 2016. Elite football player engagement with performance analysis. Int J Perf Anal Spor. 16(3):1007-1032.
19. Mackenzie R, Cushion C. 2013. Performance analysis in football: A critical review and implications for future research. J Sport Sci. 31(6):639-676.
20. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. 2009. Analysis of high intensity activity in premier league soccer. Int J Sports Med. 30(03):205-212.
21. Xiao Z, Zhang H. 2024. More substitutions changed team substitution strategy? An analysis of the FIFA World Cup 2002–2022. BMC Sports Sci Med R. 16(1):165.
22. Carling C, Dupont G. 2011. Are declines in physical performance associated with a reduction in skill-related performance during professional soccer match-play? J Sport Sci. 29(1):63-71.
23. Miyagi O, Taki H, Ohashi J, Fukudome A, Irie S. 2001. Movement distance and speed during a game J league soceer player: The subject of mid-fielder. Journal of Kanagawa Sport and Health Science. 35:1.
24. Reilly T, Drust B, Clarke N. 2008. Muscle fatigue during football match-play. Sports Med. 38(5):357-367.