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NOTA EDITORIAL

É com elevada satisfação que apresentamos o Volume 6, Número 2 (Março de 2025) da nossa revista científica, consolidando mais uma etapa no percurso de afirmação académica e científica desta publicação.

Esta edição reflete o compromisso contínuo com a produção e disseminação de conhecimento científico rigoroso nas áreas das Ciências do Desporto, Educação e Ciências do Exercício, integrando contributos que abordam a monitorização da carga de treino, o desempenho desportivo, a saúde e os processos de adaptação fisiológica em diferentes contextos competitivos.

Os artigos incluídos nesta edição evidenciam uma crescente sofisticação metodológica, com destaque para revisões sistemáticas conduzidas segundo as diretrizes PRISMA 2020, estudos longitudinais em contexto aplicado e investigações que integram métricas de carga interna e externa, reforçando a importância de abordagens multidimensionais no controlo e otimização do rendimento desportivo.

Destacamos particularmente os trabalhos dedicados:

- À monitorização da carga de treino no futebol feminino adolescente, contribuindo para colmatar lacunas existentes na literatura específica para esta população;
- À análise sistemática das cargas de treino no futsal, modalidade caracterizada por exigências intermitentes de elevada intensidade e particular complexidade mecânica;
- À compreensão das relações entre carga de treino, bem-estar, desempenho neuromuscular e risco de lesão.

Estas investigações reforçam a necessidade de modelos integrados de monitorização, combinando indicadores fisiológicos, perceptivos e biomecânicos, e sublinham a importância da individualização do treino ao longo das diferentes fases da época desportiva.

A qualidade científica desta edição só foi possível graças ao empenho dos autores, revisores e membros do corpo editorial, cujo rigor e dedicação asseguram a credibilidade e o crescimento

sustentado da revista. Manifestamos igualmente o nosso reconhecimento ao Instituto Superior de Ciências Educativas do Douro (ISCE Douro) e ao CI-ISCE – Centro de Investigação do ISCE, pelo apoio institucional contínuo.

Reafirmamos o compromisso com a promoção de investigação aplicada, metodologicamente robusta e com impacto real na prática profissional, contribuindo para o desenvolvimento sustentado das Ciências do Desporto e da Educação.

Com os melhores cumprimentos académicos,

A Direção Editorial.

ÍNDICE

Monitoring internal and external training load in adolescent female football players

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Abstract

Women's football has expanded rapidly across youth development pathways, however, scientific evidence specific to adolescent female players remains limited. Consequently, training load monitoring practices are frequently extrapolated from male or adult populations, despite important developmental, physiological, and maturational differences during adolescence. Understanding how training load is monitored in adolescent female football is therefore essential to support athlete development and inform strategies aimed at reducing injury risk. This systematic review synthesised the available evidence on internal and external training load monitoring in adolescent female football players. A systematic search was conducted in PubMed, Web of Science, and Scopus in accordance with PRISMA 2020 guidelines. Observational studies with cross-sectional or longitudinal designs examining internal and/or external training load were included. Data were extracted on study characteristics, monitoring methods, and key outcomes. Eight studies met the inclusion criteria. In the available literature, external training load evidence was derived predominantly from GPS-based match-play studies (5–15 Hz), with findings consistently showing that peak running demands substantially exceeded whole-match averages. Age-related increases in external training load were evident, and methodological choices, particularly velocity threshold selection, markedly influenced the quantification of high-speed and sprint running. Internal training load was primarily monitored using session rating of perceived exertion (sRPE) and was closely associated with perceptual responses, including fatigue, stress, sleep, and well-being. Evidence examining associations between training load patterns and health-related outcomes indicated that elevated acute–chronic workload ratios were associated with an increased risk of time-loss injury, whereas sport specialisation was not independently associated with injury or illness risk after controlling for age and training load. Overall, effective training load monitoring in adolescent female football should extend beyond average-based metrics, integrating peak-demand analysis, age-appropriate external training load quantification, and internal training load measures alongside sleep and well-being indicators to better inform monitoring practices and support performance readiness during adolescence.

Keywords: adolescent female football; training load; external load; internal load; well-being; injury risk

1. Introduction

Women's football has experienced marked growth across youth development pathways, accompanied by increasing physical and competitive demands placed on adolescent players (Vescovi, 2014; Mordillo & Zago, 2022). This evolution has heightened the need for evidence-based approaches to player preparation and monitoring. However, scientific evidence specifically addressing adolescent female football players remains limited, and training practices are frequently extrapolated from male or adult populations, despite known developmental and maturational differences.

Optimising athletic development while managing injury risk during adolescence requires an understanding of the physical demands imposed during training and competition, as well as athletes' physiological and perceptual responses to those demands. In this review, *training load* refers to the internal and external demands imposed on the athlete, whereas *training load monitoring* describes the systematic process used to quantify and interpret these demands over time. Adolescence represents a critical developmental period characterised by rapid biological changes and increasing exposure to high-intensity competition, reinforcing the importance of appropriate training load monitoring strategies in youth female football.

External training load reflects the physical work performed by the player and, in adolescent female football, has been predominantly quantified during match-play using global positioning system (GPS) technology. Match analyses consistently demonstrate that peak running demands substantially exceed whole-match averages, indicating that mean values may underestimate the most demanding phases of competition (Harkness-Armstrong et al., 2021). Furthermore, age-related increases in match demands have been reported, with older adolescent players covering greater total distances and performing more high-intensity running than younger age groups (Vescovi, 2014; Mordillo & Zago, 2022).

Importantly, training load monitoring is influenced by methodological decisions. The selection of velocity thresholds substantially affects the quantification of high-speed and sprint running, and age-specific, data-driven thresholds have been shown to provide a more accurate representation of external training load in adolescent female players compared with adult-derived thresholds (Harkness-Armstrong et al., 2022). Complementary approaches, such as metabolic power–based metrics, may further enhance the interpretation of match intensity across developmental stages (Mordillo & Zago, 2022).

Internal training load represents the biological and perceptual stress experienced in response to external demands and has most commonly been monitored using session rating of perceived exertion (sRPE). In adolescent female football, internal training load has been associated with perceptual responses including fatigue, stress, sleep quality, and overall well-being (Watson & Brickson, 2018). In addition, impaired pre-competition well-being has been shown to negatively affect players' ability to sustain peak running demands during match-play (Sydney et al., 2024).

Evidence also suggests that training load patterns are related to health-related outcomes in youth female football. Elevated acute-chronic workload ratios have been associated with an increased risk of time-loss injury in elite adolescent female players (Padua et al., 2019), whereas sport specialisation does not appear to independently increase injury or illness risk when age and training load exposure are considered (Watson & Haraldsdottir, 2021).

Despite growing interest in training load research, the literature in adolescent female football remains fragmented, with internal and external training load often examined in isolation and substantial variability in monitoring methodologies. Moreover, evidence on external training load is largely restricted to match-play contexts, with limited data available from training environments. Therefore, the aim of this systematic review was to synthesise the available evidence on training load monitoring in adolescent female football players (≤18 years), focusing on the methods used to assess internal and external training load and their associations with performance, well-being, and injury-related outcomes.

2. Methods

2.1 Search strategy

A systematic literature search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. Electronic searches were performed in PubMed, Web of Science, and Scopus from database inception to February 2026.

An initial search strategy using narrowly defined training load–specific terms yielded a limited number of eligible records. Consequently, an iterative search approach was adopted, expanding the strategy to include related constructs commonly used within contemporary training load research. The final search strategy combined terms related to football participation (football OR soccer), population characteristics (female, adolescent, youth, under 18), and training load constructs (training load, workload, external load, internal load, session rating of perceived exertion, heart rate, GPS), using Boolean operators.

Search strings were adapted to the syntax and requirements of each database. Full search strategies for all databases are provided in Supplementary Material 1 to ensure transparency and reproducibility. In addition, the reference lists of all included studies were manually screened to identify any further relevant publications.

2.2 Eligibility Criteria

Studies were considered eligible if they investigated female football players aged 18 years or younger and reported internal and or external training load data in training and or competitive contexts. Only observational studies with cross sectional or

longitudinal designs were included. Studies were required to be published in peer reviewed journals and written in English. Studies involving adult or male participants, mixed sex samples without extractable female specific data, training intervention studies, or articles not reporting training load outcomes were excluded. Reviews, editorials, conference abstracts, case reports, and non peer reviewed publications were not considered. Age of 18 years or younger was treated as a strict inclusion criterion.

2.3 Study selection

All records identified through database searches were imported into reference management software, and duplicate records were removed prior to screening. Titles and abstracts were screened to exclude clearly irrelevant studies. Full-text articles of potentially eligible records were subsequently retrieved and assessed for eligibility based on the predefined criteria.

The study selection process resulted in 135 records identified, 77 records screened after duplicate removal, 25 full-text articles assessed for eligibility, and 12 studies initially included. Following full-text assessment, three studies were excluded due to unavailable full-texts or failure to meet eligibility requirements upon detailed evaluation, resulting in eight studies included in the final qualitative synthesis. The study selection process is illustrated in the PRISMA flow diagram.

2.4 Data extraction

Data were extracted from all included studies using a standardised data extraction form. Extracted information included author and year, country, sample characteristics, age group, competitive level, study design, monitoring period, internal and external training load measures, monitoring context (training and or match play), measurement instruments, and main outcomes related to training load, performance, well being, or injury. Extracted data were cross checked for accuracy and consistency with the information presented in Tables 1 to 3.

2.5 Quality assessment

The methodological quality of the included studies was assessed using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist. Quality assessment focused on clarity of study design, sample description, measurement validity, outcome reporting, and transparency of analytical procedures. Methodological quality was considered during interpretation of the findings but was not used as a criterion for study exclusion.

3. Results

3.1 Study selection

The data base search identified a total of 135 records. After removal of duplicates, 77 records remained for title and abstract screening, resulting in the exclusion of 52 records that did not meet the eligibility criteria. Twenty-five full-text articles were subsequently assessed for eligibility, of which two could not be retrieved. Following full-text evaluation, eight studies fulfilled all inclusion criteria and were included in the final qualitative synthesis. The study selection process is illustrated in the PRISMA flow diagram.
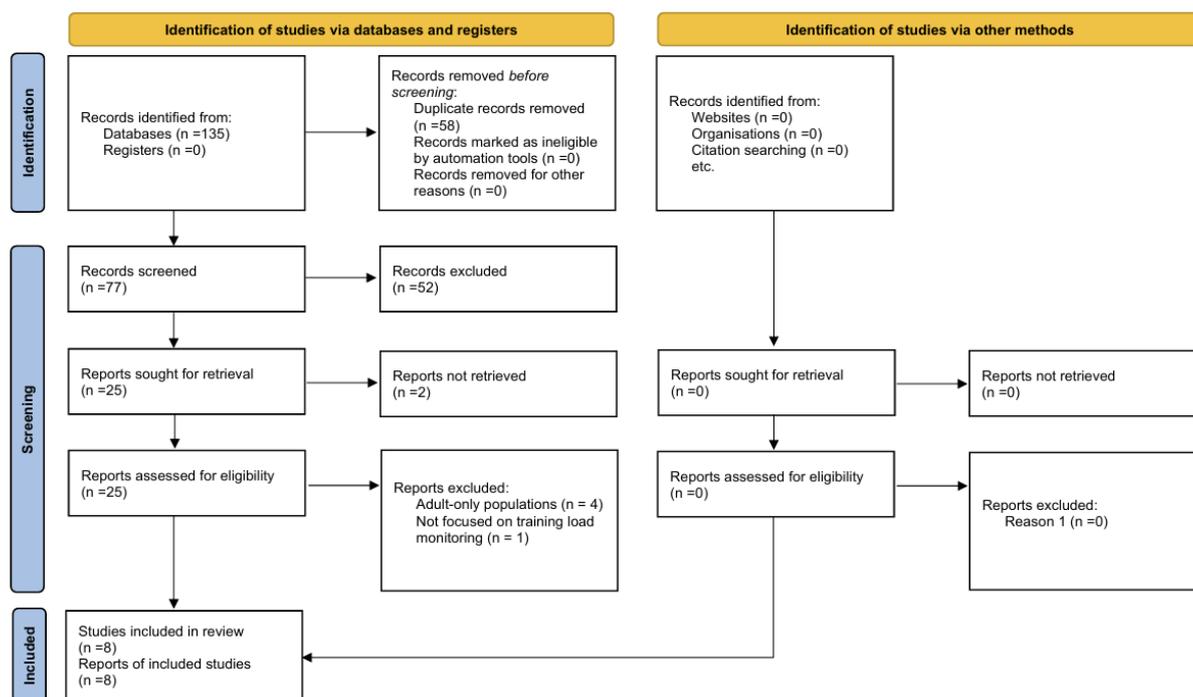
Figura 1. PRISMA 2020 flow diagram illustrating the identification, screening, eligibility assessment, and inclusion of studies in the systematic review.

3.2 Characteristics of the included studies

The characteristics of the included studies are summarised in Table 1. The eight included studies employed observational designs, including cross-sectional match-based analyses and prospective or longitudinal approaches, and were conducted across a range of competitive youth female football contexts. Samples were exclusively female and spanned early to late adolescence, with study sizes varying considerably from small cohorts monitored in tournament or training-camp settings to larger datasets derived from multiple official matches.

Most included studies primarily investigated match-play demands, with external training load commonly quantified using global positioning system (GPS) technology. Across these studies, GPS sampling frequencies ranged from 5 to 15 Hz. External training load was typically described using whole-match running outputs and, in several cases, peak (worst-case) running demands derived from moving or rolling average procedures. Methodological approaches varied, with some studies applying age-specific velocity thresholds and others complementing speed-based metrics with metabolic power–based variables.

Internal training load was less frequently examined and was most commonly assessed using session rating of perceived exertion (sRPE). Selected studies also incorporated athlete-reported measures of sleep, fatigue, stress, or overall well-being, and one study included indicators of energy availability alongside external load monitoring. Only a limited number of studies adopted prospective designs to examine associations between training load patterns and health-related outcomes, such as time-loss injury or well-being indicators. Overall, the evidence base was characterised by a strong emphasis on external training load during match-play, with comparatively fewer studies integrating internal load monitoring and health-related outcomes within a single analytical framework.

Table 1. Characteristics of the included studies

Study (first author, year)	Country / competitive context	Sample (sex, age, n)	Study design	Monitoring period	Type of load monitored	Monitoring tools / metrics

Study	Country / League	Sample	Design	Duration / Context	Load type	Measures / Technology
Sydney et al., 2024	Australia / NPLW (sub-elite)	F, 16 ± 1 years, n = 15	Observational longitudinal	One competitive season (7 months)	External + well-being	GPS (15 Hz); Likert-scale questionnaires
González-García & Romero-Moraleda, 2024	Spain & Finland / UEFA development tournament	F, U16, n = 18	Observational	7 consecutive days (congested schedule)	Internal, external + well-being	GPS (WIMU PRO); differential sRPE; Likert-scale questionnaires
McHaffie et al., 2023	United Kingdom / U18 national team	F, 17.9 ± 0.5 years, n = 23	Observational	10 days (training camp and matches)	External + health-related	GPS; RFPM (food photography); BIA
Harkness-Armstrong et al., 2022	England / Regional Talent Centres	F, U14 & U16, n = 187	Observational match-play analysis	Two seasons (2018–2019; 2019–2020)	External	GPS (10 Hz); age-specific velocity thresholds
Mordillo & Zago, 2022	Italy / high-level clubs	F, U15, U17 & U19, n = 60	Match activity profile analysis	40 official matches	External	GPS (10 Hz); speed- and metabolic power–based metrics
Harkness-Armstrong et al., 2021	England / Girls' England Talent Pathway League	F, U14 & U16, n = 201	Match physical characteristics analysis	Two seasons (2018–2019; 2019–2020)	External (whole and peak demands)	GPS (10 Hz); rolling averages (1–10 min)
Watson & Brickson, 2018	USA / youth football clubs (Wisconsin)	F, 13–18 years, n = 65	Prospective cohort	One season (≈10 months)	Internal + well-being	sRPE; Likert-scale questionnaires (fatigue, stress, sleep)
Vescovi, 2014	USA / national championship and talent identification camps	F, U15–U17, n = 89	Prospective observational	Tournament or training camp	External	GPS (5 Hz); age-specific speed zones

3.3 Monitoring approaches and load metrics

External training load was predominantly assessed using global positioning system (GPS) technology, with sampling frequencies ranging from 5 to 15 Hz. Most studies focused on match-play demands, although some also incorporated training camp or season-long monitoring contexts. External load quantification was primarily based on running-related metrics, including total distance, high-speed running, very high-speed running, sprinting activity, and peak speed. Several studies extended beyond whole-match averages by quantifying peak or worst-case running demands using moving or rolling average techniques over short time windows, highlighting that global match averages may underestimate the most physically demanding phases of play.

Methodological approaches to external load quantification varied considerably across studies. Some investigations applied age-specific velocity thresholds to account for developmental differences in physical capacity, whereas others complemented traditional speed-based metrics with metabolic power–based variables to provide additional insight into locomotor and energetic demands across age groups.

Internal training load was most commonly assessed using session rating of perceived exertion (sRPE), either as a standalone measure or alongside differential perceptual ratings. In more recent studies, internal load monitoring was increasingly integrated with daily self-reported measures of sleep quality, fatigue, stress, mood, and perceived recovery, enabling examination of the interaction between physical load, perceptual responses, and performance-related outcomes. Additionally, one study incorporated indicators of energy availability, underscoring the relevance of combining external load metrics with biological and nutritional considerations to identify potential risks associated with under-fuelling in adolescent female football players.

Table 2. Monitoring approaches and training load metrics in the included studies

Study (first author, year)	Monitoring context	Load dimension	Monitoring method	Main load metrics
Sydney et al. (2024)	Sub-elite competitive season (Australia, NPLW)	External; Well-being	GPS (15 Hz); Likert-scale questionnaires	Total distance; HSRD; VHSRD (mean and peak); fatigue; sleep; stress; mood
González-García et al. (2024)	UEFA youth development tournament (congested schedule)	Internal; External; Well-being	GPS (WIMU PRO); differential sRPE; Likert scales	Total distance; high-speed running; sRPE (respiratory and muscular); recovery and wellness perception
McHaffie et al. (2023)	National team training camp and matches (10 days)	External; Nutritional status	GPS (10 Hz); remote food photography method; BIA	Total distance; HSRD; VHSRD; sprint distance; energy availability
Harkness-Armstrong et al. (2022)	Regional Talent Centres (England)	External (velocity thresholds)	GPS (10 Hz); spectral clustering	Age-specific thresholds for HSR, VHSR, sprint running
Mordillo & Zago (2022)	Official federation matches (Italy, U15–U19)	External (locomotor; metabolic)	GPS (10 Hz); metabolic power analysis	Total distance; distance per minute; metabolic power zones
Harkness-Armstrong et al. (2021)	England Talent Pathway League	External (whole and peak demands)	GPS (10 Hz); rolling averages (1–10 min)	Whole-match and peak running demands (HSR, VHSR, sprint)
Watson & Brickson (2018)	Competitive season monitoring (USA)	Internal; Well-being	sRPE; online monitoring system	Session load; sleep duration and quality; stress; fatigue; mood
Vescovi (2014)	National tournament and talent identification camps (USA)	External (locomotor profile)	GPS (5 Hz)	Distance across speed zones; sprint count; maximal velocity

3.4 External load during match-play

Across studies examining match-play demands, peak running demands consistently exceeded whole-match average values across age groups and competitive contexts. This pattern was evident across different epoch durations used to identify peak demands, indicating that the most physically demanding phases of competition are not adequately captured by mean match metrics.

Age-related differences in external training load were also reported. Older adolescent players generally covered greater total running distances and accumulated higher volumes of high-intensity activity compared with younger age groups. However, some studies reported comparable relative intensities, such as distance covered per minute, across age categories, suggesting that differences in absolute external load may be partly influenced by contextual factors including match duration and competition format.

Methodological choices were shown to influence the quantification of external training load. Studies applying age-specific, data-driven velocity thresholds reported different distributions of high-speed and sprint running compared with those using thresholds derived from senior populations. In addition, some studies incorporated metabolic power–based metrics to characterise match demands, providing an alternative representation of intensity that identified age-related differences not consistently evident using speed-based metrics alone.

3.5 Internal load, well-being, and performance-related outcomes

Internal training load was most commonly quantified using session rating of perceived exertion (sRPE) and served as the primary indicator of athletes' perceptual responses to imposed training and competition demands. Across studies, higher accumulated internal training load was associated with changes in perceptual responses, including increased fatigue, elevated stress, and less favourable well-being profiles.

Sleep and subjective well-being were examined in a subset of studies. Poorer sleep quality and reduced sleep duration were associated with higher perceived training load and impaired well-being responses. Furthermore, impaired pre-competition well-being was associated with a reduced ability to sustain peak running demands during match-play, indicating a relationship between readiness-related measures and the expression of high-intensity performance during competition.

3.6 Workload patterns and health-related outcomes

Associations between training load patterns and health-related outcomes were examined in a limited number of studies. Prospective observational evidence indicated that elevated acute–chronic workload ratios were associated with an increased risk of time-loss injury in elite adolescent female football players. These findings suggest that abrupt increases in training load relative to recent chronic exposure may exceed players' capacity to tolerate imposed demands.

In contrast, sport specialisation status was not independently associated with injury or illness risk when age and training load exposure were accounted for. This indicates that training load magnitude and distribution, rather than early sport specialisation per se, may play a more relevant role in injury and health-related outcomes during adolescence.

Beyond injury outcomes, several studies highlighted the relevance of recovery-related factors. Sleep duration and quality were identified as key moderators of athletes' responses to training load, with poorer sleep associated with less favourable well-being profiles and heightened perceived load. Additionally, evidence from competitive tournament and congested schedule contexts suggested an increased risk of insufficient energy intake, highlighting the potential interaction between external load, recovery capacity, and nutritional availability in adolescent female players.

Table 3. Main outcomes and key findings related to training load in adolescent female football players

Study (first author, year)	Main outcomes and key findings
Sydney et al. (2024)	Pre-competition well-being was associated with subsequent running performance. Lower perceived stress was related to reduced total and high-speed running, while increased fatigue and lower-body soreness were associated with reduced peak running outputs during match-play.
González-García et al. (2024)	Starters accumulated substantially greater weekly external and internal loads (total distance, PlayerLoad™, sRPE) than non-starters during a congested competition schedule. Despite these load differences, no clear between-group differences were observed in perceived well-being.
McHaffie et al. (2023)	A high prevalence of under-fuelling was observed, with carbohydrate intake frequently below recommendations and low energy availability identified in a substantial proportion of players. External training load was not consistently matched by nutritional intake across the monitoring period.
Harkness-Armstrong et al. (2022)	Age-specific velocity thresholds were established for adolescent female players. The use of youth-derived thresholds resulted in substantially greater estimates of high-speed and sprint running compared with adult-derived thresholds, highlighting the importance of biological specificity in external load quantification.
Mordillo & Zago (2022)	Match demands increased with age, particularly from U15 to U17. While relative running intensity (distance per minute) was similar across age groups, older players performed more work in high metabolic power zones. A decline in physical output was observed across match halves.
Harkness-Armstrong et al. (2021)	Peak running demands consistently exceeded whole-match averages across all age groups and positions. Peak intensities were highest in short-duration epochs (≈1 min) and decreased as epoch duration increased, indicating that mean match values underestimate worst-case scenarios.
Watson & Brickson (2018)	Internal training load and sleep independently influenced well-being outcomes. Reduced sleep duration and quality exacerbated the negative effects of higher training loads on fatigue, stress, and mood, indicating a mediating role of sleep in load tolerance.

Vescovi (2014)	Total distance, work rate, and sprint-related metrics increased with age. Positional differences were evident, with midfielders covering greater total distance and attacking players performing more sprint actions. Maximal match speed was comparable to linear sprint test values.

3.7 Summary of findings

Overall, the evidence indicates that match-play demands in adolescent female football are characterised by pronounced peak intensities that consistently exceed whole-match averages, highlighting the limitations of mean-based metrics for describing competitive demands. Estimates of external training load are highly sensitive to methodological decisions, particularly the selection of velocity thresholds and analytical approaches used to quantify high-intensity activity. Internal training load and readiness-related factors, including sleep and subjective well-being, were consistently associated with variations in performance expression and indicators of health and recovery. Nevertheless, the current literature remains limited by a lack of integrated approaches, as few studies simultaneously examine internal load, external load, and health-related outcomes within the same cohorts.

Discussion

This systematic review synthesised the available evidence on monitoring internal and external training load in adolescent female football players. Overall, the findings indicate that match-play demands in this population are characterised by pronounced peak intensities that are not adequately represented by whole-match averages, that methodological decisions substantially influence the quantification of external training load, and that internal load and readiness-related factors, particularly sleep and subjective well-being, are associated with performance expression and health-related outcomes.

Across studies examining external load during match-play, peak running demands consistently exceeded whole-match averages across age groups and competitive contexts (Harkness-Armstrong et al., 2021). This suggests that reliance on mean match values may underestimate the most demanding phases of competition, which are likely relevant for both performance preparation and injury risk management. Age-related differences in match demands were also evident, with older adolescent players generally exposed to greater total running distances and higher volumes of high-intensity activity (Vescovi, 2014; Mordillo & Zago, 2022). However, similar relative movement intensities reported across age categories indicate that differences in absolute load may partly reflect contextual factors such as match duration and competition format rather than physiological maturation alone.

A key contribution of the reviewed literature is the demonstration that external training load monitoring is not methodologically neutral. The use of age-specific, data-driven velocity thresholds substantially altered estimates of high-speed and sprint running compared with thresholds derived from senior populations (Harkness-Armstrong et al., 2022). Additionally, metabolic power–based metrics captured age-related differences in match demands that were not consistently evident using speed-based metrics alone (Mordillo & Zago, 2022). These findings highlight that analytical choices directly shape how external load is quantified and interpreted, with important implications for research comparability and applied practice.

Internal training load was predominantly monitored using session rating of perceived exertion, reflecting its feasibility in youth football contexts. Higher accumulated internal loads were associated with increased fatigue, stress, and impaired subjective well-being (Watson & Brickson, 2018). Importantly, sleep and readiness-related factors emerged as key moderators of athletes' responses to imposed demands. Poorer sleep quality was associated with less favourable well-being profiles, and impaired pre-competition well-being was linked to a reduced ability to sustain peak running demands during match-play (Sydney et al., 2024), indicating that sleep and perceived readiness are integral components of effective training load monitoring.

Evidence linking training load patterns to health-related outcomes further underscores the applied relevance of integrated monitoring approaches. Elevated acute–chronic workload ratios were associated with an increased risk of time-loss injury in elite adolescent female football players (Padua et al., 2019). In contrast, sport specialisation was not independently associated with injury or illness risk once age and training load exposure were considered (Watson & Haraldsdottir, 2021), suggesting that how training load is accumulated and progressed may be more influential for health outcomes than participation structure alone.

Despite these insights, the evidence base remains fragmented. Most studies examined external match-play demands or internal load responses in isolation, and substantial heterogeneity in monitoring methodologies limits cross-study comparability. Future research should prioritise integrated approaches that concurrently assess external load, internal load, readiness indicators, and health-related outcomes within the same cohorts to better inform evidence-based training load monitoring in adolescent female football players.

5. Strengths and Limitations

This systematic review has several strengths. It focuses exclusively on adolescent female football players, a population that remains underrepresented in training load research, thereby avoiding the extrapolation of evidence from male or adult cohorts and providing population-specific insights relevant to long-term athlete development. In addition, the review adopts an integrated perspective by synthesising evidence on external load, internal load, and readiness-related factors, reflecting contemporary monitoring frameworks and applied practice in youth football. The emphasis on commonly used monitoring tools, such as GPS-derived external load metrics and session rating of perceived exertion, further enhances the applied and translational relevance of the findings.

Several limitations should also be acknowledged. The available evidence is largely derived from observational study designs, which limits causal inference regarding relationships between training load, performance, and injury risk. Substantial methodological heterogeneity across studies, particularly in GPS sampling frequency, velocity threshold selection, and analytical approaches used to identify peak demands, constrains cross-study comparability and the development of normative reference values for adolescent female football players. Furthermore, relatively few studies concurrently examined external load, internal load, and health-related outcomes within the same cohorts. Variability in competitive level, match exposure, and monitoring context across studies may also limit the generalisability of the findings.

6. Conclusions

This systematic review synthesises the available evidence on monitoring internal and external training load in adolescent female football players, a population for which sex- and age-specific data remain limited. The findings demonstrate that training and competition demands in youth female football are characterised by pronounced peak intensities that are not adequately captured by whole-match averages, underscoring the limitations of mean-based metrics when interpreting external load.

The evidence further indicates that methodological decisions, particularly those related to velocity threshold selection, substantially influence how external load is quantified. The use of age-appropriate, data-driven thresholds, alongside complementary approaches such as metabolic power–based metrics, appears essential for accurately characterising high-intensity exposure and developmental differences across adolescent age groups. These considerations are critical for both researchers and practitioners aiming to align monitoring practices with the physiological and maturational characteristics of young female players.

In parallel, internal load monitoring using session rating of perceived exertion, when interpreted alongside measures of sleep and subjective well-being, provides meaningful insight into athletes' responses to imposed demands and readiness to perform. Evidence linking training load patterns to health-related outcomes, including injury risk, reinforces the importance of progressive and individualised load management throughout adolescence.

Collectively, these findings support the adoption of integrated monitoring frameworks that combine external load, internal load, and readiness-related indicators to inform training prescription and recovery strategies in adolescent female football. By aligning monitoring practices with the specific developmental context of this population, practitioners may better support long-term athlete development, enhance performance readiness, and mitigate injury risk. Future research should prioritise longitudinal, integrated approaches capable of refining dose–response relationships and translating monitoring data into optimised, evidence-based practice.

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Training Loads in Futsal: A Systematic Review

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Abstract

Futsal is an intermittent indoor team sport characterized by frequent high-intensity actions, multidirectional accelerations and decelerations, and substantial physiological and neuromuscular demands. Effective training load monitoring is therefore essential to optimize performance, manage fatigue, and reduce the risk of maladaptation. The aim of this systematic review was to synthesize and critically analyze the available evidence on training load monitoring in futsal, with particular emphasis on internal and external load measures across different periods of the season.

A systematic search was conducted in Scopus, Web of Science, and PubMed in accordance with PRISMA 2020 guidelines. Studies investigating training load monitoring in adult futsal players within training and/or competitive contexts were considered eligible. Twenty-one studies met the inclusion criteria and were included in the qualitative synthesis.

The evidence indicates that the pre-season is characterized by the greatest accumulation of internal load and training volume, whereas the competitive period emphasizes load stabilization, maintenance of physical capacities, and recovery management. Weekly training organization typically follows a match-day-minus structure, with higher loads earlier in the microcycle and marked reductions prior to competition. Training load demands vary according to tactical position, with wings and defenders generally accumulating higher external loads than pivots. Session rating of perceived exertion emerged as a valid, reliable, and practical tool for internal load monitoring, particularly when integrated with external load metrics obtained through local positioning and inertial sensor technologies.

Overall, training load in futsal follows a structured and context-dependent pattern influenced by season phase, tactical role, and task design. Integrated monitoring of internal and external load provides valuable information for performance optimization and athlete well-being, although further research involving larger samples, female players, and long-term longitudinal designs is warranted.

Keywords: futsal; training load; internal load; external load; performance; recovery

Introduction

Futsal is an intermittent team sport characterized by frequent high-intensity efforts, multidirectional sprints, and rapid changes of activity, performed on a 40×20 m indoor court by two teams of five players. The unlimited substitution rule allows players to sustain very high match intensity throughout the game, resulting in repeated bouts of explosive actions interspersed with short recovery periods (Naser et al., 2017). Match analysis indicates that game actions change approximately every 8-9

seconds, imposing substantial physiological and neuromuscular demands on players. From a physiological perspective, futsal relies predominantly on aerobic metabolism to sustain match duration, while anaerobic pathways are decisive for high-intensity actions such as sprints, accelerations, decelerations, and changes of direction (Barbero-Alvarez et al., 2008; Miloski et al., 2016).

Given these demands, systematic monitoring of training load has become a central component of performance management in futsal. Evidence from futsal-specific studies indicates that appropriate control of training load supports performance optimization, facilitates training individualization, and assists in identifying excessive fatigue that may compromise adaptation and availability for competition (Clemente & Nikolaidis, 2016; Miloski et al., 2016; Rabelo et al., 2016). Importantly, players exposed to similar external demands may experience markedly different internal responses, highlighting the need for individualized monitoring approaches (Clemente et al., 2019; Teixeira et al., 2018).

Training load in futsal is commonly described through the interaction between external demands imposed by training and competition tasks and the internal psychophysiological responses elicited in the athlete. External load reflects the physical and neuromuscular demands of activity, such as distance covered, accelerations, decelerations, and movement intensity, whereas internal load represents the physiological and perceptual stress experienced by the player, typically assessed through measures such as heart rate responses and session rating of perceived exertion (s-RPE) (Clemente et al., 2019; Miloski et al., 2016; Teixeira et al., 2018). Studies conducted in futsal report meaningful associations between internal and external load indicators, reinforcing the importance of their integrated assessment to better understand training stress and adaptation processes (Chen et al., 2022; Clemente et al., 2019).

Despite the growing body of research in futsal, several critical gaps remain. A large proportion of studies are based on single-team samples, limiting the generalizability of findings due to the strong influence of team-specific training methodologies (Miloski et al., 2016; Rabelo et al., 2016). In addition, the scientific literature remains disproportionately focused on male athletes, with comparatively limited evidence available in female futsal players, particularly regarding training load, physical activity patterns, and long-term monitoring (Lago-Fuentes et al., 2020; Milanez et al., 2014).

Technological constraints have also historically limited external load monitoring in indoor environments, as satellite-based GPS systems are unreliable in enclosed spaces. Although local positioning systems (LPS) and ultra-wideband (UWB) technologies have emerged as viable alternatives, their application in futsal remains relatively limited and methodologically heterogeneous across studies (Clemente et al., 2019; Sánchez-Sánchez et al., 2024). Furthermore, evidence regarding positional-specific load demands across complete competitive microcycles is still scarce, despite indications that tactical roles such as wings, pivots, and defenders are associated with distinct physical and physiological profiles (Gadea-Uribarri et al., 2025; Illa et al., 2021).

Therefore, the aim of this systematic review is to synthesize and critically analyze the available evidence on training load monitoring in futsal, with particular emphasis on the distinction and integration of internal and external load measures. Specifically, this review seeks to examine load variations across different phases of the season, explore positional demands, and identify methodological limitations and future research directions, thereby providing evidence-based guidance for coaches and physical performance practitioners working in futsal.

2. Methods

2.1 Study Design and Reporting Guidelines

This study was conducted as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The review aimed to synthesize evidence on training load monitoring in futsal using a transparent and reproducible methodological approach. Given the substantial heterogeneity across studies in terms of monitoring tools, outcome variables, study designs, and observation periods, a qualitative narrative synthesis was deemed the most appropriate method for data integration, and a meta-analysis was not performed.

2.2 Search Strategy

A systematic literature search was conducted in three electronic databases—Scopus, Web of Science, and PubMed to identify studies addressing training load monitoring in futsal. The search was restricted to articles published in English between January 2014 and December 2025. The search strategy combined terms related to the sport, training load, monitoring methods, and performance-related outcomes, using Boolean operators. The core search string applied was: *(futsal OR "indoor soccer") AND ("training load" OR workload OR "training demands") AND ("internal load" OR "external load" OR sRPE OR*

"session RPE" OR "rating of perceived exertion" OR "heart rate" OR HRV OR GPS OR accelerometry) AND (performance OR fatigue OR recovery OR monitoring OR "injury risk"), with minor adaptations to database-specific syntax when necessary. The search yielded 43 records from Scopus, 51 from Web of Science, and 36 from PubMed, resulting in a total of 130 records before duplicate removal.

2.3 Eligibility Criteria

Eligibility criteria were defined a priori and applied during the title and abstract screening phase, before full-text assessment, to ensure methodological consistency and internal coherence of the review. In addition to standard inclusion and exclusion criteria, an additional methodological refinement was implemented to further delimit the scope of the evidence synthesis.

Studies were considered eligible if futsal was clearly identified as the sport under investigation in training and/or competition contexts; participants were adult players (≥18 years) competing at federated, semi-professional, or professional levels; and the primary focus involved training load monitoring through internal load measures, external load measures, or their integration. Eligible studies were required to report outcomes related to performance, fatigue, recovery, well-being, and/or injury risk and to adopt observational, longitudinal, experimental, or descriptive designs with empirical data. Only studies published in English between 2014 and 2025 were considered.

Studies were excluded if they focused on other modalities such as outdoor football or beach soccer, included exclusively youth or recreational participants, addressed purely technical–tactical or psychological variables without quantification of training load, or consisted of laboratory-based physiological investigations without training context. Reviews, editorials, opinion papers, and studies lacking empirical data were also excluded.

Following the initial screening, an additional methodological refinement was applied to enhance the internal coherence of the review. First, studies focusing exclusively on match-play without analysis of training load were excluded (Criterion A: context). Second, studies based on single-session or punctual assessments, methodological or instrument validation designs, and investigations lacking longitudinal monitoring across microcycles, training periods, or competitive phases were excluded (Criterion B: load monitoring). This refinement ensured that only studies providing meaningful information on training load dynamics over time were retained.

2.4 Study Selection Process

All identified records were exported to reference management software (Zotero), and duplicates were removed using a combination of automated and manual procedures. After duplicate removal, 68 unique records remained and were screened by title and abstract according to the predefined eligibility criteria. Following this screening stage, 33 studies remained eligible prior to the application of the additional methodological refinement criteria. After applying these criteria, 24 studies met the requirements for full-text assessment. However, full-text access could not be obtained for three articles, resulting in a final sample of 21 studies included in the qualitative synthesis. The study selection process is summarized in the PRISMA 2020 flow diagram (Figure 1), which details the identification, screening, eligibility, and inclusion phases.
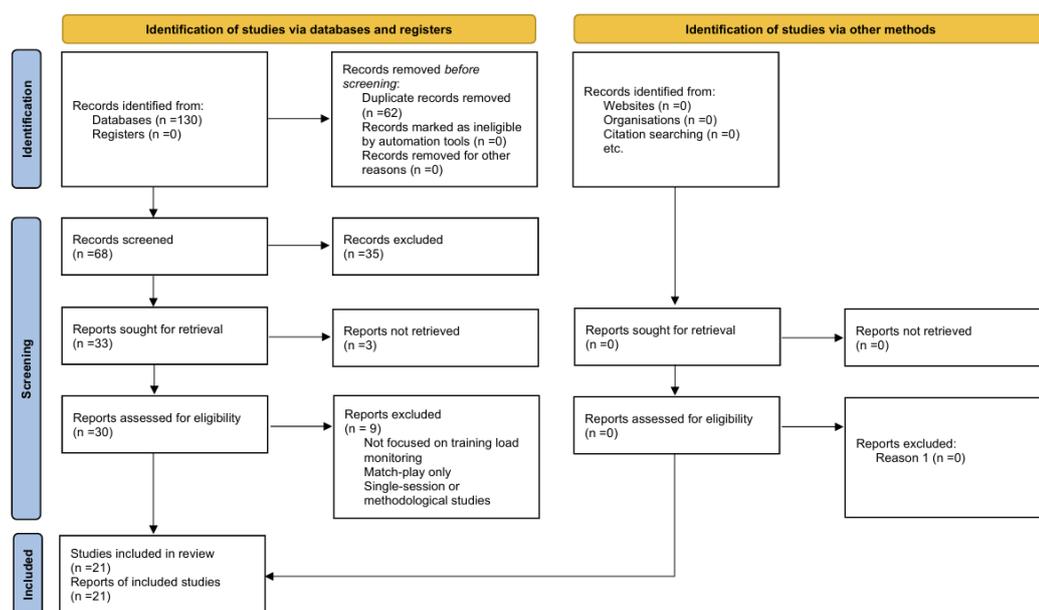
Figure 1. PRISMA 2020 flow diagram illustrating the study identification, screening, eligibility, and inclusion process for the systematic review.

3. Results

3.1 Study Selection

A total of 21 studies met the eligibility criteria and were included in the qualitative synthesis. The identification, screening, eligibility, and inclusion phases of the study selection process are presented in the PRISMA 2020 flow diagram (Figure 1).

3.2 Characteristics of Included Studies

The included studies were conducted predominantly in Brazil, Spain, and Portugal, with additional investigations carried out in Italy and Taiwan. The samples comprised male and female futsal players competing at professional, elite, and national team levels. The main characteristics of the included studies are summarized in Table 1.

Most investigations employed an observational longitudinal design, although observational cross-sectional studies, case studies, and experimental designs were also identified. Monitoring duration varied substantially across studies, ranging from short-term assessments conducted over a limited number of sessions or training camps (5-7 days) to full-season monitoring periods lasting between 43 and 45 weeks.

Regarding the competitive context, most studies examined training load during training sessions or across combined training and match contexts. Fewer investigations focused exclusively on match-play scenarios or on specific competitive situations, such as friendly or official matches.

Concerning competitive level, the included studies primarily involved professional and elite players competing in top national leagues or representing national teams. Although most samples comprised male athletes, several studies included female futsal players, indicating a growing interest in monitoring training load in women's futsal.

Tabela 1. Characteristics of the included studies

Author (year)	Country	Sample (n; sex; competitive level)	Study design	Monitoring duration	Context
Ibáñez-Pérez et al. (2020)	Spain	9 M, Professional (1st Division)	Observational, descriptive	6 weeks (14 sessions)	Training
Teixeira et al. (2019)	Brazil	28 M, Elite (1st Division)	Observational, retrospective	5 weeks (pre-season)	Training and match

Soares-Caldeira et al. (2014)	Brazil	13 M, Professional	Randomized controlled trial	4 weeks (pre-season)	Training
Beato et al. (2017)	Italy	16 F, 2nd Division	Observational, cross-sectional	2 sessions	Match (friendly)
Milanez et al. (2014)	Brazil	8 F, Professional (Elite)	Observational, longitudinal	5 weeks	Training
Illa et al. (2021)	Spain	14 M, Professional (1st Division)	Observational, longitudinal	1 season (15 matches)	Match (official)
Gadea-Uribarri et al. (2025)	Spain	10 M, Elite (1st Division)	Observational, longitudinal	30 weeks (30 microcycles)	Training and match
Sánchez-Sánchez et al. (2024)	Spain	12 M, Semi-professional (Tier 3)	Observational, longitudinal	8 microcycles	Training and match
Campos et al. (2024)	Brazil	11 M, Young players (U20)	Experimental (pre-post)	10 weeks	Training and match
Lago-Fuentes et al. (2020)	Spain	10 F, Professional (1st Division)	Observational, longitudinal	43 weeks (full season)	Training and match
Stochi de Oliveira et al. (2021)	Brazil	12 M, Adult (1st Division)	Observational, longitudinal	20 weeks (full season)	Training and match
Rabelo et al. (2016)	Brazil	18 M, Professional (Elite)	Case study	45 weeks (full season)	Training
Clemente et al. (2020)	Taiwan	28 M, National U20 team	Descriptive	6 training stages	Training
Illa et al. (2020)	Spain	13 M, Elite	Observational, retrospective	13 matches / 6 microcycles	Training and match
Chen et al. (2022)	Taiwan	27 M, National U20 team	Observational	4 international camps	Training and match
Miloski et al. (2016)	Brazil	12 M, Professional	Observational, longitudinal	22 weeks	Training
Villarejo-García et al. (2025)	Spain	8 F, Elite (1st Division)	Observational	3 weeks (incremental protocol)	Training
Lu et al. (2018)	Taiwan	11 M, National team	Observational	5 days (training camp)	Training and match
Clemente et al. (2019)	Portugal	20 M, Professional (1st Division)	Observational, longitudinal	1 full season	Training and match
Serrano et al. (2023)	Spain	14 M, Professional (1st Division)	Observational, longitudinal	3 consecutive seasons	Training
Esteves et al. (2022)	Portugal	8 M, Senior (National level)	Observational, longitudinal	1 season (3 phases)	Training and match (simulated)

3.3 Training Load Monitoring Methods

A variety of methods were used to monitor training load in futsal (Table 2). Internal load was predominantly assessed using session rating of perceived exertion (sRPE), heart rate–based measures, and wellness questionnaires, including indicators of fatigue, stress, and muscle soreness. External load monitoring primarily relied on inertial measurement units and local positioning systems to quantify distance, speed zones, high-speed running, accelerations, and PlayerLoad metrics. Monitoring frequency ranged from daily and session-based assessments to microcycle- and season-long monitoring protocols. Several studies integrated internal and external load measures, enabling a more comprehensive assessment of training demands across different contexts and periods throughout the season.

Tabela 2. Training load monitoring methods in futsal

Author (year)	Load type	Main variables	Instruments	Monitoring frequency	Context
Villarejo-García et al. (2025)	External	Segmental PlayerLoad	IMU (WIMU PRO™)	Incremental test	Training
Gadea-Uribarri et al. (2025)	External	Distance, speed zones, accelerations/decelerations	IMU (WIMU)	30 competitive microcycles	Training and match
Serrano et al. (2023)	Internal & External	HR, distance, HSR, PlayerLoad	LPS/UWB, HR sensors	3 consecutive seasons	Training tasks
Sánchez-Sánchez et al. (2024)	External	Distance, HSR, sprint actions	Indoor positioning system	8 microcycles	Training
Chen et al. (2022)	Internal	sRPE, wellness (DOMS, stress, fatigue)	Borg CR-10, Likert questionnaires	Daily during camps	Training
Esteves et al. (2022)	Internal	Peak speed, HR, lactate, RPE	LPS, HR monitors, Borg scale	3 time points	Training and simulated match
Stochi de Oliveira et al. (2021)	Internal & External	sRPE, monotony, strain, volume	Borg scale, time recording	Full season	Training
Illa et al. (2021)	External	Distance, PlayerLoad, high-intensity actions	IMU (WIMU PRO™)	15 official matches	Match
Ibáñez-Pérez et al. (2020)	Internal	Max HR, RPE	HR monitor, Borg scale	14 sessions	Training
Clemente et al. (2020)	Internal & External	HR, HRV, sRPE, distance, sprints	HR monitors, Polar Team Pro™	Daily during camp	Training
Lago-Fuentes et al. (2020)	Internal & External	sRPE, monotony, volume	Borg scale, time recording	Full season	Training
Teixeira et al. (2019)	Internal	sRPE, DOMS	Borg CR-10, questionnaire	Daily	Pre-season
Clemente et al. (2019)	Internal	sRPE, wellness, Hooper Index	Borg CR-10, Hooper questionnaire	Full season	Training
Beato et al. (2017)	Internal & External	HR, distance, HSR, accelerations	GPS, accelerometer	2 matches	Match
Miloski et al. (2016)	Internal	sRPE, CK, hormonal markers	Borg scale, blood analysis	22 weeks	Training
Rabelo et al. (2016)	Internal	sRPE (players), RIE (coach)	Borg CR-10	45 weeks	Training
Milanez et al. (2014)	Internal	Training load, monotony, stress	sRPE, DALDA, saliva	In-season	Training
Soares-Caldeira et al. (2014)	Internal	sRPE, HR variability, stress	Borg scale, HR monitor	Pre-season	Training

3.4 Main Outcomes and Relationships

The included studies examined outcomes related to performance, physiological responses, neuromuscular adaptations, and well-being in futsal players, reporting meaningful relationships between training load and biological or psychophysiological markers.

Nonlinear dose-response relationships were identified between daily training load, training strain, and immune and stress-related markers, suggesting the existence of optimal load ranges associated with more favorable psychophysiological responses. Accumulated internal load was negatively associated with neuromuscular performance, such as sprint and jump outcomes, while higher training loads were generally linked to increased physiological stress.

Comparisons between training models indicated that specific interventions, such as high-intensity interval training, were associated with greater improvements in aerobic power and neuromuscular performance than alternative approaches. Seasonal and weekly variations in training load distribution were associated with changes in physiological markers, whereas physical and technical-tactical performance tended to remain relatively stable across the competitive season.

Moderate to strong associations were reported between internal load indicators (e.g., sRPE) and well-being measures, including fatigue, muscle soreness, stress, and sleep quality, particularly during congested schedules or intensive training camps. Limited agreement between intended and perceived training load was also observed.

Overall, both internal and external training load metrics were meaningfully associated with physiological adaptations, neuromuscular performance, and well-being, with training context, load distribution, and task characteristics acting as key modulators.

Table 3. Main outcomes and relationships between training load and performance, physiological, and well-being responses in futsal

Author (year)	Outcomes analyzed	Relationships examined	Main findings
Milanez et al. (2014)	SIgA, stress (DALDA), URI symptoms	Training load and strain vs. biological markers	Non-linear dose-response relationship identified, suggesting optimal training load and strain ranges associated with lower stress and immune disturbance.
Teixeira et al. (2019)	CMJ, sprint (5-15 m), VIFT, DOMS	Accumulated sRPE vs. neuromuscular performance	Higher accumulated internal load was associated with reduced sprint performance; lower loads favored neuromuscular gains.
Campos et al. (2021)	VO_2max, RSA, CMJ, HRV	HIIT models vs. physiological adaptations	HIIT86 induced greater improvements in VO_2max, RSA, and neuromuscular performance than HIIT100.
Miloski et al. (2016)	CK, testosterone, cortisol, VO_2max, agility	Seasonal training load vs. physiological responses	High pre-season loads improved aerobic fitness and agility but increased hormonal stress markers.
Clemente et al. (2019)	sRPE, DOMS, fatigue, stress, sleep	Normal vs. congested weeks	Internal load and fatigue-related markers were higher during normal weeks, suggesting strategic load reduction during congested schedules.
Rabelo et al. (2016)	sRPE (perceived), RIE (intended)	Coach vs. athlete load perception	Limited agreement observed between intended and perceived training load across the season.
Ibáñez-Pérez et al. (2020)	Heart rate, RPE	Playing position vs. training intensity	No significant heart rate differences between positions, although perceived internal load tended to be higher in wings and pivots.
Chen et al. (2022)	sRPE, Hooper Index	Internal load vs. well-being status	Moderate to strong negative correlations were found between internal load and well-being indicators during training camps.
Illa et al. (2020)	High- and very high-demanding scenarios	Microcycle distribution vs. match demands	Players experienced repeated high- and very high-demanding scenarios within matches; MD-2 best replicated match demands.

Stochi de Oliveira et al. (2021)	CMJ, sprint speed, aerobic capacity	Volume vs. intensity across the season	Volume predominated in pre-season, while intensity increased during the competitive period, supporting performance maintenance.
Serrano et al. (2025)	HR, distance, HSR, ACC, DEC, PlayerLoad	Training task typology vs. load	Superiority/inferiority and full-court tasks elicited the highest physiological and biomechanical loads.
Esteves et al. (2022)	HR, lactate, RPE, technical-tactical performance	Seasonal adaptations	Physiological fitness improved across the season, whereas physical and technical-tactical performance remained stable.

3.5 Methodological Quality of the Included Studies

The methodological quality of the included studies was considered overall moderate to high (Table 4). Most investigations adopted observational longitudinal designs conducted in applied training or competition contexts, which enhances ecological validity but limits causal inference.

Common methodological limitations included small sample sizes, frequent single-team designs, and limited inclusion of female athletes. Several studies relied exclusively on internal load measures, particularly sRPE, without integrating objective external load metrics, whereas others focused solely on external load, lacking complementary internal or psychophysiological indicators.

Additional limitations were related to contextual constraints, such as unequal playing time, non-official match settings, short monitoring periods, or training camps with variable schedules. In some cases, the absence of detailed positional analyses, limited control of recovery strategies, or reliance on self-reported outcomes further constrained the interpretation of findings.

Despite these limitations, most studies employed validated monitoring tools and consistent data collection procedures, providing relevant and ecologically valid information on training load monitoring in futsal. Overall, the available evidence offers a robust descriptive foundation to inform future research and applied practice, although further studies with larger samples, integrated load measures, and more controlled designs are warranted.

Tabela 4. Methodological quality and main limitations of the included studies

Author (year)	Study design	Overall quality	Main limitations
Villarejo-García et al. (2025)	Observational	Moderate	Treadmill-based protocol not fully representative of game dynamics; small sample size.
Gadea-Uribarri et al. (2025)	Longitudinal	High	Small sample (n = 10); exclusion of goalkeepers; absence of internal load measures.
Serrano et al. (2025)	Longitudinal	High	Limited positional categorization in some analyses; lack of match-play data for comparison.
Sánchez-Sánchez et al. (2024)	Longitudinal	Moderate	Uncertainty regarding IPS validity indoors; unequal playing time between athletes.
Chen et al. (2022)	Observational	Moderate	Variable travel schedules; inconsistent training exposure; unequal match participation.
Esteves et al. (2022)	Longitudinal	Moderate	Very small sample (n = 8); use of simulated match instead of official competition.
Campos et al. (2021)	Experimental	High	Small sample size; absence of objective external load metrics; limited HRV recording.
Stochi de Oliveira et al. (2021)	Longitudinal	Moderate	Lack of biological/physiological markers and well-being questionnaires.
Illa et al. (2021)	Longitudinal	High	Exclusive focus on external load; absence of internal load indicators.
Lago-Fuentes et al. (2020)	Longitudinal (case study)	High	Limited range of external load variables; small female sample.
Illa et al. (2020)	Retrospective	High	Limited number of in-season weeks analyzed; absence of internal load measures.

Ibáñez-Pérez et al. (2020)	Descriptive	Moderate	Small sample (n = 9); manual heart rate collection; short monitoring period.
Clemente et al. (2020)	Correlational	High	Data from a single national team; strong dependence on coaching staff planning.
Clemente et al. (2019)	Longitudinal	Moderate	Absence of objective external load measures; limited control of recovery strategies.
Teixeira et al. (2019)	Longitudinal	Moderate	Exclusive use of sRPE; heterogeneous testing protocols across teams.
Beato et al. (2017)	Cross-sectional	Moderate	Non-official match context; substitution patterns not representative of competition.
Miloski et al. (2016)	Longitudinal	High	Single-team design; use of medication potentially influencing biological markers.
Rabelo et al. (2016)	Case study	Moderate	Coach-based intended load perception; limited generalizability.
Soares-Caldeira et al. (2014)	Randomized controlled trial	High	Small sample; short intervention period (pre-season only).
Milanez et al. (2014)	Longitudinal	Moderate	Small sample; URI assessed via questionnaire rather than clinical diagnosis.
Lu et al. (2018)	Observational	Moderate	Heart rate data included non-playing time; context limited to overseas training camp.

3.6 Temporal Organization of Training Load

The temporal organization of training load in futsal follows a structured pattern aimed at optimizing physical adaptations and tactical performance across different phases of the season. Clear variations in load distribution are observed between the pre-season, the competitive microcycle, and the competitive period, reflecting the evolving objectives of training throughout the season (Lago-Fuentes et al., 2020; Miloski et al., 2016; Rabelo et al., 2016).

The pre-season is characterized by the highest accumulation of both internal and external training loads. During this phase, training is primarily oriented toward developing fundamental physical capacities, such as neuromuscular strength and aerobic and anaerobic power, following the off-season period. Training volume is typically elevated, which is commonly associated with higher levels of monotony, training strain, and perceived fatigue compared with the competitive phase (Lago-Fuentes et al., 2020; Miloski et al., 2016; Rabelo et al., 2016). Initial sessions often function as a progressive reconditioning period, followed by a phase of intensified neuromuscular overload prior to the start of official competition.

Weekly training organization during the season is commonly structured according to a "match-day-minus" (MD-) approach, whereby training load fluctuates according to proximity to competition. Evidence consistently indicates that sessions performed on MD-4, MD-3, or MD-2 represent the most demanding days of the microcycle in terms of total distance covered, frequency of accelerations and decelerations, and overall biomechanical load (Gadea-Uribarri et al., 2025; Serrano et al., 2025). In contrast, the session immediately preceding competition (MD-1) typically shows a marked reduction in training load, emphasizing short-duration and activation-focused tasks to promote readiness and physical freshness (Lago-Fuentes et al., 2020). In congested weeks with multiple matches, this pattern is modified, with greater emphasis on recovery-oriented sessions and more selective exposure to high-intensity stimuli compared with weeks involving a single match (Chen et al., 2022; Clemente et al., 2019).

During the competitive period, the primary focus of training shifts from physical development to the maintenance of physical capacities and the refinement of technical–tactical performance. Overall training loads are generally lower than those observed during the pre-season to facilitate adequate recovery between matches and to manage cumulative physiological stress associated with competition density and travel demands (Miloski et al., 2016; Rabelo et al., 2016). Load distribution across the competitive season frequently follows an oscillatory pattern, whereby weeks with reduced match exposure are used to introduce targeted overload stimuli aimed at preventing detraining (Lago-Fuentes et al., 2020; Stochi de Oliveira & Borin, 2021).

Marked discrepancies are evident between the demands imposed during training sessions and those observed during official competition. Match play consistently elicits higher physiological and mechanical loads, including peak heart rate responses, greater distances covered at high speed, and a higher frequency of explosive mechanical actions (Illa et al., 2021; Serrano et

al., 2025). Due to the unlimited substitution rule, competitive futsal is characterized by sustained high-intensity efforts that are rarely fully replicated during training. Consequently, physiological and external load metrics recorded in training contexts are generally lower than those observed during competition, highlighting consistent differences between training and match demands (Gadea-Uribarri et al., 2025; Illa et al., 2020).

4. Discussion

The present systematic review synthesized the available evidence on training load monitoring in futsal, highlighting its temporal organization, positional demands, physiological and biomechanical responses, and implications for performance and well-being. Overall, the findings indicate that training load in futsal follows a structured, phase-dependent pattern across the season, shaped by task characteristics, competitive context, and the specific demands of the sport (Lago-Fuentes et al., 2020; Miloski et al., 2016; Rabelo et al., 2016).

Evidence consistently indicates that the pre-season represents the period of greatest accumulation of both internal and external training loads, characterized by elevated volumes aimed at promoting neuromuscular and aerobic adaptations following the off-season (Lago-Fuentes et al., 2020; Miloski et al., 2016). During the competitive season, training loads tend to stabilize or decrease, prioritizing the maintenance of physical capacities and the management of accumulated fatigue (Esteves et al., 2022; Rabelo et al., 2016). At the microcycle level, a progressive tapering structure is commonly observed, with higher loads earlier in the week and marked reductions on MD-1 to optimize recovery and match readiness (Clemente et al., 2019; Illa et al., 2020). Furthermore, the distribution of high- and very high-demanding scenarios appears to be strategically planned, with evidence suggesting that MD-2 most closely approximates match demands within the weekly cycle (Illa et al., 2020).

Positional demands further modulate load exposure. Studies consistently report that wings and defenders accumulate greater external loads, characterized by higher volumes of high-intensity actions, accelerations, and decelerations, compared with pivots (Gadea-Uribarri et al., 2025; Illa et al., 2021; Serrano et al., 2025). However, internal load responses appear less position-dependent, as players involved in frequent physical contacts may experience similar or higher perceived exertion despite lower locomotor outputs (Ibáñez-Pérez et al., 2020; Rabelo et al., 2016). Additionally, non-linear dose-response relationships between training load and stress-related biological markers have been identified, suggesting the existence of optimal internal load ranges for preserving immune function in elite female futsal players (Milanez et al., 2014). Heart rate variability has also emerged as a sensitive indicator of aerobic adaptation and recovery when combined with appropriate training stimuli (Campos et al., 2021).

Compared with outdoor football, futsal exhibits a distinct training load profile. Direct comparisons indicate that futsal training sessions elicit higher relative internal intensity, reflected by greater percentages of maximal heart rate and increased time spent in high-intensity zones, despite lower absolute distances covered (Clemente & Nikolaidis, 2016). This aligns with futsal-specific evidence demonstrating a high density of explosive mechanical actions and elevated relative intensity during match play (Illa et al., 2021; Serrano et al., 2025). These characteristics reinforce the need for futsal-specific load management and recovery strategies, rather than direct extrapolation from outdoor football models (Miloski et al., 2016).

From an applied perspective, the evidence highlights the importance of systematic and individualized monitoring of training load in futsal. Daily assessment using internal load measures such as session rating of perceived exertion, complemented by well-being questionnaires, appears particularly relevant given the frequent discrepancies observed between intended and perceived training loads (Chen et al., 2022; Clemente et al., 2019; Rabelo et al., 2016). Moreover, high-intensity interval training models incorporating futsal-specific constraints have demonstrated effectiveness in improving aerobic and neuromuscular performance (Campos et al., 2021). The ecological validity of training load monitoring further depends on representative training contexts and the use of validated indoor tracking technologies to accurately capture the complex mechanical demands of futsal (Sánchez-Sánchez et al., 2024; Villarejo-García et al., 2025).

4.1 Strengths and Limitations

Several strengths of the present review should be highlighted. Its exclusive focus on futsal is particularly relevant, given the limited volume of futsal-specific research compared with outdoor football. The inclusion of both internal and external training load metrics enables a comprehensive analysis of training demands, integrating physiological stress indicators (e.g., heart rate–based measures, session rating of perceived exertion, and biochemical markers) with mechanical and kinematic variables (e.g., distance covered, accelerations, decelerations, and PlayerLoad derived from GPS-, UWB-, or LPS-based technologies).

A further strength is the longitudinal design adopted by many of the included studies, with monitoring periods ranging from pre-season mesocycles to full competitive seasons lasting up to 45 weeks. This longitudinal perspective provides valuable insight into training periodization and biomotor adaptations over time. Moreover, most data were collected in real training and competition environments involving elite professional players and national teams, enhancing ecological validity and practical relevance.

Nevertheless, several limitations should be acknowledged. Considerable methodological heterogeneity was observed across studies, particularly regarding speed thresholds and tracking technologies, limiting direct comparison of absolute values. Sample sizes were frequently small, a common constraint in high-performance settings that nonetheless restricts statistical

power and generalizability. In addition, the predominance of observational designs limits causal inference, and variability in monitoring protocols and data reporting precluded meta-analytical procedures.

5. Practical Applications

The findings of this review provide important practical implications for coaches and physical performance staff working in futsal. Systematic daily monitoring of internal load using session rating of perceived exertion, complemented by simple well-being questionnaires, is recommended to capture individual responses to training and to address the recurrent discrepancy between intended and perceived training load.

From a training organization perspective, careful management of weekly load distribution is essential. Training loads should be concentrated earlier in the microcycle, with marked reductions on MD-1 to promote physical and cognitive freshness before competition. Task selection is critical, as full-court and numerical superiority or inferiority games elicit higher physiological and biomechanical loads than analytical or half-court drills. Positional specificity should also be considered, given that pivots typically accumulate lower external loads than wings and defenders, potentially requiring supplementary stimuli to balance demands.

For strength and conditioning professionals, sRPE emerges as a valid, reliable, and low-cost tool for internal load monitoring, particularly in contexts with limited technological resources. High-intensity interval training protocols incorporating frequent changes of direction (e.g., HIIT performed at submaximal intensities) appear effective for improving repeated sprint ability and aerobic performance. Additionally, monitoring biological and autonomic markers may support load management, as daily loads within approximately 343–419 AU are associated with more favorable immune responses, while higher values may increase physiological stress. Heart rate variability provides a sensitive, non-invasive indicator of recovery status, and segmental biomechanical monitoring highlights the need for joint-specific injury prevention strategies.

Conclusions

This systematic review demonstrates that training load monitoring in futsal follows a clear and structured seasonal pattern. The pre-season consistently emerges as the period of greatest accumulation of internal load and training volume, playing a key role in promoting initial neuromuscular and aerobic adaptations. As the season progresses, training load shifts from a volume-oriented approach toward greater tactical and technical intensity, aiming to maintain physical performance while preserving recovery capacity. Across studies, official match play imposes substantially higher physiological and mechanical demands than training sessions, and load exposure varies markedly according to tactical position, with wings and defenders consistently accumulating higher external loads and high-intensity actions than pivots.

From a practical perspective, the evidence supports the use of session rating of perceived exertion as a valid, reliable, and low-cost method for internal load quantification, particularly in contexts with limited technological resources. Effective microcycle periodization, characterized by a clear tapering strategy on MD−1, appears fundamental for ensuring physical freshness on match day. The findings also highlight the importance of managing daily training load to avoid excessive values that may compromise immune function, as well as controlling training monotony to reduce the risk of maladaptation. Persistent discrepancies between intended and perceived training load further emphasize the need for continuous adjustment of training prescription based on athletes' feedback.

Despite the growing body of evidence, important gaps remain. Future research should prioritize longitudinal studies involving female futsal players, larger multi-team samples, and integrated approaches combining internal, external, and biological load indicators. Greater attention should also be given to contextual variables such as travel demands, sleep disruption, and opponent quality, as well as to the long-term relationship between training load exposure and injury incidence across multiple competitive seasons. Addressing these gaps will contribute to a more comprehensive and applied understanding of training load management in futsal.

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Physical, Physiological, and Cognitive Load in Football Refereeing: A Systematic Review

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Abstract

Football refereeing involves complex physical, physiological, and cognitive demands that differ fundamentally from those experienced by players. Despite increasing scientific interest, the available evidence remains fragmented and is frequently derived from player-based models, which may inadequately capture the specific constraints of refereeing performance. This systematic review aimed to synthesise current evidence on physical, physiological, and cognitive load in football refereeing, integrating findings from match-based, training-based, and laboratory studies. A systematic literature search was conducted in PubMed, Web of Science, and Scopus up to January 2026, following PRISMA 2020 guidelines. Eligible studies assessed load-related outcomes in football referees across match, training, or laboratory contexts. Study selection, data extraction, and methodological quality assessment were performed independently by two reviewers using Joanna Briggs Institute critical appraisal tools. Due to substantial methodological heterogeneity, a narrative synthesis approach was adopted. Nine studies met the inclusion criteria. The evidence indicates that football refereeing is characterised by substantial physical and physiological demands, with load profiles influenced by competitive level and refereeing role. Field referees generally experience higher overall demands than assistant referees, reflecting distinct functional roles within the refereeing team. Internal load responses are modulated by contextual factors and pre-match well-being status, highlighting the relevance of readiness and recovery. Emerging evidence also underscores the importance of cognitive load, with mental fatigue and dual-task demands influencing perceived exertion and performance efficiency under match-like conditions. Football refereeing should therefore be conceptualised as a multidimensional activity **in which** physical, physiological, and cognitive demands interact. The findings support the adoption of referee-specific and role-specific load monitoring approaches that extend beyond player-derived models. Future research should prioritise integrated, ecologically valid designs and address the under-representation of assistant referees and female referees to strengthen evidence-based practice in football officiating.

Keywords: football referees; training load; physical demands; cognitive load; well-being; performance monitoring

1. Introduction

Football refereeing is characterised by substantial physical, physiological, and cognitive demands arising from the need to maintain optimal positioning, cover extensive distances, and make rapid decisions under continuously evolving match

conditions (Schenk et al., 2018; Martinho et al., 2023). Unlike players, referees must sustain performance throughout the entire match while simultaneously managing perceptual, decisional, and regulatory demands, imposing unique constraints on their performance capacity. Despite these distinctive characteristics, research on football refereeing has largely relied on conceptual and methodological frameworks originally developed for players, which may inadequately capture the specific demands of the refereeing role (Martinho et al., 2023).

Evidence consistently shows that football referees experience high physical loads during match play, with considerable running demands, frequent speed variations, and repeated high-intensity actions, varying according to competitive level and refereeing role (Gomes et al., 2024; Martínez-Torremocha et al., 2023). These movement profiles differ from those of players and reflect task-specific constraints related to positioning, anticipation, and game management (Martínez-Torremocha et al., 2023).

In parallel, referees are exposed to pronounced physiological load, commonly assessed through heart rate–derived measures and internal load indicators. Cardiovascular strain remains elevated for prolonged periods during both training and competition, while internal load measures such as session rating of perceived exertion are sensitive to organisational and contextual factors, including training session timing (Castagna et al., 2017; Martínez-Torremocha et al., 2023).

Beyond physical and physiological dimensions, fatigue and well-being have emerged as relevant modulators of refereeing performance. Pre-match well-being status, including perceived fatigue, sleep quality, stress, and muscle soreness, has been associated with subsequent internal and external match load responses, highlighting the importance of recovery status when interpreting load metrics (Ozaeta et al., 2021).

More recently, the cognitive dimension of refereeing has gained attention. Experimental evidence suggests that mental fatigue can increase perceived exertion without necessarily impairing inhibitory control, indicating a potential dissociation between subjective effort perception and objective cognitive performance (Lopes de Lima et al., 2025). Moreover, dual-task paradigms demonstrate that simultaneous motor and cognitive demands reduce both motor and cognitive performance, underscoring the relevance of cognitive load in refereeing contexts (Oguz et al., 2025).

Despite the growing body of literature, evidence remains fragmented, with many studies focusing on isolated load dimensions and adopting player-based models that may not fully reflect the functional realities of refereeing. Methodological heterogeneity across studies further limits the integration of findings and the development of comprehensive, referee-specific load monitoring frameworks (Schenk et al., 2018; Martinho et al., 2023).

Therefore, the aim of this systematic review is to synthesise available evidence on physical, physiological, and cognitive load in football refereeing, integrating findings from match-based, training-based, and laboratory studies. This review seeks to clarify how different load dimensions are assessed, identify consistent patterns and methodological gaps, and discuss implications for more specific and multidimensional approaches to referee training, monitoring, and performance management.

2. Methods

2.1 Study Design and Reporting Guidelines

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to systematically identify, select, and synthesise relevant literature addressing physical, physiological, and cognitive load in football refereeing. Given the substantial heterogeneity in study designs, participant populations, and outcome measures across the included studies, a narrative synthesis approach was employed to integrate and critically summarise the available evidence.

2.2 Eligibility Criteria

Studies were included if they involved football referees (field and/or assistant referees) and examined physical, physiological, and/or cognitive load, fatigue, or closely related constructs within the context of football refereeing. Eligible studies were required to be conducted in match, training, or laboratory settings relevant to refereeing performance and to report quantitative outcomes related to load monitoring, physiological responses, perceptual measures, or cognitive performance. Both original research articles and review papers published in peer-reviewed journals were considered eligible.

Studies were excluded if they focused exclusively on football players or athletes from other sports, investigated referees from sports other than football, combined refereeing data with other populations without clear disaggregation, or did not report outcomes relevant to load, fatigue, or performance within refereeing contexts. Additionally, non-original research, including editorials, conference abstracts, expert opinions, guidelines, theses, and case reports, was excluded.

2.3 Information Sources and Search Strategy

A systematic literature search was conducted across three electronic databases: PubMed, Web of Science, and Scopus. These databases were selected to ensure comprehensive coverage of biomedical, sports science, and interdisciplinary research relevant to football refereeing. The search was performed up to January 2026, with no restrictions imposed regarding publication year.

The search strategy combined terms related to the population of interest (football referees) with terms describing load-related constructs. The following core search string was applied, with database-specific adaptations to syntax and indexing: *"football referees" AND "training load" AND (well-being OR fatigue OR recovery OR "perceived exertion")*.

In PubMed, the search was restricted to Title/Abstract fields to increase specificity, whereas equivalent topic or keyword fields were used in Web of Science and Scopus. An initial, more restrictive strategy including only the term *well-being* yielded limited records; therefore, the search strategy was refined by expanding the well-being concept to include closely related terms (fatigue, recovery, and perceived exertion). This refinement was applied consistently across all databases to enhance sensitivity while maintaining conceptual coherence.

All records retrieved from the databases were exported to reference management software (Zotero), where duplicate entries were identified and removed prior to the screening process. No additional records were identified through alternative sources, including manual reference list screening, organisational websites, or trial registers.

2.4 Study Selection

Following the completion of the database searches, all records were imported into reference management software (Zotero), where duplicate entries were identified and removed. The remaining records were then screened based on titles and abstracts to assess their alignment with the eligibility criteria. Subsequently, full-text articles were retrieved and evaluated for final inclusion. The study selection process was conducted in accordance with PRISMA 2020 guidelines and is illustrated in the PRISMA flow diagram (Figure 1).

2.5 Data Extraction

Data extraction was performed using a standardised approach to ensure consistency across the included studies. For each eligible article, information was extracted on study characteristics (author, year, country, sample characteristics, competitive level, referee type, context, and study design), assessed variables and measurement instruments related to physical, physiological, and cognitive load, as well as the main findings and practical implications. The extracted data were organised and synthesised to support the descriptive and narrative presentation of results, as summarised in Tables 1–3.

2.6 Methodological Quality Assessment

The methodological quality of the included studies was assessed to support interpretation of the findings. Given the heterogeneity of study designs, the appropriate Joanna Briggs Institute (JBI) critical appraisal checklists were applied according to study type. The quality assessment was conducted independently by two reviewers, with any disagreements resolved by consensus. The results of the methodological appraisal were used descriptively to inform the narrative synthesis and were not applied as exclusion criteria.

2.7 Data Synthesis

Given the heterogeneity in study designs, participant characteristics, assessed variables, and measurement instruments across the included studies, a narrative synthesis approach was adopted. This approach allowed for a structured integration of findings related to physical, physiological, and cognitive load in football refereeing, without quantitative pooling of results. The synthesis was guided by thematic organisation of the evidence, focusing on study characteristics, load-monitoring approaches, and main findings, as presented in Tables 1-3.

3. Results

3.1 Study Selection

The database search yielded a total of 18 records. After the removal of duplicate entries, 15 records remained for title and abstract screening. Following this screening process, 9 studies met the eligibility criteria and were included in the final qualitative synthesis. The study selection process is illustrated in the PRISMA flow diagram (Figure 1).
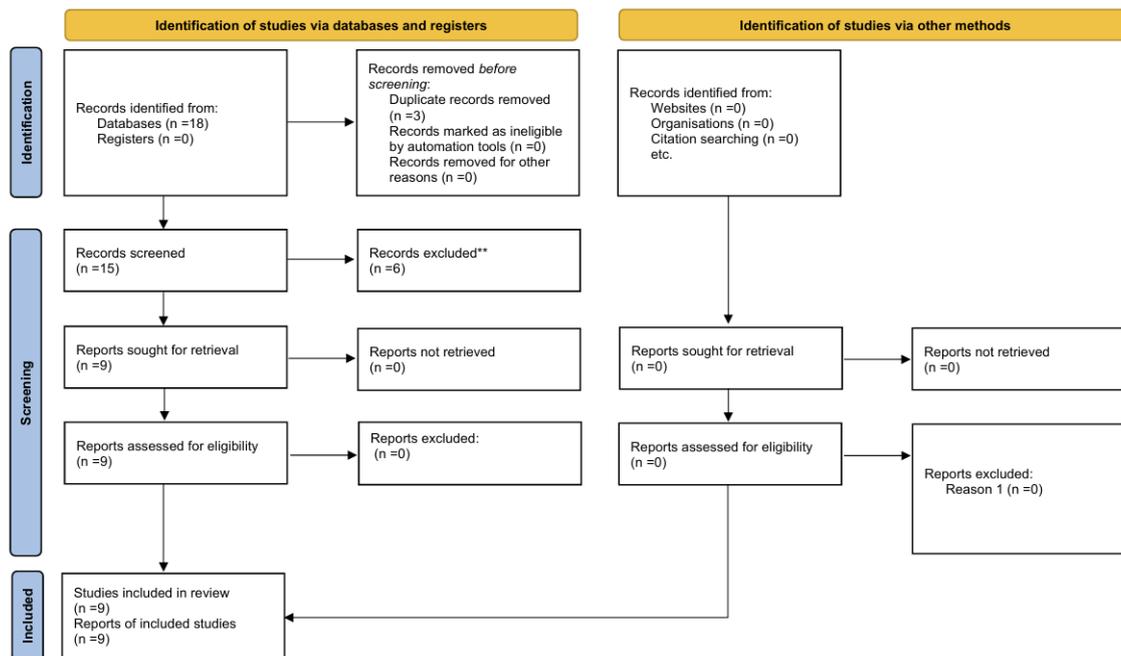
Figure 2. PRISMA 2020 flow diagram of the study selection process.

3.2 Study Characteristics of Included Studies
The main characteristics of the included studies are summarised in Table 1.

Table 1. Characteristics of the studies included in the review

Author (year)	Country	Sample (n)	Competitive level	Referee type	Context	Study design
Ozaeta et al. (2021)	Spain	40 amateur referees	Amateur	Field referees	Official matches	Longitudinal observational
Gomes et al. (2024)	Portugal	17 field referees + 36 assistant referees	Amateur (regional, division)	Field and 4th assistant referees	Official matches	Cross-sectional observational
Martínez-Torremocha et al. (2023)	Spain	Professional referees (n not specified)	Professional	Field referees	Official matches	Observational
Castagna et al. (2017)	Italy	Elite referees (n not specified)	Elite	Field referees	Training sessions	Observational
Truppa et al. (2021)	Italy	16 semi-professional referees	Semi-professional	Field referees	Laboratory / fatigue protocol	Experimental
Lopes de Lima et al. (2025)	Brazil	12 professional referees	Professional	Field referees	Laboratory / match-simulation task	Experimental (crossover)
Oguz et al. (2025)	Turkey	42 referees	National	Referees	Laboratory (dual-	Cross-sectional

Author (year)	Country	Sample (n)	Competitive level	Referee type	Context	Study design
					task paradigm)	
Martinho et al. (2023)	Portugal	–	Mixed	Football referees	–	Systematic review
Schenk et al. (2018)	International	–	Elite	Football referees	–	Narrative review

 Overall, the nine studies comprised a range of competitive levels and methodological approaches, including observational and experimental designs, as well as review papers. The studies were conducted across different countries and involved football referees operating in match, training, and laboratory contexts.

Most empirical studies focused on male referees and were conducted in amateur, semi-professional, or professional settings, with field referees being more frequently investigated than assistant referees. Match-based studies primarily examined physical and physiological demands during official competition, whereas laboratory-based studies explored fatigue-related responses and cognitive load under controlled conditions. The included review articles provided a broader contextual framework, synthesising existing evidence on the physical, physiological, and cognitive load in football refereeing.

3.3 Load Monitoring Approaches and Assessed Variables

The load monitoring approaches and assessed variables across the included studies are summarised in Table 2.

Table 2. Load monitoring approaches and assessed variables across the included studies.

Author (year)	External load variables	Internal load variables	Well-being / fatigue variables	Cognitive load	Measurement instruments
Ozaeta et al. (2021)	Total distance, high-speed running	Heart rate–derived variables	Hooper Index (fatigue, sleep, stress, DOMS)	–	GPS, HR monitors, Hooper questionnaire
Gomes et al. (2024)	Total distance, HIR, HSR, accelerations, decelerations	Average HR, %HRmax	–	–	GPS (WIMU Pro), HR strap
Martínez-Torremocha et al. (2023)	Total distance, speed zones	HR-derived variables	–	–	GPS, HR monitors
Castagna et al. (2017)	–	Session-RPE (sRPE)	–	–	Borg CR-10 scale
Truppa et al. (2021)	–	–	Neuromuscular fatigue indicators	–	Wearable inertial sensors
Lopes de Lima et al. (2025)	–	–	Mental fatigue, perceived exertion (RPE)	Inhibitory control task	Cognitive tasks, RPE scale

Author						
Oguz et al. (2025)	_	_	Dual-task cost (motor performance decrement)	Multiple Object Tracking (MOT)	ESST, MOT test
Martinho et al. (2023)	Distance, speed, accelerations (reviewed)	HR, RPE (reviewed)	Fatigue, recovery (reviewed)	_	Systematic synthesis
Schenk et al. (2018)	Match running demands (reviewed)	Physiological load (reviewed)	Recovery strategies (reviewed)	_	Narrative synthesis

Overall, a wide range of external, internal, and cognitive load indicators was used to characterise the demands of football refereeing across match, training, and laboratory contexts.

External load was primarily assessed using time–motion analysis and wearable technologies, with common variables including total distance covered, high-speed running, sprint activities, and acceleration-based metrics. These measures were predominantly reported in match-based studies and were used to describe the physical demands associated with referees' movement patterns during official competition.

Internal load was mainly quantified through heart rate–derived variables and perceptual measures, particularly session rating of perceived exertion. These indicators were applied in both match and training settings to capture the physiological responses associated with external demands and to reflect the overall internal stress experienced by referees.

Cognitive load and fatigue-related variables were assessed using experimental protocols and perceptual measures in laboratory-based and applied settings. These approaches included assessments of mental fatigue, dual-task performance, perceived exertion, and cognitive control, providing insight into the interaction between physical exertion and cognitive demands during refereeing tasks.

3.4 Main Findings and Practical Implications

The main findings and practical implications derived from the included studies are summarised in Table 3.

Table 3. Summary of main findings and practical implications across the included studies.

Author (year)	Main findings	Practical implications for referee training and management
Ozaeta et al. (2021)	Match external and internal load were significantly associated with pre-match well-being status; poorer well-being was linked to higher perceived load during matches.	Monitoring well-being (e.g., Hooper Index) before matches can help anticipate excessive internal load and guide recovery or load-adjustment strategies.
Gomes et al. (2024)	Field referees experienced higher physical and physiological demands than assistant referees; high-intensity activities and heart rate responses differed between roles and match halves.	Training programs should be role-specific, emphasizing high-intensity running and endurance for field referees and repeated accelerations for assistant referees.
Martínez-Torremocha et al. (2023)	Professional referees exhibited substantial match running demands, with variability across speed zones and competitive contexts.	Conditioning programs should reflect competitive level and match intensity profiles to reduce fatigue-related performance decrements.
Castagna et al. (2017)	Session-RPE was sensitive to training-session timing, indicating its usefulness for internal load monitoring in elite referees.	sRPE is a practical, low-cost tool for daily training-load monitoring and can support individualized load management.
Truppa et al.	Fatigue induced measurable biomechanical alterations	Wearable technology may support early detection

Author (year)	Main findings	Practical implications for referee training and management
(2021)	during running, detectable through wearable sensors.	of fatigue-related mechanical changes, potentially reducing injury risk.
Lopes de Lima et al. (2025)	Mental fatigue increased perceived exertion without impairing inhibitory control, suggesting dissociation between cognitive performance and effort perception.	Psychological load should be considered alongside physical load, as mental fatigue may influence effort perception and recovery needs.
Oguz et al. (2025)	Dual-task conditions reduced both motor and cognitive performance in referees, similarly to athletes.	Integrating dual-task and decision-making components into training may enhance referees' resilience to combined physical and cognitive demands.
Martinho et al. (2023)	Evidence shows high physical demands in refereeing, with limited integration of nutritional, recovery, and well-being variables across studies.	Multidimensional monitoring frameworks combining load, recovery, and lifestyle factors are needed in referee preparation.
Schenk et al. (2018)	Elite refereeing involves high physiological demands and requires adequate recovery and nutritional strategies to sustain performance.	Recovery and nutritional planning should be incorporated into long-term referee development programs.

Overall, the evidence indicates that football refereeing is characterised by substantial physical and physiological demands, which are modulated by contextual factors, individual readiness, and cognitive load.

Across match-based studies, external and internal load indicators highlighted the high physical and physiological requirements imposed on referees during competition, with variations according to competitive level and refereeing role. These demands underscore the need for role-specific preparation and monitoring strategies, particularly when distinguishing between field and assistant referees.

Beyond physical and physiological components, several studies emphasised the relevance of fatigue-related and cognitive factors. Pre-match well-being and recovery status were shown to influence internal load responses, whereas experimental evidence suggested that mental fatigue and dual-task demands can alter perceived exertion and performance efficiency. Collectively, these findings support the adoption of multidimensional monitoring approaches that integrate physical, physiological, and cognitive dimensions in referee training and performance management.

4. Discussion

This systematic review synthesised current evidence on physical, physiological, and cognitive load in football refereeing, integrating findings from match-based, training-based, and laboratory studies (Martinho et al., 2023; Schenk et al., 2018). The results confirm that refereeing performance is shaped by substantial physical and physiological demands that are further modulated by contextual, perceptual, and cognitive factors (Gomes et al., 2024; Ozaeta et al., 2021; Lopes de Lima et al., 2025; Oguz et al., 2025). Importantly, these demands differ fundamentally from those experienced by players, as referees must sustain decision accuracy under continuous physical load without opportunities for substitution or task relief, reinforcing the need for referee-specific performance models rather than player-derived frameworks (Schenk et al., 2018; Martinho et al., 2023).

4.1 Physical and Physiological Load in Football Refereeing

The findings of this review confirm that football referees are exposed to high physical demands during match play, characterised by extensive running volumes and repeated high-intensity actions, with load magnitude varying according to competitive context (Gomes et al., 2024; Martínez-Torremocha et al., 2023). However, referees exhibit movement patterns distinct from those of players, being primarily driven by positional requirements, anticipation, and game management rather than direct involvement in play (Martínez-Torremocha et al., 2023; Martinho et al., 2023). These task-specific constraints limit the validity of directly transferring player-based load benchmarks to refereeing contexts.

Physiological load responses, commonly assessed through heart rate-derived measures and perceptual indicators, demonstrate that referees experience sustained cardiovascular strain during both match play and training (Martínez-Torremocha et al., 2023; Martinho et al., 2023). Importantly, internal load responses do not always scale proportionally with external workload, highlighting the influence of contextual and organisational factors on physiological stress (Castagna et al., 2017). Together, these findings support the combined use of external and internal load indicators to more accurately characterise refereeing demands (Schenk et al., 2018; Martinho et al., 2023).

4.2 Role-Specific Demands and Contextual Modulators

A consistent finding across the included studies is the influence of refereeing role on load profiles. Field referees generally experience higher overall physical and physiological demands, whereas assistant referees are exposed to distinct movement patterns characterised by frequent lateral displacements and short accelerations (Gomes et al., 2024). These differences reinforce the need for role-specific conditioning and monitoring strategies rather than uniform training prescriptions across officiating roles.

Competitive level also emerged as a relevant contextual modulator of load. Evidence indicates that referees operating in professional and elite competitions are exposed to higher match intensity and greater physiological stress compared with those officiating at lower competitive levels (Martínez-Torremocha et al., 2023; Martinho et al., 2023). Such variability suggests that referee development pathways should progressively align physical and cognitive preparation with the increasing demands of competition.

4.3 Fatigue, Well-Being, and Cognitive Load

Beyond physical and physiological components, this review highlights the relevance of fatigue-related and cognitive factors in football refereeing. In amateur referees, pre-match well-being status including perceived fatigue, sleep quality, stress, and muscle soreness was shown to influence subsequent internal load responses during competition, emphasising the importance of readiness and recovery in load interpretation (Ozaeta et al., 2021). These findings support the practical value of incorporating subjective well-being monitoring alongside traditional load metrics (Schenk et al., 2018; Martinho et al., 2023).

The cognitive dimension of refereeing remains comparatively underexplored, yet emerging evidence indicates that it plays a meaningful role in performance regulation. Experimental findings suggest that mental fatigue can increase perceived exertion without necessarily impairing inhibitory control, indicating a potential dissociation between subjective effort perception and specific cognitive performance outcomes in trained referees (Lopes de Lima et al., 2025). Additionally, dual-task paradigms demonstrate that concurrent motor and cognitive demands can reduce both motor and cognitive performance, highlighting the importance of cognitive load under ecologically valid refereeing conditions (Oguz et al., 2025). Collectively, these results support conceptualising refereeing as a multidimensional task in which cognitive demands interact with physical exertion and perceptual responses (Schenk et al., 2018; Martinho et al., 2023).

4.4 Methodological Considerations and Research Gaps

Despite the growing body of research, several limitations constrain the current evidence base. Substantial heterogeneity exists in study designs, participant characteristics, monitoring tools, and outcome measures, limiting direct comparability across studies and precluding quantitative synthesis (Martinho et al., 2023). Furthermore, empirical research has predominantly focused on male field referees, with assistant referees and female referees remaining under-represented, which restricts the generalisability of findings across officiating populations (Gomes et al., 2024; Martinho et al., 2023).

Another key limitation concerns the frequent isolation of load dimensions. Most studies examined physical, physiological, or cognitive components independently, rather than adopting integrated frameworks capable of capturing the complex interaction between these dimensions in real-world refereeing contexts (Schenk et al., 2018; Martinho et al., 2023). Additionally, while laboratory-based studies provide valuable mechanistic insights, their ecological validity may be limited, reinforcing the need for research designs that combine field-based monitoring with cognitive and perceptual assessments (Oguz et al., 2025; Lopes de Lima et al., 2025).

4.5 Practical Implications for Referee Training and Monitoring

From an applied perspective, the findings of this review support the adoption of multidimensional monitoring approaches that integrate external load, internal load, and perceptual or cognitive indicators to better reflect the functional demands of football refereeing (Schenk et al., 2018; Martinho et al., 2023). Role-specific training and monitoring strategies appear particularly relevant given the distinct physical and movement demands of field and assistant referees (Gomes et al., 2024).

Routine assessment of well-being and perceptual measures may provide valuable contextual information for interpreting internal load responses and managing readiness across training and competition periods (Ozaeta et al., 2021). In parallel,

emerging evidence on mental fatigue and dual-task demands suggests that refereeing preparation may benefit from training environments that reflect the combined physical and cognitive stresses experienced during match play (Lopes de Lima et al., 2025; Oguz et al., 2025). However, further research is required to validate integrated monitoring models and to establish best-practice guidelines tailored specifically to refereeing contexts.

5. Limitations

Several limitations should be acknowledged. First, the heterogeneity in study designs, participant characteristics, monitoring tools, and reported outcomes limited direct comparisons across studies and precluded quantitative synthesis (Martinho et al., 2023). Second, the current evidence base is dominated by studies involving male field referees, with assistant referees and female referees remaining under-represented, which restricts the generalisability of findings across officiating populations (Gomes et al., 2024; Martinho et al., 2023). Third, most studies assessed isolated dimensions of load (e.g., external or internal indicators) rather than adopting integrated frameworks that simultaneously capture physical, physiological, and cognitive demands under ecological conditions (Schenk et al., 2018; Martinho et al., 2023). Finally, whilst laboratory-based designs provide valuable mechanistic insights into fatigue and cognitive constraints, their ecological validity may be limited when extrapolated to real match environments, supporting the need for field-based approaches that better reflect the complexity of decision-making under competitive pressure (Oguz et al., 2025; Lopes de Lima et al., 2025).

6. Conclusions

Football refereeing is characterised by substantial physical and physiological demands that are meaningfully modulated by contextual factors, perceptual responses, and cognitive load (Martinho et al., 2023; Schenk et al., 2018). Evidence from match-based studies indicates that referees operate under high locomotor and physiological requirements, whilst role-related differences highlight the need for referee-specific approaches rather than player-derived models (Gomes et al., 2024; Martínez-Torremocha et al., 2023). In parallel, well-being status prior to competition appears relevant for interpreting subsequent internal load responses, supporting the inclusion of readiness monitoring within applied practice (Ozaeta et al., 2021). Emerging experimental evidence further suggests that mental fatigue and dual-task constraints can alter perceived exertion and performance efficiency, reinforcing the importance of considering cognitive demands within referee preparation and monitoring frameworks (Lopes de Lima et al., 2025; Oguz et al., 2025). Future research should prioritise integrated, ecologically valid designs that combine physical, physiological, and cognitive measures, and address the persistent under-representation of assistant referees and female referees to strengthen evidence-based practice in football officiating (Martinho et al., 2023; Gomes et al., 2024).

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Training Load, Well-Being and Recovery in Soccer: A Narrative Review on Monitoring, Fatigue and Decision-Making

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Abstract

Training load monitoring is a central component of performance optimization, injury risk management, and athlete well-being in modern soccer. The increasing physical, psychological, and competitive demands of the game have exposed the limitations of relying on isolated workload metrics to evaluate player readiness and recovery. Accordingly, the purpose of this narrative review was to synthesize recent evidence on training load monitoring in soccer, with particular emphasis on the integration of external and internal load, subjective well-being, neuromuscular fatigue, recovery dynamics, and emerging data-driven decision-support approaches.

A structured literature search was conducted in PubMed, Scopus, and Web of Science, with study selection performed through title-based screening. Thirteen peer-reviewed studies were included, encompassing youth, collegiate, semi-professional, and professional soccer players. The evidence indicates that session rating of perceived exertion is a valid and practical indicator of internal load; however, its interpretation must be contextualized according to age, biological maturation, and individual characteristics. Subjective wellness measures and functional assessments of neuromuscular fatigue provide complementary information that is weakly associated with external workload but highly sensitive to cumulative load exposure and competitive congestion. Importantly, official competition consistently imposes greater recovery demands than training sessions with comparable physical loads, highlighting the independent contribution of psychological and contextual stressors.

Overall, effective training load management in soccer requires a multidimensional and individualized monitoring framework. Integrating physical, psychological, and contextual data, supported by emerging predictive and prescriptive analytics, represents a key step toward informed decision-making, optimized performance, and sustainable long-term athlete development.

Keywords: training load; soccer; internal load; external load; recovery; machine learning

1. Introduction

Training load management is a central component of performance optimization, athlete health, and competitive readiness in soccer. The increasing physical and competitive demands of the modern game have intensified the need for effective monitoring strategies capable of capturing players' responses to both training and match exposure (Havanecz et al., 2025;

Jensen et al., 2025). Inadequate load prescription or insufficient recovery may result in excessive fatigue, impaired well-being, and diminished readiness to perform, particularly during periods of high competitive density (González-Fernández et al., 2025).

From a conceptual perspective, training load is typically framed through the distinction between external and internal components. External load represents the physical work performed and is typically quantified using Global Positioning System (GPS) derived metrics, whereas internal load represents the psychophysiological stress imposed by that work. Evidence from youth and professional soccer indicates that session rating of perceived exertion (sRPE) is moderately to strongly associated with external load variables, supporting its use as a valid global indicator of internal load (Havanecz et al., 2025; Van Deuren et al., 2026). Conversely, indicators of recovery and well-being tend to show weaker and less consistent associations with physical workload, highlighting the multifactorial nature of athletes' responses to training stimuli.

Psychological well-being has emerged as a relevant determinant of how players perceive, tolerate, and respond to training load. Mood state, sleep quality, and perceived recovery have been shown to influence enjoyment, engagement, and readiness across different soccer training formats (Xu et al., 2025). Furthermore, competitive congestion has been associated with marked fluctuations in well-being profiles, particularly in youth players, emphasizing the importance of monitoring subjective responses alongside physical load metrics (González-Fernández et al., 2025).

Neuromuscular fatigue represents another key outcome of accumulated training and match demands. Studies employing functional performance measures have demonstrated that high weekly loads, especially those characterized by repeated accelerations and decelerations are associated with transient reductions in neuromuscular performance across the competitive microcycle (Springham et al., 2025; Tan et al., 2025). Notably, competitive match play appears to prolong recovery duration beyond that observed following training sessions, even when controlling for workload variables, suggesting an independent effect of competition-related stress on recovery kinetics (Jensen et al., 2025).

Recent advances in data analytics have enabled the transition from traditional descriptive monitoring toward predictive and prescriptive approaches to training load management. Machine learning models integrating external load, internal load, and maturational variables have demonstrated the capacity to estimate recovery status in youth soccer players (Afonso et al., 2025), while causal machine learning frameworks in professional soccer have extended this paradigm by enabling practitioners to simulate training scenarios and support individualized load prescription (Van Deuren et al., 2026).

Accordingly, this narrative review aims to synthesize recent evidence on training load monitoring in soccer, with particular emphasis on the relationships between internal and external load, psychological well-being, neuromuscular fatigue, recovery dynamics, and the evolution from predictive to prescriptive decision-making approaches in applied practice.

2. Methods

This study was designed as a narrative review aimed at synthesizing recent evidence on training load monitoring, well-being, fatigue, and recovery in soccer. A structured literature search was conducted in PubMed, Scopus, and Web of Science. The search strategy combined terms related to soccer (e.g., *soccer*, *football*), training load (e.g., *training load*, *workload*, *internal load*, *external load*), and recovery-related outcomes (e.g., *well-being*, *wellness*, *fatigue*, *recovery*, *readiness*). Only peer-reviewed articles published in English were considered.

Given the narrative nature of this study and the large volume of records retrieved, study selection was performed exclusively through title screening. The initial search yielded 355 records in PubMed, 502 in Scopus, and 1,095 in Web of Science. After duplicate removal, 1,236 unique records remained. Articles were included when their titles explicitly indicated a direct relationship between training load (internal and/or external) and outcomes related to well-being, fatigue, recovery, or readiness in soccer. Studies focusing primarily on unrelated topics, such as injury epidemiology, rehabilitation, nutrition, technological validation, or performance outcomes without reference to recovery or well-being, were excluded. This process resulted in a final corpus of 13 studies, which formed the basis for the thematic synthesis and critical discussion. The main characteristics of the included studies are summarized in Table 1.

Table 1. Characteristics of the Included Studies

Author (Year)	Sample and Level	Main Objective	Key Variables / Measures
Afonso et al. (2025)	40 male players (U11–U13; sub-elite)	To evaluate machine learning models for predicting total quality of recovery (TQR).	GPS metrics, sRPE, anthropometrics, maturational status, technical–tactical data (FUT-SAT).
Jensen et al. (2025)	30 female NCAA Division I players	To examine the effect of competition-related stress on recovery duration independent of physical load.	Wearable-derived load metrics (Polar), distance covered, energy expenditure, heart rate, recovery time.
Sierra-Casas et al. (2025)	19 male semi-professional players	To examine the relationship between accumulated external load and neuromuscular status.	GPS (10 Hz), Reactive Strength Index (RSI), contact time, jump height.
González-Fernández et al. (2025)	18 elite male U16 players	To assess the impact of four consecutive matches on subjective well-being.	Wellness questionnaires (muscle soreness, stress, mood, fatigue, sleep quality).
Anderegg et al. (2025)	71 youth players (U18–U19; male and female)	To explore associations between a web-based recovery score and recognized load measures.	sRPE (training and match), GPS-derived distance, Load–Recovery Score (LRS).
Springham et al. (2025)	25 male EPL academy players (U18)	To investigate within- and cross-season neuromuscular fatigue responses to training load.	Countermovement jump (CMJ), isometric strength, GPS metrics (distance, high-speed running).
Franceschi et al. (2025)	48 male youth players (U17–U19; Serie A)	To analyze post-match recovery responses following manipulation of training load.	CMJ, posterior chain isometric strength, subjective muscle soreness, fatigue.
Van Deuren et al. (2026)	14 professional male players (Belgian Pro League)	To model RPE using causal machine learning and support individualized load prescription.	GPS metrics, RPE, Hooper Index (sleep, stress, mood, fatigue), causal ML models.
Poulios et al. (2025)	10 well-trained male players	To determine recovery kinetics following maintenance training protocols.	Isokinetic strength, CMJ, RSA, movement velocity, creatine kinase (CK), DOMS.
Havanecz et al. (2025)	50 elite youth players (U15–U19; male)	To examine relationships between GPS-derived load and subjective questionnaires.	GPS metrics, RPE, sRPE, Hooper Index, TQR.
Xu et al. (2025)	77 male collegiate players (China)	To analyze relationships between well-being, exercise intensity, and enjoyment.	PACES, POMS, PRS, sleep duration, heart rate, RPE.
Tan et al. (2025)	39 male players (U15)	To analyze the effects of weekly acceleration and deceleration load on neuromuscular fatigue.	GPS accelerations/decelerations, CMJ, isokinetic strength, muscle soreness, DOMS.
Li et al. (2025)	15 male collegiate players	To validate sRPE as an indicator of internal load and identify influencing factors.	GPS metrics, sRPE, TRIMP, Edwards' training load, wellness indicators.

3. Multidimensional Training Load Monitoring in Soccer

Modern training load monitoring in soccer increasingly reflects a multidimensional perspective, integrating physical demands, psychophysiological responses, and contextual influences that collectively shape player readiness and recovery. Evidence synthesized in this review indicates that no single metric is sufficient to capture the complexity of players' responses to training and competition, reinforcing the need for integrated monitoring frameworks that combine objective workload data with subjective and functional information.

3.1 Internal vs. External Load

From a conceptual standpoint, training load monitoring in soccer is commonly structured around the distinction between external and internal load. External load represents the objectively quantifiable physical work performed by the player and is

typically assessed using Global Positioning System (GPS)–derived metrics such as total distance, high-speed running, and acceleration–deceleration profiles. Internal load, in contrast, reflects the individual psychophysiological response to this work, encompassing both physiological strain and perceptual stress.

Across youth, collegiate, and professional soccer populations, session rating of perceived exertion (sRPE) has consistently demonstrated moderate to strong associations with external load variables, supporting its validity as a practical and global indicator of internal load. In elite youth players, sRPE has shown robust relationships with volume-based GPS metrics, while in collegiate settings it has also demonstrated strong associations with heart rate–derived load indices, reinforcing its utility as a low-cost and ecologically valid monitoring tool (Havanecz et al., 2025; Li et al., 2025).

However, identical external loads do not necessarily elicit uniform internal responses. Evidence indicates that internal load and recovery status are modulated by individual characteristics and contextual influences that are not fully captured by mechanical workload alone. In top-level youth soccer players, combined load–recovery scores integrating sRPE and subjective recovery measures captured meaningful inter-individual variability that was not explained by external load metrics in isolation (Anderegg et al., 2025). These findings highlight the limitations of relying exclusively on external load to infer players' physiological state.

Importantly, age and developmental stage appear to influence the strength and consistency of the relationship between external and internal load. In younger players, weaker associations have been reported, suggesting that cognitive maturity and training experience may affect the accuracy and reliability of perceived exertion reporting (Havanecz et al., 2025). In pre-adolescent athletes, maturational and anthropometric factors have been shown to exert a stronger influence on perceived recovery than GPS-derived load metrics, emphasizing the need for age- and development-specific interpretations of internal load data (Afonso et al., 2025).

Collectively, these findings support the use of sRPE as a robust indicator of internal load while underscoring the importance of interpreting it within an individualized, developmentally informed, and context-aware monitoring framework.

3.2 Subjective Measures, Fatigue, and Contextual Influences

Beyond load quantification, subjective measures provide essential insight into players' readiness, fatigue, and recovery status. Wellness indicators such as perceived fatigue, muscle soreness, sleep quality, stress, and mood capture dimensions of athlete response that are not fully reflected in external load metrics, particularly those related to psychological and contextual stressors.

Evidence consistently indicates that subjective well-being measures exhibit weak or inconsistent associations with GPS-derived workload variables, highlighting their multifactorial nature. In elite youth soccer players, wellness scores show limited correspondence with mechanical load indicators, suggesting that recovery and readiness are shaped by factors extending beyond training volume and intensity, including sleep quality, psychological stress, and environmental conditions. Importantly, the integration of subjective wellness data with external load metrics has been shown to improve the sensitivity of monitoring systems for detecting maladaptive responses, particularly during periods of accumulated fatigue and competitive congestion (Montini et al., 2025).

Neuromuscular fatigue represents a functional manifestation of accumulated training and match demands and is commonly assessed using jump-based and strength-related measures. Evidence from youth and academy players indicates that high weekly loads, especially those characterized by repeated acceleration and deceleration actions, are associated with transient decrements in neuromuscular performance across the competitive microcycle (Springham et al., 2025; Tan et al., 2025). These responses appear to reflect cumulative rather than session-specific load exposure, reinforcing the importance of monitoring load distribution over time.

Contextual factors further modulate fatigue and recovery dynamics. Competitive match play imposes substantially greater recovery demands than training sessions with comparable physical load, suggesting that psychological stress and competitive pressure contribute independently to delayed recovery (Jensen et al., 2025). In parallel, psychological variables such as mood state and perceived recovery influence athletes' engagement and enjoyment during training, with total mood disturbance emerging as a key determinant of training enjoyment irrespective of exercise intensity (Xu et al., 2025).

Together, these findings reinforce that subjective measures, functional fatigue assessments, and contextual information provide indispensable complementary insights to external load data. Integrating these dimensions within a multidimensional monitoring framework enables a more accurate interpretation of player readiness and supports informed, context-sensitive decision-making in applied soccer environments.

4. Practical Applications

The evidence synthesized in this narrative review indicates that effective training load management in soccer should be approached as a multidimensional process integrating external workload, internal responses, subjective well-being, and functional indicators of fatigue. Reliance on a single metric provides an incomplete representation of players' readiness and recovery status. This integrated approach is consistent with contemporary consensus recommendations for training load

monitoring in team sports, which emphasize the complementary use of objective and subjective measures to support applied decision-making and injury risk management (Impellizzeri et al., 2020; Vanrenterghem et al., 2017).

Session rating of perceived exertion (sRPE) emerges as a practical, low-cost, and ecologically valid tool for daily monitoring of internal load across competitive levels. Its consistent association with external workload supports its use as a global indicator of training stress; however, sRPE values should be interpreted within an individualized and context-aware framework. In youth and developmental settings, cognitive maturity, training experience, and biological development may influence the reliability of perceived exertion reporting, reinforcing the need for cautious interpretation and complementary monitoring strategies.

Subjective wellness measures, including perceived fatigue, muscle soreness, sleep quality, stress, and mood, provide valuable insight into athlete responses that are not captured by external load metrics alone. These measures are particularly informative during periods of competitive congestion, where progressive increases in fatigue and disturbances in sleep quality may signal compromised readiness. Importantly, official competition imposes substantially greater recovery demands than training sessions with comparable physical load, highlighting the role of psychological stress and competitive pressure in modulating recovery dynamics (Impellizzeri et al., 2020).

Functional assessments of neuromuscular fatigue, such as jump-based or strength-related tests, can further support load management by informing players' capacity to tolerate subsequent training demands. Given that neuromuscular decrements often reflect cumulative rather than session-specific load exposure, practitioners should prioritize load distribution across the microcycle and carefully manage high acceleration–deceleration demands, particularly in the days following competition, in line with frameworks distinguishing mechanical and physiological load pathways (Vanrenterghem et al., 2017).

Recent advances in data analytics offer promising opportunities to enhance training load management through predictive and prescriptive approaches. Machine learning models integrating physical load, subjective responses, and maturational variables can assist in identifying compromised recovery states, while causal modeling frameworks enable practitioners to simulate training scenarios and individualize load prescription. When embedded within comprehensive monitoring frameworks, these tools can enhance precision in decision-making without replacing practitioner expertise.

5. Limitations and Future Directions

This synthesis of current literature provides important insights into training load monitoring in soccer while acknowledging several limitations that should be considered when interpreting the findings. First, the heterogeneity of study populations, including sub-elite youth, elite academy, collegiate, and professional players, introduces variability in biological maturation, cognitive development, and competitive demands. In youth settings, maturational and anthropometric factors often exert a stronger influence on perceived recovery than external workload, limiting generalizability across age groups and complicating the interpretation of self-reported internal load.

A second limitation relates to the underrepresentation of female athletes within the current evidence base. Most studies focused on male players, restricting the applicability of findings to female soccer populations, who may exhibit distinct physiological, hormonal, and psychological recovery responses. Greater emphasis on sex-specific research is therefore warranted.

Methodological limitations are also evident in the predominance of short-term observational designs, which constrain causal inference regarding relationships between training load, fatigue, and recovery. Although machine learning approaches show promise for individualized monitoring and prescription, many existing models rely on small, single-club samples and lack external validation, limiting their scalability and practical implementation. In addition, variability in monitoring tools and analytical approaches across studies hinders direct comparison and synthesis of findings, highlighting the need for greater methodological standardization.

Future research should prioritize longitudinal and multi-season designs that capture cumulative load exposure and long-term adaptation. Integrating external load, internal responses, subjective well-being, neuromuscular function, and contextual variables within unified monitoring frameworks will be essential to advance understanding of player readiness. Finally, continued development of prescriptive analytics, combining causal machine learning approaches with practitioner expertise, may support more precise, individualized, and context-sensitive training load management in applied soccer settings.

Conclusions

This narrative review synthesizes current evidence demonstrating that modern training load monitoring in soccer must be conceptualized as a multidimensional, individualized, and context-sensitive process. External workload metrics quantify the physical demands imposed on players, whereas internal load indicators, subjective well-being measures, and functional

assessments of neuromuscular fatigue capture the biological and psychological responses to those demands. Interpreting these metrics in isolation provides an incomplete understanding of player readiness and recovery.

Session rating of perceived exertion emerges as a valid and practical global indicator of internal load across competitive levels; however, its interpretation must be contextualized according to age, biological maturation, and individual characteristics. In younger players, maturational and cognitive factors may influence the accuracy of perceived exertion and recovery reporting, reinforcing the need for complementary monitoring approaches. Subjective wellness measures and neuromuscular performance tests further contribute essential information, particularly during periods of competitive congestion, where match-related stress imposes substantially greater recovery demands than training sessions with comparable physical loads.

The findings also highlight that players' responses to training are shaped by the interaction of physical, psychological, and contextual factors. Mood state, sleep quality, and competitive pressure influence recovery dynamics and training engagement, underscoring the limitations of purely mechanical monitoring models. In this context, emerging data analytics and machine learning approaches represent an important evolution, enabling the integration of multidimensional data and supporting the transition from descriptive monitoring toward predictive and prescriptive decision-making frameworks.

Overall, effective training load management in soccer relies on integrated monitoring systems that respect individual variability, developmental stage, and competitive context. Advancing toward precision-based load prescription, supported by data-driven decision tools and informed practitioner expertise, represents a key pathway for optimizing performance, safeguarding player health, and promoting sustainable long-term development in modern soccer.

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