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Translating player monitoring into training prescriptions: Real world soccer scenario and practical proposals

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Abstract

Data-driven training prescription based on previous training or match data is thought to be associated with better training outcome, compared to prescription without considering any monitoring data. Understanding the complex relationship between training load, physical performance, fitness status, fatigue and injury risk represents a challenge for health and performance practitioners and researchers. Although studies have revealed a positive correlation between training load and injury risk, this cause-effect relation cannot be determined given the multifactorial nature of injuries. Additionally, conflicting findings have been published explaining the relationship between training load and injuries, underlining the importance of training load management, prescription, and communication within the multidisciplinary team to improve physical performance and reduce injury risk. In this sense, practitioners may benefit from practical examples based on training load data to make informed decisions for prescribing training. This narrative review provides real-world examples of training decisions based on training load data in soccer, including training prescription, drill design and multidisciplinary team communication. Finally, a framework was provided to make informed training prescription from a physiological standpoint and elucidate the relationship between training load and injury risk.

Keywords

Association football, athletic performance, injury risk, playing position, training load

Introduction

Soccer performance is multifactorial, characterized by interdependent aspects, such as physiological, psychological, technical, and tactical, along with contextual factors that should be considered during training practice. In recent years, training load (TL) [referring also to match load] monitoring practices have increased through Electronic Performance and Tracking Systems (EPTS) such as Global Positioning System (GPS), with the aim of better understanding the physical demands of soccer. Given the multifactorial nature of soccer physical demands, several indicators derived from monitoring practice should be considered by practitioners to better understand the effects of training and matches.[1,2] TL has been conceptualized by Impellizzeri et al., as an external load (EL) wherein the activities performed by the players (such as total distance [TD], accelerations and decelerations) determine an internal athlete's response defined as the internal load (IL).[3]

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Due to the multifactorial nature of soccer performance, there is no single gold standard of reference for performance outcome.[3–5] Indeed, it would be impossible to consider a single TL indicator to evaluate performance which is based both on the match-demand (e.g., high-speed running [HSR] distance) and on the physiological component (e.g., energetic system involved such as metabolic and neuromuscular factors related to players responses). In this way, the activities effectively performed during match/training (i.e., EL) and the players' physiological responses (i.e., IL)[6] has been conceptualized[3] as highlighting the different demands among playing position.[2,7–9]

Although soccer performance has been assessed through several physiological-related factors, as well as considering match-demand-related indicators derived from GPS such as external load indicators (e.g., TD, HSR, acceleration, decelerations, metabolic power) and internal indicators (Rating of Perceived Exertion [RPE], oxygen consumption [VO_2] and Heart Rate [HR]),[3] some studies have investigated EL and IL as integrated approaches implementing new indices or ratio for IL and EL[10] aiming to assess the athlete's performance and fitness status. For example, authors computed a Effindex (as the ratio between mean speed in m·min[1] divided by the mean exercise intensity [%HRmax]) for every entire first half of the match to quantify the match stimuli doseresponse.[10,11] They reported that the higher the overall running performance during the entire game, the higher the Effindex.[10,11] However, to the authors' knowledge, no studies have investigated the association between EL/IL ratio and injury risk (IR) despite a correlation between low fitness status (evaluated through EL/IL ratio) and IR being reported by literature.[6,12–15]

Despite controversial results,[16] studies have consistently revealed a positive correlation between TL and injuries.[17] However, the cause-effect relation to explain a multifactorial phenomenon such as sports injuries is challenging.[18–21] Therefore, they may require complex studies supported by machine learning [ML]-based analyses.[21–24] In light of this, Kalkhoven and colleagues[21] have reported that the appropriate interplay among IR factors, such as EL, and tissue loading response, must be understood from a complex multifactorial perspective. However, interpreting the association or relationship between TL and match load and injuries or performance require a holistic approach, considering the interconnection between each risk factor, to bring the scientific evidence into the "field" practice.[18,19,21]

The literature shows controversial results concerning the relationship between TL and injury, revealing statistical limitations and biases among studies.[18,19,25] For example, Drew et al.,[26] have reported moderate evidence for relationship between TL (considering both EL and IL indicators) and risk of injury. In the same way, Jasper et al.[16] reported a weak evidence when both EL and IL load were related to injuries, suggesting that the implementation of continuous TL monitoring combined with the individual physiological characteristics such as (speed or endurance player)[27] is essential to examine the relationship between TL, physical fitness status (high/low fitness level) and IR with the aim of tailoring the training program based on individual needs.[28–30] The relationship between TL and injury is mediated by several factors,[15,31] in the real world scenario, TL management represents the main strategy to implement good training practice aiming to enhance physical performance while reducing IR.[3,6,12,19,21,25,32–34] In light of this, Gabbett[12] reported that appropriate TL management including a training prescription of high TL, avoiding TL spikes (i.e., avoiding increasing acute TL [absolute workload performed in 1 week]) and monotony (i.e., defined as the daily mean workload divided by the daily workload standard deviation).[35] In the same way, enhancing chronic load (4-week average acute workload) may improve players' fitness status and protect them from injuries.[36] Indeed, when an athlete is subjected to appropriate training stimuli (according to training principles such as graduality, variability, load modulation, frequency), following the supercompensation criteria (derived from knowledge of physiology), the level of fitness will chronically increase protecting him from injuries.

Worth noting, monitoring both EL and IL allows the training program to be addressed based on an individual approach.[29,34,37] Although studies have examined the implications of the TL on training outcomes such as injury and physical fitness,[16,17,26,38–41] results are conflicting and often lead to conceptual errors or misinterpretations where a lack of cause-effect relationship lead us to apply a more holistic study design including TL monitoring data, athlete's physiological characteristic (e.g., tissue load tolerance), well-being assessment, environmental factors[21] analysed thought Machine Learning approach.[21,22,24]

We highlight that training prescription[27,42] is supported by training/match load monitoring, including the characteristics of individual players,[29,43] where athletes are driven by an objective evidence[6] that play an essential role in increasing physical performance while reducing IR.[17,20,38,41,44,45] In this sense, to take evidence-based decisions influencing training prescription, practitioners should understand the complex relationship between TL and training outcomes (physical fitness, injury, and fatigue[4,16,46]). Physiological information should also be considered during the exercise prescription process as adaptations occur when appropriate and individualized stimuli (i.e., external activities) are administered to athletes.[3,19,47–49]

Revé et al., 2020[50] have proposed a practical approach concerning the use of GPS data for TL monitoring in a "real world" soccer context by suggesting that the planning of external TL should be carried out on a monthly, weekly, and daily level in order to improve physical performance of the team, based on individual approach. In fact, based on the evaluation of the TL including both the EL and IL and EL/IL indices, it is possible to tailor the training program based on the specific needs of each player.[3,29,34]

Accordingly, correctly interpreting the TL data collected, accurately communicating the results within the staff (i.e., informed-making process) is essential to increase the physical performance of each player, and consequently of the entire team.

This narrative review aims to provide an overview on training monitoring and training prescription to improve or maintain[51] soccer physical performance considered as key factors to reduce non-contact IR. In this context, we provided two conceptual frameworks. The first concerns the relationship between TL (based on application of EL and IL) and IR. The second is based on the monitoring process and its implication on informed-making process related to training prescription. We also provide practical examples on the relationship between the TL and soccer physical performance to understand the different concepts behind the use of the operationalization based on specific EL and IL indicators. Moreover, we reported relevant key questions and relative answers that fitness coaches, supported by sports scientists, should consider on monitoring process and training prescription to improve the informed decision-making process and communication within the technical and medical staff.

Training load in soccer

TL has been defined by Impellizzeri et al., 2019 as "the input variable that is manipulated to elicit the desired training response".[3] Two essential components have conceptualized training load as being either external and/or internal. EL refers to the amount of activity performed by players/athletes generally described by distance (with different speed thresholds), number of accelerations, decelerations, and metabolic power in a given training section or official match. EL is determined by the physical work prescribed in the training plan. Activities performed determine the athlete's psychophysiological response corresponding to the IL In soccer, it has been described by HR, RPE scale or lactate blood concentration.[9]

It is worth noting that, given a lack of a gold standard, the training load may be quantified by several indicators, including the EL or the internal response during the exercise.[3,19] For further information on the TL and its variables, we refer the reader to Impellizzeri et al., 2019,[3] and McLaren et al., 2017.[52] Following Gabbett et al., 2017,[6] we highlight that monitoring of training load (both EL and IL) represents an essential practice that should involve the whole staff team (both technical/physical and medical) to optimize training prescription aiming enhancement of physical performance while reducing IR.

Nevertheless, several conceptual questions considering both internal and external intensity indicators in soccer have been reported in the literature.[34,53–55] For example, studies found that S-RPE and HR-derived measures were more associated with volume (i.e., Total Distance, Low Running Intensity) than intensity indicators[53,54] highlights that this correlation is lower when intensity thresholds increase. Also, Scott et al. (2013) reported that cardiac response is more associated with distance covered at low speeds than the one covered at high speeds.[56,57] As a matter of fact, HR and RPE underestimate the IL response derived from anaerobic metabolism because this mechanism is mainly involved during short, high-intensity activities.[57] Hence, RPE could underestimated the workload sport specific tasks such as SSG because it may be more related to non-specific metabolic activities in which HR show a linear response.[57,58]

Moreover, concerning EL indicators, evaluating soccer training/match using speed measures allows for assessing only a partial component of external physical demand.[59] In this way, Gaudino et al. (2015) reported that the use of metabolic power for assessing physical performance demands (derived by speed and accelerations) is more appropriate concerning the use of only speed indicators.[58] Hence, both categories of EL (i.e., speed and acceleration) should be considered as they may be more related to S-RPE than the use of only one alone to monitor training in soccer.[39]

Soccer physical performance

From the work-setting perspective, performance has been defined as "the accomplishment of goals by meeting or exceeding predefined standards".[60] Actually, performance assesses how much "work" someone has performed compared to a gold standard. At the same time, soccer performance results from the interaction between technical, tactical, cognitive, psychological and physiological factors. In this narrative, we will refer to "soccer physical performance" which measures how much "physical work" an athlete has performed compared to a gold standard (i.e., match-demand or physiological demand). Different indicators related both external (imposed match-demand), internal (physiological response to a given imposed stimulus) factors and EL/IL ratio (athlete-related physical performance) allows us to assess "soccer physical performance" since both the physiological and match-demand components are implicated in soccer performance. Accordingly, it has been conceptualized three components related to soccer physical performance: (1) *match-demand* (i.e., an external component such as distance, speed, accelerations, metabolic power, change of directions, and strength); (2) *physiological-demand* (internal component such as heart rate, maximal oxygen consumption, rate of perceived exertion); (3) *athlete-related performance* refers to an individual internal response to a given EL. The relevant component of soccer physical performance is an essential part of the current review and will not be further discussed here. We suggest to refers to Stolen,[49] Harper,[61] Rico-González,[62] and Sarmento.[63]

The implication of training monitoring in soccer

Assessing training monitoring data can be considered as a support for practitioners to optimize training process ensuring that athletes appropriately adapt to the training program and cope with match-demands, which could reduce IR.[64] Gabbett et al.,[6] have provided a practical guide to interpreting and applying training monitoring data. They have suggested considering a combination of external workload, internal workload, perceptual well-being, and readiness to train/compete as delivering more meaningful individual training prescriptions compared to data derived from any single athlete monitoring tool/indicator.[6]

Coyne et al., have reported some issues and limitations related to subjective TL calculation (e.g., RPE) as both volume and intensity indicators should be considered accordingly.[33] Indeed, they have recommended using the training impulse (the product of training volume and intensity factors) for IL and EL, rather than a singular volume or intensity factor. This allows comparing "apples with apples" avoiding methodological differences among studies which make comparisons difficult inducing possible misleading interpretation.[33] In addition, authors suggested to consider relevant analysis such as the lagged effect of multiple concurrent time series (e.g., TL and physical performance) to better understand the TL implication on soccer training.[33,65] Moreover, practitioners should also use methods of TL model calculation (e.g., rolling averages [RA] and exponentially weighted moving average [EWMA], over different acute and chronic periods, varying "fitness"- "fatigue" decay rates) that is most strongly related with physical performance and IR.[33,65]

As reported by Coyne et al.,[33] inconsistent findings examining the relationship between TL and injury and performance[66] may be related to TL (computed as duration x intensity) that is defined as "a relatively simplistic and somewhat limited tool for accurately modeling training responses in elite athletes".[35,67,68] According to Renfree et al.,[67] TL (given by the product of exercise intensity and duration) may be limited as does not account for nonlinearities in the biological response to stress. In agreement with the previous authors, the TL may not be fully satisfactory even if it remains the only tool available to monitor soccer training. Rather than considering the use of TL as "simplistic," we believe that, given the complexity and multifactorial nature of both soccer physical performance and the "physiology" of human beings, it would be illogical trying to calculate the TL based one indicator alone (considering both internal and external) during the monitoring process. Accordingly, seems cognitive bias consider a single TL indicator as "causative" of injuries. Moreover, "intensity" and "performance" concepts should be well defined to provide consistency among studies reducing methodological and conceptual bias.[5]

Thus, it is recommended that practitioners should rely on traditional training principles (e.g., overload progression[32,69,70]) and adjust the TL based on athletes' responses.[18] Although we recognize a lack of causality and direct connection between TL and IR, especially when considering a single indicator of internal or external load, keeping in mind training programming as a primary injury prevention strategy. We strongly suggest controlling and manipulating workload in order to reduce IR accordingly with previous studies (i.e., Gabbett 2017[6] and Windt et al., 2017[15]). For example, despite the fact that high-speed running distance has been associated with IR,[71–73] being the aetiology multifactorial,[31,74] it would not make sense to consider it a cause of injury. Indeed, it can only predisposed players (i.e., weak athletes subjected to maladaptation due to non-optimal training planning, previous injuries, etc.) may get injured when exposed to large volumes of high-speed running. Logically, even if a direct cause between workload and IR does not exist,[19] the workload, especially whether it is not well managed, could be highly implicated in the onset of injuries. Indeed, injuries occur during workload load exposure (i.e., training or match).[75–77] Accordingly, practitioners should focus on TL management,[3,18,19,69] where monitoring practice (i.e., data-driven approach) allow to take objective information on TL, aiming to enhance physical performance while reducing IR.

Soccer training prescription: programming strategies

Even if the scientific community has provided useful contributions, practitioners should take into consideration that the science and practice of periodization is largely based on the hypothesis based on casual observation[78,79] where the data-driven approach has shed light and supported the concept of training prescription.[2,3,6,8,9,19,21,23,80,81] Starting from the knowledge provided by exercise physiologists, evidence of specific adaptations to imposed demands (SAID)[82] should be kept in mind during the training prescription phase. The SAID principle allows coaches to facilitate neural and metabolic adaptations, as well as muscle fibers changes for increased strength and refined motor skill. Hence, to appropriately adapt muscles, the frequency and intensity of the exercise must be adequate in order to provide a "overload" for the target muscle or muscle groups related to match-demands.[83] Thus, it is easy to understand that there is a significant difference between track and field and team sports athletes that must be considered in the planning phase.[42] In soccer, given the high-intensity physical demand imposed by the match (i.e., cardiorespiratory, metabolic, neuromuscular and cognitive function), coaches have focused on High Intensity Training (HIT) methods.[84] In this way, Buchheit and Laursen have carried out a review on HIT training[42,84] reporting theoretical and methodological insight on HIT.

HIT involves "repeated short (<45 seconds) to long (2–4 minutes) bouts of rather high-intensity exercise interspersed with recovery periods".[32,84]

In order to maximize daily and/or weekly training periodization, HIT prescription consists of the manipulation of at least nine variables (e.g., work interval intensity and duration, relief interval intensity and duration, exercise modality, number of repetitions, number of series, between-series recovery duration and intensity).[32,42] Hence, when programming HIT, both cardiopulmonary responses, anaerobic glycolytic energy contribution and neuromuscular load should be considered to maximize the training outcome. In team sports athletes, the physiological effort induced by HIT along with other physical and technical/tactical sessions should be considered to avoid overload and optimize adaptation (i.e., maximize a given training stimulus and minimize musculoskeletal stress and/or IR). We highlight that a significant difference concerning HIT training methodology between track and field and team sport athlete exists. Indeed, while running training prescription can be determined a-priori (considering both external and internal load) for endurance runners,[85] accurate soccer-drills programming is challenging due to the intrinsic variability[35] of soccer activity compared to HIT running drills as shown in Supplementary files.

Accordingly, soccer training prescription required an appropriate knowledge of physiological (both metabolic and neuromuscular) response induced by each specific HIT (including Small Sided Games [SSG]) format.[32,37,81,86] In order to appropriately support the training prescription based on the training methodologies principle[49,70,84,87,88] and applied physiology knowledge,[82] practitioners should take into account a large amount of external load data (provided by EPTS devices such as GPS or Inertial Sensor Device [ISD]) to classify appropriately each drill and programs training day, microcycle and mesocycle in soccer.[50] From this perspective, player's density on the pitch (i.e., area per player, m^2/player) has been considered a key factor of the SSG that determines different EL and estimates physiological match-demands in elite soccer players.[81] For example, Riboli et al., have reported that to achieve higher TLs at high speed, a higher density is necessary regardless of the type of SSG.[81,86] Moreover, larger area per player determines higher total distance, high and very HSR distance and sprint. Moreover, a minimum of ∼200 m^2/player may appropriately determine the high-speed running and sprint events in youth players.[89] Interestingly, replications of the whole official match (∼357 m^2/player) including the sprint distance, a density of ∼288 m^2/player is required while a ∼340 m^2/player has been recommended to replicate the official match peak demands.[86] A great contribution on SSG prescription in soccer has been provided by Rampinini et al., 2007 that have examined the effects of exercise type, field dimensions, and coach encouragement on the intensity and reproducibility of SSG.[90]

Authors found that by using different combinations of these factors, coaches could modulate exercise intensity within the high-intensity zone and control the TL. Clemente et al. have presented a theoretical methodological recommendation on SSG periodization.[91] Specifically, it was suggested that changing the number of players, field dimensions, and task constraints could possibly stimulate different physiological responses. It is worth noting that SSG do not fully replicate the physical stimuli derived from match-demand.[92] Indeed, Pillitteri et al., have investigated the EL differences between specific types of soccer drills (including SSG) and official match for each playing position using a supervised Machine Learning approach.[93] Authors found that the performance model for each role in SSG seems completely different compared to official match as the players' playing positions are not distinguishable during SSG as the maintenance of a specific role in these kinds of exercises is not required{.[93] Accordingly, care should be taken when prescribe sport-specific task such as SSG within a soccer microcycle.

Buchheit & Laursen (2013)[42] have reported the application of the Thibault model[94] to select the most appropriate HIT sessions obtained while manipulating work interval duration and the number of repetitions. Authors have highlighted that the session with high metabolic and neuromuscular responses (targeting long-term adaptations) and the time needed to recover from the session should be considered to "fit into the programming puzzle".[32] Hence, some practical examples of HIT sessions to optimize the time spent at VO_2max (T@VO_2max) have been provided, focusing on the strategy to appropriately manipulate the training variables aiming to involve higher amount of anaerobic glycolytic energy contribution associated with higher neuromuscular and musculoskeletal load. In addition, authors reported some relevant practical considerations, supported by physiological knowledge and training principles,[22,27,32,42,48,49,82,95] suggesting that HIT sessions should be separated by 48 to 72 hour (depending on the expected metabolic and neuromuscular load).[32,42] They are generally followed by an easy session (i.e., active recovery, low intensity aerobic training, low intensity soccer drills, low neuromuscular effort) the following day to accelerate post-HIT metabolic and neuromuscular recovery. Moreover, as suggested by the framework by Sandford et al., 2021,[27] high-intensity interval training formats should be tailored to the athlete's locomotor profile accordingly (i.e., "speed", "endurance" or "hybrid" profiles). Authors have shown the importance of employing the anaerobic speed/power reserve (ASR/AP) required to individualize training appropriately.[27] Indeed, as reported by Hostrup & Bangsbo,[96] implementing speed endurance training such as all-out efforts or sprinting of typically 10- to 40-s duration with longer recovery periods, positive adaptations relating to anaerobic energy systems, ion handling, and fatigue resilience have been observed, allowing to enhance performance in elite soccer players during the late preparation phase and competitive season.

In summary, many factors should be considered when planning the microcycle in elite soccer, including session content, orientation and load, or when to rest players, bearing in mind that there are many approaches among coaches and different cultures.[69,97] As reported by Buchheit et al., 2023,[70] "The Original Guide to Football Periodisation – Part 1", by R. Verheijen in 2014[98] is the first and by far the most complete source of information on soccer programming along with the FC Barcelona.[97] An appropriate microcycle soccer periodization is challenging as several factors should be considered in complex relationship between technical-tactical and physical performance components to prescribe training programs appropriately.

In this way, a review carried out by Buchheit,[99] explored various principles useful for programming the training microcycle on the basis of scientific evidence which has the task of "informing " the experts to make decisions. Specifically, author highlighted the microcycle structured in three phases (recovery, acquisition and reduction) based on the scheduling of the matches (i.e., duration of the microcycle). The second principle addressed rest day mapping, emphasizing the rest day placement strategy, particularly effective in (actual Match Day) MD + 2, in order to reduce injury rates within different microcycle lengths (and probably also allow substitutes to train on MD + 1). The third point explored the management of post-match recovery and compensation training, suggesting post-match (MD + 1) upper body training as compatible with recovery, with potential benefits varying between players and underlining the need compensation for high intensity and speed training (at MD + 1) to maintain the performance of substitutes and reduce the risk of injury.[69,70,99] The fourth point is important as it goes into the merits of weekly training loads and the management of HSR. The information provided by scientific evidence identifies the optimal ranges of training load (60–90% of the match load, achieved through football training) to balance the improvement of performance and the reduction of injuries.[69,99–101] A paramount factor concerns the high-speed peaks, as a strategy to reduce the risk of injury. Indeed, the importance of training at near-maximum speed (>95%) in MD-2 may be associated with a reduction in injury rates.[100,101] Finally, strategic tapering leading up to the match was suggested, as a balance between moderate and light load on the pre-match days (MD-2 and MD-1) with a greater focus on recovery leads to optimal performance and injury prevention.[70]

Implement an appropriate training program during a soccer season is challenging as different component such as both physiological aspects related to soccer players and the references values derived from match-demand knowledge should be considered. For examples, professional players to regularly cover total distances ranging between 10–13 km of which around 900 m and 250–300 m traveled at HSR (speed ranging from 19.8 $km*h^{-1}$ to 25.2 $km*h^{-1}$) and sprinting (speed ≥ 25.2 $km*h^{-1}$), respectively.[102–104] The importance of HSR and sprinting distance has been recently discussed in a systematic review [34]. Specifically, during official matches, HSR and sprint running distances ranged from 618 to 1001 m and 153–295 m, respectively, in professional male soccer players. In this perspective, Miguel et al.[105] carried out a review on load measures in training/match monitoring in soccer, while Oliveira et al.[106] reported detailed reference values for external and internal training intensity monitoring in young male soccer players. However, match-demand differences do exist between and within specific contexts such as professional and amateur level. Indeed, HSR distance ranged from 106–539 m, (12–61% match loads) at the professional level [14,15] compared to 6–135 m (1–30% of game loads) in collegiate players [17].

Starting from the reference values offered by match-demand, the amount of load (how much load should be carried out during a specific training section?) that should be obtained during each training section within the micorcycle structure represent a complex task for practitioners. Accordingly, periodized exposure to both HSR and sprinting within the microcycle of a soccer season could help players to withstand the match demands while reduce injury risk.[107] In this perspective, an optimal training-to-match HSR ratio should be considered, despite high variability exists due to different training methodologies and context among teams. In this way, Clemente et al.[108] investigated the training-match ratio (calculated based on total distance, player load and total number of high (> 3 $m*s^{-2}$) accelerations and decelerations) and found that, on average, training sessions represent 1.8 times the effort expended in a single match. However, variability significantly exist depending on the player's position and the number of training sessions per week.[109]

Discussion and implications

To achieve our propose, this section is structured as follows: section 4.1 delves into the monitoring process and data management, reporting some theoretical concept on training monitoring and data interpretation and communication. Section 4.2 explores the relationship between EL and IL training emphasizing the differences between training load and physical performance trough practical examples. Section 4.3 reports a conceptual framework on players readiness and injury risk while section 4.4 describes a conceptual framework on the informed-making process starting from training prescription, trying to answer some question as follow: how should practitioners start prescribing soccer training? From what perspective should practitioners prescribe training? In this perspective, section 5, considered as a core of our work delves into the theoretical aspect of training prescription. Section 4.6 provides some practical application, supported by scientific evidences, on the ways in which practitioners should report the "physical outcomes" derived from monitoring, relating to the match/training; section 4.7, delves into the complex relationship between the physical trainer head coach or the head managers, suggesting practical solution to reporting the information derived from monitoring.

Monitoring process and data management

TL management is a relevant practice that allows optimal design of training to maximize physical performance while minimizing IR. TL management includes prescription, monitoring, and adjustment of EL and IL, for which several practical guidelines have been developed. Indeed, in 2006 the International Olympic Committee consensus statement on load in sport and risk of injury[45] offered practical guidelines for load management. In this way, athlete monitoring systems should be supported by appropriate data analysis and interpretation to support the rapid reporting of clear, appropriate and scientifically valid feedback for teamwork (i.e., staff).[110]

Different analytical methods and tools have been implemented to monitor soccer players such as GPS[111] and RPE.[112] Several factors should be considered when collecting the data, including methods for determining meaningful changes such as Standard Deviation (SD), typical error, effect sizes, smallest worthwhile change (SWC), coefficient of variation (CV) and magnitude-based inferences (MBI) and various data visualization approaches by using specific software such as Power BI® (Microsoft, Redmond, Washington) are also available.[110] In this regard, the ability to communicate and present relevant information to coaches and/or managers is the basis of an effective monitoring system. A review carried out by Thornton et al., 2018[110] reported a range of data analytical methods commonly used in applied and research settings and can be used to determine and interpret meaningful changes in data, assisting in advising informed-making.

Moreover, the authors have provided various data visualization concepts and methods to improve the quality of the monitoring system through effective communication of relevant information.[110] Importantly, as reported by Thornton et al.,[110] "these data and the meaningful information derived should be used, simply, to inform coaches regarding athlete status but should not dictate the informed-making process". For examples, during a specific training session with the aim to reach a given amount of HSR distance (based on an individualized approach which takes into account reference values derived from the match-demand), a data-driven approach allow to support the training prescription.[12,22,32,69,104] Indeed, it is possible to administer an integrative work (considering a training/match ratio of HSR and sprinting with a range of 0.8–1.2) such as sprinting (e.g., 2–3 reps of 30 m with > 90% of maximal velocity with 45 seconds recovery in between reps)[113] to reach the HSR quantities set during planning phase.[22,104] In this way, practitioners should consider to monitoring EL based on an individualized approach by adjusting the indicators threshold based on a combination of maximal aerobic speed (MAS, derived from the Yo-yo Intermittent recovery test level 1), maximal sprinting speed (MSS, derived from the maximal speed reached during training) and anaerobic speed reserve (ASR) to respect players' individuality.[114]

Relationship between external training load and internal training load: differences between training load and physical performance

Table 1, Figure 1 and Table 2 report information to better clarify this complex relationship by providing more insight into the management of data derived from training and match monitoring. In detail, the examples provided in Table 1 and Figure 1 show that each EL indicator provides specific and essential match/training information. Based on these examples, we suggest: 1) to apply both EL and IL indicators during the monitoring phase; 2) to assess the athlete's fitness status by using EL/IL ratio[11,55] including the indicators deemed appropriate (e.g., speed-related and acceleration related [for example, Total Distance/RPE]); 3) to compare the athlete TL (e.g., considering different EL indicators such as TD, HSR distance, intense accelerations and decelerations, and metabolic power) with references provided by official matches; 4) to compare the athlete TL (e.g., considering different EL indicators) with references provided by official matches specific for playing position (e.g., midfielder vs midfielder); 5) to compare the athlete TL (e.g., considering different EL indicators) with references provided by the average provided by previous training sessions performed in the same day of the microcycle (e.g., [MD]-2 vs average MD-2 [assessed throughout the season]). Moreover, based on the outcomes reported in the Table 2, practitioners should consider: 1) to assess TL and physical performance of official match by including volume and intensity EL indicators; 2) to include EL/IL ratio (e.g., TD/RPE) to assess the athlete's fitness status taking into account individual variations.

Relationship between athlete fitness status and load: conceptual framework on players readiness and injury risk

As reported by Jeffries et al.,[4] a conceptual framework "synthesizes evidence, assists in understanding the phenomena under investigation, informs future research and acts as a reference guide in practical settings," including explanations of the relationships between the construct to be measured.[115] It can be carried out through visual representation and logical structure, illustrating presumed relationships between key concepts, constructs, or measures

Table 1. Relationship between external training load and internal training load: differences between training load and physical performance.

ATHLETE A (Wide Midfielder)	ATHLETE B (Central Back)
ST: 102' **Day: Tuesday/MD + 3/-4** **Target: metabolic** Warm up: 10' Rest 2' Technical drill: 15' Rest 2' Tactical drill: 15' Rest 2' SSG: 20' (including rest) Rest 3' Match drill: 15' Rest 3' Intermittent drill: 15'	**ST: 102'** **Day: Tuesday/MD + 3/-4** **Target: metabolic** Warm up: 10' Rest 2' Technical drill: 15' Rest 2' Tactical drill: 15' Rest 2' SSG: 20' (including rest) Rest 3' Match drill: 15' Rest 3' Intermittent drill: 15'
External training load indicators Volume indicators: • TD: 10 Km • HSRD (>21 Km/hour): 800 m • N°DEC: 100Intensity indicators: • TD per minute: 98 m/minute • HSRD per minute: 7,8 m/minute • N°DEC per minute: 0,98/minute **Internal indicators** RPE: 7	**External training load indicators** Volume indicators: • TD: 8 Km • HSRD (>21 Km/hour): 400 m • N°DEC: 150Intensity indicators: • TD per minute: 78 m/minute • HSRD per minute: 3,9 m/minute • N°DEC per minute: 1,5/minute **Internal indicators** RPE: 9
TRAINING LOAD **EXTERNAL TRAINING LOAD** **ETL VOLUME (ETLV)** • ETLV: based on TD:ST*TD = 102* 10 = 1020 ua • ETLV: based on HSRD:ST*HSRD = 102* 800 = 81600 ua • ETLV: based on N°DEC:ST*N°DEC = 102* 100 = 10200 ua **ETL INTENSITY (ETLI)** • ETLI: based on TD per minute:ST*TD/minute = 102* 98 = 9996 ua • ETLI: based on HSRD per minute:ST*HSRD/minute = 102* 7,8 = 796 ua • ETLI: based on N°DEC:ST*N°DEC = 102* 0,98 = 99,96 ua **INTERNAL TRAINING LOAD (ITL)** ITL: based on RPE: 7 × 102 = 714 ua	**TRAINING LOAD** **EXTERNAL TRAINING LOAD** **ETL VOLUME (ETLV)** • ETLV: based on TD:ST*TD = 102* 8 = 816 ua • ETLV: based on HSRD:ST*HSRD = 102* 400 = 40800 ua • ETLV: based on N°DEC:ST* N°DEC = 102* 150 = 15300 ua **ETL INTENSITY (ETLI)** • ETLI: based on TD per minute:ST*TD/minute = 102* 78 = 7956 ua • ETLI: based on HSRD per minute:ST*HSRD/minute = 102* 3,9 = 3978 ua • ETLI: based on N°DEC:ST*N°DEC = 102* 1,5 = 153 ua **INTERNAL TRAINING LOAD (ITL)** ITL: based on RPE: 9 × 102 = 918 ua
OUTCOMES (considering the same ST (i.e., 102')) **TRAINING LOAD** Athlete A shows higher external training load (for TD, HSRD, TD/minute, HSRD/minute) than Athlete B; Athlete B shows higher external load (for Decelerations number and Decelerations number/minute) and internal load.	
ATHLETE PERFORMANCE INDEX (FITNESS STATUS)	**ATHLETE PERFORMANCE INDEX (FITNESS STATUS)** Based on EL/IL ratio

(continued)

Table 1. (continued)

ATHLETE A (Wide Midfielder)	ATHLETE B (Central Back)
Based on EL/IL ratio **EXTERNAL TRAINING LOAD** **ETL VOLUME (ETLV)** • ETLV: based on TD:1020/714 = 1,42 • ETLV: based on HSRD:81600/714 = 1142 • ETLV: based on N°DEC:10200/714 = 14,2 **ETL INTENSITY (ETLI)** • ETLI: based on TD per minute:9996/714 = 14 • ETLI: based on HSRD per minute:796/714 = 1,11 • ETLI: based on N°DEC:99,96/714 = 0,14	**EXTERNAL TRAINING LOAD** **ETL VOLUME (ETLV)** • ETLV: based on TD:816/918 = 0,88 • ETLV: based on HSRD:40800/918 = 44,4 • ETLV: based on N°DEC:15300/918 = 16,6 **ETL INTENSITY (ETLI)** • ETLI: based on TD per minute:7956/918 = 8,6 • ETLI: based on HSRD per minute:3978/918 = 0,43 • ETLI: based on N°DEC:153/918 = 0,17

OUTCOMES (considering the same ST (i.e., 102')

FITNESS STATUS (ATHLETE PHSYICAL PERFORMANCE)

Athlete A presents higher athlete-related performance (fitness status) than Athlete B (based on TD, HSRD, TD/minute and HSRD/minute) while Athlete B shows higher athlete-related performance (fitness status) considering Decelerations number and Decelerations number/minute.

REFERENCES VALUES (1)

OFFICIAL MATCH-DEMAND*

*Average match duration: 90'

OFFICIAL MATCH REFERENCES VALUE	TRAINING MD + 4/-3 ATHLETE A	TRAINING MD + 4/-3 ATHLETE B
External training load indicators Volume indicators: • TD: 11 Km • HSRD (>21 Km/hour): 900 m • N°DEC: 50Intensity indicators: • TD per minute: 122 m/minute • HSRD per minute: 10 m/minute • N°DEC per minute: 0,5/minute	**External training load indicators** Volume indicators: • TD: 10 Km (90,1% of the OM) • HSRD (>21 Km/hour): 800 m (88,8% of the OM) • N°DEC: 100 (200% of the OM)Intensity indicators: • TD per minute: 98 m/minute (80,3% of the OM) • HSRD per minute: 7,8 m/minute (78% of the OM) • N°DEC per minute: 0,98/minute (196% of the OM)	**External training load indicators** Volume indicators: • TD: 8 Km (72,7% of the OM) • HSRD (>21 Km/hour): 400 m (44,4% of the OM) • N°DEC: 150 (300% of the OM) Intensity indicators: • TD per minute: 78 m/minute (59% of the OM) • HSRD per minute: 3,9 m/minute (39% of the OM) • N°DEC per minute: 1,5/minute (300% of the OM)

OUTCOMES

OFFICIAL MATCH-DEMAND AVERAGE

Both Athletes A and B showed lower external load values (both volume and intensity) during training compared to the match except for deceleration and deceleration per minute. Both athletes A and B performed greater decelerations number and decelerations number per minute during training compared to the official match. All percentage values refer to OM reference values (excluding playing position specific reference values).

(2) PLAYING POSITION OFFICIAL MATCH REFERNCES VALUES

WIDE MIDFIELDER REFERENCES VALUE	CENTRAL BACK REFERENCES VALUE
External training load indicators Volume indicators: • TD: 12 Km • HSRD (>21 Km/hour): 1000 m • N°DEC: 80Intensity indicators: • TD per minute: 133 m/minute • HSRD per minute: 11 m/minute • N°DEC per minute: 0,8/minute	**External training load indicators** Volume indicators: • TD: 9,5 Km • HSRD (>21 Km/hour): 300 m • N°DEC 30Intensity indicators: • TD per minute: 1055 m/minute • HSRD per minute: 3,3 m/minute • N°DEC per minute: 0,3/minute

(continued)

Table 1. (continued)

ATHLETE A (Wide Midfielder)	ATHLETE B (Central Back)

OUTCOME

PLAYING POSITION OFFICIAL MATCH

Athlete A (wide midfielder) showed lower external load values in training **MD + 4/-3** compared to the official match (considering the average values relating to playing position) except for decelerations number and deceleration number per minute. Athlete B (central back) showed lower external load values in training **MD + 4/-3** compared to the official match (considering the average values relating to playing position) except for HSRD, HSRD/minute, decelerations number and decelerations number per minute.

(3) **ATHLETE TRAINING REFERENCES VALUES MD + 4/-3* *** Previous training performed in the same days of the microcycle (MD minus/plus system) considering the same structure of mycrocicle

ATHLETE A

External training load indicators

Volume indicators:

- TD: 9 Km (90% of the all **MD + 4/-3 average**)
- HSRD (>21 Km/hour): 700 m (87% of the all **MD + 4/-3 average**)
- N°DEC: 110 (110% of the all **MD + 4/-3 average**)

Intensity indicators:

- TD per minute: 88,2 m/minute (90% of the all **MD + 4/-3 average**)
- HSRD per minute: 6,9 m/minute (88,4% of the all **MD + 4/-3 average**)
- N°DEC per minute: 1,07/minute (109% of the all **MD + 4/-3 average**)

ATHLETE B

External training load indicators

Volume indicators:

- TD: 8 Km (100% of the all **MD + 4/-3 average**)
- HSRD (>21 Km/hour): 500 m (125% of the all **MD + 4/-3 average**)
- N°DEC: 140 (93,3% of the all **MD + 4/-3 average**)Intensity indicators:
- TD per minute: 78 m/minute (100% of the all **MD + 4/-3 average**)
- HSRD per minute: 4,9 m/minute (1256% of the all **MD + 4/-3 average**)
- N°DEC per minute: 1,4/minute (93,3% of the all **MD + 4/-3 average**)

OUTCOMES

ATHLETE TRAINING MD + 4/-3 VALUES

Athlete A showed lower external load values (TD, HSRD, TD/minute, HSRD/minute) and higher decelerations number and decelerations number per minute in the previous training compared to the actual training. Athlete B showed higher external load values (HSRD and HSRD/minute), lower decelerations number and decelerations number per minute and the same TD and TD/minute in the previous training compared to the actual training.

Legend: ST: session time; TD, Total Distance; HSRD, high-speed running distance (>21 Km/hour); RPE, rating of perceived exertion; N°DEC, intense deceleration number; EL, external load; IL, internal load; OM, Official Match.

(e.g., EL and IL indicators). In this way, our conceptual framework includes an integrative synthesis of the literature and analysis of existing frameworks linked to information and concepts from previously established models and theories. Starting from the model used by Gabbett et al.[6] on athlete monitoring data in the sporting environment, we combined athlete fitness status (given from the external and internal load ratio[116–119]) with workload (considering or a single indicator or a more appropriate parameter such a global load "score"[120] which includes several EL and IL load indicators derived from players monitoring). However, more sophisticated analysis such as machine learning approaches, could calculate a global load score[121,122] (Figure 2) allowing trainers to prescribe training following an individualized approach. In detail, the Principal Component Analysis was used to reduce the feature dimension space in order to aggregate features to summarize the training workloads performed by soccer players during training and matches. This simple relationship based on data monitoring simply helps to establish whether an athlete is ready to compete (both training or match) or may be at high IR. For example, suppose an athlete shows a low fitness status (i.e., has performed a low rate of external activity with a relatively high internal response) and presents a high-performance score (i.e., high overall performance score derived from high neuromuscular effort for a long duration). In that case, this athlete may be at high IR as he would not be prepared to withstand the stress imposed by training/match demands. Accordingly, practitioners can prescribe training based on an individualized approach. The combination of EL/IL ratio with load represent a simple way to understand the athletes' readiness in a daily routine while different strategies such as laboratory and on-field test (e.g., submaximal fitness test during warm-up)[123] can be also applied to determine whether an athlete is ready to train or compete. Accordingly, a daily routine of TL monitoring, in comparison with laboratory and on-field tests, which present disadvantages such as cost, human resources, time, complexity, equipment), should be guarantee during a soccer season.

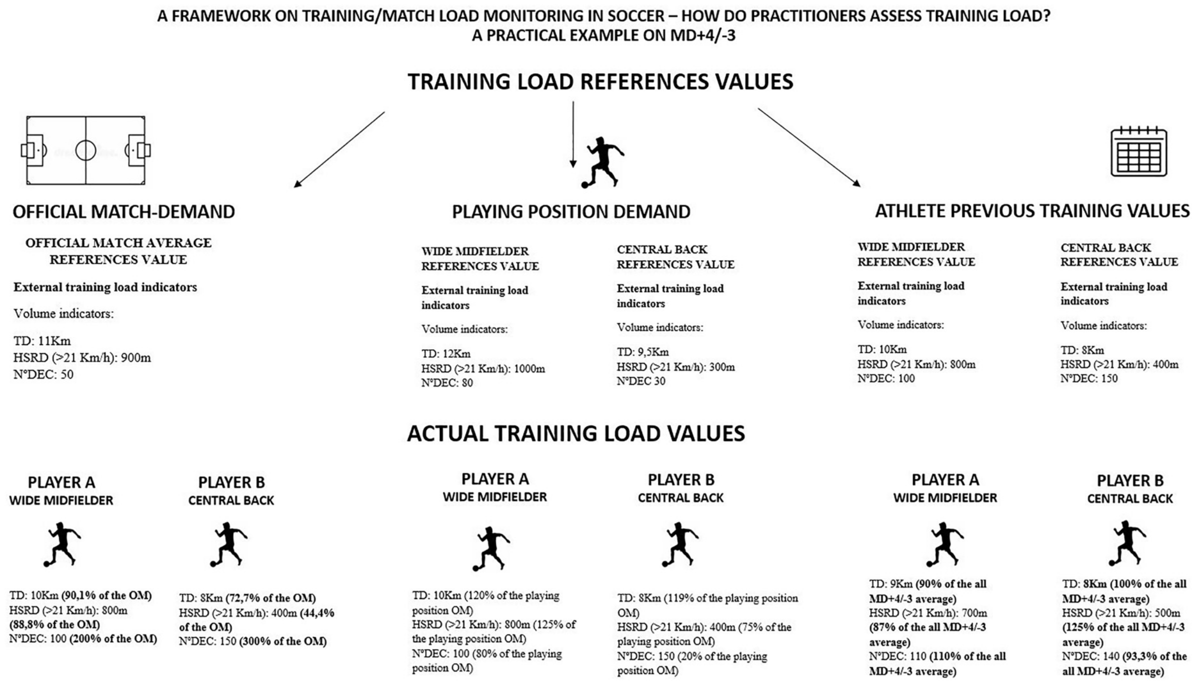

Figure 1. A framework on training/match load monitoring in soccer - how do practitioners assess training load? - a practical example on MD+4/-3.

Conceptual framework: from training prescription to the informed-making process

Although previous published conceptual frameworks[3,4,6,27,42,84] have provided fundamental theoretical and practical insight, some misconceptions, confusion, and lack of practical examples in TL monitoring and training prescription area may still exist. For example, how should practitioners start prescribing soccer training? From what perspective should practitioners prescribe training? The diatribe between the training prescription based exclusively on the physiological approach as opposed to "data-driven", where the reference match is made considering the external load, is still open. In this session, we briefly reported a new framework concerning the relationship between player monitoring process and informed-making on training prescription. Figure 3 describes the monitoring process to help practitioners make the best possible decision on training prescription to optimize adaptation (i.e., enhance physical performance) and reduce IR. In detail, our revised conceptual framework highlight that several factors should be considered to implement an appropriate training prescription including match-demand, physiological-demand, contextual factors, training methodology principles, individual athlete knowledge, athlete profile and information derived from monitoring process.

Training prescription

To appropriately implement soccer training prescription, such as HIT game-based, practitioners should refer to the support provided by the EL monitoring data (derived from EPTS devices[50]), the information provided by scientific literature and the knowledge of training principles and applied sport physiology.[124] Appropriate training prescription is a complex practice that could lead to positive as well as negative adaptations. Nevertheless, TL data provide a useful support to appropriately prescribe training.[6,50,64] Are we sure that the indices and indicators most used among practitioners are always useful? Some suggestions on training prescription have been reported in supplementary file 1.

In detail, based on the outcome reported in the supplementary file 1, practitioners should consider: 1) to assess TL and physical performance of HIT specific drills (e.g., SSG) trough IL and EL by including metabolic and neuromuscular indicators; 2) to create a drills database, based on EL monitoring, should be created to help during the training programming process of soccer specific training (i.e., technical-tactical session or drill).

Supplementary file 2 reports an example of general running training prescription based on external load indicators highlighting the poor applicability of the common TL calculation approaches. Indeed, the use of TL indicators along with EL/IL ratio could be poorly appropriate when compare works with different physiological demands.

Also, in supplementary file 3 we highlight that various formulas to calculate TL and physical performance may not be adequate to compare players who stress different physiological systems when perform general running exercises

Table 2. Differences between training load, physical performance and athlete fitness status: practical example of HIIT soccer specific (SSG) training prescription.

Small Sided Games: 4 × 4' (5v5) (40 × 50 m) rec 1'30"

ATHLETE A	ATHLETE B
Target: development of metabolic and neuromuscular components **QUANTITY** Duration 16' TD: 2000 HSRD: 1300 N° DEC: 60 **INTENSITY** TD per minute: 125 m/minute HSRD per minute: 81 m/minute N° DEC per minute: 3,8 n°/minute	**Target: development of metabolic and neuromuscular components** **QUANTITY** Duration 16' TD: 1500 HSRD:800 N° DEC: 90 **INTENSITY** TD per minute: 93,7 m/minute HSRD per minute: 50 m/minute N° DEC per minute: 5,6 n°/minute
• **EXTERNAL TRAINING LOAD VOLUME**TD: 16*2000 = 32000 HSRD: 16*1300 = 20800 N° DEC: 16*60 = 960	• **EXTERNAL TRAINING LOAD VOLUME**TD: 16*1500 = 24000 HSRD: 16*800 = 12800 N° DEC: 16*90 = 1440
• **EXTERNAL TRAINIG LOAD INTENSITY**TD per minute: 16*125 = 2000 HSRD per minute: 16*81 = 1296 N° DEC per minute: 16*3,8 = 60,8	• **EXTERNAL TRAINIG LOAD INTENSITY**TD per minute: 16*93,7 = 1449,2 HSRD per minute: 16*50 = 800 N° DEC per minute: 16*5,6 = 89,6
INTERNAL TRAINING LOAD **RPE: 5** 16*5 = 80	**INTERNAL LOAD** **RPE: 3** 16*3 = 48
ATHELTE PERFORMANCE **EL/IL** TD: 32000/80 = 400 HSRD: 20800/80 = 260 N° DEC: 960/80 = 12 TD per minute: 2000/80 = 25 HSRD per minute: 1296/80 = 16,2 N° DEC per minute: 60,8/80 = 0,76	**ATHELTE PERFORMANCE** **EL/IL** TD: 24000/48 = 500 HSRD: 12800/48 = 2666 N° DEC: 1440/48 = 30 TD per minute: 1449,2/48 = 30,2 HSRD per minute: 800/48 = 16,6 N° DEC per minute: 89,6/48 = 1,9
OUTCOME Athlete A performed higher volume (TD, HSDR) and intensity (TD/minute and HSRD/minute) than athlete B who showed higher N° DEC and N°DEC/minute. Since both trained for the same duration, it is possible to establish that the training load is higher for athlete A, considering (TD, HSDR, TD/minute and HSRD/minute), while is higher for athlete B referring to N°DEC and N°DEC/minute. Moreover, athlete A showed higher internal response (i.e., internal load calculated as RPE*duration) than athlete B. In this way, it is possible establish that athlete B presents grater athlete-related performance (based on EL/IL ratio). Since athlete A has reached a greater intensity (i.e., a better performance both in relation to match-demand and physiological responses) it is possible to assume that athlete B could have performed more in this exercise. The use of these calculations to establish training load and performance is fundamental in this type of training (HIIT sport-specific) since, given the unpredictability and variety of the activities present, it is impossible to program based on the external load established a-priori. In this regard, practitioners can create a database of exercises/drills to well known about the external load and the related target (mainly metabolic or neuromuscular profile) useful for programming. Caution should be considered as athlete internal responses can vary from player to player based on current training status, fatigue and recovery conditions and player profile.	

Legend: TD, Total Distance; HSRD, high-speed running distance (>21 Km/hour); RPE, rating of perceived exertion; N°DEC, intense deceleration number; EL, external load; IL, internal load.

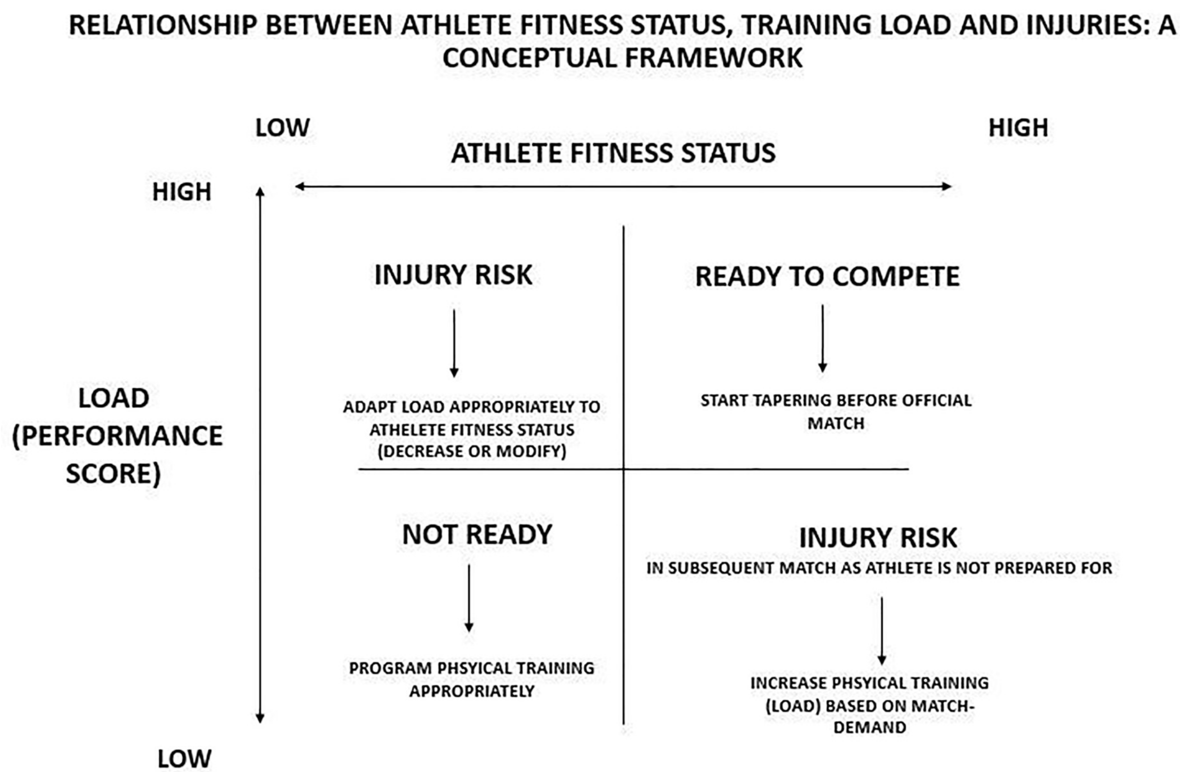

Figure 2. Relationship between athlete fitness status, training load and injuries: a conceptual framework. Note: athlete fitness status derived from external and internal load ratio while "score performance" can be calculated by machine learning approach considering external and internal data collected (e.g., by using Principal Component Analysis). When athlete shows low fitness status, and high-performance score (i.e., performed a large amount of external activity such as high-intensity running) may not be prepared to withstand match or training-demand increasing his injury risk. Even if athlete presents high fitness status and low performance score may be at high risk of injury as could be not prepared (appropriately adapted) to cope match-demand. This framework can make sense in a long-term perspective monitoring process. High fitness status and high score means that athlete is ready to compete (even if practitioners have to pay attention to tapering strategy to be implemented before the official match).

(e.g., HIT long interval). Conversely, as reported in supplementary file 4, when comparing the physical performance of two athletes who perform sport-specific exercises (e.g., SSG) with different physiological target, caution must be taken not to rely exclusively on the mathematical calculation of the TL or physical performance, considering the physiological target as well. Moreover, based on the great contribution provided by the framework carried out by Standford et al., 2021,[27] we have reported (supplementary file 5) a practical insight on training prescription considering the individual integrated approach (i.e., starting from the athlete profile knowledge, the physiology target definition and the expected IL, it is possible prescribe the external activities appropriately). Moreover, the comparison of two typologies of drills/exercises (i.e., SSG vs HIT based on general running short distance [intermittent exercise]) exclusively through TL indicators could be difficult and meaningless as present different physiological target stimuli (i.e., generic vs. game-based). Accordingly, caution should be taken, when prescribe training based exclusively on data-driven approach, while the physiological target of the drill should be considered.

How practitioners should manage the information derived from monitoring?

Best practice allows for optimization quality of work within teams. How should sport scientists act to optimize the training process and obtain useful information from the data derived from monitoring? We provided a key point that allows prescribing training appropriately based on the contribution offered by data monitoring collected;

- Training/match monitoring and data collection;
- Data mining and data analysis;
- Data interpretation;
- Load analysis (internal and external);
- Performance analysis (compared to): reference official match; playing positions; teammates; opponents;
- Understand athletes' fitness status (internal/external load ratio);
- Understand athlete recovery ability and readiness;
- Informed-making process for training prescription.

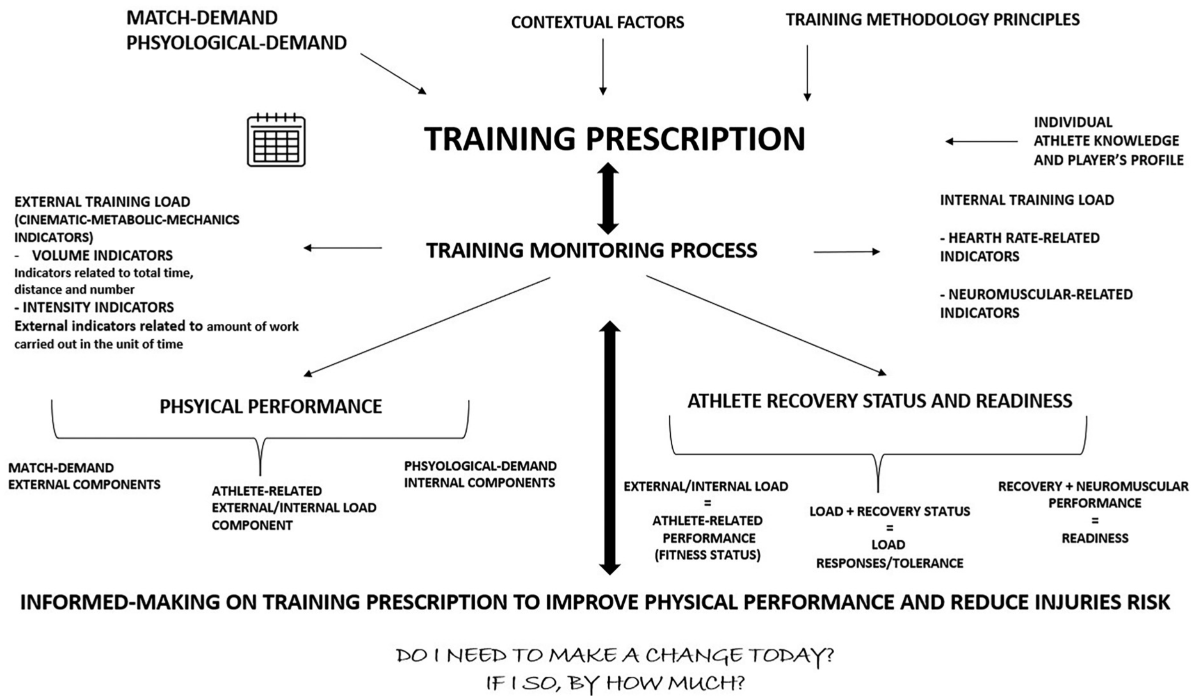

Figure 3. Conceptual framework: from training prescription to the informed-making process. Note: based on revised previous works (i.e., Impellizzeri, Jeffries, Gabbett and Buchheit), we have reported a revised conceptual framework on training prescription informed-making process and load monitoring. Several factors should be considered to implement an appropriate training prescription including match-demand, physiological-demand, contextual factors, training methodology principles, individual athlete knowledge, athlete profile and information derived from monitoring process. In order to establish if some factors related to training should be changed or modify (during the planning phase), practitioners have to consider the aforementioned factors.

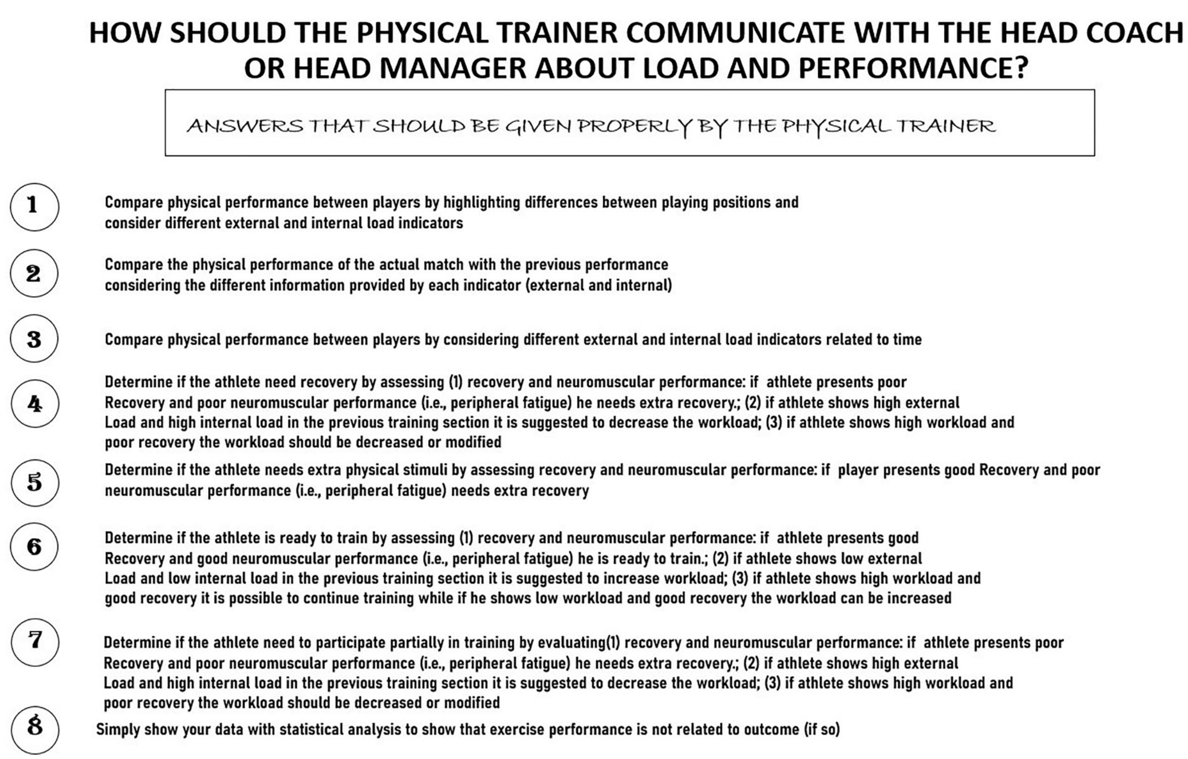

Figure 4. Report «soccer physical performance outcomes» related to match/training.

How should the physical trainer answer the questions of the head coach or the head managers?

As reported by Ekstrand et al.,[125] the four most common factors related to risk factors contributing to IR are the workload imposed on players, the player well-being, the quality of internal communication within the team and the head coach and the chief medical officers of clubs in the UEFA Elite Club Injury. The authors found that the quality of internal communication within a team was associated with both IR and player's availability. In this way, the internal communication quality within a team can be considered a fundamental strategy to decrease the IR.[126] While head coaches and managers often focus on performance results, and the medical staff on injuries risks, physical trainers (i.e., sport scientists) are required to facilitate a communication bridge between departments. To avoid reporting incorrect and inappropriate communications, confusing performance, TL, and risk of injury, we have provided some key questions that physical trainers should consider:

- Which players had the best EL and IL in the last match?
- Was the last match more intense than the others already played?
- Which players showed the best physical performance (considering EL indicators per minutes) in the last match (i.e., best intensity)?
- Which players needs recovery?
- Which players needs extra physical training?
- Which players may perform the entire training session?
- Which players may partially perform the training session?
- Is physical performance associated with the match results?

In addition, we have reported the possible answer, including operational strategies to optimize TL and performance communications within the team (Figure 4).

Conclusion

Practitioners may need practical guidelines to understand the complex relationship between TL, physical performance and IR. Accordingly, a conceptual framework helps to clarify some theoretical and practical aspects such as training monitoring and prescription. While establishing a causal relationship between workload and injuries may not make sense given the multifactorial aetiology of injury, the accurate tracking of workload and the careful planning of training sessions, based on the indicators most related to physical fitness and fatigue, represents a good injury prevention strategy.

Appropriate, complete, and straightforward communication within the staff is also essential to increase the quality of teamwork to enhance physical performance while reducing IR.

In this way, in this narrative review we have provided an overview of the fundamental concepts related to the practice of soccer training (i.e., TL and physical performance), also focusing on injury prevention to propose practical applications by improving the informed-making process related to training monitoring practice, training programming and communication within the staff. Moreover, some practical examples have been provided to strengthen the theoretical concepts.

Abbreviations list

TL	Training Load
EPTS	Electronic Performance and Tracking Systems devices
GPS	Global Positioning System
EL	external load
IL	Internal load
TD	Total Distance
HSR	High-Speed Running
RPE	Rating of Perceived Exertion
Effindex	Efficient Index
%HRmax	Percentage of Hearth Rate Max
IR	Injury Risk
ML	Machine Learning
RA	Rolling Averages
EWMA	Exponentially Weighted Moving Average
SAID	Specific Adaptations to Imposed Demand
HIT	High Intensity Training
SSG	Small Sided Games
ISD	Inertial Sensor Device
T@VO2max	Time at Maximal Oxygen Consumption Max
ASR/AP	Anaerobic Speed/Power Reserve
MD	Match Day

Author contribution statement

Conceptualization: [G.P and G.B. A.B.]; Methodology: [F.M.C., H.S., G.P.,] Formal analysis and investigation: [T.B, G.PU,.M.P.,]; Writing - original draft preparation: [G.P., F.M.C., C.F., A.R.]; Writing - review and editing: [G.B., C.F., A.B.]; Funding acquisition: [none]; Resources: [none]; Supervision: [G.B., A.B., H.S., M.P., A.F.] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of conflicting interests

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Supplemental material

Supplemental material for this article is available online.

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