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Review

Load Monitoring Methods for Controlling Training Effectiveness on Physical Conditioning and Planning Involvement: A Narrative Review

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Abstract: Monitoring the training load during training is important for quantifying the demand on psychological and physiological responses. This procedure is achieved through subjective and objective methods applied to the control of the level of training, to the attainment of conditioning and performance goals, and to the prevention of injuries. Training load refers to either external load, such as the variables of speed, distance, accelerations, and decelerations, or internal load, which is related to the psychological and physiological responses during an exercise session or training period (e.g., rating of perceived exertion—RPE; and heart rate—HR). To measure external load, traditional methods include pedometers, accelerometers, global positioning systems, and volume load. For internal load, methods include RPE, training monotony, strain, and impulse, HR, hormonal and biochemical markers, and training diaries and questionnaires. The current review reinforces the assumption that the methods should be combined to improve confidence with the information, mainly when assessing internal load stress during training. Moreover, training load provides an objective assessment of performance levels and involvement in different training phases, thus providing relevant information to analyse strategies for the effectiveness of conditioning progress, performance enhancement, and injury prevention.

Keywords: workload; performance; rating of perceived exertion; performance indicators

1. Introduction

The process of prescribing and periodizing a training program, whether for sports performance, fitness, or health, is systematic and complex, aiming to induce morphological, metabolic, and functional changes to enhance performance or health [1]. Given the complexity and systematic nature of the training process, rigorous monitoring is necessary to implement all planned changes effectively. Typically, assessments are conducted throughout load monitoring, which involves controlling and analyzing the athletic responses to training through less time-demanding or invasive procedures; however, these assessments are usually recommended at specific intervals (e.g., weeks or months) to ensure the effectiveness of the monitoring strategies [1]. Hence, optimizing the daily training plan according to the individual responses (e.g., performance and conditioning adjustments, fatigue and pain levels, and recovery capacity) is essential for individualizing tasks (i.e., exercise mode, intensity, and volume adjustments) and for enhancing athletic and health goals while preventing maladaptive responses and injuries [2–4].

Indeed, training load monitoring can quantify the psychological and physiological stress levels induced by single or multiple training sessions using objective and subjective methods and tools, such as the rating of perceived exertion (RPE), training impulse (TRIMP), heart rate (HR), amount of movement (accelerometers), and metabolic activation (blood lactate and oxygen uptake) and disturbance (serum levels of creatine kinase and cortisol) [3,4]. The main advantages of monitoring training load include minimizing errors in training prescription through different metrics, enabling the control of dose-response stimuli from one or more training sessions, assessing individual stress and fatigue levels, preventing undesirable overreaching, early detection of overtraining, and preventing acute and chronic injuries [2,3]. These advantages have contributed to the effectiveness of physical adaptations, performance enhancement, and injury prevention [3,4].

In sports science, training load can be classified into external and internal loads. External load refers to the training variables corresponding to the work performed during training or a set of sessions. In contrast, internal load refers to the psychological and physiological stress imposed on the body during exercise, which are crucial factors in the adaptation process to training [2,5]. Understanding these concepts is crucial for selecting the appropriate method or tool for quantification. In recent years, a growing body of scientific evidence has emerged supporting the use of these tools and strategies in sports and fitness [2,5].

Measurements of external load can be made using parameters such as distance covered, global positioning data, sprints performed, power output, and/or weight lifted [1,6]. However, more than merely understanding the methods and tools related to external load, there is a need to ensure successful monitoring. In this process, coaches play a crucial role which involves being aware of the most appropriate methods and tools for monitoring the specific external load demands of a given sport or exercise, and they must also recognize how the external load metrics may vary between individuals [5].

On the other hand, some methods for monitoring internal load include RPE, monotony, training strain, TRIMP, HR, hormonal and biochemical markers, questionnaires, and diaries [2,3]. Similar to external load, it is essential that the selected methods for monitoring internal load are appropriate for the specific sport or type of exercise practiced and that internal load responses can differ between individuals even when experiencing the same external workload [5].

Although different methods of monitoring training load can provide useful information for adjusting planning according to individual needs and goals, it is crucial to highlight the inter- and intra-individual variability when assessing external and internal load during training. Indeed, training load is influenced by factors such as training level, body composition, team position, environmental condition, and health status [7]. For example, resistance-trained individuals perform a higher number of repetitions at a given relative strength (e.g., 60% and 80% 1RM—one maximal repetition) than low or moderate-trained individuals, evidencing the influence of muscle endurance, strength, and power on external

load (i.e., volume load) monitoring [8]. Similarly, displacement during soccer matches varies by player position (e.g., midfielders cover ~11.5 km, while defenders and attackers cover 10 to 10.5 km) [9]. Furthermore, RPE scores have shown differences when comparing experienced individuals regarding the level of fatigue and pain during exercise [5,7], as well as the athletes who train at a target similar HR zone might show differences indifferently perceived and metabolic responses (e.g., RPE and blood lactate concentration) if the mode of exercise differs (e.g., cycling vs. running: 12.8 ± 0.4 vs. 11.6 ± 0.3 , and 6.2 ± 0.3 vs. 2.9 ± 0.3 mmol/L), due to the differences in the level of muscle activation and fiber type II recruitment (both higher in cycling than running) [10].

Understanding, selecting, and applying methods and tools for monitoring external and internal load in physical training programs is crucial for controlling and improving training planning. Therefore, this study aimed to present and describe the use of the main tools and methods for assessing internal and external load to assist in the monitoring of the level of responses to the planning (according to the expected level of training) or the analysis of the planning (rethink the strategies according to the proposal of training, i.e., whether sports performance or healthcare). The search for this revision was not constrained to a given period and was conducted in the Embase, ESPORTDiscuss, LILACS, PEDro, PubMed, and SciELO electronic databases, covering studies published until 30 May 2024. The search used the terms “training load” OR “internal load” OR “external load” OR “training monitoring” OR “planning” OR “sport performance” OR “athletic enhancement” OR “health improvement” OR “humans”. Manual searches were conducted in the references of eligible articles in the PubMed, Scopus, and Google Scholar databases to add other relevant titles. Seventy-eight references were selected among the titles screened.

2. External Load Monitoring

The external load can be monitored by quantifying the parameters performed during the training session, such as distance covered, sprints performed, power output, number of repetitions, and/or weight lifted [2,3]. Quantifying individual sessions or the cumulative load across sessions allows coaches to assess the external load applied to the individual, whether in a training program for performance or for fitness [3]. However, some of these methods for quantifying external load monitoring may involve calculations and require technological instruments, ranging from simpler devices like pedometers to more complex ones like accelerometers or global positioning systems (GPS). In addition, the choice of methods may vary depending on the type of sport (e.g., team, individual, endurance, strength, or power) [2,3]. Moreover, utilizing two or more methods can be beneficial for monitoring external load and identifying variables that influence performance [2,5]. For example, monitoring the swimming velocity and stroke rate can support coaches regarding metabolic pace and swimming efficiency, informing about the swimmer's skill and conditioning levels [11]. In this way, GPS and accelerometers have been considered tools with accuracy in assessing swimming velocity and stroke rate due to the correlation to data from kinematics analysis [12]. For example, stroke counting with accelerometer and video analysis correlated in breaststroke ($r > 0.98$) and butterfly ($r > 0.99$), as well as the measurements of velocity with GPS, and video analysis showed an acceptable standard error in freestyle (0.13 m/s) and breaststroke (0.12 m/s) swimming. Hence, in other sports in which displacement velocity and motion rate are important variables to infer the level and progress in conditioning and performance (e.g., running and cycling velocity, step rate and length in running, and rotation per minute in cycling), the information from different variables of external loads might reduce mistakes while planning and evaluating training [5,13].

2.1. Time–Motion Analysis

For many sports and even for fitness, time–motion analysis is important for performance and training programs. Methods for time–motion analysis include pedometers, accelerometers, and GPS [2,3,7,14].

2.1.1. Pedometers and Accelerometers

Pedometers are simple instruments used to measure the steps taken by individuals during exercise, such as walking or running [15]. These devices are programmed to detect vertical movement of the hip, providing an approximate estimate of the horizontal distance covered during exercise [16]. Although pedometer use in monitoring the total number of steps during physical activity has been correlated with other devices, such as accelerometers (i.e., $r = 0.86$), the high mean difference in steps measured by these devices (accelerometers > pedometers) suggests a poor convergent validity of the pedometer [17]. However, the high correlation between pedometer and accelerometer regarding the counts of steps per a given unit of time suggests that pedometers can be considered a feasible method for providing individual feedback on time spent at different categories of step intensities (light, moderate, and vigorous), as were estimated using an accelerometer [17].

It is important to note that the pedometer only registers steps when the body moves vertically; therefore, pedometers cannot independently discriminate intensity levels during the movement, exercise mode, duration, distance, physical activity level, or the tolerance. However, when combined with other devices (e.g., stopwatch, pace tracker, accelerometer, and GPS) or additional information (e.g., age, body composition, height, weight, RPE, heart rate, and oxygen uptake), pedometers can estimate these variables with reasonable accuracy [7,14,18]. For example, the amount of steps per day determined with a pedometer correlates positively with conditioning tests (e.g., 6 min walk, $r = 0.69$), exercise tolerance (e.g., time in treadmill test, $r = 0.41$) and cardiorespiratory function (peak VO_2 , $r = 0.22$), and negatively with index of obesity (body mass index, $r = -0.27$) and aging (e.g., age, $r = -0.21$) [18]. Although pedometers are simpler instruments compared to devices such as accelerometers or GPS, an important application as a step counter device is the monitoring of the quantity of movement to achieve a recommended level of daily physical activity [15,17]. Despite the low accuracy in measuring steps during walking and running, pedometers should not be dismissed as a tool for monitoring light to moderate aerobic activity, especially when other methods are unavailable. In such cases, pedometers can help individuals without training supervision to follow the World Health Organization 2020 guidelines on physical activity [19]. Consequently, because of the aforementioned limitations and the possibility of applying pedometers in controlling exercise for health purposes, it may be better recommended for training to enhance conditioning levels for a healthy lifestyle than athletic performance.

On the other hand, accelerometers offer a greater range of information compared to pedometers [14,16,20]. For more than two decades, this instrument has been used in performance and fitness training programs [11,12]. The accelerometer provides a wide range of data that facilitate monitoring external load, including distance covered, session duration, intensity times within the training session, HR, energy expenditure, sleep duration and quality, body temperature, and more [16,20]. Moreover, monitoring step frequency with accelerometers presented high correlations with measurements of running velocity ($r^2 = 0.80$), and when taking into account the effect of leg length and mass on the step frequency and displacement, the energy expenditure can be estimated accurately during walking ($r^2 = 0.84$) and running ($r^2 = 0.86$) [21]. Thus, accelerometers are considered suitable tools for controlling training load and adjusting planning according to individual goals, since data from external (distance, speed, and power) and internal (estimating energy demand) loads can be assessed and combined to enhance the analysis of training effects on health and performance [16,20].

All this information assists coaches and athletes in understanding the intensity of training sessions and making informed decisions about the progression of training variables [13,14,20]. The use of accelerometers is widespread in both team and individual sports and endurance activities [14,20].

2.1.2. Global Positioning Systems (GPS)

GPS is widely used for measuring external load, especially in team sports [22]. These devices are integrated with satellites, providing information about distance, speed, and acceleration. For example, GPS measurements of player displacement during a specific test on an Australian football field were compared with data from computer-based tracking (CBT) analysis and a trundle wheel pedometer. The results showed a high correlation between GPS and CBT data ($r = 0.99$), and both methods were strongly correlated with the pedometer ($r = 0.99$) despite a slight overestimation of the distances traveled compared to the actual values [23]. Therefore, when combined with accelerometers, GPS can offer a comprehensive range of data about player movement during sports performance [24–27].

An important aspect of using GPS in team sports is the ability of this device to quantify specific demands according to players' positions, which is essential information to adjust training in line with player needs. Additionally, this instrument aids in categorizing athletes by better individualizing the workload within the training program [28]. The literature has investigated the validity and reliability of GPS in various team sports such as rugby, soccer, and American football [28]. For example, in soccer, which is characterized by technical-tactical complexity that defines match performance, the external load is usually measured using GPS for tracking positioning and understanding factors contributing to successful performance, such as high-speed running, player load, accelerations, and decelerations during matches [29]. In rugby, GPS devices can provide information on the specific match demands according to the player's position, thereby enabling better planning of training tasks aligned with the physical demands of official match requirements [30].

However, the validity and reliability of GPS can be influenced by factors such as duration, speed, type of activity, and different devices used. For example, studies have shown that GPS accuracy can decline at higher speeds or in complex environments (e.g., the standard error for the estimate of the velocity is 0.7% during walking, but can attain 5.6% during running, as well as the coefficient of variation for the measurement of the velocity tending to be lower ($<5.3\%$) with a higher sampling rate) [22,24,31]. Furthermore, while GPS provides reports with various data points, many coaches and athletes may still struggle with interpreting or relating these parameters effectively for monitoring external load (e.g., the control of the velocity—ranging from 2 to 20 km/h—correlated with $r = 0.99$ with the stopwatch record, as well as distance measures improving with longer duration, showing the coefficient of variation being reduced from ~32 to 4% in distances ranging from 10 to 140 m) [22,31]. In addition, the use of inertial devices to analyze training load in different sports modalities has increased over the past decade, with GPS being the most commonly used technology [26,27,31].

Although GPS provides a significant amount of information for monitoring external load, one of its limitations is the use of speed zones for athletes [17]. Consequently, the combination of GPS with accelerometers has become common in team sports, not only to complement the information limited by GPS but also because accelerometers provide additional complementary data [27,28,31]. The combined use of GPS and accelerometers enables coaches to better interpret performance, conditioning, and physical fitness, especially in team sports, allowing for more effective monitoring of external load throughout the training program [28,31].

2.2. Power Meters and Linear Encoder

The measurements of power meters, including power output, acceleration, speed, cadence, average power, and peak power, among others, can be used for monitoring and quantifying external load [2,31]. These parameters are particularly important for sports like cycling and provide coaches with information on adaptation and performance related to the training program [31]; power meters can inform about exercise power at different exercise intensities due to the high correlation with power increment during incremental tests in cycling ($r = 0.992$ to 0.997) [32]. Power parameters can be recorded during tests, training, or competition by specific measurement instruments and analyzed later using

software [2]. While power meter measurements are valid, the expected power output may vary depending on the conditions or location of the meter [31,32].

The linear encoder is a sensor device that measures linear position and velocity during exercises and can be attached to barbells or body segments [33]. When combined with an external constant load or synchronized with load measuring devices (such as strain gauges), mechanical power during the movement can also be assessed, allowing the monitoring of external load during strength and/or power training [34]. Indeed, linear encoder sensors have provided reliable measurements of power and velocity variables during strength training and are recommended to simplify the testing and monitoring of training routines for athletes and non-athletes [35].

2.3. Repetition Method and Volume Load

The repetition method is a simple tool for measuring the total number of repetitions and volume (i.e., when combined with the number of sets) performed in an exercise, session, week, or training cycle. Due to its simplicity, absolute volume load is often more suitable for measuring external load and monitoring the balance between exercise intensity and volume in resistance training [36]. Volume load is a method for quantifying external load by calculating the product of load and volume during resistance training (load in kg $\times$ number of sets $\times$ number of repetitions). This method allows for the determination of the exercise volume load, and the sum of the volume loads of the exercises in a session quantifies the total volume load [36,37].

While absolute volume load is widely used, it has some limitations, particularly regarding differences in movement force–velocity profile and endurance between individuals with varying levels of strength. A more effective way to compare volume load between two individuals is a calculation using the number of sets $\times$ number of repetitions $\times$ % 1RM (in arbitrary units), which is better for comparing volume load between two individuals [37].

Lastly, a recommended strategy for determining the intensity of a session or exercise in resistance training is to divide the volume load (session or exercise) by the number of repetitions performed (session or exercise), providing the average load (kg) lifted per repetition [37]. In addition, movement velocity is another variable of exercise intensity, which, in combination with the load lifted, can be useful for monitoring the level of exertion when planning training to develop muscle power (i.e., the ability to increase work per time) [34]. In practical terms, velocity is indeed a costly variable to be measured accurately [35], and power measurements are restricted to laboratory conditions. While this information can provide valuable insights for external load analysis, there is still not easy applicability to real-world training management [7].

3. Internal Load Monitoring

The literature has shown a wide range of methods for monitoring internal load, primarily including HR, RPE, monotony, strain training, TRIMP, physiological markers, and the use of diaries and questionnaires. Among these methods, HR is the most commonly used response to measure and quantify the internal load of players during training sessions and matches, due to the functional meaning of this variable [5,38]. However, combining these methods is often recommended for a more comprehensive understanding of training internal load [2,3].

An example of the enhanced potential of combining two or more internal load methods to analyze the physiological demand imposed with training is evident in studies reporting a low association between cognitive perception of effort (e.g., RPE) and metabolic responses (e.g., blood lactate accumulation) [3,4,7]. Therefore, despite the assumption that individuals can monitor physiological stress using perception, studies have shown that physiological variables, rather than perceptual ones, can better distinguish the training demands of similar exercise modes that are planned differently [5,6,13].

In addition, it is interesting to consider the variability in responses to training (i.e., conditioning and performance adjustments), which can be observed when comparing different

individuals experiencing the same training load (i.e., inter-individual trainability) and when comparing the same individual across different seasons (i.e., intra-individual trainability) [13]. These variabilities indicate that individuals not only respond and adapt differently to training, but their responses also oscillate over time, regardless of sex, age, and conditioning level [5,13], ratifying the importance of monitoring internal loads to avoid untoward outcomes with training [38].

3.1. Rating of Perceived Exertion (RPE)

The RPE score is a commonly used and cost-effective scale for monitoring internal load demands during training, supported by solid scientific evidence showing correlations with exercise intensity, HR, and lactate concentrations [7]. The RPE scale involves the practitioner pointing to the descriptor (perceived effort intensity) and then the corresponding number. Initially proposed in 1974 by Borg [39], the scores of efforts ranged from 6 to 20 points, which was the former index to rate the post-exercise level of exertion perceptually from a “very, very light—6” to a “very, very hard and maximal—19 or 20” [40]. Over the years, other scales, such as the category ratio (CR-10) and the session RPE (sRPE), have also been introduced [41–43].

The RPE scale proposed by Borg reflects the exerciser’s subjective intensity of effort during or immediately after exercise. This RPE scale was initially based on HR during running, with 6 corresponding to resting HR (60 beats per minute) and 20 to maximum effort, which would be (200 beats per minute) [39]. This correspondence was investigated in sedentary and athletic individuals, either to discriminate the exercise intensity or the demand upon the cardiocirculatory system. For example, the 6–20 RPE scale was considered a reliable tool for prescribing and self-regulating high-intensity interval training (HIIT) in the sedentary population. This was an assumption postulated after no significant differences were shown in HR responses to HIIT sessions prescribed and regulated by the HR reserve method and RPE at low-intensity interval planning (~50% of HR reserve or 9–11 points on the RPE scale: 135 ± 15 bpm vs. 138 ± 20 bpm), and at high-intensity intervals (~85% of HR reserve or 15–17 points on the RPE scale: 168 ± 15 bpm vs. 170 ± 18 bpm) [44].

The application of the RPE scale in sports and fitness has also been used in the CR-10 [39,45]. The CR-10 scale has a narrower numeric range, with 0 representing rest and 10 representing maximum effort. In contrast to the 6–20 scale, the CR-10 features twice the intensity range of the previous scale, but its application is similar to that of the 6–20 RPE scale [5,41,46].

In 2001, Foster and colleagues introduced the sRPE scale. Unlike the other RPE scales (6–20 and CR-10), which assess the perceived intensity of effort during or immediately after exercise, the sRPE scale evaluates the perceived intensity of effort over the entire training session [5]. Originally, this scale was meant to be applied only 30 min after the conclusion of the training session. To use this scale, the individual should be familiarized with it and select the descriptor followed by the corresponding number representing the perceived effort intensity during the training session, where 0 represents rest, and 10 maximum effort [43]. The use of sRPE to monitor training is a reasonably accurate measure of internal load in different exercises, regardless of mode and intensity, such as resistance training, high-intensity interval training, or plyometric training [13].

Indeed, the literature has evidenced that applying the sRPE scale 10 min after the conclusion of the training session does not significantly differ from applying it after 30 min [47], despite the initial recommendation for a longer waiting period. The sRPE, developed by Foster, has proven reliability concerning HR zones, with strong correlations reported between HR zones and sRPE ($r = 0.75$ to $r = 0.90$) [38]. Moreover, another study involving soccer players also demonstrated a strong correlation between sRPE and HR zones ($r = 0.54$ to $r = 0.85$) [5,42]. Typically, sRPE is combined with other factors such as exercise duration, HR, or blood lactate levels to provide a better understanding of the internal load experienced by the individual [7,13].

The literature has demonstrated that training session load can be calculated using arbitrary units by multiplying the training session duration (exercise time, recovery intervals, warm-up, and cool-down) by the sRPE [42,48]. However, for resistance training sessions, arbitrary units are quantified by multiplying the sRPE by the total number of repetitions in the session. It is worth noting that there is currently no standardized classification of session load for this type of training [49,50]. Calculating arbitrary units for a training session is essential for applying the concepts of monotony and training strain.

However, some factors such as individual experience, training level, training specificity, fibre distribution, environmental conditions, and psychological states, affect RPE reports, hence limiting its use for monitoring internal load, regardless of its wide scientific support [13].

3.2. Monotony and Training Strain

Training monotony reflects the variability of the training load, and depending on this variability, the adaptive responses to training can be either positive or negative [51]. A 7 to 10-day period is typically used to calculate training monotony, with calculations often based on a 7-day window. Initially, the average of arbitrary units for the sessions within the analyzed period (e.g., 7 days) is calculated by averaging the daily load (i.e., sRPE multiplied by session duration) in arbitrary units. This value is then divided by the standard deviation of the average weekly load (i.e., the sum of daily loads over a week) to determine the monotony index, from which the strain index can be assessed by multiplying the weekly load by the monotony [51–53].

For example, if a training session lasts 120 min and is reported as 6 (on RPE scale ranging from 0–10), the daily load is 720, which can be considered heavy training [50]. Therefore, if the next planned sessions demand slight variation in RPE (e.g., 5 to 7) but not in session duration, the weekly load can total 2160 arbitrary units with three sessions per week. The monotony also tends to approach high values (e.g., average load in a week = 720 divided by the standard deviation of the weekly load = 97.98, resulting in 7.3 arbitrary units), which indicates a higher strain (e.g., weekly load multiplied by the standard-deviation of the weekly load, resulting in 15.873 arbitrary units).

Thus, when analyzing sRPE, monotony, and strain responses to training, information regarding an exacerbated demand on a single training stimulus can be obtained, supporting training plan revision to avoid unsatisfactory results [51–53]. Therefore, monitoring sRPE, weekly load, monotony, and strain during physical sports practice can be essential for controlling the demands required based on the specific modality practiced.

3.3. Training Impulse (TRIMP)

TRIMP is a widely used method for assessing training load and can identify the time spent at each training intensity [3,52,53]. Bannister and Calvert [53] were the first to present the TRIMP model to quantify internal training load. Subsequently, other TRIMP models were introduced using different physiological parameters for TRIMP calculations [3,53,54].

The TRIMP method by Edwards [55] involves multiplying the duration that individuals spend within designated intensity zones during the training session. These zones of intensities are determined according to the percentage of maximum HR elicited during exercise (Zone 1: 50–60%; Zone 2: 60–70%; Zone 3: 70–80%; Zone 4: 80–90%; and Zone 5: 90–100%). The TRIMP method proposed by Lucia et al. [56] is based on ventilatory thresholds and is divided into three phases or zones: Phase I, representing low intensity below the ventilatory threshold; Phase II, indicating moderate intensity between the ventilatory threshold and the respiratory compensation point; and Phase III, signifying high intensity above the respiratory compensation point. In the TRIMP model, each phase is assigned a coefficient multiplied by the training duration within each zone, resulting in the TRIMP score [57,58].

Lastly, the Bannister and colleagues modified TRIMP model, known as Stagno's TRIMP, relates blood lactate levels to HR zones [41]. It is important to note that all TRIMP

models were initially developed for endurance sports, and further research is needed to address the applicability to sports demanding other physical abilities (e.g., power, and anaerobic capacity).

3.4. Physiological Markers

Physiological markers for monitoring training internal load can be used to detect fatigue levels, physiological stress, and training recovery [2,3,5]. Among the physiological markers, HR is the commonly used method by athletes and exercise practitioners. This variable primarily assesses whether an individual can tolerate the training load and the recovery process.

The most applied HR analyses for monitoring internal load are HR recovery (HRR) and HR variability (HRV) [2,3,59]. Every time an exercise is completed, there is an immediate rapid reduction in HR. Decreases in HRR can indicate fatigue, detraining, an inability to withstand the training load, or undesirable overreaching [60,61]. HR recovery corresponds to the decline in HR after the end of the exercise. Typically, this recovery interval can vary from 30 to 120 s after the session's conclusion, with 60 s being the commonly used duration [61]. HR recovery can be expressed in two ways: absolute HRR (the number of heartbeats recovered within a certain period) and relative difference (the relative difference between the average HR in the final 30 s of exercise and the rate 60 s after exercise completion) [5,61,62].

Similar to HRR, the HRV has been used to obtain insights about an individual's positive or negative adaptations to physical training [63,64]. HRV involves measuring the intervals between cardiac beats. A reliable method for its measurement is the natural logarithm ($\ln$ rMSSD) of the differences between intervals (R-R), calculated for 10 to 60 s [63]. For HRV monitoring, it is recommended to measure it at least three times a week over a prolonged period to obtain adaptive responses to training. A reduction in HRV may indicate that the individual is experiencing a negative response to training, while an increase in HRV suggests that the individual is experiencing positive adaptations [61,63]. Monitoring HR through HRR or HRV can provide important information about an individual's training adaptations. However, monitoring should not solely rely on HR and should be complemented by other methods and tools, such as RPE or lactate concentrations, to enhance the reliability of internal load assessments [3,61,63].

Saliva samples that monitor hormonal markers can provide information about an individual's health status and prevent overtraining [64,65]. Hormones measured in saliva, such as testosterone, cortisol, or the testosterone/cortisol ratio, seem to have implications for detecting overreaching or overtraining states [38,66]. Testosterone is an anabolic hormone that plays a role in growth and protein synthesis, as well as in psychological aspects contributing to performance [65]. Cortisol, on the other hand, is crucial for metabolism as it increases substrate availability to muscles and regulates immune system function. Increased levels of cortisol after physical exercise or competition are expected due to exercise-induced stress [64], which is further supported by a high correlation between cortisol levels and exercise intensity ($r = 0.86$) [66]. Due to its crucial importance, cortisol is one of the most measured hormones for training monitoring, especially among athletes [47,65].

The testosterone/cortisol ratio is an interesting tool for monitoring sports since it reflects the balance between anabolism and catabolism states. A high ratio suggests anabolic adaptations, while a low ratio may be detrimental as it indicates a catabolic state [65]. Hormonal monitoring can be valuable for managing training loads and the individual's recovery process [64,67]. Blood samples are also used for biochemical analyses, providing information to assess an individual's training status. Among the primary biochemical markers for exercise monitoring is creatine kinase. Due to the ease of collecting and examining this enzyme, serum creatine kinase (CK) activity has become an important marker widely used in sports and fitness, with increases in CK activity indicating structural muscle damage at the level of the sarcolemma and Z-disks [68,69]. Therefore, this biochemical marker has been used to assess muscle damage since its levels increase acutely in response

to training loads [69]. Other muscle enzymes, such as serum lactate dehydrogenase (LDH), myoglobin, and troponin, can also be measured to indicate the extent of muscle damage with excessive exercise training [69]. For instance, LDH activity is a marker of cell damage, with increases helping to assess adaptation to training, while myoglobin release indicates degradation of protein structures within muscle and correlates with neutrophil response induced by stress [69]. In addition, cardiac and skeletal muscle troponins are released with high-intensity exercise, indicating disruption of the actin–myosin structure [69]. Given these molecules' structural and functional importance, they are considered valuable markers for monitoring the effects of training load on muscle tissue.

Immunological and inflammation markers can be used to assess physiological stress in response to training load. Excessive training can lead to immunosuppression and inflammation, increasing the individual's risk of illness [70]. Several immunological and inflammatory markers are associated with physical exercise and sports; among them, cytokines play a significant role in acute and chronic responses to physical training. The most commonly measured cytokines include interleukin-6 (IL-6), interleukin-8 (IL-8), interleukin-10 (IL-10), and interleukin-1 β (IL-1 β) [71,72]. Hence, cytokines are molecules that modulate inflammation and immune responses. According to Suzuki [71], increases in interleukin IL-1ra, IL-6, IL-8, and IL-10 appear to be more closely related to exercise intensity (physiological load/stress) than to muscle damage. Furthermore, long-duration exercise tends to elicit a significantly higher response of these cytokines compared to short-duration intensive exercise. Even with the complexity of the cytokine network, the pro-inflammatory cytokines (e.g., IL-1 β , IL-6, IL-8, TNF- α) and the anti-inflammatory cytokines, also with immunosuppressive function (e.g., IL-1ra, IL-10, and IL-4), contribute to muscle injury and susceptibility to infections. Therefore, the inflammatory cytokines, neutrophils, and macrophages can be markers of exhaustive exercise-induced muscle tissue damage [71].

3.5. Questionnaires and Diaries

Athletes and exercise practitioners frequently use questionnaires and training diaries as simple and cost-effective tools to gain insights into training loads for individual or upcoming sessions. These tools collect subjective data; thus, it is important to complement the information with data from objective methods for monitoring training loads (i.e., physiological or performance metrics) to improve accuracy [5,72,73]. Among the primary questionnaires and diaries, the following stand out: the training diary, profile of mood states (POMS), recovery–stress questionnaire for athletes (RESTQ-Sport), and total quality recovery (TQR). These tools can be applied to athletes, trained individuals, or those beginning their exercise journey [72–74].

In training diaries, the individual describes everything that occurred during the training session, such as difficulties, pain, and more, and is used more commonly by athletes than by physical exercise practitioners [72,73]. The POMS questionnaire consists of 65 items that assess six mood states: vigorous activity, anxiety-tension, dejection-depression, anger-hostility, fatigue-inertia, and confusion-bewilderment [56,58]. The RESTQ-Sport comprises 76 questions divided into 19 scales, of which 7 assess overall stress, 5 evaluate overall recovery, 3 assess sport-related stress, and 4 evaluate specific recovery issues [72,75]. Lastly, the TQR assesses the individual's recovery over the last 24 h by asking “how do you feel now?” on a scale from 6 to 20, where 6 means “not recovered at all” and 20 means “completely recovered” and is widely used between training sessions [72]. The TQR in its modified form with a 0–10 scale can also be found and used [76].

4. Practical Considerations for Training Load Monitoring

When applying and using methods for monitoring training load, it is essential to take into account several key points: the method's validity and reliability with scientific evidence, having a good understanding of how to apply the chosen method, using methods or tools that are relevant to the training and specific sport, providing feedback to the practitioner based on the collected data, and being capable of interpreting the data collected

through the utilized methods [1]. Table 1 summarizes the methods covered, specifying the type of load, application methods, and the sports and fitness disciplines in which each method can be used. Figure 1 suggests practical approaches for the methods discussed in this article for monitoring training load in sports and fitness.

Table 1. Training load monitoring methods characteristics.

Method	Load Monitoring	Evaluated Parameters	Application	Sports and Fitness Modalities
Accelerometers	External load	Time-motion analysis	During exercise or competition, assess HR, distance covered, and energy expenditure.	In individual or team sports.
GPS	External load	Time-motion analysis	During exercise or competition, assess distance, speed, and changes of direction, and provide performance insights for players in different positions.	Mainly in team sports.
Power Metrics	External load	Power output analysis	During exercise or competitions.	Mainly in cycling
Linear encoder	External load	Measurement of linear position and velocity during exercises	Used for assessing a single exercise of a session	Mainly in resistance exercise and power training
Method Repetitions	External load	Quantification of the number of repetitions of exercise or session.	Used for assessing a single exercise or the entire session.	Mainly in resistance exercise and power training.
Volume Load	External load	Absolute: Quantification of the product: number of sets $\times$ number of repetitions $\times$ load (kg). Relative: Quantification of the product: number of sets $\times$ number of repetitions $\times$ % 1RM	Used for assessing a single exercise or the entire session, representing the sum of the set of exercises.	Mainly in resistance exercise and power training.
RPE	Internal load	Subjective perceived effort intensity of the exercise by the individual.	The RPE (6–20 or CR-10) assesses subjective intensity during or immediately after exercise. The sRPE (0–10) measures the subjective effort intensity of the training session.	In individual or team sports.
TRIMP	Internal load	Identify the time spent at each training intensity.	It is determined by multiplying the duration that individuals remained within intensity zones during the session. These zones are based on different physiological factors (HR, ventilatory threshold, and blood lactate)	Usually in individual sports, especially in endurance sports.
HRR and HRV	Internal load	Recovery and adaptation	The recovery interval following the sessions lasted for 60 s, with this duration being predominantly employed for HRR and HRV analyses.	In individual or team sports.
Hormonal and Biochemical Markers	Internal load	Fatigue control, recovery, and adaptation.	Collection of saliva post-exercise and during the recovery process between sessions, as well as assessment of chronic exercise adaptation through hormonal concentration measurements. Blood collection for acute or chronic exercise recovery and adaptation assessment.	In individual or team sports, encompasses both strength and endurance exercises.
POMS, RESTQ-Sport, and TQR	Internal load	Recovery and fatigue.	Subjective information through questionnaires.	In individual or team sports.

Abbreviations: HR, Heart rate; RPE, Rating of perceived exertion; TRIMP, Training impulse; HRR, Heart rate recovery; HRV, Heart rate variability; POMS, Profile of mood states; RESTQ-Sport, Recovery–stress questionnaire for athletes; TQR, Total quality recovery.

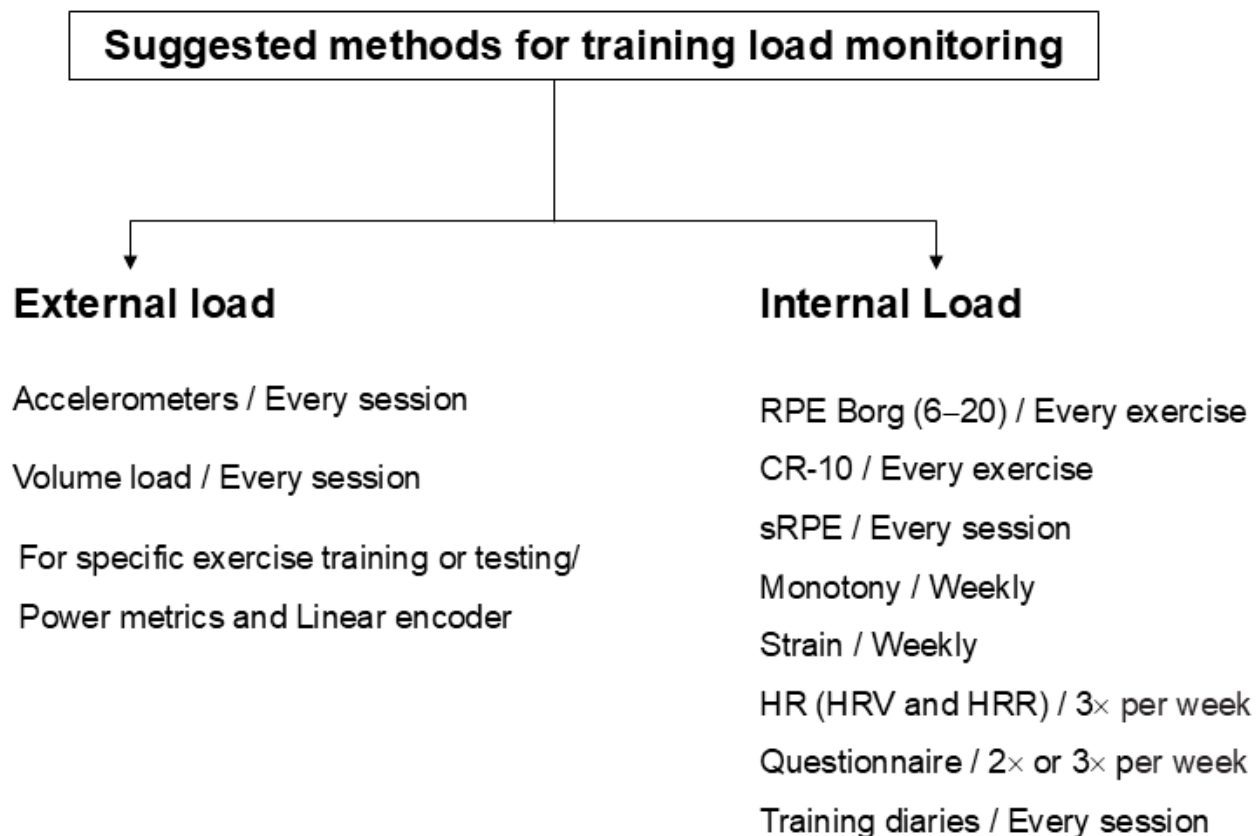


Figure 1. Training load monitoring suggested methods.

5. Final Considerations

Training load monitoring methods are essential for tracking physical training adaptations and reducing the risk of injuries and overtraining. Despite the separate approach in the literature to external and internal load methods, not only are both methods important but also several measurements as well and should be monitored to quantify better psychological and physiological stress induced by training in individuals. The choice of method may vary depending on the athlete's sport, financial resources, or practicality.

The large number of variables recorded by monitoring devices during training sessions and official matches provides the opportunity to understand the athlete's demands and make decisions regarding training management and injury risk assessment.

Analyzing athletes' physical demands through monitoring systems will allow team technical staff to personalize training loads and determine the intensities at which athletes must perform tasks during training sessions to improve sports performance. Thus, it will also help to reduce the number of injuries associated with overload. Therefore, it is essential to use the different types of existing monitoring systems.

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