The Fine-Tuning Approach for Training Monitoring

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Purpose: Monitoring is a fundamental part of the training process to guarantee that the programmed training loads are executed by athletes and result in the intended adaptations and enhanced performance. A number of monitoring tools have emerged during the last century in sport. These tools capture different facets (eg, psychophysiological, physical, biomechanical) of acute training bouts and chronic adaptations while presenting specific advantages and limitations. Therefore, there is a need to identify what tools are more efficient in each sport context for better monitoring of training process. Methods and Results: We present and discuss the fine-tuning approach for training monitoring, which consists of identifying and combining the best monitoring tools with experts’ knowledge in different sport settings, designed to improve (1) the control of actual training loads and (2) understanding of athletes’ training adaptations. Instead of using single-tool approaches or merely subjective decision making, the identification of the best combination of monitoring tools to assist experts’ decisions in each specific context (ie, triangulation) is necessary to better understand the link between acute and chronic adaptations and their impact on health and performance. Future studies should elaborate on the identification of the best combination of monitoring tools for each specific sport setting. Conclusion: The fine-tuning monitoring approach requires the simultaneous use of several valid and practical tools, instead of a single tool, to improve the effectiveness of monitoring practices when added to experts’ knowledge.

Keywords: physical fitness, readiness, recovery, athletic performance, physical testing, exercise tests

Exercise monitoring is an essential part of the training process. It serves to verify whether programmed loads are effectively executed by the athlete, which is likely to lead to performance improvements. A number of different monitoring tools exist to follow the progression of individuals with different fitness levels and objectives, including the measurement of both external and internal loads.1 In simple terms, external load is observable exercise behavior, which can be measured with standard units, such as kilograms, meters, seconds, velocity/speed, and power. Within an individual, they might be thought of as index training sessions, which are intended to demonstrate improvement over time. On the other hand, internal training loads refer to the individual psychophysiological responses, which can be measured as, for example, heart rate (HR), [blood lactate], rating of perceived exertion (RPE), and biochemical and molecular responses. Thus, manipulation of external load parameters results in specific internal load responses intended to optimize adaptations supporting performance.2 Tracking external load parameters is easier, particularly in the era of wearable devices. Tracking internal responses is more challenging, particularly between athletes depending on the nature and complexity of the target response.3

Current evidence supports the use of a number of monitoring tools with known validity and reliability. These tools have evolved during the last century in conjunction with technological development.4 These tools are as simple as counting the volume load during a resistance training session or the mean %HR reserve during an endurance workout to more complex methods such as the number of accelerations during a soccer match or the HR variability (HRV) upon awakening. However, and independently of their complexity level, all these measures have inherent limitations regarding validity and reliability in applied settings. For instance, it is well known that cardiovascular/perceptual drift exists during sustained exercise compared with the internal and external loads identified during incremental testing.5 This means that the external loads required to produce a given internal load during sustained exercise are actually lower than that prescribed from the parameters obtained during incremental testing. To overcome this problem, a generalization-based formula was proposed; therefore, a prediction of the responses could be applied based on available data.5 However, this prediction has still some error and does not account for differences in individual responses related to several contextual factors of the exercising individual, such as environmental conditions, psychological stress, the training status of the exerciser, or accumulated fatigue.6-8 In this regard, a recent study9 has shown how decoupling of HR (ie, internal load) and running speed (ie, external load) during marathons may explain difference in performance. This decoupling is emerging as an index of durability in endurance running,9 which can be also applied to cycling.10 This exemplifies how some monitoring practices may lead to arbitrary coaching decisions, based on the absence of accuracy or sensitivity of the selected monitoring tools (eg, inappropriate signal-to-noise ratio), especially when using a single monitoring tool.
On the other hand, some practitioners aim to perform a precise testing sequence, with objective and subjective measures, before, during, and after appropriate training intervals. This approach attempts to better identify the readiness of individuals (ie, how prepared they are to face the programmed loads)\textsuperscript{11,12} and, more importantly, how the applied loading and subsequent recovery yield responses within the expected range.\textsuperscript{13,14} To the best of our knowledge, there are no studies addressing this problem from a comprehensive perspective. This approach, which we will name as “Fine-Tuning,” can be defined as the combined use of different monitoring tools (either objective or subjective and external or internal) that practitioners experience. Its main intention is to reduce the divergence between the programmed and executed loads, and better predict their potential effects on short- and long-term adaptations. This fine-tuning approach can be applied to any form of workout and proposes the use of several specific monitoring tools (ie, triangulation) over the use of any single tool to reduce the noise and increase the signal for improved diagnosis and prediction by practitioners.

Thus, the aim of this article is to assist practitioners to better develop fine-tuned approaches in sport and exercise settings. As an example, while we need different criteria (ie, RPE, [blood lactate], respiratory exchange ratio, and %predicted maximum HR) to confirm a true exhaustion and validate the maximum oxygen consumption recorded at the end of an incremental test,\textsuperscript{15} we would also need to develop criteria to better identify both valid and more efficient approaches of fine-tuning in every exercise setting. To better illustrate this approach, we will present and discuss the proposed criteria and some real examples from different scenarios.

**Understanding the Fine-Tuning Model**

A previous monitoring cycle model has been proposed which includes the external and internal workloads, the perceptual well-being, and the readiness of the athlete in a closed loop.\textsuperscript{16} While we recognize its merits, we suggest that this model needs to be expanded to meet the necessity of practitioners to adapt monitoring practices to their specific reality while allowing a better diagnosis and predictability.

The technological advances during recent decades have permitted the evolution from simple monitoring tools, such as HR, to new sophisticated approaches, such as big data, machine learning, and artificial intelligence. The first fallacy to consider within this reality is an inherent complexity bias, which is based on the human tendency to anticipate that sophisticated methods are likely better than simple ones. This is contrary to the classic concept of Occam’s razor, which postulates simplicity as the best option. Thus, more complex tools are not necessarily better.\textsuperscript{17} In other words, the model with fewer and simpler parameters should be always preferred, following the principle of parsimony. Nevertheless, training for sport is inherently a complex and multifactorial process. Therefore, when monitoring athletes, there is at least potentially the need for a holistic approach with sufficient information to be able to capture the “big picture.” Thus, an equilibrium between simplicity and complexity should be warranted to allow the correct flux of information for appropriate diagnosis and decision making. For instance, while the session RPE (sRPE) is a valid and simple monitoring tool including both the volume and intensity in a single metric,\textsuperscript{18} this simplicity would not allow the differentiation of what physiological system is more taxed (eg, cardiometabolic vs neuromuscular). Thus, depending on specific requirements of each sport, additional measures are needed for fine-tuning the athlete’s training adaptations.

The data-driven approach has recently been criticized by Gamble et al,\textsuperscript{19} which arose with the emergence of new technologies in sport. Data-driven monitoring is a modern problem generated by the pressures of the industry that induce practitioners use of lot of information collected with complex and expensive technologies. Sometimes this use is indiscriminate. This may be the case for wearables and software platforms with algorithms that have been poorly validated.\textsuperscript{20,21} Contrary to this, a data-informed approaches should be implemented. This means that valid and reliable metrics should be selected a priori to answer specific questions to assist practitioners for appropriate decision making.\textsuperscript{15} Furthermore, the reduced validity of the selected tools and parameters would generate poor data leading to ineffective and cost-expensive procedures.

Veracity refers to the accuracy, quality, relevance, uncertainty, reliability, and predictive values of the collected data. Interestingly, a recent systematic review on the veracity metrics of monitoring tools and parameters used in soccer has revealed limited validity for most of them.\textsuperscript{22} Therefore, there is a risk for generating inaccurate diagnosis when using limited tools in practice because of the large error. Furthermore, the noise accumulated through the error propagation is a common risk in sport science when using monitoring tools that estimate but do not directly measure phenomena (eg, force–velocity profile).\textsuperscript{23,24} Thus, it is mandatory to document the veracity of the monitoring tools selected in each setting before their use. Meanwhile, a large number of data may provide the possibility of discerning between “good,” “bad,” or even “anomalous” values as well as establishing reference values.\textsuperscript{25,26}

Another issue of concern refers to the false dichotomy of objectivity versus subjectivity. While it is true that we need objective data to interpret reality and make correct decisions, it is also true that subjective measures, when conceptualizing athletes as complex adaptive systems, can provide continuous and multi-level integrated information about performer-environment interactions.\textsuperscript{27} Furthermore, a recent meta-analysis has suggested that subjective measures can outperform the objective ones.\textsuperscript{28} However, these 2 assumptions mean that we need to collect information from both sources for an appropriate diagnosis as subjective data are inaccurate and biased per se and can be better understood and interpreted when put into context.

The different characteristics of every sport should be considered when selecting the best method for monitoring. The simplest sport classification would be to separate individual sports from team sports. Performance in individual sports is typically more related to objective measures of external and internal loads and thus can be better predicted.\textsuperscript{29} Performance in team sports is more complex and subject to contextual factors. Therefore, it is more random and unpredictable.\textsuperscript{6} Some individual sports with a high degree of uncertainty and high technical, tactical, and cognitive demands (eg, combat sports) share some characteristics with team sports and cannot be approached as other physically demanding individual sports (eg, track and field, swimming). This classification affects the level of individualization which is easier to implement in individual sport than in team sports. However, it would be desirable to optimize all the periodization factors (ie, training load, recovery strategies, psychological skills, nutrition, and skill acquisition)\textsuperscript{30} for every athlete to achieve a more effective individualization in different sport settings.\textsuperscript{6} In this respect, it should be considered that the effect of contextual factors on the relationship between internal and external loads is more relevant in team sports than in other sports in which performance is more dependent upon physical and physiological capacities.\textsuperscript{29} Therefore, the identification of the contextual factor that may influence on the association
between internal and external loads31 is critical for optimal fine-tuning following the premises of the own training methodology.

The general fine-tuning approach is represented in Figure 1. This approach assumes that the coach–athlete system is assisted by sport scientists with information based on scientific evidence to support the training methodology. This evidence would provide the best monitoring tools to the context in which both the coach–athlete system and the sport scientist work. While both internal and external loads and objective and subjective measures could be used, the available evidence and the specific context would define what specific measures are most appropriate and at what specific time (ie, readiness, exercise, recovery) would be implemented to effectively monitor the purported physical and physiological responses. Of note, the selection of the specific monitoring tools for triangulation may be also adapted to the moment of the season for the same sport. For a better understanding of the fine-tuning approach, we provide some examples in different sport settings in the next sections.

Endurance Running

Sue is a healthy 30-year-old, regionally competitive female long-distance runner (ie, 5000 m in 17:12 and 10,000 m in 36:25). Her critical velocity, estimated from competitive during mid-season results,32 is 4.55 m·s$^{-1}$. The current training volume is 80 km·wk$^{-1}$, with 1 day per week in zone 2 and 1 day per week in zone 3. Sue’s coach has prescribed as 10×800 m with 400-m jog, at 4.65 m·s$^{-1}$ (2:52 for 800 m in zone 3). The workout is intended to have an sRPE of 7/10 (CR-10 scale). HR,33 RPE, and the talk test34 are monitored at the end of the warm-up, with 1600-m run in 7:00 (3.83 m·s$^{-1}$). During warm-up, the HR is ∼160 (normally 150–155), and the talk test is equivocal (normally positive). The RPE is 6 (normally 4–5). These results, obtained during the warm-up period when the coach has decision-making ability, clearly indicates that Sue is feeling more tired than usual. On this basis, the coach could either cancel the body of training session (converting the session into a recovery day) or, if they wanted to maintain zone 3 training on this day, reduce the volume of the session (eg, 5×800 m in 2:52 with 400-m jog between).

Resistance Training in a Basketball Team

The strength and conditioning coach of a professional basketball males’ team competing at national level has scheduled a resistance training session in the morning, 48 hours after the last game. The 8 players who played most of the game are evaluated before the training session, with a 5-point Likert scale for muscle soreness35 and countermovement jump (CMJ).36 A positive result for incomplete neuromuscular recovery is considered if (1) there is a jump capacity loss greater than the smallest worthwhile change (SWC),1 and (2) the athlete reports a score ≥3 for muscle soreness. If there is a contradictory response (eg, preserved jump capacity with a score of 4/5 for muscle soreness), an additional evaluation of creatine kinase37 is generated for a definitive diagnosis based on the SWC. A negative response for incomplete neuromuscular recovery implies the completion of the resistance training session following a velocity-based training38 approach with the other players who did not play. In case of a positive diagnosis with all parameters indicating an incomplete neuromuscular recovery, the athletes should complete a recovery session with the physiotherapist. A positive diagnosis with a partial recovery implies the execution of a single set of all the programmed exercises. During the afternoon, the athletes complete a tactical session with a low physical load. The next day (72 h after the game) before the technical tactical session, the same monitoring tools are used to identify if there are still players with insufficient neuromuscular recovery to take decisions on an individual basis.

Repeated-Sprint Training in a Soccer Team

After a 2-week passive winter break, the players of the second division of a national-level league are regaining their deteriorated repeated-sprint ability within the third week of the preparation period. This is a precompetitive microcycle following the ordinary and shock microcycles scheduled for the first and the second weeks. While training volumes were markedly reduced, some players might still feel heavy due to the accumulated fatigue from the previous microcycles. After an easy session (2 d ago) and a following day off, the players are in for an intensive repeated-sprint
training session. They should be fresh and ready for this hard session, but there is a possibility that some players are still sore and under-recovered. As the training session requires maximal repeated running exertion, there is a necessity for accurate assessment of both the neuromuscular fatigue as well as the cardiorespiratory readiness to perform. Only fully recovered players should participate in this session, thus deviation of only 1 SWC is taken as a threshold for identification of under-recovered players. Morning-measured perceived rating of fatigue scores is the initial indicator for unready players. This measure is sensitive to daily changes in acute training load but also exhibits the highest correlation with accumulated 3-day load.39 A submaximal fitness test, consisted of continuous-fixed protocol and incorporated within the warm-up, is used to assess cardiorespiratory readiness with exercising HR being analyzed.40 If possible, a submaximal intermittent-use test can also be incorporated into the training schedule earlier that day to assess neuromuscular fatigue. Vertical accelerometry load, assessed through this submaximal fitness test, provides better sensitivity to fatigue in comparison to jumping-related protocols as running-related neuromuscular fatigue is actually being assessed.41 Alternatively, checking for flight time/contact time ratio and braking phase time during CMJ, instead of only testing for CMJ height, may provide better fine-tuned insight into the neuromuscular fatigue level.42 Namely, because of the low load of the previous 2 days, the CMJ height might be restored, while possible fatigue can still be detected with these more sensitive tools. Only if all measured variables are within the 1 SWC bandwidth, the player can undertake the planned repeated-sprint training session. If neuromuscular fatigue is detected in combination with optimal cardiorespiratory status, the player is selected for an aerobic type of session which may include high-intensity interval training but with a low neuromuscular load. If the contrary status is confirmed (ie, optimal neuromuscular status with low cardiorespiratory status), the player is directed to undertake a strength or power-oriented session. The total load of these substituting sessions should be equated to the corresponding load imposed on by the initially planned repeated-sprint training session.

Tennis

Jay is a young tennis player starting his career as professional player after a successful junior trajectory, achieving number 3 in the world. Apart from on-court tennis training and strength and conditioning practices, tournament scheduling appears as an uncontrollable factor, with participation in multiple draws that often require to complete numerous training sessions and competitive matches on consecutive days,35 or even 2 consecutive tennis matches or more on a single day.44 Thus, the need for adequate load monitoring, as well as the implementation of effective recovery strategies, is paramount for tennis players like Jay. During the preseason, Jay is training 2 to 3 times per day, combining technical training and fitness sessions. To quantify external training loads, the coaching staff uses video analysis for the activity profile (ie, duration of rallies, rest times, effective playing time, and hitting demands)35 and global positioning systems to quantify movement demands (ie, total/relative distance covered, movement speed, player load).46 For measurements of internal load, the session RPE is used43 while including its derivatives such as the monotony index or the acute:chronic workload ratio.47 The player’s HR is recorded during training sessions, especially those “on-court” to assess physiological strain and estimate exercise intensity.43 HRV is also measured on a daily basis, using a mobile app (ie, HRV4training) for detecting symptoms or prevalence of non-functional overreaching and athletic status.48 These measurements are also combined with practical neuromuscular tests, as CMJ before and after training sessions, and strength and range of motion tests of joint integrity (eg, hip and shoulder) performed once a week.49,50 Moreover, resistance training is conducted during these weeks following a velocity-based training approach.38 Finally, in terms of training periodization, although a block periodization approach or shock microcycle may be implemented,51 a day-to-day approach is commonly used based on the HRV and other performance metrics (eg, variations in jump performance), adapting the training load according to athletic status.52 Under this context, an incomplete recovery between matches and training sessions or an excessive level of accumulated fatigue are considered when (1) a decrease in HRV occurs together with an increase in resting HR, and (2) there is a decrease of a given performance metric (eg, CMJ, shoulder strength) higher than the SWC calculated from the multiple testing sessions.

Last Remarks

While we have presented here some examples of fine-tuning in different sport settings, it is important to highlight that any of the examples used should not be considered as models but only as examples of an evidence-informed53 methodology adapted to the peculiarities of the specific coach–athlete system and the available facilities. Future studies should identify the best combination of monitoring tools for triangulation in each specific training setting. Furthermore, the issue of optimal training prescription based on this approach remains a key challenge. For instance, although various “readiness” metrics are of undoubted value, identifying the optimal dose of exercise for the individual athlete is still an extremely difficult endeavor that should be experimentally approached in future research. Finally, the use of this approach in sports, in which the coach does not always have direct contact with the athlete because they are in different places (eg, mountain running), may be limited. However, communication and technological advances would allow the implementation of the best available tools for every specific case.54

Practical Applications

Coaches should first identify the best monitoring tools available in the scientific literature to assess, in the context of their specific sport, the readiness, exercise load, and recovery of athletes during training and competition. The use of the selected monitoring tools should be adapted to their setting while looking for simplicity and practicality. The information acquired with the monitoring tools should be used to complement their decision making based on their knowledge and experience.

Conclusion

By using different monitoring tools at the same time (ie, triangulation), the fine-tuning approach improves the diagnosis and predictive capacity of monitoring practices at different moments of the monitoring cycle (ie, before, during, and after exercise) over the competitive season. The selection of these monitoring tools should be based on scientific evidence while adapting to the training methodology used by the coach and the available instruments in each specific training setting.

(Ahead of Print)
Notes

I. It should be pointed out that if the SWC is calculated using a distribution-based method as, for example, 0.2 × between-subjects SD, this SWC had only 16% of probability to find the true value (ie, 0.2 × SD = 0.1585, ie, 16%). For other SWC calculations as 0.3, 0.5, or 1.0 × SD, the probabilities are 24%, 38%, and 68%, respectively. This probability range

0.1585, ie, 16%). For other SWC calculations as 0.3, 0.5, or 1.0

reported in the scientific literature to monitor neuromuscular status with CMJ height.

References


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