Review

Monitoring of Daily Training Load and Training Load Responses in Endurance Sports: What Do Coaches Want?

Lilian Roos[1,2], Wolfgang Taube[2], Monika Brandt[1,2], Louis Heyer[1], Thomas Wyss[1]

[1] Swiss Federal Institute of Sports Magglingen SFISM, Magglingen, Switzerland
[2] University of Fribourg, Department of Medicine, Movement and Sport Science, Fribourg, Switzerland

Abstract

Accurate assessment of training load (TL) and training load responses (TLR) might be useful for an optimized training regulation and prevention of overtraining. No consensus on a gold-standard for measuring TL or intensity in endurance sports has been reported in the available literature so far. The aim of the present article is i) to identify feasible parameters to measure TL and TLR in daily training and ii) to compare these scientific approaches with the needs of elite endurance coaches. Therefore, the first part provides a systematic review of the current literature and the second part concentrates on the results of a questionnaire that assessed the coaches' requirements for monitoring daily endurance training. The systematic review revealed that the combination of both quantitative and qualitative data seems most promising to evaluate TL and TLR. Thus, validated questionnaires or rating of perceived exertion (RPE), combined with physiological parameters, such as heart rate, are often used and seem to provide the most reliable results. From the coaches' perspective, duration and kind of training, RPE, as well as personal remarks in the athletes' training diaries are considered to be essential information. Further, the coaches favor a feasible system that collects large amounts of directly measurable and perceived data and that is able to learn from previous events in order to present the most important information in a short individual overview. When comparing both parts of the present study, it becomes clear that the scientific research cannot yet fully respond to the coaches' requests, however, based on the coaches' propositions, scientific research might be stimulated to tackle this challenge in the near future.

Key words:
training load and responses, monitoring training, training intensity, endurance athletes

Zusammenfassung

Die präzise Erfassung der Belastung und Beanspruchung eines Trainings kann zu einer verbesserten Trainingssteuerung und zur Vermeidung von Übertraining führen. In der Literatur wurde bisher keine einheitliche Gold-Standard-Methode zur Messung der Trainingsbelastung oder -intensität von Ausdauerathleten präsentiert. Das Ziel dieser Publikation ist i) die Identifikation von validen, praktisch anwendbaren Parametern zur Messung von Belastung und Beanspruchung im täglichen Training und ii) der Vergleich der wissenschaftlichen Erkenntnisse mit den Bedürfnissen von Spitzensport-Trainern für ein tägliches Trainingsmonitoring mit Ausdauerathleten. Dazu enthält der erste Teil eine systematische Literaturübersicht, während der zweite Teil die Resultate einer Befragung von 22 Spitzensport-Trainern mittels Fragebogen aufzeigt. Die systematische Literaturübersicht zeigte, dass die Kombination von quantitativen und qualitativen Daten am vielversprechendsten für die Erfassung von Trainingsbelastung und -beanspruchung ist. Daher werden oft valide Fragebogen oder die wahrgenommene Erschöpfung (RPE) mit physiologischen Daten wie der Herzfrequenz kombiniert. Aus Sicht der Trainer sind die Dauer und Art des Trainings, RPE sowie persönliche Bemerkungen im Trainingstagebuch der Athleten die wichtigsten Daten für das Trainingsmonitoring. Zusätzlich wünschen sich die befragten Trainer ein praktisch anwendbares System zur Sammlung verschiedener objektiv messbarer und subjektiv wahrgenommener Parametern, welches aufgrund der früheren Daten lernfähig ist und die essenziellsten Daten jeweils in einer individuellen Übersicht präsentiert. Ein Vergleich der beiden Teile der vorliegenden Studie zeigt, dass die wissenschaftlichen Erkenntnisse die Bedürfnisse der Trainer noch nicht umfassend berücksichtigen. Wenn man jedoch die Vorschläge der Trainer in die wissenschaftliche Forschung mit einbezieht, könnte diese Herausforderung in näherer Zukunft angegangen werden.

Schlüsselwörter:
Belastung, Beanspruchung, Trainingsmonitoring, Trainingsintensität, Ausdauerathleten

Introduction

Monitoring training intensity and load might be a key factor for further improvements in elite athletes' training programs. Generally, monitoring training means the systematic collection of data about duration, intensity, and content of training sessions. Both coaches and athletes may benefit from monitoring daily training load (TL) for at least two important reasons: first, training regulation can be improved to accomplish more efficient and individual training sessions and second, overtraining may be prevented [19]. With reference to monitoring training, the present study distinguishes between the terms TL and training load response (TLR). Training load explains the forces acting on the body [3], TLR summarizes the body's internal responses to this external stimulus [50]. These TLRs can be further divided into measurable data and perceived responses.

Although several monitoring studies and reviews have been published, there is no consensus on a gold-standard method for assessing TL and TLR and, more importantly, the interrelation of TL and TLR [7, 33]. The reason for this is that the correlation between training and the corresponding physical responses is highly individual. Interestingly, few studies have been conducted that focus on monitoring daily training with elite endurance athletes. However, endurance athletes often train alone, without their coaches present. Therefore, it could be of great importance for endurance athletes to systematically collect individual data for an optimized training regulation.

The publication at hand is divided into two parts. The first part concentrates on a systematic literature review on monitoring daily TL and TLR of endurance athletes. In the second part, elite coaches who train top athletes discussed the most important requirements of coaches when monitoring TL and TLR. The results from the focus group discussions were compared with the systematic literature review to see how the scientific results match up with the coaches' requirements for monitoring daily training.

Methods

Part 1: Review

The protocol for the systematic search was defined beforehand and not altered afterwards. The PubMed database was searched up to July 18, 2013 using the following keywords: (quantification, quantify, measuring, measurement, monitoring, GPS, accelerometer, diary, heart rate, sleep OR EPOC) AND (exercise, training intensity, training load, athletic performance, endurance athlete, rate of perceived exertion, session RPE, sport, subjective OR objective) NOT (disease, cancer, patient, animal, rat, primate, pig, cow, paraplegia, child, children, drug, plant, cells, pregnant OR pregnancy). All publications were screened by their title and abstract. Those publications not relevant to this review were discarded after this step. The full texts of the remaining publications were read and analyzed in detail, focusing on study population, setting, and outcomes of monitoring physiological and psychological markers for TL and TLR during and after daily training. Moreover, the reference lists of the pertinent publications were manually scanned to check for other publications that met the inclusion criteria.

Inclusion and exclusion criteria

Only studies focusing on endurance activities and training interventions were included in this review. Studies concerning resistance training, team sports, performance tests, or recovery and sleep quality were not considered for analysis. Publications without sufficient information about the methods used were also excluded.

Part 2: Focus Group Discussions

Two focus group sessions with Swiss elite coaches were conducted in Fall 2012. The topic was monitoring training in endurance sports. The coaches discussed current and previous approaches for monitoring daily training of their athletes and what methods they would like to use in the future. The focus group discussions were conducted in small groups with up to eight participants. The groups had a nondirective group leader who asked the input questions but did not judge or lead the discussion in a certain direction [40]. The discussions were then transliterated into a text protocol. The statements were allotted to predefined categories, and analyzed with the MAXQDA 10 software (VERBI GmbH, Berlin, Germany), as described previously [32]. The most important findings were summarized in a questionnaire, which was sent to the participants and further coaches. The completed questionnaires were re-sent to the investigator and analyzed quantitatively.

Participants

Eleven previous or current coaches of elite athletes in the sports disciplines of cycling, triathlon, orienteering, track and field, and alpine skiing participated in the two focus group sessions. The focus group participants gave written informed consent. Finally, 22 participants answered the questionnaire, which was based on the most important findings from the focus groups.

Results

Part 1: Review

The PubMed search generated 8532 publications. All the publications were screened by title, and the full abstracts of 151 articles were read. The full texts of 25 publications were evaluated for this paper. By manually scanning the reference lists of the abovementioned publications, another 25 studies that met the inclusion criteria were found.

The available literature cited several parameters to assess TL and TLR: duration of training, distance covered on foot or bike, speed, intensity, or kind of activities in the past were reported for TL. Training load response was assessed by measuring heart rate (HR), heart rate variability (HRV), blood lactate concentration (BLC), blood and saliva hormones, oxygen consumption ($\dot{V}O_2$), or by perceived measures such as rating of perceived exertion (RPE) or self-reported questionnaires *(Table 1)*. The relationships among variables assessing TL and TLR were further used to predict performance outcomes.

Table 1: Parameters for Monitoring Daily Training in the Literature

Parameter	Number of Studies	Sports		Feasibility	Validity	References
Duration and Kind of Activity	16	Triathlon, Running, Cycling, Track and Field, Swimming, Rowing		+	+	[9, 12, 14, 16, 17, 22, 23, 25, 28, 38, 46, 47, 48, 52, 54, 57]
Heart Rate	23	Triathlon, Running, Cycling, Swimming		0/+	+	[2, 4, 8, 9, 10, 15, 16, 17, 23, 25, 26, 27, 36, 39, 41, 46, 47, 48, 49, 53, 54, 55, 57]
Heart Rate Variability	8	Triathlon, Running, Rowing		0/+	0	[9, 11, 22, 24, 44, 45, 46, 55]
Blood Lactate Concentration	9	Triathlon, Cycling, Swimming, Rowing		–	+	[2, 8, 17, 36, 39, 42, 52, 53, 54]
Hormones in Blood and Saliva	11	Triathlon, Running, Cycling, Swimming, Rowing	B S	– 0/+	+ 0	[4, 14, 16, 17, 23, 27, 36, 52, 53, 54, 55]
Oxygen Consumption	6	Triathlon, Cycling		–	+	[2, 10, 14, 23, 39, 54]
Rating of Perceived Exertion	16	Triathlon, Running, Cycling, Swimming		+	+	[4, 8, 10, 14, 19, 20, 25, 26, 27, 36, 38, 48, 49, 55, 56, 57]
Questionnaires	11	Triathlon, Running, Cycling, Track and Field, Swimming, Rowing		0	+	[4, 12, 14, 16, 17, 27, 28, 36, 38, 44, 52]

Note. Feasibility for daily use and validity are summarized from the conclusions of the included studies. + = recommended; 0 = neither recommended nor inadvisable; – = inadvisable; B = blood, S = saliva.

Part 2: Focus Group Discussions

Monitoring of training load in daily practice

The coaches who participated in the focus group discussions agreed on the requirement of measured and self-reported data from the athletes on a daily basis in order to adapt training plans to the athletes' actual conditions. The most important information seems to be the personal comments of athletes regarding their training or health status in the training diary, such as "My knees hurt". This type of information comprises essential data for 95% of the 22 elite performance coaches answering the follow-up questionnaire. The RPE (90%), as well as duration and kind of training (81%), are also regarded as important to regulate training. Almost two-thirds (63%) of the coaches stated that they demanded reports about the duration and RPE of each training session from the athletes to calculate session RPE. Interestingly, only 22% of the coaches think that a fatigue index is relevant for their daily work *(Fig. 1)*. A reason might be the coaches' lack of confidence in one of the existing indexes to quantify fatigue, e.g. HRV [30, 31], or the missing practicability and knowledge of analysis and interpretation. An often-mentioned problem was the low return rate of training data by many athletes. According to 86% of the coaches, athletes have to be convinced of the benefits of monitoring training, or they will not properly report their training data. Furthermore, coaches reported that the coaches themselves should better acknowledge the information sent by the athletes and give them prompt feedback.

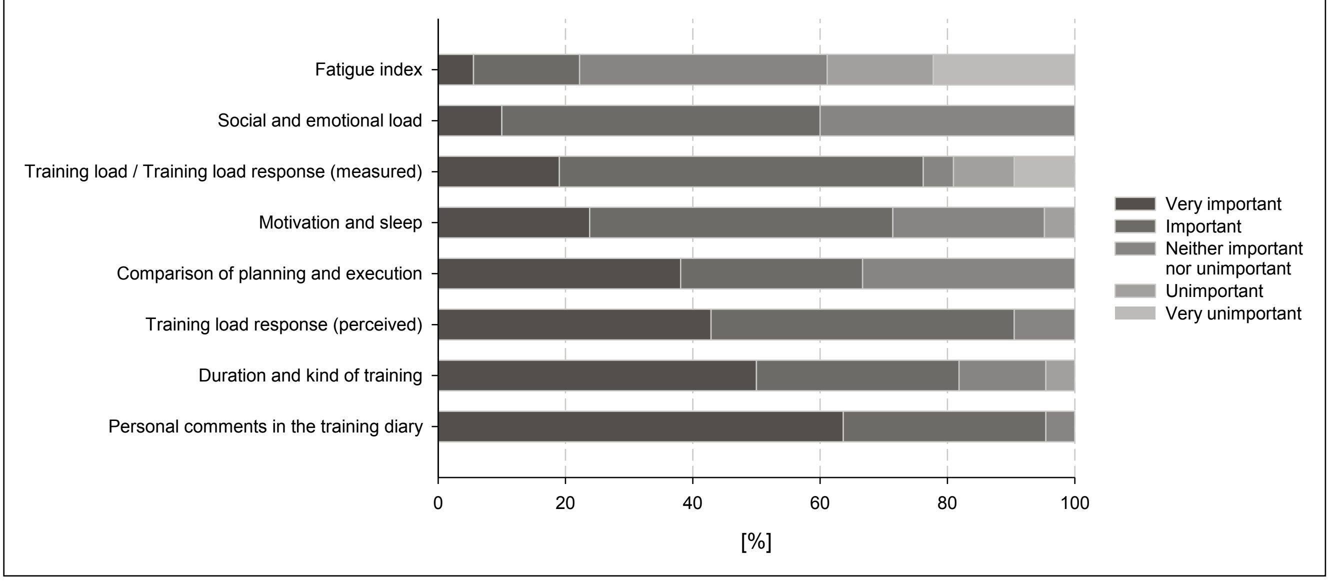

Figure 1. Coaches' opinions about the importance of monitoring daily training parameters for training regulation.

Coaches' visions of monitoring daily training in the future

Coaches would like a feasible system that collects a large amount of different data, with the adapting intelligence to present only the most important information in a short individual overview. The majority of the interviewed coaches (95%) believed that feasibility is most important when creating a new monitoring system. Therefore, 91% of the coaches would like to use data transition from athlete to coach by a smartphone application. For 86% of the coaches, an automated summary of all monitoring data into a simple index, with the possibility to review all original data, would be desirable. In the focus group discussions, the coaches mentioned a colored warning system to visualize positive or negative training patterns. However, all the coaches agreed that no system can replace their judgment and personal interaction with each athlete. Further, even with a functioning learning system, coaches still need to have the knowledge on how to appropriately adapt training content after a warning sign.

Discussion

Training Load

Kind of activity, duration, distance, speed, and intensity

The kind of activity was named and assessed in almost every study included in the present review *(Table 1).* Training duration per day has been used in several studies to calculate training impulse (TRIMP) or training intensity, either in combination with HR or RPE data [23, 38, 55]. Banister proposed the TRIMP formula: *training impulse = duration* × *ΔHR ratio* × $e^{b \times \Delta HR\ ratio}$. Training duration is measured in minutes and b is equal to 1.67 or 1.92 for women and men, respectively [1]. Edwards [18] proposed the summated HR zone score to measure TL. Five HR intensity zones were defined, starting with factor 1 corresponding to 50–60%HR_{max} and ending with factor 5 corresponding to 90–100%HR_{max}. The duration in minutes in each HR intensity zone was multiplied with its specific factor (1–5) and then summed in order to obtain the summated HR zone score [18]. Lucia [37] proposed the same approach, but with only three intensity zones. Further, Foster et al. [20] proposed the session RPE, where the duration of the training is multiplied with the corresponding RPE value on a scale from 0–10. This is a simple method to compute perceived TLR. In conclusion, kind of activity, duration, distance, and speed are simple and valid measures in endurance sports [21, 29].

Training Load Response – Directly Measured Variables

Heart rate

The HR can easily be assessed, therefore many athletes and scientists monitor this parameter *(Table 1).* However, the benefit of using HR to determine TLR is still up for debate, and studies reveal divergent results. For instance, Sperlich et al. [53] concluded that HR monitoring during MTB racing is a valuable tool for coaches and athletes to describe exercise intensity, whereas Burr et al. [10] deemed that HR and RPE measurements alone are not sufficient to assess the physical demands in that sport. In another study by Le Meur et al. [36], HR data were shown to be a valid indicator of an overtraining state. However, another study with triathletes was not successful in identifying a useful diagnostic pattern in HR and BLC markers when comparing an overtraining with a normal training group [13]. Although results of the abovementioned studies are not consistent, they nevertheless show that HR is often used in combination with other parameters and that this may improve the added value. In many studies, HR is therefore used in combination with duration of training to quantify TLR and is often expressed as $TRIMP_{HR}$, so that a single number represents total TLR [48].

Finally, HR seems to be an important parameter to assess individual TLRs in endurance sports. However, HR values have to be interpreted with caution, because even under controlled conditions, when no change of training status can be observed, HR variation is 6–7 beats per minute [34, 35]. Furthermore, several factors, such as temperature, dehydration, medication, diurnal changes, or participation in competition, can influence HR [34]. However, the validity of this measure can be increased when taking into account additional parameters such as RPE or BLC.

Heart rate variability

In a study with middle-distance runners HRV was reported to be a potentially good indicator of cumulated TL and a useful measure for regulation of training content [43]. Large correlations were observed (r=-0.62 and r=0.73) when comparing relative changes in 10-km performance time with 1-week averaged resting HR and HRV [46]. The same authors concluded that longitudinal HRV data averaged over a 1-week period might be a more susceptible variable for identifying changes in fatigue, recognition of overreaching states, and fitness than single-day values. Resting HR might be the better measure when assessing single-day values only [44, 46]. These authors also pointed out that to comprehend individual HRV, long-term monitoring of each athlete is necessary.

The measurement of HRV is reliable and applicable in everyday monitoring of training. The HRV measures might constitute an added value for coaches' training regulation when averaged over several days and monitored for a longer period of time. It has to be kept in mind that HRV measures are highly individual, even more so than regular HR recordings, and it is therefore not possible to apply a general HRV concept to every athlete [11, 35, 46, 45].

Blood lactate concentration

Several studies measured BLC during and after exercise [2, 16, 52]. Le Meur et al. [36] considered ΔBLC to be the most precise parameter in differentiating between normal and overtraining states. However, BLC reacts differently during a continuous aquatic cycling protocol compared to an intermittent protocol [8]. The advantages of ΔBLC and ΔHR are their objectivity and the little cost to measure them [36]. Nonetheless, BLC measures are usually invasive and therefore more difficult to apply than the assessment of HR [39, 53]. To counteract this problem in the future, measuring the lactate concentration on the skin surface was suggested [42]. A study indicated that this might be feasible, as it was shown that the skin surface lactate concentration on the working muscle increased significantly after five minutes of exercise, whereas concentration did not change significantly on nonworking muscles [42].

Hormones and proteins in blood and saliva

High levels of creatine kinase (CK) were reported in a study assessing the demands of a multistage mountain running race [23]. This marker is a symptom of muscle damage and strain. However, no systematic interrelations between inflammatory blood and urea markers and overreaching or overloading were observed in rowers and triathletes [14, 52]. Bloomer and Farney [4] studied changes in plasma volume during different exercise types (from aerobic cycle exercise to interval sprints). Plasma volume decreased significantly for all exercise bouts, but greatest reduction was observed after the sprint exercises (~19%). Thirty minutes after exercise cessation, plasma volume values almost returned to baseline [4]. However, the consequences of these changes and implications for performance, regeneration, and risk of overtraining are still unknown.

Due to the easier collection and analysis of salivary proteins, as compared to blood parameters, this marker is more feasible in assessing athletes' training activities [16, 17]. Nonetheless, it remains unclear how well salivary proteins can be used to measure TLR. In the abovementioned study by Smith et al. [52], cortisol and testosterone levels were assessed from saliva samples. Contrary to the results with the blood CK, no significant results for cortisol or testosterone concentrations were observed. However, very recently published studies are more promising [16, 17, 27]. Gomez et al. [16] analyzed plasma and salivary proteins in relation to TL in elite swimmers. During a 21-week training period, the plasma catecholamines and salivary proteins showed a significant inverse relationship with intensity and TL (all $p<0.01$). In particular, adrenaline correlated strongly with TL. Salivary alpha-amylase and total protein strongly correlated with adrenaline ($r=0.83$ and $r=0.59$, respectively) [16]. Similarly, Hough et al. [27] reported decreased testosterone and cortisol levels after a group of cyclists underwent an 11-day intensified training period. Collection and analysis of salivary markers is easy, affordable, and has obvious advantages compared to blood markers. However, further research to advance this non-invasive method is needed.

Training Load Response – Perceived, Self-Reported Variables

Rating of perceived exertion

Almost all studies analyzed utilized some sort of self-reported RPE scale. The scales used most often were the Borg 6-20, Borg CR10, and the Foster scale [6, 20]. Previous studies reported a strong correlation between RPE and physiological TLRs, such as $\dot{V}O_{2max}$, HR_{max}, HR reserve, or BLC [5, 20, 25, 49, 51]. The RPE can be used to compare differences among training protocols or sports disciplines [8, 26, 27, 38, 56] and may prevent overtraining when monitored continuously [19]. Session RPE, equal to the $TRIMP_{RPE}$, is normally reported about 30 minutes after cessation of exercise [20]. Rodriguez-Marroyo et al. [48] observed cyclists during a 21-stage cycling tour, comparing $TRIMP_{HR}$ with $TRIMP_{RPE}$. $TRIMP_{HR}$ and $TRIMP_{RPE}$ correlated between 0.62–0.89. In line with other authors, their suggestion was to prefer $TRIMP_{RPE}$ to $TRIMP_{HR}$ [48, 57].

Questionnaires

Self-reported questionnaires are a common tool for monitoring training. They are applied to assess perceived sensations during training, as well as physical and physiological well-being before and after training [13]. Diaz et al. [16] used the Profile of Mood States questionnaire (POMS) to assess how athletes were feeling during the training period. The POMS assesses tension, depression, anger, confusion, vigor, and fatigue [16]. Some studies used a training diary to recollect TL, injuries and illness incidences [12, 28]. This method was successful in documenting acute, overuse injuries and illnesses with a Cronbach's α of 0.96 [12]. Hough et al. [27] concluded that assessing training stress with different methods of questionnaires and hormonal markers might be useful in the prevention of overtraining states [27]. Coutts et al. [14] reported similar results about the RESTQ-76 sport questionnaire being a useful tool to monitor stress-recovery balance in athletes. Le Meur et al. [36] successfully combined a questionnaire on athletes' pain, tiredness, and well-being with physiological measurements to detect overreaching among endurance athletes. It seems the use of a validated questionnaire and diary, combined with physiological measures, is an applicable method to assess TL and TLR.

Prediction of Endurance Performance

Some of the analyzed studies showed that combining TL with TLR variables can be used to predict athletes' performance or fitness levels. Many authors support the use of HR as a value for TLR in relation to TL to monitor changes in training status [8, 15, 27, 35, 41, 55].

Coaches' Visions are Ahead of Scientific Research

Based on the coaches' statements, directly measured physiological parameters and self-reported information is necessary to adequately and individually regulate training. At the same time, coaches want a system that reduces the total amount of information to the most relevant facts and that is able to learn from previous events. The current review highlights that these requests cannot be met by scientific approaches at the moment. However, some of the discussed parameters in this paper do have the potential to be assessed regularly and may serve as inputs in a learning system. The most feasible parameters today are HR, HRV, and RPE, often used in combination with the duration of the training session. Furthermore, the non-invasive assessment of hormone and protein concentration from saliva samples may allow the integration and evaluation of these parameters in daily training, when the necessary equipment is available.

Study Limitations

Although a systematic approach was employed, relevant publications might have been missed. Despite assessing the same parameter, the measurement methods varied often; thus, comparability was limited. Moreover, one should bear in mind that different requirements exist for elite versus regularly trained athletes. It might be that results from one group cannot be generalized to the other group.

Conclusion

Monitoring daily training load might be beneficial for an optimized athlete development, due to better training regulation and the possibility of detecting overtraining or injuries early on. Only a few studies exist on the systematic collection of data about duration, intensity, and content of daily endurance training sessions. More publications focus on the pre- and post-effects of a prolonged overload intervention. Performance tests and medical check-ups are relevant and should be conducted regularly to track changes in performance. Unfortunately, the methods to assess performance are not convenient for daily training, since they tend to be invasive, exhausting, expensive, and time-consuming. Several physiological and psychological markers or questionnaires have been suggested as feasible for the assessment of TL and TLR. However, at present, no generally applicable method for directly measuring TL and TLR has been reported for endurance disciplines. The most frequently used methods seem to be the calculation of a HR- or RPE-based TRIMP and the use of questionnaires. Despite the obvious benefits of the TRIMPs, further research is needed in the setting of daily training, given that the current findings of scientific research cannot live up to coaches' requirements. The assessment of feasible markers for TL and TLR, and their implementation in a learning system database that collects and analyzes large amounts of data to identify the most essential information for coach and athlete, might still take time. Coaches and sports scientists should initiate a more intense dialogue about the development and interpretation of a TL and TLR classification system without compromising on feasibility, validity, objectivity, and reliability.

Conflict of Interest

No external funding was received, and the authors declare no conflict of interest with the publication of this study.

Address corresponding author

Lilian Roos, Performance Sports Division, Swiss Federal Institute of Sports Magglingen SFISM, CH-2532 Magglingen, Phone +41 32 327 61 23, Fax +41 32 327 64 04, E-Mail Lilian.Roos@baspo.admin.ch

References

1 Banister E.W. (1991). Modeling elite athletic performance. Champaign, Illinois: Human Kinetics.
2 Barbosa L.F., Montagnana L., Denadai B.S., Greco C.C. (in print). Reliability of cardiorespiratory parameters during cycling exercise performed at the severe domain in active individuals. J Strength Cond Res.
3 Beyer E. (1987). Wörterbuch der Sportwissenschaft / Dictionary of sport science. Schorndorf: Karl Hofmann.
4 Bloomer R.J., Farney T.M. (2013). Acute plasma volume change with high intensity sprint exercise. J Strength Cond Res, 27(10), 2874–2878.
5 Borg G. (1970). Perceived exertion as an indicator of somatic stress. Scand J Rehabil Med, 2(2), 92–98.
6 Borg G.A. (1982). Psychophysical bases of perceived exertion. Med Sci Sports Exerc, 14(5), 377–381.
7 Borresen J., Lambert M.I. (2009). The quantification of training load, the training response and the effect on performance. Sports Med, 39(9), 779–795.
8 Brasil R.M., Barreto A.C., Nogueira L., Santos E., Novaes J.S., Reis V.M. (2011). Comparison of physiological and perceptual responses between continuous and intermittent cycling. J Hum Kinet, 29A, 59–68.
9 Buchheit M., Chivot A., Parouty J., Mercier D., Al Haddad H., Laursen P.B. et al. (2010). Monitoring endurance running performance using cardiac parasympathetic function. Eur J Appl Physiol, 108(6), 1153–1167.
10 Burr J.F., Drury C.T., Ivey A.C., Warburton D.E. (2012). Physiological demands of downhill mountain biking. J Sports Sci, 30(16), 1777–1785.
11 Cipryan L., Litschmannova M. (2013). Intra-day and inter-day reliability of heart rate variability measurement. J Sports Sci, 31(2), 150–158.
12 Clarsen B., Ronsen O., Myklebust G., Florenes T.W., Bahr R. (in print). The Oslo Sports Trauma Research Center questionnaire on health problems: A new approach to prospective monitoring of illness and injury in elite athletes. Br J Sports Med.
13 Coutts A.J., Slattery K.M., Wallace L.K. (2007). Practical tests for monitoring performance, fatigue and recovery in triathletes. J Sci Med Sport 10(6), 372–381.
14 Coutts A.J., Wallace L.K., Slattery K.M. (2007). Monitoring changes in performance, physiology, biochemistry, and psychology during overreaching and recovery in triathletes. Int J Sports Med, 28(2), 125–134.
15 Daanen H.A.M., Lamberts R.P., Kallen V.L., Jin A.M., Van Meeteren N.L.U. (2012). A Systematic Review on Heart-Rate Recovery to Monitor Changes in Training Status in Athletes. Int J Sports Physiol Perform, 7(3), 251–260.
16 Diaz Gomez M.M., Bocanegra Jaramillo O.L., Teixeira R.R., Espindola F.S. (2013). Salivary surrogates of plasma nitrite and catecholamines during a 21-week training season in swimmers. PLoS One, 8(5), e64043.
17 Diaz M.M., Bocanegra O.L., Teixeira R.R. Soares S.S., Espindola F.S. (2013). Salivary nitric oxide and alpha-amylase as indexes of training intensity and load. Int J Sports Med, 34(1), 8–13.
18 Edwards S. (1993). Heart rate monitor book. Sacramento: Fleet Feet Press.
19 Foster C. (1998). Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc, 30(7), 1164–1168.
20 Foster C., Florhaug J.A., Franklin J., Gottschall L., Hrovatin L.A., Parker S. et al. (2001). A new approach to monitoring exercise training. J Strength Cond Res, 15(1), 109–115.
21 Frencken W.G.P., Lemmink K.A.P.M., Delleman N.J. (2010). Soccer-specific accuracy and validity of the local position measurement (LPM) system. J Sci Med Sport, 13(6), 641–645.
22 Furholz M., Radtke T., Roten L., Tanner H., Wilhelm I., Schmid J.P. et al. (2013). Training-related modulations of the autonomic nervous system in endurance athletes: is female gender cardioprotective? Eur J Appl Physiol, 113(3), 631–640.
23 Gatterer H., Schenk K., Wille M., Raschner C., Faulhaber M., Ferrari M. et al. (2013). Race performance and exercise intensity of male amateur mountain runners during a multistage mountain marathon competition are not dependent on muscle strength loss or cardiorespiratory fitness. J Strength Cond Res, 27(8), 2149–2156.
24 Grant C.C., Janse van Rensburg D.C. (2013). The contribution of preintervention blood pressure, VO2max, BMI, autonomic function and gender to exercise-induced changes in heart rate variability. Br J Sports Med, 47(9), 575–578.
25 Herman L., Foster C., Maher M.A., Mikat R.P., Porcari J.P. (2006). Validity and reliablity of the session RPE method for monitoring exercise intensity. S Afr J Sports Med, 18(1), 14–17.
26 Hornsby J.H., Green J.M., O'Neal E.K., Killen L.L., McIntosh J.R., Coates T.E. (2013). Influence of terminal RPE on session RPE. J Strength Cond Res, 27(10), 2800–2805.
27 Hough J., Corney R., Kouris A., Gleeson M. (2013). Salivary cortisol and testosterone responses to high-intensity cycling before and after an 11-day intensified training period. J Sports Sci, 31(14), 1614–1623.
28 Huxley D.J., O'Connor D., Healey P.A. (in print). An examination of the training profiles and injuries in elite youth track and field athletes. Eur J Sport Sci.
29 Johnston R.J., Watsford M.L., Pine M.J., Spurrs R.W., Murphy A.J., Pruyn, E.C. (2012). The Validity and Reliability of 5-Hz Global Positioning System Units to Measure Team Sport Movement Demands. J Strength Cond Res, 26(3), 758–765.
30 Kaikkonen P., Hynynen E., Mann T., Rusko H., Nummela A. (2010). Can HRV be used to evaluate training load in constant load exercises? Eur J Appl Physiol, 108(3), 435–442.
31 Kaikkonen P., Hynynen E., Mann T., Rusko H., Nummela A. (2012). Heart rate variability is related to training load variables in interval running exercises. Eur J Appl Physiol, 112(3), 829–838.
32 Kuckartz U. (2012). Qualitative Inhaltsanalyse. Methoden, Praxis, Computerunterstützung. Weinheim: Beltz Juventa.
33 Lambert M.I., Borresen J. (2010). Measuring training load in sports. Int J Sports Physiol Perform, 5(3), 406–411.
34 Lambert M.I., Mbambo Z.H., St. Clair Gibson A. (1998). Heart rate during training and competition for long-distance running. J Sports Sci, 16 Suppl, S85–90.

35 Lamberts R.P., Lemmink K.A., Durandt J.J., Lambert M.I. (2004). Variation in heart rate during submaximal exercise: Implications for monitoring training. J Strength Cond Res, 18(3), 641–645.
36 Le Meur Y., Hausswirth C., Natta F., Couturier A., Bignet F., Vidal P.P. (2013). A multidisciplinary approach to overreaching detection in endurance trained athletes. J Appl Physiol, 114(3), 411–420.
37 Lucia A., Hoyos J., Carvajal A., Chicharro J.L. (1999). Heart rate response to professional road cycling: The Tour de France. Int J Sports Med, 20(3), 167–172.
38 Malisoux L., Frisch A., Urhausen A., Seil R., Theisen D. (in print). Monitoring of sport participation and injury risk in young athletes. J Sci Med Sport.
39 Mann T., Lamberts R.P., Lambert M.I. (2013). Methods of prescribing relative exercise intensity: Physiological and practical considerations. Sports Med, 43(7), 613–625.
40 Mayring P. (2010). Qualitative Inhaltsanalyse. Weinheim: Beltz.
41 Nelson M.J., Thomson R.L., Rogers D.K., Howe P.R., Buckley J.D. (in print). Maximal rate of increase in heart rate during the rest-exercise transition tracks reductions in exercise performance when training load is increased. J Sci Med Sport.
42 Ohkuwa T., Tsukamoto K., Yamai K., Itoh H., Yamazaki Y., Tsuda T. (2009). The relationship between exercise intensity and lactate concentration on the skin surface. Int J Biomed Sci, 5(1), 23–27.
43 Pichot V., Roche F., Gaspoz J.M., Enjolras F., Antoniadis A., Minini P. et al. (2000). Relation between heart rate variability and training load in middle-distance runners. Med Sci Sports Exerc, 32(10), 1729–1736.
44 Plews D.J., Laursen P.B., Kilding A.E., Buchheit M. (2012). Heart rate variability in elite triathletes, is variation in variability the key to effective training? A case comparison. Eur J Appl Physiol, 112(11), 3729–3741.
45 Plews D.J., Laursen P.B., Stanley J., Kilding A.E., Buchheit M. (2013). Training adaptation and heart rate variability in elite endurance athletes: Opening the door to effective monitoring. Sports Med, 43(9), 773–781.
46 Plews D.J., Laursen P.B., Kilding A.E., Buchheit M. (in print). Evaluating training adaptation with heart rate measures: A methodological comparison. Int J Sports Physiol Perform.
47 Rodriguez-Marroyo J.A., Pernia R., Cejuela R., Garcia-Lopez J., Llopis J., Villa J.G. (2011). Exercise intensity and load during different races in youth and junior cyclists. J Strength Cond Res, 25(2), 511–519.
48 Rodriguez-Marroyo J.A., Villa J.G., Fernandez G., Foster C. (2013). Effect of cycling competition type on effort based on heart rate and session rating of perceived exertion. J Sports Med Phys Fitness, 53(2), 154–161.
49 Rodriguez-Zamora L., Iglesias X., Barrero A., Torres L., Chaverri D., Rodriguez F.A. (in print). Monitoring internal load parameters during competitive synchronized swimming duet routines in elite athletes. J Strength Cond Res.
50 Röthig P. (2003). Sportwissenschaftliches Lexikon. Schorndorf: Hofmann.
51 Scherr J., Wolfarth B., Christle J.W., Pressler A., Wagenpfeil S., Halle M. (2013). Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. Eur J Appl Physiol, 113(1), 147–155.
52 Smith T.B., Hopkins W.G., Lowe T.E. (2011). Are there useful physiological or psychological markers for monitoring overload training in elite rowers? Int J Sports Physiol Perform, 6(4), 469–484.
53 Sperlich B., Achtzehn S., Buhr M., Zinner C., Zelle S., Holmberg H.C. (2012). Salivary cortisol, heart rate, and blood lactate responses during elite downhill mountain bike racing. Int J Sports Physiol Perform, 7(1), 47–52.
54 Tschakert G., Hofmann P. (in print). High-intensity intermittent exercise – Methodological and physiological aspects. Int J Sports Physiol Perform.
55 Vesterinen V., Hakkinen K., Hynynen E., Mikkola J., Hokka L., Nummela A. (2013). Heart rate variability in prediction of individual adaptation to endurance training in recreational endurance runners. Scand J Med Sci Sports, 23(2), 171–180.
56 Wallace L., Coutts A., Bell J., Simpson N., Slattery K. (2008). Using session-RPE to monitor training load in swimmers. J Strength Cond Res, 30(6), 72–76.
57 Wallace L.K., Slattery K.M., Coutts A.J. (2009). The ecological validity and application of the session-RPE method for quantifying training loads in swimming. J Strength Cond Res, 23(1), 33–38.