

Monitoring the swimmer's training load: A narrative review of monitoring strategies applied in research

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The high incidence of injury during swim training and the increasing demands of the sports make monitoring of the swimmer's training load a key concept requiring further investigation. Research has previously introduced numerous methods for the purposes of monitoring the swimmer's training load, but a narrative review discussing the strengths and limitations of each method is lacking. Consequently, this narrative review aims to summarize the monitoring strategies that have been applied in research on competitive swimmers. This knowledge can assist professionals in the field in choosing which method is appropriate in their particular setting. The results from this study showed that external training load was predominantly obtained through real-life observation of the swimmers' training volume. However, research has investigated a number of internal load monitoring tools, including blood lactate, training heart rate, and perceived effort of training. To date, blood lactate markers are still considered most accurate and especially recommended at higher levels of competitive swimming or for those at greater risk of injury. Further, mood state profiling has been suggested as an early indicator of overtraining and may be applied at the lower competitive levels of swimming. Professionals in the field should consider the individual, the aim of the current training phase, and additional logistical issues when determining the appropriate monitoring strategy in their setting.

KEYWORDS

load monitoring, review, swimming

1 | INTRODUCTION

Since the establishment of the Olympic Games in 1896, competitive swimming has grown to become one of its largest disciplines.¹ As a result, its competitive level has increased accordingly but this requires the swimmers to prepare differently for major swimming events. Modern swim-training programs are now characterized by year-round swimming with little time for off-season recovery.^{2,3} In fact, these training programs seem inherently volume dependent, with elite athletes swimming up to 57.1 km/wk.⁴

Swim-training programs primarily aim to induce adaptations to the body that allow the swimmer to perform better in competition⁵ but this requires a carefully pre-determined combination of training intensity, volume, and rest.⁶ However, researchers have suggested that swimmers train too much according to their capabilities^{3,4,7} and that they restrain their body from sufficient rest and recovery that is required for optimal adaptation.⁸ During their 10- to 15-year careers, swimmers frequently practise up to seven days per week,³ logging between 10 000 and 14 000 meters.² This excessive exposure to swimming has been linked to overtraining⁹ and increases the risk of

soft-tissue injury, pain, and dissatisfaction.^{3,7,10} Shoulder pain is particularly frequent^{11,12} and, with prevalence rates reported as high as 91%,⁷ is a major cause of missed practice.¹³

The establishment of a high injury incidence and the increasing demands of swim-training programs make monitoring of the swimmer's training load a key concept requiring further investigation.¹⁶ The competitive swimmer's training load units can be thought of as either external or internal.¹⁷ External load refers to the actual work completed by the athlete^{17,18} and provides valuable information in determining the swimmer's capabilities. However, coaches frequently prescribe these loads regardless of the athlete's individual characteristics¹⁹ and these seem to play an important role in how the athlete perceives and, subsequently, adapts to training.²⁰ The internal load, or the relative physiological, psychological, and biomechanical stress imposed on the athlete^{17,18} is also critical in determining the training load.¹⁸ Even more so, this combination of external with internal load has been suggested to aid in revealing fatigue or in identifying periods when the athlete might be more prone to injury.^{21,22}

Previous research has introduced a number of methods to quantify either the external or internal load of swim training. However, this variety of available methods makes it difficult for the end-user to choose which is appropriate in their particular setting²³ and a narrative review discussing the strengths and limitations of each method is lacking. Consequently, this study aims to summarize the monitoring strategies that have been applied in sports medicine research for the purposes of quantifying the swimmer's training load.

2 | METHODS

This narrative review was reported following the IMRAD (introduction, methods, results, discussion) format.²⁴ Although this study was qualitative of design, we used a systematic search and screening strategy to identify relevant literature. PubMed, Web Of Science, and SportDiscus databases were searched using combinations of the terms covering the topics of *competitive swimmers (swim* OR swimmer OR swimming) AND monitoring (monitor or track or observe or record or measure) AND training load (training volume or training load or exercise or practice or training program OR workload OR training intensity OR physical exertion)*. The search was performed by two researchers (N.D and T.D) up to January 2020. No limits were used for age or competitive level. Studies that longitudinally assessed at least one parameter of external or internal load were considered eligible for inclusion. Case-studies and systematic reviews were excluded. Studies conducted on synchronized swimmers, water-polo players, and triathletes were also excluded. Two reviewers (N.D and T.D) independently assessed the articles for eligibility based on evaluation of first the title and abstract

and second the full text. Finally, data related to (1) the investigated parameter of training load and (2) the method of monitoring were extracted from the included studies.

3 | RESULTS

Electronic database and manual searches returned 792 results. Screening excluded 764 articles, mainly because populations other than competitive swimmers were included. Finally, data were extracted from 28 eligible studies. Authors of 19 out of the 28 studies reported monitoring parameters of both external and internal training load simultaneously. Three studies assessed external training load,^{10,25,26} whereas seven studies exclusively investigated parameters of internal load.²⁷⁻³³ The monitoring methods are listed in Table S1.

3.1 | External training load

External parameters of training load were monitored in 19 out of 28 studies. Swimming volume was typically obtained and reported as the average distance^{10,25-27,34-45} or duration^{37,39,44,46,47} swam per week or per year. A number of studies also reported the volume of dry-land exercise in hours per week.^{34,35,38,40} External load parameters were either observed in real life by the coach or researcher^{10,25-27,34-37,39-45,48-50} or obtained through self-reported questionnaires during the study.^{46,47}

3.2 | Internal training load

3.2.1 | Physiological markers

Physiological markers were used either to provide an average measure of training over time (incremental testing) or to monitor a training session in progress.⁵¹ Blood lactate concentration (LA) has particularly been obtained. In these studies, researchers measured LA immediately after a workload session either by taking fingertip^{27,34-36} or earlobe^{28,30,31,42,50} blood samples. Although frequently monitored, most of the studies measuring LA solely used this parameter as a criterion value to determine the validity and reliability of other markers in estimating the internal training load,^{27,30,34-36,42} whereas only few studies applied LA profiling across the season to assess the swimmer's individual fitness level and monitor training-induced changes.^{28,31}

Training heart rate (HR) has also been used to monitor the internal load of a swim-training session.^{29,30,36,42} HR monitoring reflects a general overall body response to stress but does not necessarily tell us what is happening in the muscles or energy systems.⁸ In swimming research, traditional

tracking devices were applied immediately after a swimming session to monitor the swimmer's HR. However, similar to LA monitoring, these measures of HR were mainly obtained as a criterion value to determine the validity and reliability of alternative methods in estimating the training intensity.

Alternatively, a number of investigations have used a pre-study incremental swimming test in which the response to progressive, incremental swimming was evaluated.⁵⁴ In these studies, researchers first assessed the relationship between swimming pace and measures of HR or LA and then estimated the intensity of the training session based on the volumes that had been swum at a specific pace.^{38,40,41,45,49}

Finally, several subjective markers have been investigated for their use as an indirect measurement of the training intensity. The 15-grade scale (6-20) for rating of perceived exertion (RPE)⁵⁵ is such a marker which allows the athlete to rate its own perception of endured stress and effort during training based on a single rating. The session RPE (sRPE) is a similar subjective marker, which is based on the RPE scale and was proposed to further simplify the quantification of training load.⁵⁶ The sRPE is expressed in arbitrary units (AUs) and is calculated by multiplying the category ratio (CR-10) RPE score,⁵⁷ which is obtained 30 minutes after the training session, with the duration of the training.⁵⁶

3.2.2 | Psychological markers

Psychological markers of training load were assessed in the literature using a number of questionnaires. These include the Profile of Mood States (POMS)^{59,60} and the 19-item Training Distress (TDS)⁶¹ scale. The POMS focuses on mood disturbance as an indicator of training load⁵⁹ and describes six dimensions of the construct "mood": anger, confusion, depression, fatigue, tension, and vigor. Although its validity in assessing the training load has been confirmed,⁶² only one study reported using this questionnaire for such purposes in a competitive swimming setting.⁴⁶ Another approach to psychological monitoring of the training load involves the use of symptom checklists.^{33,47} One study investigated the swimmers' training distress over a 2-wk training period by asking participants to complete the TDS scale⁶¹ prior to every evening session. The TDS investigates a variety of symptoms such as emotionality, general fatigue, concentration difficulties, physical discomfort, sleep disturbance, and appetite changes that are likely to be representative of athlete's experiences during acute overload.

4 | DISCUSSION

We aimed to summarize the methods that have been used in research for the purposes of monitoring the swimmer's

training load. Knowledge of the inherent strengths and limitations of these monitoring strategies can aid professionals in the field in choosing which method is appropriate in their setting. The literature search resulted in 28 eligible studies. Studies that included external parameters typically monitored the swim-training volume through direct observation of the training session in real life.^{10,25-27,34-37,39-45,48-50} Internal load was investigated in 23 studies. Nine studies reported physiological measures of blood lactate,^{27,28,30,31,34-36,42,50} whereas four studies assessed the training heart rate.^{29,30,36,42} Authors of seven out of the 28 studies reported using questionnaires of perceived exertion,^{32,37,39,43,44,46,48} whereas another three studies monitored training load through psychological parameters.^{33,46,47}

4.1 | Interpretation and exploration of the findings

Our findings highlight that although investigators frequently obtained training data in real life, there is still plenty of research that reported the use of cross-sectional questionnaires for monitoring the swimmer's external training load.^{3,7,63-66} However, these data are arguably biased by social desire, individual differences, and seasonal variations in the sport,^{18,67} whereas real-life observation provides a more valid measurement of the athlete's actual work.^{67,68} Based on the literature, we advise to monitor the swimmer's external load in real life whenever a reasonably small number of swimmers are to be studied or coached. Alternatively, certain upcoming global positioning tracking systems (GPS) have already been suggested a "game changer" in this area and may aid in the conducting of long-term observational studies in large groups of swimmers.⁷²

One interesting finding of our study is that although psychological markers have not frequently been used in a swimming setting, investigators have recently suggested that continuous psychological profiling can aid in determining poor recovery state and prevent overtraining.^{60,74} The POMS is one of the few tools used in competitive swimming which has also been considered an effective and reliable warning of overtraining.⁷⁴⁻⁷⁶ This questionnaire represents the athlete's mood either by an iceberg or inverted iceberg profile, which refers to a successful athlete or one at greater risk of overtraining, respectively.⁷⁷ Although this connection has been shown reliable in a variety of sport contexts, including swimming,⁴⁷ it should be acknowledged that as with any other psychological testing, the POMS may not be suitable for all swimmers because of the intra-individual differences between the athletes. Nevertheless, many competitive swimmers face the continuously growing pressure to perform because of the increasing popularity and competitive level of the sport.^{15,78}

Failure to cope with these stressors may result in burnout or other disorders that can significantly decrease performance or increase the swimmer's susceptibility to injury.⁷⁹ These findings make psychological profiling require more attention in research. Based on the literature, a cross-sectional assessment of the POMS will only provide little information and we recommend multiple measurements across the season and advise to complement these tests with similar tools such as the TDS scale.

The results of this study also draw special attention to the rating of perceived exertion (RPE) marker. This RPE scale appears to be gaining momentum in research due to its promising correlations with training HR and LA.^{30,80,81} Although the RPE has been found valid for determining the swimmer's internal training load^{32,37,39,43,44,46,48}, its use may still be restricted due to the complex interaction of many factors that contribute to the personal perception of physical effort.⁸⁴ Investigators, therefore, recommend to complement the RPE with an objective assessment of internal training load.^{22,73,85}

Findings of our study highlight that both HR and LA were predominantly used as an objective assessment of the swimmer's training intensity. Training HR has been found to be valid⁸⁶ and reliable⁸⁷ in steady-state training sessions but is deemed rather inaccurate in a setting characterized by fluctuations in intensity (eg, competitive swimming). In contrast, LA measurements are considered more accurate in determining the training intensity as they allow assessment of the real workload of an exercise on the muscle.⁸ Most of the studies included in our review have monitored LA either by fingertip^{27,34-36} or through earlobe^{30,42} measurements. These procedures have become fairly easy to perform over the past few years¹⁸; however, it is the interpretation of LA measurements that remains rather complex⁸: lactate is produced during the anaerobic (eg, oxygen-independent) metabolism of glucose,⁸⁸ which is of particular importance during short-duration exercise at high intensity.^{54,88,89} During exercise, LA will accumulate only when its rate of efflux from the working muscles to the blood exceeds its removal to carbon dioxide.⁸⁹ This mechanism suggests that the concentration of LA is a good indicator of the muscles' capacity for an athletic performance⁸ which allows coaches to tell what physiological adaptation has taken place over time. An increase in LA for the same training stimulus may, for instance, point to an increased anaerobic metabolism and therefore higher levels of LA at slower speeds, which may be indicative of impending overtraining.⁸

The usefulness of LA measurements and the frequency with which it should be applied may ultimately depend on the swimmer's competitive level. Its complex interpretation requires LA measurements to be performed exercise-specific, even to the specific stroke one would use the information for.

This means that for a young low-level competitive swimmer, who focuses more or less on improving the swimming technique, a few lactate tests per year may be sufficient to characterize his or her physiological profile and provide an appropriate training framework. However, at higher competitive levels we advise a more accurate monitoring of the training load and recommend LA tests to be scheduled at least every few weeks, with supplemental measurements performed during training.⁸

4.2 | Limitations and recommendations for future research

There are some limitations that should be acknowledged. First and foremost, the non-systematic nature of this study limits generalizability of our results. There is no consensus on the standard structure of reporting narrative reviews,²⁴ which is a major limitation of our study methodology and restricts us from providing strong recommendations for practice.

This review focused solely on those monitoring strategies that were applied in an observational setting. Although alternative methods such as the training impulse measurement,⁴⁴ oxygen measurements,⁹⁴ or the Wingate test for anaerobic capacity and power⁹⁵ may provide additional information regarding training management, these methods have not been widely used in a longitudinal research setting involving competitive swimmers. In addition, the more invasive nature, complex calculations, or logistical difficulties of these methods may limit their use in a practical setting. Next, parameters such as stroke length, stroke rate, and the prevalence of biomechanical errors in swimming stroke may be assessed to improve the swimmer's propulsive efficiency while also decreasing the risk of injury.⁹⁶ However, the benefits of such parameters are hard to obtain when faced with large groups of swimmers. Tools such as complex video analysis and accelerometers can aid in monitoring these stroke parameters but these methods need further research before they can be implemented.⁹⁷

Psychological profiling may be another powerful tool with great potential in managing one's own training program, particularly when combined with biological markers such as hair cortisol levels for the control of chronic stress^{98,99} or cytokine profiling for the detection of overtraining and injury.^{90,100,101} In addition, measures of salivary proteins such as alpha-amylase and salivary nitrite have already shown valid responses to varying intensities and loads during swimming.^{36,92} Given the results of these studies, biological parameters may arguably grow to become standard monitoring strategies in a swimming setting but until then further research is necessary before these markers can be implemented.

5 | PERSPECTIVES TO SPORTS MEDICINE

Accurate monitoring of the athlete's training load is a key concept for optimizing performance while reducing the risk of injury. The increased risk of injury and overtraining due to the high volumes of swimming has for long been a hot topic among swimming athletes, coaches, and sport scientists. In fact, competitive swimming is in need of practice guidelines to reduce injury, but none exist. Monitoring the training load has gradually been incorporated in research but a comprehensive overview summarizing the available methods and discussing their inherent strengths and weaknesses is lacking. The findings of this study may aid clinicians working with the swimmer in determining which monitoring strategy is appropriate in their specific setting and, subsequently, enhance monitoring across the field.

CONFLICTS OF INTEREST

There are no conflicts of interest to declare.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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