Physical Therapy in Sport 53 (2022) 51–59

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

International survey of training load monitoring practices in competitive swimming: How, what and why not?

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A R T I C L E I N F O

Article history:
Received 8 July 2021
Received in revised form
10 November 2021
Accepted 12 November 2021

Keywords:
Training load
Monitoring
Barriers
Coaching
Method

A B S T R A C T

Objective: The purpose of this study is to identify the training load (TL) monitoring practices employed in real-world competitive swimming environments. The study explores data collection, analysis and barriers to TL monitoring.
Design: Cross-sectional.
Setting: Online survey platform.
Participants: Thirty-one responders working in competitive swimming programmes.
Main outcome measures: Methods of data collection, analysis, level of effectiveness and barriers associated with TL monitoring.
Results: 84% of responders acknowledged using TL monitoring, with 81% of responders using a combination of both internal and external TL, in line with current consensus statements. Swim volume (mileage) (96%) and session rate of perceived exertion (sRPE) (92%) were the most frequently used, with athlete lifestyle/wellness monitoring also featuring prominently. Thematic analysis highlighted that “stakeholder engagement”, “resource constraints” or “functionality and usability of the systems” were shared barriers to TL monitoring amongst responders.
Conclusions: Findings show there is a research-practice gap. Future approaches to TL monitoring in competitive swimming should focus on selecting methods that allow the same TL monitoring system to be used across the whole programme, (pool-based training, dryland training and competition). Barriers associated with athlete adherence and coach/National Governing Body engagement should be addressed before a TL system implementation.

1. Introduction

Swimming competitions are scheduled over several days and typically incorporate heats, semi-finals, and finals. While the majority of events last no longer than 2 min and 20 s, the traditional training practices of competitive swimmers are high in volume (m/km/min) (Nugent et al., 2019). Careful planning and periodization are at the forefront of achieving success at elite performance levels (Hellard et al., 2019). Coaches strategically fluctuate training load (TL) and recovery to push the limits of adaptation and avoid overtraining, injury or detraining (Hellard et al., 2019). The popularity of TL monitoring in sport has grown considerably in recent years (Newton et al., 2019) and has been the focus of much interest in the scientific approach to training and recovery (Hamlin et al., 2019). This is primarily due to increased sports science support (Foster et al., 2017), technological developments (Hauer et al., 2020) and professionalisation of sport (Gabbett, 2016).

Abbreviations: TL, Training Load; RPE, Rate of Perceived Exertion; sRPE, SessionRate of Perceived Exertion; NGB, National Governing Body; S&C, Strength and conditioning; TRIMP, Training Impulse.

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https://doi.org/10.1016/j.ptsp.2021.11.005
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TL monitoring is multi-dimensional, often incorporating measures of training frequency, intensity and duration, monitoring heart rate alterations, neuromuscular function, biochemical/hormonal/immunological markers and subjective wellness measures (Halson, 2014). TL can be divided into internal and external load (Bourdon et al., 2017). External load is most commonly collected and includes objective measures of the work performed by the athlete (e.g. power output, speed and distance). Internal loads are the relative biological stressors imposed on the athlete (e.g. heart rate, rate of perceived exertion (RPE), session rate of perceived exertion (sRPE) and blood lactate) (Bourdon et al., 2017). There is a consensus that both internal and external loads should be considered congruently; however, no one marker has been validated to identify a maladaptation to training and thus a holistic approach to TL monitoring is needed (Soligard et al., 2016).

The pursuit of best practice related to TL monitoring has caused an exponential increase in empirical and applied research (Bourdon et al., 2017). Much of this research has focused on land-based sport, as opposed to Olympic aquatic sports (i.e. diving, open-water swimming, pool swimming, synchronised swimming and water polo). Three systematic reviews have been published in recent years, investigating the relationship between TL, injury, illness or soreness in a broad range of sports (Drew & Finch, 2016; Eckard et al., 2018; Jones et al., 2017). Of the 160 studies reviewed, just six studies included aquatic-based populations. A recent narrative review summarised the monitoring strategies used to quantify a swimmer's TL within sports medicine research (Feijen et al., 2020). The review (28 studies) highlighted that external TL (19/28) was frequently monitored through the collection of swimming volume (average distance, duration swam per week or year) and dryland volume (hours per week). The use of internal TL (23/28) was also investigated with blood lactate concentration testing and heart rate monitoring being commonly employed. However, in this research context, both heart rate and blood lactate were often used as a criterion value to determine the validity and reliability of other markers in estimating the internal TL. RPE, sRPE (8/28) and psychological parameters/scales (3/28) were used to a lesser extent within the research investigated. Collette et al. (2018) and Zera et al. (2015) did investigate psychological parameters in more detail and found that psychological variables have high inter/intra individual differences and can fluctuate throughout a season to align with periods of high and low TL (Collette et al., 2018; Zera et al., 2015).

Even with the increased popularity and implementation of TL monitoring in professional sport, research into TL monitoring in competitive swimming is growing but not widespread. The narrative review by Feijen et al. (2020) presents a clear picture of the monitoring strategies being employed in sports medicine research. However, as the findings rely on monitoring strategies used within a research context it may not truly reflect the practices employed in a real-world context. Therefore, this study aimed to identify the TL monitoring practices being used in competitive swimming environments, while also exploring how data collection and analysis are being implemented and what measures are considered effective. Finally, barriers and facilitators to TL monitoring were also examined.

2. Methods

2.1. Experimental approach to the problem

A survey was designed to explore the TL monitoring practices of high-performance support teams in competitive swimming. The overarching research question was deliberately designed using interpretive methods, rather than a leading hypothesis. An open survey was self-administered through an online platform (Qualtrics.com). The TL survey consisted of thirty-eight questions including open and closed questions and used branch, display and skip logic functions to tailor the content depending on the specific responses. The study is reported in line with the Checklist for Reporting Results of Internet Surveys (CHERRIES) (Eysenbach, 2004). A copy of the survey is available online (Supplementary Information A) along with the CHERRIES checklist (Supplementary Information B) authors used to ensure a complete description of this web-based survey was provided (Eysenbach, 2004).

2.2. Participants

The survey was circulated globally, using swimming National Governing Bodies (NGBs) from Ireland, Great Britain, Spain, Australia and New Zealand, as well as a number of coaching associations (International Swim Coaches Association, World Coaches Swimming Association, UK Strength and Conditioning Association). In addition, coaches and practitioners from the NGBs were asked to circulate the survey to relevant contacts within the swimming community. It was requested that the individual whose primary responsibility was TL monitoring within their swim programme, irrespective of their job title, was invited to complete the survey. A total of 58 responses were collected, with 31 complete responses being included. The remaining 27 responses were excluded due to not reaching a completeness rate >85% on primary questions (excluding branch logic and optional open-ended questions). Ethical approval was granted by the University's Ethics Committee (2019_10_09_EHS). Participant information sheets (including a GDPR statement) were circulated with the questionnaire and each participant had to agree to an online informed consent form to participate in the research.

2.3. Procedures

The online survey was circulated primarily by email, but also through social media platforms (LinkedIn, Twitter) (Copy of this material can be found at supplementary information C). The aims, objectives and duration of the survey were included with each email, along with a participant information sheet. Data were collected from March 2020 to July 2020. Data gathered were identified using a code number and unnecessary personal details were not recorded or used in any part of this project. All data were stored in a locked filing cabinet in the principal researcher's office or password-protected/encrypted based on the data type. Unique responses were identified using the IP address of the participant. IP addresses were crosschecked for duplications in Microsoft Excel during analysis and not used if found to be a replication. The survey consisted of five blocks: (1) Informed Consent; (2) Demographics; (3) TL Monitoring Practices; (4) Barriers to TL Monitoring; and (5) Open-Ended Questions. Open-ended questions sought to give the responder the option of providing additional information on the links between TL monitoring and additional aspects of their programme and the barriers experienced with accurate TL monitoring. Participants could review questions, go back, and change answers throughout the survey. The survey was pilot tested, refined and redrafted in consultation with two academic colleagues with a background in survey design, as well as two multi-sport high-performance support staff who regularly use TL monitoring systems in a practical setting. Modifications of the survey in line with these consultations came in the form of improved technical terminology, clarity on the phrasing of the questions and removal of irrelevant questions. Finally, the survey was sent to two support staff working in a high-performance swim programme who completed the survey for a trial analysis.

2.4. Statistical analyses

Responses were typically analysed using frequency analysis within Microsoft Excel. Absolute frequencies and percentages were most commonly used to report the data. Where data were qualitative, a thematic analysis was used (Braun et al., 2016). The thematic analysis employed a six-step process, including data familiarisation, coding, theme selection, refining themes, defining themes and finalising the report (Braun et al., 2016). Line by line coding was applied to the answers to the open-ended questions by one author (LB). Themes were then developed from these codes by two authors (LB, KM). Representative quotations were extracted and presented for each theme.

3. Results

A total of 31 responders participated fully in the survey. The result sections "demographics" and "barriers to TL monitoring" includes responses from all 31 responders. Five responders reported not using TL monitoring practices and therefore, sections reporting on TL monitoring practices only includes the remaining 26 responders.

3.1. Demographics

Out of 31 responders, 58% were swim coaches, 78% of whom had greater than ten years' experience in competitive swimming. The remaining responders included sport scientists (19%), strength and conditioning (S&C) coaches (13%), physiologists (7%) and physiotherapists (3%). Academic and industry-specific qualifications were common aspects of the responders' education. Nearly all responders (97%) had some level of academic qualification, while most (90%) had an industry-specific qualification. Most responders (87%) coached athletes across a range of abilities. Practitioners of national standard athletes were most frequently represented (87%), followed by international level (77%) and club level athletes (42%).

3.2. TL monitoring practices

Out of 31 responders, five (16%) declared that they did not employ TL monitoring practices in their swim programme. These five responders consisted of three swim coaches (60%), one S&C coach (20%) and one physiologist (20%). The remaining 26 responders (84%) who did employ TL monitoring practices were asked to rank the top three goals of their TL monitoring practices. The frequency at which each goal was ranked at one, two or three is presented in Table 1. The goal to "monitoring athlete's response to training" was ranked most frequently at number one which was closely followed by "improve athlete performance".

Responders were asked to outline the methods they used to monitor TL within their programmes and to highlight the types of variables they collected. A small percentage (8%) of responders only collected internal TL markers, with some responders (11%) collecting external TL markers exclusively. A substantial number of responders (81%) collected both internal and external TL markers. Several responders (69%) used two or more methods to collect and record their TL data. The most widely used method was Microsoft Excel or similar software (45%), followed by a specifically designed software package (24%), pen and paper (16%) and a generic web-based tool such as Google Docs (13%). The responsibility of recording the data was predominantly split between the swim coach (46%) and self-reported by the athlete (35%). S&C coaches (8%) and sports science support staff (11%) were also reported to be responsible for data collection. Data were generally recorded immediately post-session (60%) or within the first hour (12%). Data were recorded within 24 h' post-session in the remaining 28% of cases, with no one recording the information outside of the initial 24-h window.

Responders were asked to outline the type of variables collected as part of their TL practices. Training volume (mileage) (96%) and sRPE (92%) were the primary data variables collected, closely followed by subjective ratings of lifestyle/wellness (73%), heart rate (69%) and total load (RPE x Duration) (69%). Sleep duration and quality (79%) were variables collected as a key lifestyle/wellness metric. Psychological questionnaires (Profile of Mood States Questionnaire, Daily Analysis of Life Demands Questionnaire, Recovery-Stress Questionnaire for Athletes, Multicomponent Training Distress Scale) (42%) and energy, fatigue, and soreness Likert scales (21%) were also frequently utilised under this category.

Biomarkers (27%) and objective measures of fatigue (19%) featured less often in the TL practices of the responders. Of those who did monitor fatigue, assessments such as a swim specific set were reportedly used (71%) as well as countermovement jumps (57%), handgrip strength (57%) and self-reported questionnaires (57%). Similarly, responders who monitored biomarkers highlighted that cardiovascular status (e.g. Serum Ferritin, Haemoglobin) (67%), muscle status (e.g. IGF-1, Cortisol, Creatine Kinase) (33%), metabolic status (e.g. Glucose, Lipids, HbA1c) (33%), salivary biomarkers (17%), as well as hydration status (e.g. Urine Specific Gravity, Osmolality) (17%) were used in TL monitoring practices.

Responders were also asked how TL data were sub-categorised during data analysis and how data were reported. Responders sub-categorised the data into multiple groups in 50% of the responses, with 62% of those categorising both swim and dryland TL separately. Categorising swim sessions by session target (speed, aerobic, race pace) was also popular (38%). As regards reporting the data, a large portion (92%) of responders used two or more methods in combination to report the data, with the hierarchy of methods being presented in Fig. 1.

When asked who the key decision-maker was based on the TL data, responders indicated that either a head coach (61%) or a swim coach (27%) were responsible. Nearly all (96%) of the responders indicated that they provided TL information back to the athlete after analysis. Fifty-eight per cent of those always provided feedback, while 38% provided feedback in a specific circumstance. The responders were provided with the opportunity to give further information on the circumstances where they would provide feedback to the athlete, which is presented in the qualitative data below.

Responders also contributed information on the effectiveness of their TL monitoring practices in key situations (i.e. improving performance, preventing injury, informing training prescription and enhancing training adaptations). Fig. 2 shows the breakdown of the responses. Monitoring TL was seen as very effective in terms of improving performance and enhancing training adaptations but only moderately effective in relation to preventing injury and informing training prescription.

3.3. Barriers preventing TL monitoring

Five responders (16%) stated that they did not employ any TL monitoring practices. The barriers that prevented them from employing TL monitoring practices were cited as "limited time" (50%) "lack of support from coaching team" (25%), "insufficient funding available" (12.5%) and the "age/experience level of their athletes" (12.5%).

3.4. Open-ended section

Responders were asked if they found a specific TL variable or

Table 1
The goal of TL monitoring practices is in ranked order according to the primary goal.

Goal	Primary Goal	Secondary Goal	Tertiary Goal
	No. of responses per category		
Monitor athletes' response to training	9	6	1
Improve athlete performance	8	7	5
Aid coaches in planning and training prescription	5	4	5
Reduce injuries	3	4	4
To enhance training adaptations	1	3	7
Prevent over-training	0	1	3
Research purposes	0	0	0

[1] One participant response is removed from secondary and tertiary goals due to an error in data collection/reporting.

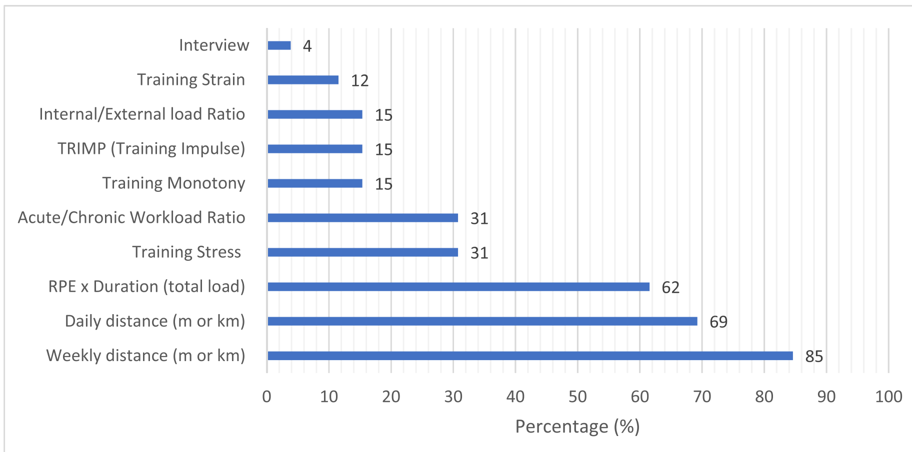

Fig. 1. The percentage of selected TL analysis categories used by 26 responders (responders could select multiple options).

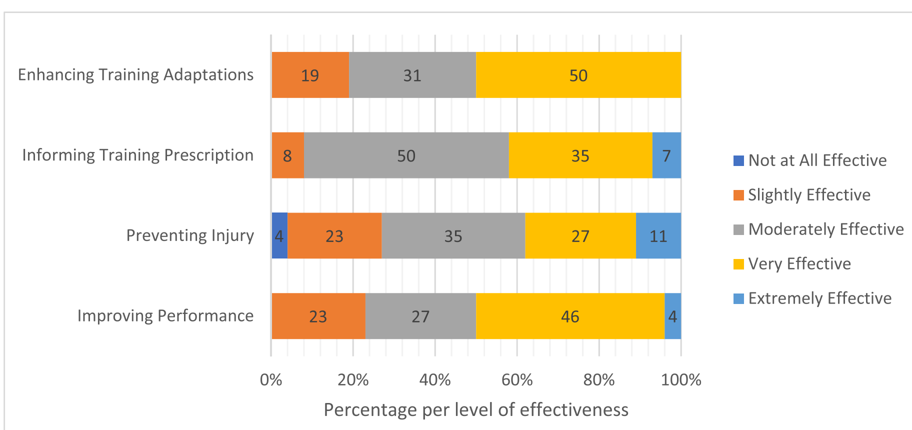

Fig. 2. Perceived effectiveness of TL monitoring practices in key situations as reported by 26 responders.

metric most effective in helping to prevent injury. The open-ended responses highlighted the use of specific TL metrics, wellness markers and physiological assessments. Many of the responders cited specific TL monitoring metrics that they felt were helpful, such as the acute chronic workload ratio (ACWR) which is a method of quantifying fitness and fatigue by using the most recent TL (acute) with the athletes' recent history of TL (chronic) (Hulin et al., 2014). Internal versus external load was also highlighted and is a method of quantifying fitness and fatigue status based on different variables used (i.e. total distance: TRIMP) (Akubat et al., 2018). Variables such as monotony and strain were mentioned as being helpful. Training monotony is a measure of day-to-day training variability, while training strain is a value that represents the overall stress that the athlete was exposed to (Comyns & Flanagan, 2013). Finally, training impulse (TRIMP) which is a method of quantifying physical effort using training duration and heart rate during exercise (Halson, 2014) was also referred to. The word cloud below (Fig. 3) highlights the interactions of the keywords within the responses. This word cloud was developed through a frequency analysis, where phrases or themes within the responses were counted. The size of the word or phrase within the word cloud is adjusted based on the frequency seen within the responses (i.e. the larger the word, the more frequently it was mentioned). In this instance three sizes (Font size 20, 40, 60) were used, the smallest words were mentioned once and the largest words were mentioned three times.

A thematic analysis was carried out for the open-ended questions. Three higher-order themes were prevalent across all questions and are presented below. Table 2 highlights the higher-order themes, along with representative quotations from responders.

3.4.1. Stakeholder engagement

Stakeholder (i.e. athlete, coach, support staff, NGB) engagement was a major recurring theme across all open-ended questions. Responders were asked to report on the situations where TL feedback was given to the athlete. Feedback was often provided when the athletes' data were showing abnormalities or when trying to generate athlete engagement. Feedback was provided to educate or reassure the athlete, ensuring the athlete would see personal value in the information. This theme was also prominent when asked about barriers to accurately monitoring TL. TL monitoring was made difficult due to a lack of compliance from the athletes. This, coupled with a coach's reluctance to engage with the information and an unwillingness to make adaptations based on the information were considerable barriers. When asked how TL monitoring could be made easier, the role of the stakeholder was frequently highlighted. It was suggested that a top-down approach to the application of a TL monitoring culture within the system would be of benefit.

3.4.2. Resource constraints

Resource constraints were another determinative factor in the application of TL monitoring. When asked if any links between TL variables warranted further investigation, logistical issues in handling the data tended to hamper progress. This theme carried over directly into the barriers of TL monitoring, where resources such as support, finances and time were highlighted as major barriers. Additional personnel, undertaking separate data collection and analysis roles, was seen as a potential solution to these issues. This opinion was echoed when responders were asked what they felt may be important in effectively monitoring and recording TL at an elite level. It was suggested that an experienced sport science support practitioner within the system would be vital to effective monitoring and recording at an elite level.

3.4.3. Functionality and usability

The functionality of the technological systems involved in TL monitoring were consistently highlighted across the responses particularly when the barriers and solutions to TL monitoring were discussed. It was emphasized that technology, including software and hardware systems, need to be more user-friendly, sport-specific, reliable and cost-effective. Responders remarked that standard TL monitoring systems may not always be specific to swimming and the information can go against a coach's perceptions. Responders also commented that at an elite level, the data analysis must be more sensitive to additional factors outside of TL. External factors such as lifestyle stress and sleep need to be accounted for while the need for detailed biomechanical analysis is also greater, as the technical efficiency of swimming needs to be quantified.

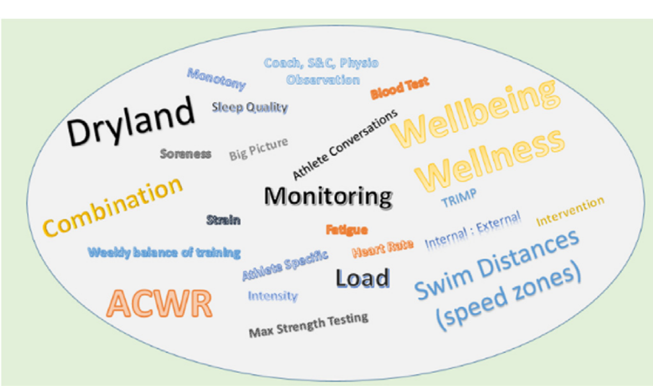

Fig. 3. Word cloud representation of the specific variables, which are seen to be most effective in preventing injury.

4. Discussion

This study aimed to identify TL monitoring practices in competitive swimming and is the first to explore these concepts concertedly in this population. The survey explored how data collection and analysis is implemented, what metrics are being utilised and their perceived effectiveness. The barriers and facilitators to TL monitoring were also investigated. The findings show that swimming coaches are primarily responsible for TL monitoring, while physiotherapists and S&C coaches were represented to a lesser extent and tended to work in swimming for the least amount of time. The lower responses from support staff may be linked to the relatively new influence of these practitioners in competitive swimming. The majority of responders worked with multi-ability groups, highlighting the need for a TL monitoring system to be age/ability appropriate. The key finding that 84% of responders participated in some level of TL monitoring is higher than amateur rugby (Griffin et al., 2021) and highlights how swimming has incorporated the implementation of sports science support.

The hierarchy of TL monitoring goals (Table 1) illustrates that responders were more driven towards performance outcomes than injury prevention. While historically, TL monitoring was performance-orientated (Foster et al., 2017), its utilisation for injury risk mitigation has increased considerably (West et al., 2021). Research suggests that using TL monitoring as a predictor for injury is not best practice and may encourage a risk-averse culture of protecting athletes rather than preparing them for the TL needed to promote physical adaptation (Impellizzeri et al., 2020). The primary role of TL load monitoring should be to act as a safeguard for the coaches' periodization strategy. It can be used to assess if the athlete trained as planned or coped as expected. This allows both the art and science of coaching to work in harmony. Based on these goals, monitoring the athletes' perception of effort, as well as the amount of work completed, is essential.

The widespread implementation of both internal and external TL markers is in accordance with the consensus statement recommendations on TL monitoring (Bourdon et al., 2017). The high prevalence of sRPE as an internal TL measure is in agreement with other sport disciplines. The popularity of monitoring external TL as the weekly or daily volume (m/km/min) is a common theme in endurance-based sports, particularly in swimming and running where it is easily quantified and prescribed (Casado et al., 2021). Nevertheless, caution is needed as training stress can be underestimated using training volume (m/km/min) in isolation (Paquette et al., 2020). The addition of an internal TL metric such as sRPE or total load (RPE x Duration) provides a more complete quantification of an athlete's overall TL stress. The use of volume (m/km/min) or mileage as a key external TL measure was anticipated. However, the high prevalence of subjective internal TL (sRPE) is more surprising. The use of sRPE was seen to be limited in a recent systematic review examining pain, injury and illness in competitive swimmers (Barry et al., 2021). This review concluded that monitoring TL in

Table 2
Thematic analysis with representative quotations from responders.

Theme	Coding	Representative Quotes	Responder
Stakeholder Engagement	Athlete Education	*" …. athlete themselves is interested in the information for their own learning"*	R1
	Athlete Reassurance	*" …. .reassuring an athlete in low self-confidence moments"*	R2
	Barriers	*"Athlete compliance without nagging is poor"*	R6
		"Coaches willingness to truly open up to the data and allow their prescription to be interrogated by the data for the good of the swimmer's prescription. i.e. coach ego"	R7
		"Compliance of athlete to complete daily - this is helped greatly when coach and support team can see the value in the data and are on board"	R28
	Facilitators	*"Better coach buy in and drive for the athletes to complete rather than support staff. More drive from the National program to make it part of an athlete contract."*	R6
Resource Constraints	Logistical Issues	*"We have a HUGE amount of data from training, but nobody who can actually turn them into proper investigation/results"*	R5
	Time & Resources	*"Not enough support help. Too many athletes. Not enough money to pay for it"*	R1
		"Time to get all data accounted for logged and assessed. Financial resources"	R12
	Workforce	*"Having a separate member of staff that's sole responsibility is to record this data could also be easier and take the load off the coach"*	R27
		"It's vital to have very experienced sports science support".	R1
Functionality & Usability	Technology	*"more reliable measurement tools, easier automatic analysing"*	R25
		"adapted software to world class swimming"	R5
	Monitoring Limitations	*"On occasion the self-reporting of wellness and internal loads can be at odds with the external loads provided. i.e. there have been times when the data is saying back off a bit but the athlete is saying no I'm good let's go"*	R24
	Logistical Issues	*"Capturing information on the non-structured load experienced by the athlete i.e. demands in school or at home"*	R15
		"The ability to accurately perform any dose response/training performance modelling is currently limited in swimming as it is hard to accurately measure the internal/external TL and determine the physiological performance of an athlete at a given point in time given the large role that technique plays on how fast a swimmer moves through the water"	R17

*TL = Training Load.

competitive swimming research often did not include a measure of both internal and external TL, while the use of sRPE needed more extensive inclusion in the sport of swimming. These findings are in direct contrast to the findings in this paper, showing a research-practice gap.

Heart rate was another TL measure frequently employed by responders (69%), which is in agreement with other research (Feijen et al., 2020). Environmentally, the swimming arena provides logistical challenges to accurately monitoring heart rate. However, new technologies have made it possible to accurately track heart rate in real-time during a session (Olstad et al., 2019), allowing TL monitoring methods such as TRIMP to be utilised. TRIMP was reportedly used by 15% of the responders within this survey. This method has received some criticism for its use of a total session mean heart rate, encompassing both "working" and "resting" intervals during the session, possibly underestimating the total stress of the session (García-Ramos et al., 2015). It also has difficulties in monitoring all aspects of a swim programme. Swimming training typically comprises of pool-based training, with a variety of session targets (speed, aerobic, anaerobic etc.) and dryland training. The use of a TL measure relying on mean heart rate may not be accurately transferable to all types of training activities (Hellard et al., 2006). The responders of this survey tended to separate the swimming and dryland based TL in most cases, while others categorised TL by session target. It would seem appropriate to use a measure of TL that accurately depicts all aspects of a modern training regime and break the TL into sub-categories such as total TL, swim TL separated per session target and dryland TL.

In addition, TL measures including subjective ratings of lifestyle/wellness were often collected by responders and primarily involved the collection of sleep duration and quality. Sleep quantity and quality have been linked to performance and is seen as an essential aspect of an athlete's physical preparation (Surda et al., 2019). Swimmers have been shown to suffer from significantly poorer sleep profiles than their fellow athletes (Biggins et al., 2021). This is thought to be a result of the early morning training culture (Sargent et al., 2014). Sleep disturbances have also been linked to increased TL (Taylor et al., 1997) and are prevalent amongst "dual career" student-athlete swimmers, particularly during periods of high academic stress and competition periods (Astridge et al., 2021). This suggests that the collection of subjective wellness data, in combination with TL and sleep quantity and quality are appropriate for a swimming population and are particularly necessary for student-athletes.

Monitoring TL is used to determine the individual athletes' response to training and to regulate the training stimulus to improve the effectiveness of training, without increasing the risk of maladaptation (Bourdon et al., 2017). Responders indicated that TL monitoring was very effective in improving performance and enhancing training adaptations. Responders also found TL monitoring to be moderately effective in terms of injury prevention and moderately effective in terms of informing training prescription. The prediction of performance or injury has been a major debate topic in recent times (McCall et al., 2017). Despite this, research has yet to conclusively cite TL monitoring as a definitive predictive tool (Akenhead & Nassis, 2016). This is primarily due to the multifactorial nature of sport and quantifying TL alone is not sufficient to accurately predict performance (Mitchell et al., 2020) or injury (Impellizzeri et al., 2020). Considering the lack of predictive qualities, TL monitoring should be used in combination with the practitioners' experience, allowing an informed decision-making process to occur.

A key goal of this survey was to investigate the barriers to TL monitoring and three fundamental themes emerged; 1) stakeholder engagement; 2) resource constraints and 3) functionality or usability of the systems available. Athlete adherence to providing the information, the coaches' reluctance to engage with the information provided, and a lack of sufficient financial, personnel or technological support from NGBs, are all interlinked barriers to TL monitoring. Successful implementation of TL monitoring is strongly related to end-user buy-in (Neupert et al., 2019). Athletes have reported that feedback on their TL data is a significant factor in their adherence (Neupert et al., 2019). Nearly all responders in this survey indicated that they provided TL information back to the athlete after analysis, with some of those only doing so when the athlete needs reassurance or when ensuring the athlete would see personal value in the information. As athlete feedback is a key consideration in creating a culture of buy-in, the method of feedback needs consideration. A TL report sent to the athletes may not be sufficient as the athlete's understanding of the information cannot be assumed. Practical, periodic face-to-face discussions may be better received, allowing the athlete to ask questions in real-time.

The coaches' reluctance to engage with the information was another frequently cited barrier. Saw et al. (2017) noted that the decision to implement a TL monitoring system should be dependent on a commitment to the process from the coaching team and the NGB (Saw et al., 2017). This stakeholder engagement process can be improved through formal or informal education of those involved, including clear protocols on how the system is used, data responsibility and how it will benefit the sports organisation/individuals (Saw et al., 2017).

The NGB can also play a substantial role in barriers surrounding “stakeholder engagement” and “resource constraints”. A recent study on the complexities of implementing a TL monitoring system highlighted that while stakeholder buy-in was important, this importance needs to translate into the applied setting (Duignan et al., 2019). An example of this would be a situation where an athlete, who does not adequately adhere to TL monitoring practices within a squad, continuously gets “rewarded” through NGB funding or support systems. This diminishes the importance of TL monitoring within the system and may unravel global athlete engagement in the process.

Responders also emphasized logistical issues, time and resources and limited workforce as being major contributing factors. The NGB can play a strong role in this aspect of the TL monitoring process. The implantation and success of such a system relies on its feasibility in the applied setting (Saw et al., 2017). If the available resources do not meet the demands of the monitoring process, then it may be necessary for the NGB to support the process through financial investment, staff recruitment or redeployment of skilled labour. The investment of technology may help offset the cost of practitioner hours by automating the TL monitoring process (Saw et al., 2017) Our findings showed that a sole staff position dedicated to the role of TL monitoring and sport science services would be of great benefit. Amplified support from the NGB through providing a skilled and knowledgeable practitioner may consequently improve the decision-making processes by reducing the lag time to process and analyse the data. The accuracy of the data collected may also improve, thus improving the insight gained from the TL monitoring system. The influence of the NGB in reinforcing a TL monitoring culture from the top down is also of utmost importance.

While it is imperative to quantify TL, the assessment of competition load is of equal importance. An athlete's load cannot be accurately reviewed and acted upon unless all elements are considered (Mujika, 2017). There is some research to suggest the reporting of competition loads are difficult, given the influence of the environment and psychological state of the athletes (Griffin et al., 2021). The ability to quantify competition loads can be hampered by the method used. Using measures such as live heart rate is not a viable option in the competition environment, while using external measures such as volume (m/km/min) may severely under-report the stress of maximal exertion in the athlete over shorter distances. Those using a subjective rating of internal TL (e.g., sRPE), alongside an external measure (e.g., duration) may be best placed to gather an accurate representation of the competition stress. The sRPE method can be applied to all elements of activity during the competition process, including on-deck mobility, priming activities, swim based warm-up, racing and cool down.

5. Limitations

The survey was circulated globally (1) to NGBs from Ireland, Great Britain & Northern Ireland, Spain, Australia and New Zealand (2) to a number of coaching associations and (3) through social media outlets. The nature of circulating a survey internationally through specific contact points within an NGB however resulted in two limitations to this study. The first is the inability to track non-respondents as well as those who completed the survey in full, outside of the initial contact point. Consequently, the response rate (as defined by Phillips et al. (2017)) cannot be calculated and presented; it is also not possible to confirm the degree of international representation of the data.

6. Practical application

Those wishing to implement a TL monitoring system should consider stakeholder buy-in and financial, personnel and technological resources. The NGB needs to be invested in the TL requirements of the programme, while the coaching staff also need to create a culture of importance on the collection and utilisation of TL data. This can be done by having a dedicated member of staff for TL monitoring services. Once the system is in place, athlete adherence to reporting the data can be improved through the feedback of individual athlete TL information.

Findings showed that practitioners primarily used TL data to monitor the athlete's response to training and to improve performance, while injury prevention was less of a priority. This would suggest that TL data needs to be specific to the individual athlete and reviewed with training and competition performance in mind.

Much of the research into competitive swimming relies heavily on external TL and rarely features the use of sRPE (Barry et al., 2021). However, the findings of this survey highlight that both internal and external TL are frequently collected by practitioners. The frequent use of sRPE as a TL measure is a welcome finding, it does highlight that there is a gap between research and real-world application. Those wishing to design a TL monitoring system for competitive swimming should prioritise the use of sRPE. sRPE is beneficial in competitive swimming as it can transcend all aspects of a modern-day swim programme. Dryland activities, competition and swim TL can be quantified utilising the same method, allowing for an accurate measure of total TL. The reporting of TL data can be done by splitting swim and dryland activities and potentially further sub-categorising the TL into swim sessions by session target (speed, aerobic, race pace). Lifestyle and wellness data should also be considered an important aspect of the monitoring process with sleep quality and quantity used as key metrics, especially for student-athletes.

Consent for publication

Approved.

Code availability

Not applicable.

Availability of data and material

Data and materials are available from the corresponding author, upon reasonable and appropriate request.

Funding

LB is funded by the Irish Research Council Employment Based Programme in conjunction with Swim Ireland.

Authors' contributions

All authors contributed to the review conception and design. Material preparation, data collection and analysis were performed by LB, TC, ML, KMcC and CP. The first draft of the manuscript was written by LB and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics approval

Ethical approval was granted by the University's Ethics Committee (2019_10_09_EHS) and participants gave informed consent to their information being used for research and publication purposes.

Declaration of competing interest

Authors declare that they have no competing interests. LB is an employee of Swim Ireland, but this does not constitute a competing interest.

Acknowledgments

LB is an employee of Swim Ireland, but this does not constitute a conflict of interest. None of the other authors has any conflicts of interest to declare. The authors would like to acknowledge Swim Ireland for their support throughout the study period. They would like to thank participating NGBs, coaching associations and the wider swimming community for their help in circulating this survey. The authors would also like to thank the Irish Research Council and Swim Ireland for financially supporting this research, through the Employment Based Postgraduate Programme.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2021.11.005.

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