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Monitoring of training in high-performance athletes: What do practitioners do?

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ABSTRACT

Monitoring tools have been evaluated extensively, but it is unclear which training monitoring tools are favoured in high-performance sport settings. The primary aim of this study was therefore to describe the current practice of training monitoring used by coaches in high-performance sport settings. Secondary aims included determining (i) which monitoring tools were used with female athletes, (ii) whether these differ from those used with male athletes, and (iii) the challenges of implementing a monitoring programme. 530 national, state, and regional clubs were directly emailed and social media recruitment was also used to invite practitioners who monitored training of athletes at the pre-elite, elite, or professional level to participate in an online survey. Overall, 52 complete, and 3 partially complete responses were received. Commonly reported workload measures were training duration and training intensity that were measured every session (89% and 81%, respectively). Performance tests, measures of heart rate, and global positioning system variables were also recorded commonly (92%, 79%, and 52%, respectively). Measures of the psychological state of the athlete were used by fewer than half of the practitioners, with custom-designed wellness questionnaires focusing on fatigue, sleep quality, and general muscle soreness more common for daily use. Biochemical monitoring was reported by 25% of participants, which comprised of measures of blood lactate (88%) glucose (38%), testosterone, cortisol, and the testosterone:cortisol ratio (25% each). Of the 33 participants who identified that they monitored the training of female athletes, seven monitored hormone contraception or the menstrual phase. Monitoring performance was the most important reason for the monitoring programme; the athletes' acceptance of the monitoring programme was recognised as the greatest challenge of training monitoring. In conclusion, commonly implemented tools by practitioners were those that were easy to implement, inexpensive, and that allowed an efficient data collection and analyses over tools that may be more valid. This information is important for both sports science practitioners and researchers to continue to optimise ecologically valid training monitoring programmes and tools.

1. Introduction

Athletic training often involves periods of overloading the athlete with high volume or intensity of workload. For physiological adaptation to occur in line with the supercompensation principle, training overload must be balanced with adequate rest (Meeusen et al., 2013). When workload and recovery are not balanced, the athlete is at risk of suffering from adverse outcomes, such as prolonged fatigue, deteriorated performance, increased injury risk, overtraining syndrome, and burnout (Halson, 2014; Meeusen et al., 2013; Soligard et al., 2016). As such, monitoring an athlete and their response to training is essential to aid in training prescription and reduce the risk of these adverse outcomes (Bourdon et al., 2017).

Recently, practitioners such as sports scientists have been assigned the role of measuring the 'training load' completed by athletes (Foster, Rodriguez-Marroyo, & de Koning, 2017). The training load is defined as the work completed by the athlete and

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the associated physiological response (Akenhead & Nassis, 2016). Two different types of load have been described: external and internal (Impellizzeri, Marcora, & Coutts, 2019). The external load involves monitoring the objective measures of workload the athlete has completed during training, and may be monitored through training volume, such as the duration, intensity and the number of exercise sessions (Bourdon et al., 2017; Impellizzeri, et al., 2019). Internal load is the physiological and psychological stress imposed on the athlete in response to the training sessions. As these stressors are internal, they reflect the biochemical, physiological, psychological and anatomical aspects of the training response. The internal load may be measured using a variety of measures such as blood markers (e.g., lactate, testosterone, cortisol), heart rate indices, or mood inventories (Bourdon et al., 2017; Impellizzeri, et al., 2019). As no single marker can accurately monitor an athlete's training progress, several tools, systematically monitoring both external and internal load over long periods are recommended (Bourdon et al., 2017; Halson, 2014).

Despite considerable research into monitoring tools (Greenham, Buckley, Garrett, Eston, & Norton, 2018; Saw, Main, & Gastin, 2016), knowledge of their use by practitioners in the field is limited. McGuigan et al (2020) investigated the use of training monitoring tools and identified that tools used in the field are those that are easy to implement and use (e.g., heart rate measures, GPS data, wellness questionnaires, duration of training) compared to the more advanced monitoring tools (e.g., biochemical analysis, maximal rate of oxygen consumption). However, several gaps in the literature on the application of training monitoring provides an incomplete picture of monitoring practices. For example, self-reported wellness data have been identified as a common tool (McCall, Dupont, & Ekstrand, 2016; Starling & Lambert, 2018), but it is not often clear whether validated questionnaires or custom-designed questionnaires were used. Although measures of heart rate are also common, few studies describing applied practice report the cardiac indices being recorded (Akenhead & Nassis, 2016; Taylor, Chapman, Cronin, Newton, & Gill, 2012). The methods, timing of data collection and longitudinal consistency can also influence the effectiveness of the monitoring tools. Understanding the reasons why practitioners choose particular monitoring tools over others will provide valuable insights into the actual reasoning of training monitoring in high performance sports.

Differences in male and female physiology and biochemistry are well documented, particularly in the sport context. Men typically possess greater muscle mass and less body fat than females, contributing to greater strength, anaerobic power and aerobic power compared to their female counterparts (Sandbakk, Solli, & Holmberg, 2018). Also, female sex hormone concentrations change with the menstrual cycle and may also affect the recovery period from exercise in women (Hackney, Kallman, & Aggon, 2019). Studies on the applied practice of training monitoring have focused on male athletes (McGuigan et al., 2020), and consequently special considerations for female athletes, such as menstrual phase, have not been identified.

As such, the aim of this study was to comprehensively describe the current practice of training monitoring used by a sample of coaches in high-performance sport settings. Secondary aims included determining (i) which tools were used to monitor female athletes and whether practitioners monitor the menstrual cycle or contraceptive use, (ii) whether these tools differed to those used with male athletes, and (iii) the challenges of implementing a monitoring programme.

2. Methods

2.1. Participants

Eligible participants were practitioners monitoring the training of elite, pre-elite, or professional athletes. Athletes were defined as elite if they regularly competed at the highest national or international level of their sport; pre-elite if the athlete has the potential to reach elite status and are involved in talent development programmes; professional if they competed at the highest tier in a professional league. 530 national, state, and regional, sporting organisations and eligible participants identified from websites were emailed the survey link and asked to distribute the link within their organisation and/or complete the survey themselves. Participants were also recruited from social media and personal contacts. The study was approved by the Southern Cross University ethics committee (ECN-19-052).

2.2. Task and procedure

An online questionnaire was created using Qualtrics (2019, Utah, USA). The questionnaire items were designed and refined according to similar published articles, personal experience, and literature on training monitoring methods. The study was reviewed by the research team and a small group of external academics and coaches with specific knowledge in the area to ensure the survey had face validity and the questions were relevant to the aims of the study. The questionnaire was also piloted with ten participants with knowledge and experience in the area before further refinement. The final survey was divided into seven sections, including participant demographics, general training monitoring information, the quantification of training load, physiological monitoring, the use of validated or custom made psychological and wellness questionnaires, biochemical monitoring, and monitoring of female athletes. Each item had an 'other' option allowing participants to provide an answer that was not available. This was designed to reduce possible bias within the survey design and allow for an accurate representation of the training monitoring tools used. Participants were requested to complete the survey thinking about the training monitoring tools they have used in the past 12 months.

2.3. Statistical analysis

Frequency analysis was conducted for each item, including rank-order items and presented as frequency counts and percentages. The mean response and standard deviations are presented where applicable.

3. Results

3.1. Participant characteristics

Overall, 52 complete and 3 incomplete responses were received for monitoring of elite (n = 29; 53%), pre-elite (n = 19; 35%), or professional (n = 7; 13%) athletes. The incomplete responses were used where possible. The 55 participants in this study consisted of 45 males (81%) and 10 females (18%). Participant roles were head coach (n = 17; 31%), assistant coach (n = 5; 9%); strength and conditioning coach (n = 11; 20%); sports scientist (n = 11; 20%). Other roles included head of performance/performance manager (n = 7), sport director, head of psychological science and welfare, and physiotherapist (n = 1 each). Participants ranged in age from 22 to 69 years (*M* = 39; SD = 13) and had an average of 7.1 years (SD = 6) working with athletes at their current level. Participants monitored a range of sports including football (Australian football, rugby union, rugby league, soccer; n = 19; 35%), water sports (canoe slalom, sprint kayak, dragon boating, swimming, underwater rugby, rowing, sailing; n = 13; 24%), striking sports (cricket, hockey, squash, table tennis; n = 9; 16%), cycling and triathlon (n = 7; 13%), other (volleyball, netball, combat sports, petanque sport boules, athletics; n = 7; 13%).

3.2. General monitoring information

Participants monitored male athletes only (n = 21; 38%), female athletes only (n = 5; 9%), or both (n = 29; 53%). Participants monitored athletes in team sports (n = 15; 27%), individual sports (n = 13; 24%), or both (n = 27; 49%), and were most commonly in contact with their athletes daily (n = 18; 33%), four to six (n = 19; 35%) or two to three (n = 10; 18%) times per week. The proportion of respondents who monitored the training of only male athletes, only female athletes, or both male and female athletes for each of these measures is presented in Figure 1.

3.3. Workload monitoring

Workload monitoring was used by 54 (98%) respondents to monitor training. The frequency of use of global positioning system (GPS), session rating of perceived exertion (sRPE), and rating of perceived exertion (RPE), training duration and intensity, and workload calculations are reported in Table 1. RPE (n = 32; 73%), heart rate (n = 23; 52%), and blood lactate (n = 7; 16%) and other (e.g., athlete perception, time-based measures, power-based measured; n = 8; 18%) was used to measure training intensity. When asked what workload calculations they used, 25 (55%) respondents indicated they used acute:chronic workload ratio (n = 22; 88%), tonnage (n = 5; 19%) and training impulse (TRIMP; n = 5; 19%). Although, it was not stated which derivation of the TRIMP method was used. Participants also recorded other workload calculations (n = 9; 35%), which included: training duration multiplied by intensity based on workload training zone, monotony and strain, performance index value, principal-component analysis derived variables, 21-day rolling average, and quartiles, dive monitor (length, frequency, recovery, and underwater percentage).

GPS variables utilised by practitioners included measures of distance (n = 23; 82%), total distance covered (n = 20; 71%), speed intensity (n = 18; 64%), peak acceleration (n = 15; 54%), velocity change (n = 13; 46%), change of direction (n = 10; 36%) and other (n = 10; 36%). Respondents used an average of 5 (SD = 2; min = 2, max = 10) GPS variables for training monitoring.

3.4. Performance testing to monitor training

Physiological and performance monitoring was reported by 34 (63%) respondents to monitor training. These performance tests included sport-specific tests (n = 19; 61%), strength tests (n = 12; 39%), jump tests (n = 11; 36%), submaximal cycle test (n = 7; 23%), submaximal running test (n = 5; 16%), overground sprints (n = 4; 13%), and other tests (n = 12; 39%) including the beep test, a hybrid beep test (12.5 m surface swim and 12.5 m underwater swim), submaximal swim test, maximal oxygen consumption test, time trials, critical power test, aerobic threshold test, time to exhaustion tests across various power outputs, sport-specific training sets, aerobic and anaerobic lactic, and performance measures embedded into blocks of work.

3.5. Musculoskeletal screening

Musculoskeletal screening tests were used by 19 (56%) participants. These tests were conducted biannually (n = 6; 32%), annually (n = 4; 21%), weekly (n = 3; 16%), monthly and quarterly (n = 2, 11%, each), and daily and at other time points (n = 1; 5%). Tests included the functional movement screen (n = 12; 63%), hop test (n = 6; 32%), landing error scoring system (n = 4; 21%), star excursion balance test (n = 3; 16%), weight-bearing lunge test (n = 2; 11%), tuck jump (n = 1; 5%), and 'other' (n = 7; 37%).

3.6. Heart rate

The frequency of heart rate measurement collection is reported in Table 1. The types of heart rate indices used, and the timing of their collection are illustrated in Table 2.

3.7. Training diary

The frequency of the training diary reviews is reported in Table 1. The content recorded in the training diary included training type (n = 23; 100%), training duration (n = 22; 96%), sleep quality (n = 20; 87%), illness (n = 19; 83%), athlete's mood (n = 17; 74%), supplement usage (n = 7; 30%), water intake (n = 4; 17%), and other (n = 5; 22%) including urine specific gravity, type of training, sRPE, technique and learning, readiness score, soreness, medications, appetite, fatigue, stress, worry, sleep quantity, and additional comments.

Table 1: The practitioner reported frequency of use of workload, physiological, and psychological monitoring variables

	GPS n (%)	sRPE n (%)	RPE n (%)	Training duration n (%)	Training intensity n (%)	Workload calculations n (%)	Performance tests n (%)	Heart rate n (%)	Sleep quality n (%)	Training diary n (%)	POMS n (%)	RESTQ-Sport n (%)	DALDA n (%)	Other validated questionnaires n (%)	Custom designed wellness questionnaire n (%)
Every session	20 (71)	27 (74)	26 (63)	46 (89)	36 (82)	12 (48)	1 (3)	12 (48)	-	4 (17)	1 (20)	1 (25)	-	-	3 (25)
Daily	1 (4)	1 (3)	5 (12)	1 (2)	2 (5)	4 (16)	-	-	15 (58)	4 (17)	1 (20)	1 (25)	-	2 (33)	8 (67)
4-6 times a week	2 (7)	2 (5)	3 (7)	1 (2)	2 (5)	3 (12)	-	1 (4)	4 (15)	1 (4)	-	-	-	-	1 (8)
2-3 times a week	-	2 (5)	1 (2)	1 (2)	1 (2)	2 (8)	2 (7)	2 (8)	4 (15)	5 (22)	-	-	-	-	-
Weekly	3 (11)	3 (8)	1 (2)	2 (4)	1 (2)	2 (8)	5 (17)	3 (12)	-	7 (30)	-	1 (25)	-	2 (33)	-
Fortnightly	1 (4)	-	1 (2)	-	1 (2)	-	-	1 (4)	-	-	-	-	-	-	-
Monthly	1 (4)	2 (5)	-	1 (2)	1 (2)	-	6 (20)	1 (4)	-	1 (4)	-	-	-	-	-
Quarterly	-	-	-	-	-	-	9 (30)	-	-	-	-	-	-	-	-
Biannually	-	-	-	-	-	-	3 (10)	1 (4)	-	-	-	-	-	-	-
Annually	-	-	-	-	-	-	-	-	-	-	-	1 (25)	-	1 (17)	-
Other*^	-	1 (3)	1 (2)	-	-	2 (8)	4 (13)	4 (16)	3 (12)	1 (4)	-	-	-	1 (17)	-
Total n	28	28	41	41	44	27	31[#]	25	26	23	5	4	1[#]	6	12

Note: *other time periods include during specific training blocks. GPS = global positioning system; n = number of responses; sRPE = session rating of perceived exertion; RPE = rating of perceived exertion; POMS = Profile of Mood States; RESTQ-Sport = Recovery Stress Questionnaire for Athletes; DALDA = Daily Analysis of Life Demands for Athletes. Nb: Some data for frequency of use of questionnaires are missing due to participants not completing that section of questionnaire. ^Other questionnaires including the Mental Toughness Questionnaire, the Short Recovery Stress Scale, and Total Quality Recovery. [#]Two respondents measuring heart rate and one respondent reporting performance tests and use of the DALDA did not report frequency of use.

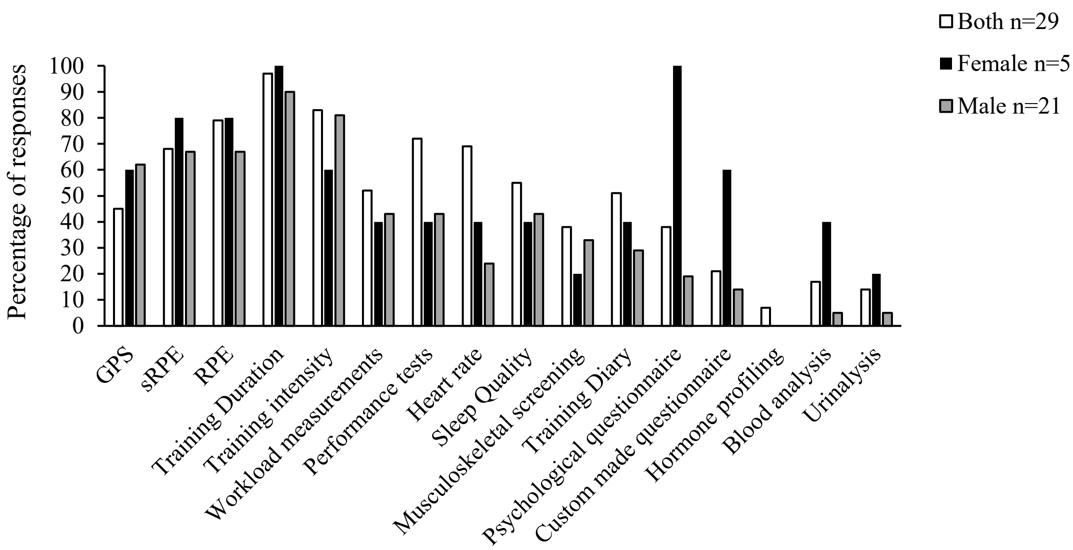

Figure 1: Percentage breakdown of monitoring tool use by respondents who monitored only male athletes, only female, or both male and female athletes

Table 2: The practitioner reported collection time of heart-rate indices

	Resting heart rate n (%)	Submaximal heart rate n (%)	Heart rate variability n (%)
After waking	6 (60)	-	5 (39)
Before exercise	3 (30)	2 (11)	4 (31)
During exercise	-	11 (61)	2 (15)
After an exercise interval	-	4 (22)	-
Immediately after exercise cessation	1(10)	-	-
15 min after exercise cessation	-	1(6)	1(8)
30 min after exercise cessation	-	-	1(8)
Total n	10	18	13

Note: n = number of responses; ‘other’ heart rate indices were collected before exercise, during exercise, immediately after exercise cessation, and 30 minutes after exercise cessation (n = 1; 25%, each)

Table 3: Biochemical monitoring in athletes and monitoring of female specific variables

	Hormone profiling n (%)	Blood analysis n (%)	Urinalysis n (%)	Hormone contraceptive use n (%)	Menstrual cycle phase n (%)
Daily	-	-	-	-	1 (14)
Weekly	-	1 (13)	1 (17)	2 (29)	-
Fortnightly	-	1 (13)	1 (17)	-	1 (14)
Monthly	1 (50)	-	1 (17)	1 (14)	2 (29)
Quarterly	-	3 (38)	-	-	-
Biannually	-	-	-	2 (29)	-
Annually	1 (50)	-	-	-	-
Other*	-	3 (38)	3 (50)	2 (29)	2 (29)
Total n	2	8	6	7	6^

Note: *Other collection; ^One respondent did not report frequency of use.

3.8. Psychological monitoring

Psychological monitoring was reported by 20 (36%) respondents. A total of 10 (50%) of these participants reported using validated questionnaires. The use of a custom-designed wellness questionnaire was used by 12 (22%) participants. These questionnaires comprised of between 4 and 15 questions (M = 7; SD=3), focussing on fatigue (n = 12; 100%), sleep quality (n = 12; 100%), general muscle soreness (n = 11; 92%), stress (n = 9; 75%), mood (n = 8; 67%), energy levels (n = 5; 42%), mental focus (n = 4; 33%), preparedness (n = 1; 8%) and 'other' (n = 5; 42%). Other areas include sleep quantity, new injuries, symptoms of illness, whether a medical assessment was required, and appetite. Table 1 shows the frequency of validated and custom questionnaires used.

3.9. Biochemical monitoring

Biochemical monitoring was reported by 13 (24%) respondents. The types of hormone profiling conducted by practitioners included female hormone (n = 2; 100%), male hormone (n = 2; 100%), adrenal hormone (n = 1; 50%), thyroid hormone (n = 2; 100%), and other (n = 1; 50%). Blood samples were collected via venepuncture or capillary blood sampling (n = 4; 50% each). The most commonly assessed variable was blood lactate (n = 7; 88%), followed by glucose (n = 3; 38%), and testosterone, cortisol, and the testosterone:cortisol ratio (n = 2; 25% each). Other variables (n = 4; 50%) reported include blood gas measures and haemoglobin mass. The urine sample was frequently collected first thing in the morning (n = 5; 83.3%) or after exercise (n = 1; 17%). Variables assessed included creatinine (n = 2; 33%); ketones (n = 1; 17%); glucose (n = 2; 33%); pH (n = 3; 50%), protein (n = 1; 17%); and other (urine specific gravity/ hydration levels; n = 3; 50%). Table 3 shows the frequency of assessments.

3.10. Monitoring female athlete

Thirty-three (60%) respondents who completed the survey reported monitoring either both male and female athletes or solely female athletes. Seven respondents monitored either hormone contraceptive use and/or menstrual cycle phase. The frequency of these assessments are reported in Table 3. Conditions associated with the female athlete triad were monitored by 11 (33%) of the respondents who monitored female athletes. Of these conditions, iron status and eating disorders were most commonly monitored (n = 10; 91%, for both), while bone density was not commonly monitored (n = 3; 27%).

3.11. Purpose and challenges of monitoring

Performance was the most important reason to monitor training (32%; Figure 2A). 'Athlete buy-in' was the major challenge to implement/maintain a monitoring programme (34%; Figure 2B.). Table 4 shows why participants did not use workload, physiological, psychological, or biochemical monitoring (Table 4).

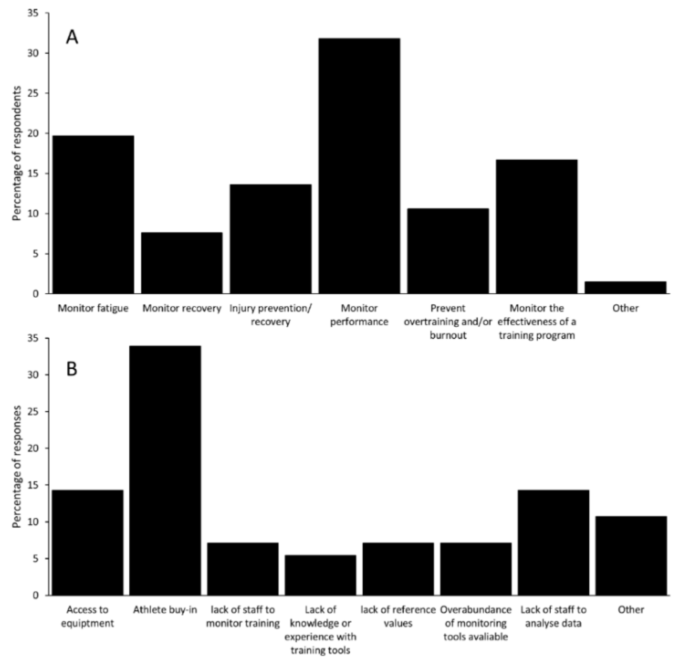

Figure 2: Key reasons to monitoring training (A) and key challenges to maintaining and/or implementing a training monitoring programme (B). *Multiple responses were allowed; some participants reported more than one key reason as the most important or challenge as the biggest barrier, therefore, Figure 2A includes 66 responses and Figure 2B includes 56 responses. The frequency of the most important factor is displayed as a percentage of respondents.

Table 4: The frequency of reasons practitioners chose not to use workload, physiological, psychological, or biochemical monitoring

	Workload	Physiological	Psychological	Biochemical
Lack of equipment	-	11 (55%)	6 (19%)	21 (53%)
Not relevant to the programme	1 (100%)	2 (10%)	3 (9%)	7 (18%)
Too time consuming	-	6 (30%)	6 (19%)	15 (38%)
Lack of staff	-	11 (55%)	10 (31%)	17 (43%)
Staff not familiar / untrained with load monitoring	-	10 (50%)	17 (53%)	16 (40%)
Results take too long to process	N/A	N/A	N/A	10 (25%)
Other	-	2 (10%)	7 (22%)	6 (15%)

4. Discussion

Monitoring the work completed by the athlete through training duration and measures of intensity were the most common ways to monitor training. Iron status and eating disorders were training monitoring considerations for female athletes. Practitioners identified that the most important reason to monitor training was to monitor performance, while the biggest challenge to monitoring was athlete 'buy-in'. These findings provide a basis for sports science researchers to optimise training monitoring programmes in the field to detect (mal)adaptation in athletes better.

4.1. Workload measures

Monitoring the work completed by the athlete was used by almost all practitioners. As the current survey investigated sports conducted both indoors and outdoors, practitioners conducting training sessions indoors would be less likely to use GPS as it is inaccurate indoors. Those who did use GPS implemented it every session, consistent with previous research (Akenhead & Nassis, 2016; Starling & Lambert, 2018; Taylor et al., 2012). Although the most commonly measured GPS variables were measures of distance, practitioners reported using an average of 5 (SD = 2.2) GPS variables to monitor load. The common parameters reported by respondents (distance, total distance covered, speed intensity, peak acceleration) are similar to the common variables reported in Akenhead and Nassis (2016). These parameters are easy to implement and interpret, indicating that practitioners may value this form of measurement.

4.2. Tools to measure performance and training response

Performance tests were reported by over half of the participants, and the current results support the previous findings of their wide use in an applied setting (Akenhead & Nassis, 2016; Starling & Lambert, 2018; Taylor et al., 2012). Commonly used performance tests (e.g., strength tests, sprints, submaximal running or cycling tests) reported in this study can be highly fatiguing. To achieve their best test performance athlete's may need to taper (Halson, 2014). Therefore, trade-off exists between the information that can potentially be gained from a performance test with the training sacrificed to taper and the fatigue subsequently experienced. This trade-off is potentially reflected by the practitioners in the current study implementing these fatiguing performance tests quarterly compared to weekly and monthly in previous research (Akenhead & Nassis, 2016; Starling & Lambert, 2018). This difference could be explained by the performance tests used, with non-fatiguing performance tests (e.g., jump tests) reported in the previous studies (Akenhead & Nassis, 2016; Starling & Lambert, 2018) compared to the more fatiguing tests (e.g., sprint tests) reported in the current study.

The use of questionnaires to monitor psychological state and wellness was low (36%). Custom-designed questionnaires were utilised as often as validated questionnaires (n=10 and n=12, respectively. This is in contrast to previous research that reported higher use of custom-designed questionnaires compared to validated questionnaires (Taylor et al., 2012). Respondents in the current study suggest that the low use of validated questionnaires may be due to a lack of education on their use (application, analysis, and results) and the time required for their implementation. Additionally, factors such as the accessibility of the measure, the time to complete, reinforcement, and social and environmental factors may influence the use of self-report measures in practice (Saw, Main, & Gastin, 2015). However, subjective monitoring is more sensitive than objective measures to both acute and chronic changes in training load (Saw et al., 2016). Therefore, the addition of a wellness questionnaire into an already established monitoring programme could be beneficial and should be implemented by to monitor the effect of training load (Saw et al., 2016).

The use of biochemical monitoring (hormone profiling, blood and urine analysis) was low. The practitioners within this study reported the main reasons they did not monitor biochemical variables was due to the lack of equipment, staff availability, knowledge and the time required to conduct the testing. This is consistent with previous literature (Taylor et al., 2012) citing the time, expenses, and knowledge of biochemical monitoring techniques being the main limitations. This study appears to be the first to investigate that markers of nutrition and metabolic health (e.g., glucose, protein, ketones), muscle status and recovery (e.g., testosterone, cortisol, testosterone: cortisol ratio), and hydration levels (e.g., urine specific gravity, pH, creatinine) are of interest to the practitioners who do monitor such biomarkers. However, biomarkers are not without their limitations. For example, the use of urine specific gravity to measure hydration status has seen inconsistent results in the literature with a delay between dehydration and rehydration impacting its applicability in acute settings (Zubac, Reale, Karnincic, Sivric, & Jelaska, 2018). Nonetheless, consistent and long-term use of selected sport and athlete-specific biomarkers are recommended to provide objective information about the health and wellbeing of the athlete (Lee et al., 2017).

4.3. Monitoring the female athlete

Few participants monitored the use of hormone contraceptives or menstrual phase. A slightly higher number monitored issues associated with the relative energy deficiency in sport (i.e., low energy availability, disordered eating, menstrual dysfunction, and low bone density). Limited research has specifically investigated the role of contraception use and menstrual cycle phase on training loads from a monitoring perspective. However, previous research in the area (e.g., menstrual phase and physical performance; Julian, Hecksteden, Fullagar, & Meyer, 2017) suggest an influence on performance and recovery. Therefore, these considerations may assist with training prescription to optimise adaptation.

The majority of respondents who indicated monitoring for the female athlete triad reported monitoring the iron levels of their female athletes. Iron deficiencies can lead to fatigue and anaemia, cognitive impairment, and immune deficiencies and have a high prevalence in athletes from a variety of sports which can impact on athletic performance (Lee et al., 2017). Therefore, it is important for practitioners to continue to monitor for iron deficiencies.

A higher percentage of respondents who monitor only female athletes reported using psychological questionnaires, including custom made questionnaires, and blood analysis compared to respondents who monitored only male athletes, or both male and female, athletes. The higher percentage of practitioners that conducted blood analysis may be due a higher risk of relative energy deficiency and lower iron levels than their male counterparts due to menstruation and therefore a greater need to monitor the status of these biochemical measures (Pedlar, Newell, & Lewis, 2019). Due to the small sample size and uneven groups this conclusion is tentative, and further research is needed to ascertain whether a difference in tool use among genders occurs to support these results.

4.4. Purpose and challenges of monitoring

The current study demonstrated that the most important reasons to monitor training for practitioners were to monitor performance, fatigue, and effectiveness of a training programme. Practitioners in previous research (Starling & Lambert, 2018; Taylor et al., 2012; Weston, 2018) have indicated that injury prevention/ reduction was the most important reason for monitoring training load and the athlete's response. This difference may be due to the previous studies investigating practitioners in team sports (Starling & Lambert, 2018; Weston, 2018), or samples consisting of majority team sports, which contrast the current sample of both individual and team sports (Taylor et al., 2012).

Athlete 'buy-in' was the biggest challenge to implementing/ maintaining a training monitoring programme. It has previously been considered a barrier to implementing and sustaining an accurate training monitoring programme (Neupert, Cotterill, & Jobson, 2019). Coaches have indicated that many athletes do not return their training data and need convincing of the benefits of providing the data (Roos, Taube, Brandt, Heyer, & Wyss, 2013). Athletes, however, reported that frequent and open feedback, and appropriate modification of training monitoring programmes as a result of the data is needed to promote adherence (Neupert et al., 2019). Coach and athlete education on training monitoring programmes may be a step forward in improving athlete buy-in.

4.5. Practical applications

The main findings of the current study were the details in the use of training monitoring tools in high-performance sport settings. This investigation has furthered previous knowledge by examining what tools are used in the field by practitioners, when they are used, and what type of information is collected. The practitioners commonly used measures of workload (training intensity and duration). Although practitioners commonly monitored their female athletes for eating disorders, less monitored the athlete's menstrual cycle. Finally, athlete buy-in was considered a challenge to the implementation and maintenance of a training monitoring programme.

Despite extensive email recruitment, only a small sample of high-performance coaches responded to the survey. As the sample is self-selecting, the results may not accurately represent the broader population. Additionally, caution should be taken when interpreting the results due to the perception of truth (consciously or subconsciously) and completeness of the answers provided. The dissemination of the results of this investigation allows practitioners to discover what their peers are using to monitor training, and how these tools are implemented (e.g., the frequency or timing), and compare to their practice and discover other monitoring strategies. Furthermore, understanding the tools that are used and valued in practice enables researchers to develop these tools and practices to be relevant and practical to coaches. Knowing what is practical and valued can help to bridge the gap between research and practice by further developing the commonly implemented tools, assessing their validity and reliability, the researcher can improve training monitoring programmes.

Conflict of Interest

The authors declare no conflict of interests.

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