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Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review

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ABSTRACT

Background Monitoring athlete well-being is essential to guide training and to detect any progression towards negative health outcomes and associated poor performance. Objective (performance, physiological, biochemical) and subjective measures are all options for athlete monitoring.

Objective We systematically reviewed objective and subjective measures of athlete well-being. Objective measures, including those taken at rest (eg, blood markers, heart rate) and during exercise (eg, oxygen consumption, heart rate response), were compared against subjective measures (eg, mood, perceived stress). All measures were also evaluated for their response to acute and chronic training load.

Methods The databases Academic search complete, MEDLINE, PsycINFO, SPORTDiscus and PubMed were searched in May 2014. Fifty-six original studies reported concurrent subjective and objective measures of athlete well-being. The quality and strength of findings of each study were evaluated to determine overall levels of evidence.

Results Subjective and objective measures of athlete well-being generally did not correlate. Subjective measures reflected acute and chronic training loads with superior sensitivity and consistency than objective measures. Subjective well-being was typically impaired with an acute increase in training load, and also with chronic training, while an acute decrease in training load improved subjective well-being.

Summary This review provides further support for practitioners to use subjective measures to monitor changes in athlete well-being in response to training. Subjective measures may stand alone, or be incorporated into a mixed methods approach to athlete monitoring, as is current practice in many sport settings.

physical and psychological well-being and the athlete's readiness to compete, yet it is impractical to test athletes daily via performance tests.¹¹

A considerable body of research has investigated potential physiological mechanisms underlying the progression towards overtraining syndrome.^{12–16} Hormonal, immune, inflammatory and haematological parameters along with cardiovascular responses have been proposed as markers of these mechanisms, however findings have been inconsistent. This has been attributed to factors such as intra-assay and interassay variability, intraindividual and interindividual variability, the influence of circadian and pulsatile rhythms, nutrition and hydration status, climate, psychosocial factors and particular exercise characteristics.^{12 14 17–19} Whether markers are elevated or depressed may also depend on the position along the athlete well-being continuum, with proposed physiological mechanisms involving an initial heightened response that later becomes exhausted.^{13–16}

While there remains debate on the specific physiological mechanisms underlying the progression towards overtraining syndrome, there is agreement that progression is associated with psychological signs such as mood disturbances and symptoms similar to clinical depression.^{5 20} These signs and symptoms may be self-reported by athletes as perceived physical and psychological well-being, collectively termed 'subjective measures'. Subjective measures for routine athlete monitoring are also relatively cheap and simple to implement compared to objective measures. However, it is unknown whether subjective measures accurately reflect changes in athlete well-being, and how they can be effectively integrated into applied practice.³

Therefore, we systematically reviewed whether subjective measures accurately reflected changes in athlete well-being (as objectively measured by performance, physiological and biochemical indicators) and whether subjective measures were responsive to acute changes in training load, and chronic training.

METHODS

Search strategy

An electronic search was conducted using the Academic search complete, MEDLINE, PsycINFO, SPORTDiscus and PubMed databases. The complete search strategy is presented in [table 1](#). Databases were searched from the earliest available record up to 5 May 2014, with results limited to humans and English language.

INTRODUCTION

Training imposes stress on an athlete, shifting their physical and psychological well-being along a continuum that progresses from acute fatigue to overreaching, and ultimately overtraining syndrome.^{1 2} While overreaching may be carefully incorporated into a periodised training plan, progression towards overtraining syndrome is undesirable. Athletes should be closely monitored to ensure training elicits the desired effects on athlete well-being and performance.^{1–10}

Performance, physiological, biochemical and subjective measures are all options for athlete monitoring. There is currently a relatively poor understanding of which measures are most appropriate.² Performance is the ultimate indicator of



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Table 1 Database search strategy

1. Athlete	TI OR SU (*athlete* OR sportspeople OR sportsperson* OR sportsm?n OR sportswom?n OR archer* OR "badmington player*" OR baseballer* OR "baseball player*" OR basketballer* OR "basketball player*" OR bastm?n OR *boarder* OR bobsledder* OR *bowler* OR *boxer* OR canoeist* OR cricketer* OR *cyclist* OR *dancer* OR footballer* OR "football player*" OR golfer* OR gymnast* OR handballer* OR "handball player*" OR "hockey player*" OR hurdler* OR jockey* OR kayaker* OR "lacrosse player*" OR *marathoner* OR "martial artist*" OR netballer* OR "netball player*" OR orienteer* OR sprinter* OR swimmer* OR racewalker* OR "race walker*" OR *rider* OR rower* OR *runner* OR *sailor* OR "soccer player*" OR *skater* OR *skier* OR softballer* OR "softball player*" OR "squash player*" OR swimmer* OR "tennis player*" OR volleyballer* OR "volleyball player*" OR "water polo player*" OR weightlifter* OR "weight lifter*" OR *wrestler*)
2. Subjective measure	SU OR AB (self-report* OR "self report" OR diary OR diaries OR questionnaire* OR survey* OR scale OR scales OR journal OR journals OR inventory OR inventories OR self-evaluation OR "self evaluation" OR self-appraisal OR "self appraisal" OR self-assessment OR "self assessment" OR self-rating OR "self rating" OR subjective OR perceive* OR perceptual OR "profile of mood states" OR "daily analys?s of life demands for athletes")
3. Objective measure	SU OR AB (blood OR saliva* OR urine OR sweat OR serum OR plasma OR biological OR biochemical OR hormon* OR endocrine OR inflammat* OR immune OR immunological OR cytokine OR haemato* OR physiological OR "heart rate" OR performance OR psychomotor OR neuromuscular OR metaboli* OR "oxygen consumption" OR VO2* OR threshold OR "sleep actigraph*" OR electrocardiogra* OR ECG OR electromyogra* OR EMG OR electroencephalogra* OR EEG OR "rate of force development")
4. Athlete well-being	SU OR AB (wellbeing OR well-being OR "well being" OR wellness OR health OR psychological OR "mental state*" OR "state of mind" OR affect OR affective OR affects OR mood* OR emotion* OR anxiety OR confidence OR self-esteem OR self-efficacy OR motivation OR depression OR stress OR tension OR feeling* OR "physical state" OR "physical functioning" OR "perceived recovery" OR "perceived strength" OR soreness OR "quality of life" OR readiness OR vitality OR vigor OR vigour OR sleepiness OR "sleep quality" OR fatigue OR tiredness OR alertness OR distress OR "social function" OR appetite OR overtrain* OR overreach*)
	1 AND 2 AND 3 AND 4

Study selection

Results were initially screened by title and abstract against the selection criteria. If it was unclear from the title or abstract whether a study met the inclusion criteria, the full-text was sought and screened against the selection criteria. The first author (AS) screened all articles.

Inclusion criteria:

- Original research;
- Study population of athlete(s) who were currently in training;
- Not include a non-training experimental intervention;
- Include a subjective self-report measure of athlete well-being with published validity and reliability;
- Include an objective measure of athlete well-being; and
- Have subjective and objective measures that coincide in timing, but not coincide with competition and be repeated at intervals reflective of the applied setting.

Studies that included a non-training experimental intervention such as nutritional supplementation or recovery strategy were excluded as the intervention may have confounded findings. Experimental manipulations of training (eg, overload, taper), were included as such manipulations are reflective of normal training periodisation and also enable evaluation of the sensitivity of subjective and objective measures to changes in training load.

Subjective measures were restricted to established self-report measures with validity and reliability reported in the literature to improve the credibility of findings and enable comparison between studies. Rating of perceived exertion was not included as a subjective measure as it is a measure of perceived exertion to a particular bout of exercise rather than a measure of athlete well-being.

Competition periods were excluded as they introduce acute perturbations to athlete well-being that are dependent on various individual and sport characteristics.²¹ Competitive performances are also influenced by external factors such as opponent and weather conditions that could affect athlete well-being and performance measures. The timing of administration of subjective and objective measures enabled the detection of concomitant change, while being practical for the applied setting (ie, excludes frequent measures across a day or measures taken during exercise).

Data extraction

The first author extracted data for all included studies using a specifically developed spreadsheet. Two authors (AS and PG) independently extracted data from five randomly selected studies. Discrepancies were resolved via adjudication by the third author (LM).

The relative weighting of study findings was determined by the magnitude of stimulus experienced by the athletes, and the magnitudes of change noted for subjective and objective measures. The magnitude of the stimulus influencing athlete well-being was rated as normal, moderate or high. Normal training stimuli included an ongoing training load without particular phases which may disrupt athlete well-being. Moderate training stimuli included overload and taper phases, while high-training stimuli included shock loads not reflective of normal practice that were designed to elicit considerable disruption to athlete well-being. Changes in subjective and objective measures across repeated measurements were noted if the study's analysis showed statistical significance or a meaningful effect size (ES) in a results table and/or text. For each measure, the magnitude of change (small ($p=0.05$, $ES=0.6$), moderate ($p<0.05$, $ES<1.2$), large ($p<0.01$, $ES >1.2$)), along with the direction of change, was noted.

Other data extracted from studies included the age, gender and participation level of athletes, sport characteristics, training phase and measures used. Measures of performance capacities were grouped as those measuring sustained performance (eg, time trial, submaximal workload) or short performance (eg, grip strength, vertical jump).

Risk of bias assessment

Studies were assessed for risk of bias to give a weighting to their contribution to the review. As no suitable published assessment criteria were available, specific criteria were developed (table 2). Scores were allocated based on how well each criterion was met, up to a maximum possible score of 8 (low risk of bias). Studies with a risk of bias assessment score of 4 or less were considered poor and their contribution to results was weighted as half.

Data synthesis

Meta-analysis was precluded due to heterogeneity in methods and reporting. Therefore, data were synthesised descriptively.

Table 2 Risk of bias assessment criteria

Criteria	Definition	Scoring		
		0	1	2
A	Peer reviewed	No	Yes	
B	Number of participants*	<5	5–50	>50
C	Population defined	No	Partly	Yes
D	Training or competition load described	No	Partly	Yes
E	Response set on self-report measure described	No	Yes	

*Arbitrary cut-offs used to distinguish between case study, single cohort and larger/multiple cohort study designs.

To determine the association between changes in subjective and objective measures, each association from an individual study was rated according to its direction (positive, negative, no association) and strength as determined from reported correlations (small ($r < 0.3$), moderate ($r = 0.3–0.5$), large ($r > 0.5$)) or average magnitudes of change. Individual associations were then summed and rated according to the predetermined levels of evidence outlined below (adapted from Van Tulder *et al*²² and Reurink *et al*²³).

Strong evidence: consistently identified in two or more studies, and greater than or equal to 75% of all contributing findings.

Moderate evidence: consistently identified in two or more studies, and greater than 50% of all contributing findings.

Limited evidence: identified in one study, with greater than 50% of all contributing findings.

Conflicting evidence: inconsistency in two or more studies. If half of all contributing sources were in agreement, with the other half conflicting, a potential direction was indicated.

No evidence: no change in subjective or objective measures.

To determine the responsiveness of each subjective and objective measure to acute and chronic training load, the sensitivity and consistency of responses were evaluated. To evaluate the sensitivity of responses, the magnitude of change was multiplied by a factor weighting for the magnitude of stimulus (normal stimulus $\times 1$, moderate $\times 0.75$, high $\times 0.5$). In the instance of no change, factor weightings (normal $\times 1$, moderate $\times 1.5$ and high $\times 2$) were applied to reflect a lack of sensitivity. Individual changes were then summed to determine typical patterns, with the strength of evidence rated by the criteria above.

RESULTS

Included studies and measures

From an initial 4244 articles retrieved from database searches, 1377 were excluded as duplicates. A total of 2803 articles did not meet the inclusion criteria and were excluded (figure 1). Of the 64 remaining articles, 2 shared data with another article^{24–27} and so were combined and considered as a single data set in each instance. A further six articles^{28–33} were excluded as the presentation or use of their data precluded interpretation of change across all athletes (eg, data used to retrospectively group athletes as overtrained or control). Finally, 56 studies were included in the analysis. Two of these studies were excluded from the responsiveness analysis as their primary stimulus was dietary restriction rather than training.^{34–35} Characteristics of included articles and results of the risk of bias assessment are provided in online supplementary table S1.

The most common subjective measures of athlete well-being were the Profile of Mood States (POMS)³⁶ (including derivatives of the POMS³⁷), Recovery Stress Questionnaire for Athletes (RESTQ-S)³⁸ and Daily Analyses of Life Demands of Athletes (DALDA).³⁹ Other measures included the overtraining

questionnaire of the Societe Francaise de Medecine du Sport (SFMS),⁴⁰ State-Trait Anxiety Inventory (STAI),⁴¹ Perceived Stress Scale (PSS),⁴² Multi-Component Training Distress Scale (MTDS),⁴³ Competitive State Anxiety Inventory-2 (CSAI-2),⁴⁴ Derogatis Symptom Checklist (DSC),⁴⁵ State-Trait Personality Inventory (STPI)⁴⁶ and a mood questionnaire by Choi and Salmon⁴⁷ (Mood).

Associations between subjective and objective measures of athlete well-being

There was moderate evidence for a negative association between stress and cortisol (table 3), and a positive association between vigour and leukocytes (table 4). There was moderate evidence for a positive association between four RESTQ-S stress subscales and creatine kinase (CK), yet evidence was conflicting for total stress (table 4). Between the POMS and maximal oxygen consumption (VO_{2max}), there was strong evidence for a positive association with the vigour subscale and moderate evidence for a negative association with the fatigue subscale, which was also reflected by strong evidence for a negative association with total mood disturbance (table 5). There was strong evidence for a negative association between symptoms of stress (measured by DALDA) and sustained performance (table 5).

Responsiveness of subjective and objective measures to training

Within studies (ie, under the same conditions), subjective measures were more sensitive and consistent than objective measures in 22 of the 54 studies. Objective measures were generally unresponsive to acute changes in training load, with moderate evidence of a typical response in three measures (CK, short and sustained performance) to both increased and decreased training (table 6). With ongoing training, there was moderate to strong evidence of responsiveness for five objective measures, including impairment of epinephrine/norepinephrine and leukocytes (table 6).

Subjective measures were more responsive to training than objective measures. There was moderate to strong evidence of impaired well-being with an acute increase in training load for 13 subjective measures (table 7). There was moderate to strong evidence of improved well-being with an acute increase in training load for 17 subjective measures (table 7). There was moderate to strong evidence of impaired well-being with ongoing training for 13 subjective measures (table 7). Six of the RESTQ-S measures (stress, fatigue, recovery, physical recovery, general well-being, being in shape) demonstrated moderate to strong evidence of responsiveness to all three of the training load conditions. Consolidation of subjective measures into a total score typically resulted in reduced sensitivity, with one in five studies reporting both subscale and total scores noting a change in only the subscale score(s).

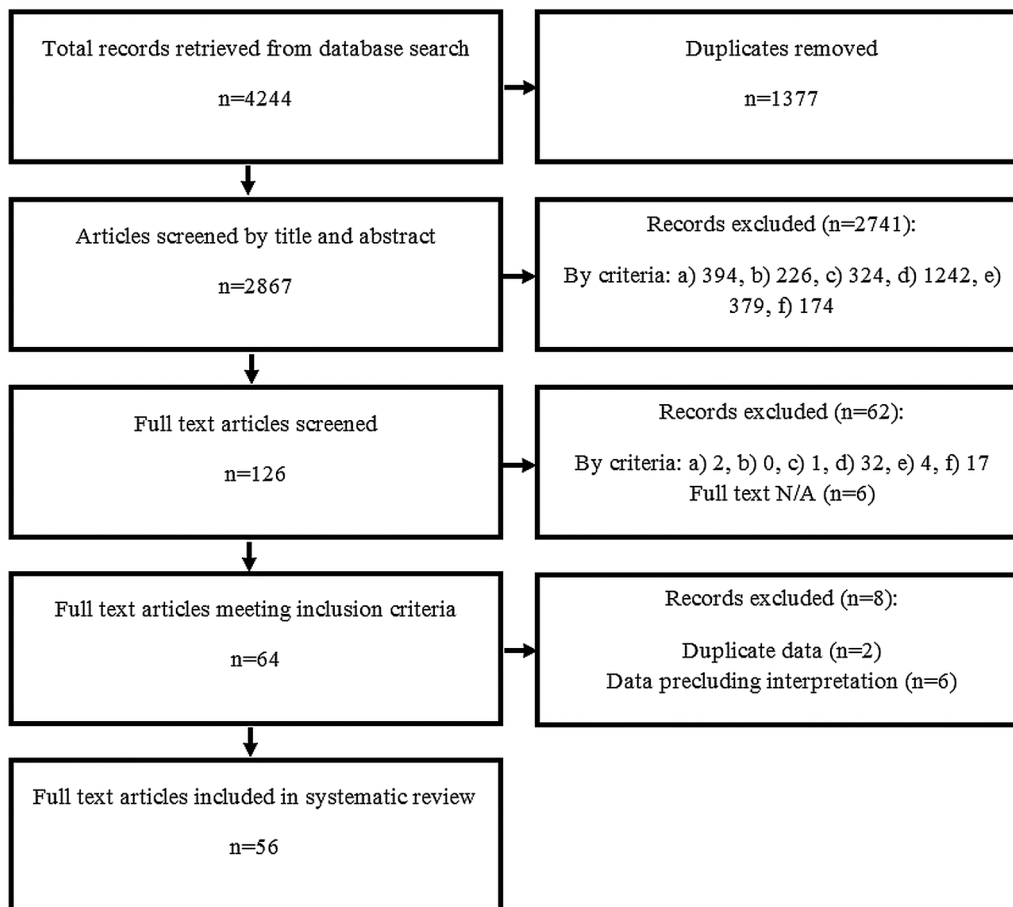


Figure 1 Selection of studies flow chart. Studies excluded for not meeting the following criteria: (A) original research; (B) study population of athlete(s); (C) no non-training intervention; (D) include a subjective measure; (E) include an objective measure; and (F) appropriate timing of measures.

DISCUSSION

This systematic review evaluated the ability of individual subjective measures, assessed by self-report measures, to reflect changes in athlete well-being. The findings provide support for subjective measures to reflect acute and chronic training-related changes in athlete well-being. In particular, measures of mood disturbance (eg, POMS), perceived stress and recovery (eg, RESTQ-S) and symptoms of stress (eg, DALDA) were widely investigated and appear to be useful for athlete monitoring.

Subjective measures are responsive to acute and chronic training load

Subjective measures consistently identified impaired well-being with acute increases in training load,^{26 48–62} and improved well-being with an acute reduction in training load.^{26 48 49 52–58 60 63–67} This extends previous narrative reviews of overtraining markers that suggested subjective measures change in a dose-response manner to training load.^{3 7 8} The ability of subjective measures to reflect both acute increases and decreases in training indicates that the measures are indeed responsive to training load.⁶⁸

Subjective measures also identified impaired well-being in response to chronic training load.^{63 64 69–78} This is particularly important for ongoing monitoring because progression towards overtraining syndrome may be gradual and less easily identified than in situations of acute overload.³ However, it is important to note that this finding does not take into account the different

scenarios across studies, or the influence of non-training stressors on athlete well-being. Consequently, the tendency for well-being to be impaired with ongoing training should be interpreted cautiously as there was no way to discern where athletes may have been placed on the athlete well-being continuum.

A case for subjective measures having some advantages over objective measures

Subjective measures, particularly measures of mood disturbance, perceived stress and recovery and symptoms of stress, responded with superior sensitivity and consistency compared to objective measures. Within studies (ie, under the same conditions), sensitivity, consistency and/or timing differed in 46% of studies and 85% of these favoured subjective measures. Superior responsiveness of subjective measures over objective measures has been noted previously in experimental overload^{48 55} and observational⁷⁹ studies.

We found moderate evidence that creatine kinase increases and decreases with acute training load. Subjective well-being typically has the opposite response to acute loads, however only four subjective measures of stress (general stress, emotional stress, fatigue, emotional exhaustion) were moderately associated with creatine kinase. The lack of an association between creatine kinase and subjective measures may be explained by the different responses of these measures to chronic training. We found that creatine kinase was unresponsive to chronic training, likely due to minimal muscle damage induced by accustomed

Table 3 Evidence of associations between subjective and objective (endocrine and erythrocytes) measures

	Endocrine										Erythrocytes		
	C	T	T:C	E/NE	Pro	GH	ACTH	LH	Dop	IGF-1	RBC	Hct	Hb
POMS													
Total mood disturbance	xx	xxx	xxx	xx	x			x	x		–	–	–
Tension	xxx	xx	xx	xxx	x			x	x	–	–	–	–
Depression	xx	xx	xx	xxx	x			x	–	–	–	–	?
Anger	xx	xx	xxx	?	xxx			x	–	–	?	?	xxx
Confusion	xx	?x	xx	xxx	x			x	x	–	–	–	?
Vigour	?	xx	?x	?	–			–	x	–	x	x	?
Fatigue	xx	xx	xxx	xx	x			x	x	x	–	–	?
RESTQ-S													
Recovery-Stress Index	xxx	xxx	x	x	x	–	x				–	?	?
Stress	↓↓	x	x	x	x	x	x				–	?	?
General stress	xx	x	–	?	–	–	–				–	–	?
Emotional stress	xxx	x	–	?	–	–	–				–	–	?
Social stress	xxx	x	–	?	–	–	–				x	?	xxx
Conflicts/pressure	?	x	–	?	–	–	–				–	–	?
Fatigue	?	↓	–	↑	–	–	–				–	–	?
Lack of energy	?x	xxx	x	x	x		x				–	?	?
Physical symptoms	xxx	?	x	xxx	x		x				–	?	?
Injury	xxx	↓	x	x	x		x				?	?x	?
Emotional exhaustion	xxx	x	–	?	–	–	–				–	–	?
Disturbed breaks	xx	x	–	?	–	–	–				–	–	?
Recovery	?x	?	x	x	x	x	x				–	?	?
Social recovery	?	↑	–	?	–	–	–				–	–	?
Physical recovery	xx	xxx	x	x	x		x				–	?	?
General well-being	xx	xxx	x	x	x		x				–	?	?
Sleep quality	xxx	↑	–	?	–	–	–				–	–	?
Success	xx	↑	–	?	–	–	–				–	–	?
Being in shape	xxx	?	x	x	x		x				x	xxx	?x
Personal accomplishment	xx	x	–	?	–	–	–				–	–	?
Self-efficacy	xxx	↓	–	?	–	–	–				–	–	?
Self-regulation	?	x	–	?	–	–	–				?	–	xxx
SFMS													
Overtraining score	?	?	?	x									
DALDA													
Sources of stress	–			–									
Symptoms of stress	x			x									
n	24	11	8	7	3	1	1	1	1	1	2	3	4

Associations rated as positive (1), negative (1), not associated (x), conflicting findings (?), no change (–). Three symbols indicates strong evidence, two symbols for moderate evidence, and one symbol for limited evidence. Shading highlights strong (dark grey) and moderate (light grey) associations. Abbreviations for objective measures: cortisol (C), testosterone (T), epinephrine and norepinephrine (E/NE), prolactin (Pro), growth hormone (GH), adrenocorticotrophic hormone (ACTH), luteinising hormone (LH), dopamine (Dop), insulin-like growth factor-1 (IGF-1), erythrocytes (RBC), Haematocrit (Hct), haemoglobin (Hb). n refers to number of contributing studies.

POMS, Profile of Mood States; RESTQ-S, Recovery Stress Questionnaire for Athletes; SFMS, Societe Francaise de Medecine du Sport; DALDA, Daily Analyses of Life Demands of Athletes.

training.⁸⁰ Chronic responses in the instance of overtraining are also inconsistent, questioning the utility of creatine kinase to monitor athlete well-being.^{7,8}

We found moderate evidence that a reduction in acute training load was associated with an improvement in VO₂max. The noted positive association between VO₂max and subjective well-being may indicate that subjective measures reflect an athlete's ability to perform a sustained, maximal effort. Alternatively, subjective measures may reflect an athlete's psychological readiness to perform, with psychological state known to influence performance.⁸¹ Impaired VO₂max may also be attributable to reduced exercise time during the test rather than a decrement in physiological function.^{3,82} Notably, a similar association with sustained performance was not found.

The lack of association between subjective and objective measures provides support for the inclusion of both in different yet complementary athlete monitoring roles.

While a lack of responsiveness is a limitation of objective measures for monitoring athlete well-being, their utility lies in measuring certain constructs which are related to athlete well-being, but do not necessarily reflect an athlete's position on the continuum. For instance, objective measures quantify physiological and performance capacities (eg, VO₂max, lactate threshold) which may be used to guide training prescription, and laboratory tests can detect medical conditions (eg, recurrent infection,⁸³ iron deficiency⁸⁴).

Table 4 Evidence of associations between subjective and objective (immune, inflammation and muscle damage) measures

	Immune			Inflammation and muscle damage													
	Leuk	IgA	IgG	IL-1B	IL-6	IL-8	IL-10	IL-12p70	TNF- α	α -amylase	CRP	Ox. Stress	GSH:GSSG	Urea	Creatinine	CK	
POMS																	
Total mood disturbance	xxx	?	xxx								x	?	x	x	x	xx	
Tension	xxx	?	x		x						x	?	x	x	x	-	
Depression	xxx	?	x		x						x	?	x	-	x	?	
Anger	xx	?	x		x						-	?	?	-	x	?	
Confusion	xxx	?	x		x						x	?	x	xx	x	-	
Vigour	↑↑	?	?		x						↑	xxx	↓	xxx	↑	?	
Fatigue	xx	?	?		↑						xxx	?	x	xxx	↑	?	
RESTQ-S																	
Recovery-Stress Index	xxx										x	-	x	↓	x	?x	
Stress	xxx										↓	x	-	x	↑	?	
General stress	xxx										↓	x	-	x	x	-	
Emotional stress	xxx										x	x	-	x	x	-	
Social stress	?										x	↑	x	↓	x	-	
Conflicts/pressure	xxx										↓	x	-	x	x	-	
Fatigue	xxx										↓	x	-	x	x	-	
Lack of energy	xxx										↓	x	-	x	↑	x	
Physical symptoms	xxx										x	x	-	x	↑	x	
Injury	xxx										x	↑	x	↑	↑	x	
Emotional exhaustion	xxx										x	x	-	x	x	-	
Disturbed breaks	xxx										x	x	-	x	x	-	
Recovery	xxx										↑	x	-	x	↓	x	
Social recovery	xxx										x	x	-	x	x	-	
Physical recovery	xxx										↑	x	-	x	↓	x	
General well-being	xxx										↑	x	-	x	↓	x	
Sleep quality	xxx										x	x	-	x	x	-	
Success	xxx										↑	x	-	x	x	-	
Being in shape	xxx										↑	↑	x	↓	↓	x	
Personal accomplishment	xxx										x	x	-	x	x	-	
Self-efficacy	xxx										x	x	-	x	x	-	
Self-regulation	?										↑	?	x	?	x	-	
DALDA																	
Sources of stress	-	-			x												x
Symptoms of stress	x	x			↑										x		↑
STAI																	
State anxiety		x															
PSS																	
				x	↑	x	x	x		↑							
MTDS																	
Total score				x	x	x	x	x		x							
Depressed mood				↑	↑	x	↓	x		↑							
Perceived vigour				x	↓	x	↑	x		↓							
Physical symptoms				x	↓	x	↑	x		x							
Sleep disturbance				↓	↑	x	↓	x		↑							
Perceived stress				↑	x	↑		x		↑							
General fatigue				x	↑	x	↓	↑		↑							
Mood																	
All subscales		-															
n	6	7	2	2	4	2	2	2	2	2	1	3	2	2	4	2	10

Associations rated as positive (↑), negative (↓), not associated (x), conflicting findings (?), no change (-). Three symbols indicates strong evidence, two symbols for moderate evidence and one symbol for limited evidence. Shading highlights a moderate association. Abbreviations for objective measures: leukocytes (Leuk), immunoglobulin-A (IgA), immunoglobulin-G (IgG), interleukins (IL-), tumour necrosis factor α (TNF- α), C reactive protein (CRP), oxidative stress (Ox. stress), reduced-oxidised glutathione ratio (GSH:GSSG), creatine kinase (CK). n refers to number of contributing studies.

POMS, Profile of Mood States; RESTQ-S, Recovery Stress Questionnaire for Athletes; DALDA, Daily Analyses of Life Demands of Athletes; STAI, State-Trait Anxiety Inventory; PSS, Perceived Stress Scale; MTDS, Multi-Component Training Distress Scale.

Athlete monitoring is not limited to either subjective or objective measures, instead they can be used to complement each other. Combining both types of measures is common in applied

settings, as evident by the large number of studies included in this review and a recent survey of high performance sports.⁸⁵ This is also consistent with recent recommendations.^{2 86}

Table 5 Evidence of associations between subjective and objective (physiological and performance) measures

	Physiological										Performance	
	La submax	La max	HR rest	HRV	HR submax	HR max	HR rec	BP rest	VO ₂ submax	VO ₂ max	Sust.	Short
POMS												
Total mood disturbance	–	x	x	↑	xx	?		x	xxx	↓↓↓	?	xx
Tension	x	x	↓	x	xxx	↓		x	x	?	xx	?
Depression	–	–	↓	x	xx	x		x	–	xxx	xx	?
Anger	–	–	↓	x	xx	x		x	–	xxx	xx	xx
Confusion	x	x	↓	x	xxx	↓		x	x	?	?	xx
Vigour	x	xxx	x	x	xx	?		x	xxx	↑↑↑	?	xxx
Fatigue	x	xxx	?x	↑	xx	?		x	xxx	↓↓	?	xx
RESTQ-S												
Recovery-Stress Index					–	–					xx	xxx
Stress		x			x	–					xxx	xx
General stress		x			x						xxx	↑
Emotional stress		x			x						xxx	↑
Social stress		x			x						xxx	↑
Conflicts/pressure		x			x						xxx	?
Fatigue		–			–						?	xxx
Lack of energy		x			x						xx	?
Physical symptoms		x			x						xx	↑
Injury		x			x						xx	?
Emotional exhaustion		x			x						xxx	↑
Disturbed breaks		x			x						xxx	?
Recovery		x			x	–					xxx	xx
Social recovery		x			x						↑↑	x
Physical recovery		–			–						?x	xxx
General well-being		x			x						xx	?
Sleep quality		x			x						xx	?
Success		–			–						xx	xxx
Being in shape		–			–						?	xxx
Personal accomplishment		x			x						xxx	↓
Self-efficacy		x			x						?x	?
Self-regulation		x			x						xxx	?
SFMS												
Overtraining score	↓	↓		↑		↓					↓	x
DALDA												
Sources of stress	–	–	–		–	x	x		–	x	xxx	x
Symptoms of stress	xxx	xxx	x		xxx	?	↑		x	↓	↓↓↓	↓
CSAI-2												
Cognitive anxiety										–	x	x
Somatic anxiety										x	x	x
Self-confidence										x	x	x
MTDS												
Total score											↑	
DSC												
										–	x	x
STPI												
Anxiety										x	x	x
Anger										–	x	x
n	3	6	4	2	9	7	1	1	4	5	29	16

Associations rated as positive (↑), negative (↓), not associated (x), conflicting findings (?), no change (–). Three symbols indicates strong evidence, two symbols for moderate evidence and one symbol for limited evidence. Shading highlights strong (dark grey) and moderate (light grey) associations. Abbreviations for objective measures: blood lactate (La), heart rate (HR), heart rate variability (HRV), blood pressure (BP), oxygen consumption (VO₂), sustained (Sust.). n refers to number of contributing studies.

POMS, Profile of Mood States; RESTQ-S, Recovery Stress Questionnaire for Athletes; SFMS, Societe Francaise de Medecine du Sport; DALDA, Daily Analyses of Life Demands of Athletes; CSAI-2, Competitive State Anxiety Inventory-2; MTDS, Multi-Component Training Distress Scale; DSC, Derogatis Symptom Checklist; STPI, State-Trait Personality Inventory.

Use of subjective measures in practice

The potential efficacy of subjective measures for athlete monitoring has been established, however optimal implementation practices are yet to be determined. Implementation practices affect how well athlete well-being is reflected, and whether the

data can be used in a meaningful way.⁸⁷ The differing practices among the included studies lends to discussion regarding the particular self-report measure used to assess subjective well-being, the response set and rating scales and the timing and frequency of administration.

Table 6 Typical patterns of objective measures to acute changes in training load and chronic training

	Acute		Chronic	n
	Increased training load	Decreased training load	Ongoing training	
Endocrine				
C	---	?	?	23
T	--	?	?	10
T:C	---	---	--	8
E/NE	---	---	↓↓↓	6
Prolactin	-	-	-	2
GH	-	-	-	1
ACTH	-	-	-	1
LH	-	-	-	1
Dopamine	-	-	-	1
IGF-1	-	-	-	0
Erythrocytes				
RBC	-	-	---	2
Hct	-	-	---	3
Hb	↓↓↓	↑	---	4
Immune				
Leuk.	--	--	↓↓↓	6
IgA	---	---	↑↑	7
IgG	?	-	-	2
IL-1β	-	-	---	2
IL-6	-	?	---	3
IL-8	-	-	---	2
IL-10	-	↑	↓	2
IL-12p70	-	↓	↑	2
TNF-α	-	↑	↓	2
α-amylase	-	-	↑	1
Inflammation an muscle damage				
CRP	-	-	↓	2
Oxidative stress				
GSH:GSSG	-	-	↓	2
Urea	-	-	-	3
Creatinine	-	-	↓	2
CK	↓↓	↑↑	---	10
Physiological				
La submax	--	--	-	3
La max	---	---	---	6
HR _{rest}	-	?-	---	4
HR _{variability}	-	-	?↑	2
HR _{submax}	---	--	---	9
HR _{max}	--	--	---	7
HR _{recovery}	-	-	↑	1
BP _{rest}	-	-	-	1
VO ₂ submax	---	---	↓	4
VO ₂ max	-	↑↑	---	5
Performance				
Sustained	↓↓	↑↑	↑↑	28
Short	↓↓	↑↑	↑↑	25

Typical patterns rated as improve (↑), decline (↓), conflicting findings (?), or no change (-). Three symbols indicates strong evidence, two symbols for moderate evidence and one symbol for limited evidence. Shading highlights strong (dark grey) and moderate (light grey) associations. Abbreviations for objective measures: cortisol (C), testosterone (T), epinephrine and norepinephrine (E/NE), growth hormone (GH), adrenocorticotrophic hormone (ACTH), luteinising hormone (LH), insulin-like growth factor-1 (IGF-1), erythrocytes (RBC), Haematocrit (Hct), haemoglobin (Hb), leukocytes (Leuk.), immunoglobulin-A (IgA), immunoglobulin-G (IgG), interleukins (IL-), tumour necrosis factor α (TNF-α), C reactive protein (CRP), reduced-oxidised glutathione ratio (GSH:GSSG), creatine kinase (CK), blood lactate (La), heart rate (HR), blood pressure (BP), oxygen consumption (VO₂). n refers to number of contributing studies.

Self-report measures may be characterised by: (1) whether or not they are specifically designed for athletes, (2) if they evaluate single or multiple constructs and (3) whether the constructs are based on stressors, or resulting symptoms. It has been suggested

that athlete-specific measures evaluating multiple constructs may better reflect performance capacities.⁸⁸ Broader measures may also cater to the differing circumstances and responses of individuals, capturing both training and non-training stressors and

Table 7 Typical patterns of subjective measures to acute changes in training load and chronic training

	Acute		Chronic	n
	Increased training load	Decreased training load	Ongoing training	
POMS				
Total mood disturbance	↓↓	↑↑↑	?	27
Tension	?	↑↑	—	27
Depression	?-	--	--	28
Anger	?	↑↑	?	28
Confusion	--	--	---	27
Vigour	↓↓↓	↑↑	?	29
Fatigue	↓↓↓	↑↑↑	?	30
Recovery-Stress Index	↓↓	↑↑↑	↓	7
Stress				
General stress	--	↑↑	↓↓↓	11
Emotional stress	--	?	--	11
Social stress	--	↑↑	↓↓	11
Conflicts/pressure	---	---	↓↓↓	11
Fatigue	↓↓↓	↑↑	↓↓	11
Lack of energy	---	--	↓↓↓	11
Physical symptoms	↓↓	↑↑	--	11
Injury	↓↓	↑↑↑	?-	11
Emotional exhaustion	--	--	--	11
Disturbed breaks	---	--	--	11
Recovery				
Recovery	↓↓	↑↑	↓↓	10
Social recovery	--	---	---	11
Physical recovery	↓↓	↑↑↑	↓↓	11
General well-being	↓↓	↑↑↑	↓↓↓	11
Sleep quality	---	--	--	11
Success	---	---	↓↓	11
Being in shape	↓↓↓	↑↑↑	↓↓	11
Personal accomplishment	---	---	↓↓	11
Self-efficacy	--	--	--	11
Self-regulation	---	---	↓↓↓	11
SFMS				
Overtraining score	↓	↑	--	4
DALDA				
Sources of stress	---	---	—	4
Symptoms of stress	↓↓↓	↑↑↑	↓	5
STAI				
State anxiety			—	1
CSAI-2				
Cognitive anxiety			—	1
Somatic anxiety			?	1
Self-confidence			?	1
PSS	?	↑		1
MTDS				
Total score			↓	1
All subscales				0
DSC			—	1
STPI				
Anxiety			?	1
Anger			—	1
Mood				
All subscales			—	1

Typical patterns rated as improve (↑), decline (↓), conflicting findings (?), or no change (-). Three symbols indicates strong evidence, two symbols for moderate evidence and one symbol for limited evidence. Shading highlights strong (dark grey) and moderate (light grey) associations. n refers to number of contributing studies.

POMS, Profile of Mood States; RESTQ-S, Recovery Stress Questionnaire for Athletes; SFMS, Societe Francaise de Medecine du Sport; DALDA, Daily Analyses of Life Demands of Athletes; CSAI-2, Competitive State Anxiety Inventory-2; PSS, Perceived Stress Scale; MTDS, Multi-Component Training Distress Scale; DSC, Derogatis Symptom Checklist; STPI, State-Trait Personality Inventory.

their systemic influence on subjective well-being.³ Therefore, on balance, the RESTQ-S³⁸ and MTDS⁴³ are more promising self-report measures.

We found that the RESTQ-S was the only investigated self-report measure to be responsive to both acute and chronic training load. One stress (fatigue) and three recovery (physical recovery, general well-being, being in shape) subscales responded to both acute and chronic training. Interestingly, while a larger number of subscales were less responsive or unresponsive, the overall stress and recovery scores were shown to be responsive across training conditions. This is in contrast to the observation that consolidation of subscales into a total score typically reduced sensitivity. Nevertheless, the non-uniform responsiveness of subscales within a measure illustrates the need to consider subscales on an individual basis.

The MTDS is a more recently developed and hence less widely investigated self-report measure. The strength of the MTDS over the RESTQ-S is the inclusion of mood disturbance, stress and behavioural symptom subscales with a smaller number of items (22 compared to 76 for the RESTQ-S). Breadth and a small number of items is a key consideration to sustain use of self-report measures in practice.⁸⁹ These two issues are often the reason that sports programmes tend to incorporate elements of established measures into their own brief custom self-report measure rather than adopting an existing measure from the literature.⁸⁵ Implications of this review for practice should therefore be for sports programmes to consider which independent subscales may offer greater utility for monitoring athlete well-being.

To monitor acute changes in athlete well-being, the following subscales may be useful: vigour/motivation, physical symptoms/injury, non-training stress, fatigue, physical recovery, general health/well-being, and being in shape. These subscales provide the practitioner with insight into the athlete's ability to perform training that day, so may be useful for guiding adjustments to prescribed training on an individual basis. These subscales are consistent with previous recommendations.^{1 4 8} Previous recommendations have also included irritability, sleep, willingness to train, enjoyment of training and how training felt, which correspond to symptoms of stress as recorded by the DALDA,³⁹ which may also be useful for monitoring acute well-being.

For ongoing monitoring, utility was demonstrated in five of the subscales which responded acutely (non-training stress, fatigue, physical recovery, general health/well-being, being in shape). Three other subscales (conflicts/pressure, self-regulation, lack of energy) also presented utility for monitoring chronic well-being, however it is unclear whether their inclusion would offer any additional benefit beyond the previously mentioned subscales.

Importantly, we also identified subscales that were unresponsive (eg, depression, confusion, emotional stress, social recovery, sleep quality, self-efficacy). These may not be useful for monitoring athlete well-being. There appeared to be no value in quantifying non-training stressors, instead it is their effect on athlete well-being that is most meaningful. Interestingly, the depression subscale (POMS) was unresponsive despite depression being a symptom of overtraining syndrome.^{5 20} This may be attributable to different patterns of mood disturbance between overreached and overtrained athletes, with depression only increasing in overtraining syndrome.⁹⁰ Therefore, the inclusion of this subscale may be valuable if an athlete were to progress to overtraining syndrome.

The response sets used by reviewed studies typically utilised the standard questionnaire response set (eg, POMS 'in the past

week', RESTQ-S 'in the past 3 days/nights'), which assessed a relatively transient state of acute well-being. This was the case regardless of time between measurements. Capturing transient well-being is important, particularly during acute changes in training load,³ as relevant changes may be diluted or compromised by recall error if athletes are asked to summarise a period too long in the past.⁹¹ Typically subjective measures utilise Likert scales (eg, never (0) to always (6) as in the RESTQ-S), yet their use in the applied setting requires repeated measurement to establish an individual's baseline from which changes can be determined. This may be avoided by having athletes compare their current well-being to normal (ie, worse than normal, normal, better than normal) as in the DALDA.

With regard to the timing and frequency of administration, consideration must be given to minimising the burden on athletes, while obtaining meaningful data that can be acted on if required. Of the reviewed studies, changes in response to acute training loads were typically detected under monitoring on a daily to weekly basis, whereas changes in response to ongoing training were typically monitored at intervals of 1 month or more, either at regular intervals or coinciding with transitions between training phases. In practice, frequent monitoring is needed to enable acute adjustments to training as required. Consequently, previous recommendations for daily monitoring using a measure self-administered by the athlete remain appropriate.^{1 3-6 8 89 92 93} This may be supplemented with a more comprehensive measure such as the POMS or RESTQ-S on a weekly basis,^{1 8 92} and objective measures on a less-frequent basis such as once per training microcycle.^{1 8 82}

Limitations and strengths

We included studies with concurrent subjective and objective measure which allowed us to compare the relative responsiveness of subjective and objective measures as they were exposed to the same study conditions. Within the methods of included studies, differing sampling frequencies and response sets is an inherent limitation of this review. Also, while subjective and objective measures had to be concurrent, in most cases athletes were responding retrospectively on a subjective measure (eg, 'in the past week') while the objective measure was of their present well-being. Theoretically these timeframe inconsistencies may have reduced the associations between these two types of measures, and affected the conclusions drawn in this review, but in practice this seems unlikely to explain our overall findings.

An additional limitation when interpreting and comparing study findings is the dependence on the statistical methods used in each study. Most studies used traditional methods (p values), however this may have increased the risk of type II error, particularly given small participant numbers.⁹⁴ Some studies may have been underpowered to detect change which would lead us to under-estimate the strength of evidence in our review. Meta-analysis may help to address this limitation in the future. The presentation of group responses may have discounted potentially relevant individual responses. On the other hand, findings may have been overestimated as a result of selective reporting by included studies (publication bias) when there was a lack of change in subjective subscales or objective markers.

SUMMARY

Subjective well-being responded consistently to stress imposed by training, deteriorating with increased and chronic training and improving with reduced training. There was negligible evidence for an association between subjective and objective measures. This was likely due to superior responsiveness of

subjective measures over objective measures. Given that subjective measures reflect changes in athlete well-being and provide a practical method for athlete monitoring, coaches and support staff may employ self-report measures with confidence.

What are the findings?

- ▶ Subjective measures respond to training-induced changes in athlete well-being.
- ▶ Subjective well-being typically worsened with an acute increase in training load and with a chronic training load; and improved with an acute decrease in training load.
- ▶ There was no consistent association between subjective and objective measures.

How might it impact on clinical practice in the future?

- ▶ Subjective measures are useful for athlete monitoring, and practitioners may employ them with confidence.
- ▶ Subscales which evaluate non-training stress, fatigue, physical recovery, general health/well-being and being in shape are responsive to both acute and chronic training.
- ▶ We recommend that athletes report their subjective well-being on a regular basis and alongside other athlete monitoring practices.

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*Denotes studies included in systematic review and outlined in online supplementary table S1.