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Review

Preventing overtraining in athletes in high-intensity sports and stress/recovery monitoring

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In sports, the importance of optimizing the recovery–stress state is critical. Effective recovery from intense training loads often faced by elite athletes can often determine sporting success or failure. In recent decades, athletes, coaches, and sport scientists have been keen to find creative, new methods for improving the quality and quantity of training for athletes. These efforts have consistently faced barriers, including overtraining, fatigue, injury, illness, and burnout. Physiological and psychological limits dictate a need for research that addresses the avoidance of overtraining, maximizes recovery, and successfully negotiates the fine line between high and excessive training loads. Monitoring instruments like the Recovery–Stress Questionnaire for Athletes can assist with this research by providing a tool to assess their perceived state of recovery. This article will highlight the importance of recovery for elite athletes and provide an overview of monitoring instruments.

During the past decade, physical and mental recovery in sport has received increasing attention in research and practice (e.g., Kellmann, 2002a; Montgomery et al., 2008; Richardson et al., 2008; Vaile et al., 2008). The opening of recovery centers in the US Olympic Training Centre (Colorado Springs, USA), the Australian Institute of Sport (Canberra, Australia), and more recently the Queensland Academy of Sport (Brisbane, Australia), highlights the importance of, and financial investment in recovery. As a further evidence of this, the Australian Institute of Sport and the US Olympic Committee provided portable recovery facilities for their athletes to recover during and after training and competition at the Olympic Games 2008 in Beijing. This initiative aimed to optimize athlete performance. However, competing at a major event is often the final stage of a successful long-term training program that is conducted over several years. Furthermore, often athletes can only compete at these events when they have had a training–recovery balance maintained throughout the duration of the training program. Stress from training, competition, and lifestyle factors has been acknowledged as a major cause of overtraining and underperformance in sport (Lehmann et al., 1999). Equally important is the role of recovery in the stress–recovery–performance relationship.

Coaches and researchers suggest that enhanced recovery allows athletes to train more, and thus improves their overall fitness (aerobic, strength, and power), technique, and efficiency. Although most coaches recognize that recovery is crucial within the sport setting, they often have limited knowledge of what recovery modalities and monitoring tools are available (e.g., Simjanovic et al., 2009). Moreover, recent research has indicated that elite coaches are seeking more evidence-based research into recovery activities for athletes (Williams & Kendall, 2007). That is, coaches are seeking guidance in designing recovery techniques to maximize training and subsequent performance. However, it is often difficult for researchers to conduct research that is ecologically valid, due to limited access to elite athlete populations (Kellmann & Beckmann, 2003). It is important, however, to identify the special needs and techniques of high-performing athletes.

The balance of stress and recovery

The avoidance of overtraining and the achievement of optimal performance can only be realized when

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athletes are able to recover and optimally balance training stress and subsequent recovery. When intensity and volume are increased during training, the subjective assessment of athletes becomes very important, because a long-term imbalance of stress (including training, competition and non-training stress factors) and recovery can lead to a state of overtraining (Lehmann et al., 1999). Therefore, it is recommended that stress and recovery be continuously monitored during the training process (Hooper et al., 1999; Kellmann et al., 2001). Smith and Norris (2002) list a number of training errors that can lead to overtraining. However, overtraining is not only due to training errors but also to a high frequency of competitive events that do not allow for sufficient recovery time. To avoid underrecovery, an identified precursor to overtraining, physiological and psychological recovery should be an integral part of the training plan (Hooper & Mackinnon, 1995).

During overtraining, athletes are on a chronic performance plateau that cannot be influenced positively by short amounts of rest and recovery. The symptoms of overtraining include depressed mood, general apathy, decreased self-esteem, emotional instability, impaired performance, restlessness, irritability, disturbed sleep, weight loss, loss of appetite, increased resting heart rate, increased vulnerability to injuries, hormonal changes, and a lack of supercompensation. In theory, a workout or training load results in a degree of fatigue or depletion that is followed by a supercompensation or training effect. It is believed that if the rest intervals between consecutive workouts are of optimal duration the next training session will coincide with the supercompensation phase and the performance ability will increase (Zatsiorsky, 1995). An important clinical feature of overtraining is the increased susceptibility to infections with corresponding symptoms, suggesting an impaired immune response (see Kellmann, 2002a).

Recovery

Coaches and athletes need to be educated about the importance of optimal recovery and its potential impact on performance. Kallus and Kellmann (2000) have established a list of general recovery features (for a detailed description, see Kellmann, 2002a; Elbe & Kellmann, 2007). The key defining features are

- Recovery is a process in time and is dependent on the type of and duration of stress.
- Recovery depends on a reduction of stress, a change of stress, or a break from stress.
- Recovery is specific to the individual and depends on individual appraisal.
- Recovery can be passive, active, or pro-active.
- Recovery is closely tied to situational conditions.

Furthermore, Kellmann und Kallus (2001) defined recovery as

> an inter-individual and intra-individual multi-level (e.g., psychological, physiological, social) process in time for the re-establishment of performance abilities. Recovery includes an action-oriented component, and those self-initiated activities (proactive recovery) can be systematically used to optimize situational conditions and to build up and refill personal resources and buffers (p. 22).

This definition also demonstrates the complexity of recovery, as discussed in more detail by Kellmann (2002a), and highlights the need to individually tailor recovery activities.

Interrelation of stress-states and recovery demands

The above discussion has shown that recovery is critical to the prevention of overtraining. In this context, Kellmann (2002a) has proposed a general model that describes the interrelation between stress-states and recovery demands (Fig. 1). The central tenet of this model is that increased recovery must co-occur with the increasing stress if the stress-state is to remain stable. If this does not occur, a negative cycle can result if resources are limited (e.g., time), whereby increased stress coupled with the inability to meet increased recovery demands results in an individual experiencing more stress. Recovery demands are defined as the quality and/or quantity of recovery activities needed to balance the stress-state. People can become overwhelmed by stress and as a consequence be unable to find or make time to recover appropriately or to adopt more effective strategies for coping with the situation.

The model further argues that with intermediate levels of stress, individuals can achieve an optimal level of performance through adequate recovery. When stress levels are further heightened, however, individuals may become unable to meet recovery demands if they do not engage in additional recovery activities. As a consequence of this, stress will accumulate and without intervention, the symptoms of overtraining are likely to ensue. Optimal performance is associated with balanced stress and recovery states. If recovery is adequate, the individual can react effectively and cope successfully with stress without extra recovery activities. However, a lack of recovery, or underrecovery, can initiate a process that results in an elevated stress state. In order to re-establish an optimal level of performance, athletes must be afforded with special opportunities for

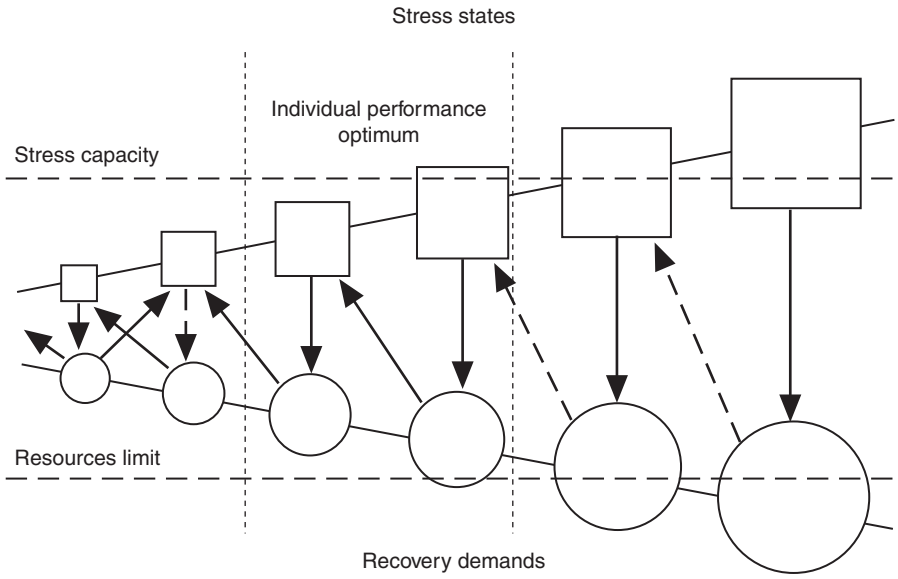

Fig. 1. The "scissors-model" of the interrelation of stress-states, and recovery demands. Reprinted, by permission, from Kallus and Kellmann (2000).

recovery, as the increasing stress can limit the capacity for individuals to recovery.

The model can be applied to sports to explain the development of overtraining. Stress-states occur on a continuum of increasing training load, with endpoints of "no training" and "overtraining". Organismic recovery demands are required to parallel extended training loads. By incorporating recovery into training schedules, long-term performance is enhanced (e.g., supercompensation). However, if increases in training loads and intensity persistently increase over time without adequate recovery, underrecovery is likely to occur, which can then results in the overtraining syndrome. Consequently, to achieve the optimal recovery–stress state, athletes must self-initiate recovery activities to balance stress states. Recovery functions as a regulation mechanism at every stage of the model, by increasing the distance between the two axes into a higher recovery debt (days to weeks). The further an individual progresses along the stress-state, or the more overtraining occurs, increases in recovery efforts are also needed for an optimal recovery–stress state to occur. Because of the regulatory function of recovery, the model proposes that increased levels of stress are only detrimental if the person does not engage in adequate recovery.

Rowing

Rowing requires athletes to be in good physical condition and to possess strong motor skills due its cyclic nature, with motions being repeated over and over. This sport requires an intermediate capacity for endurance, high-intensity loads, and physiological diversity, particularly with an intermediate rowing time between 5 min 20 s and 8 min, depending on the type of boat. Flexibility, strength, and endurance are especially important in rowing and interact in a complex way (e.g., Mäestu et al., 2005).

Rowing is a training-intensive sport, whereby training consists of complex programs that must be well-prepared and monitored closely. In addition to actual on-water sessions, training incorporates gymnastic exercises, strength and power endurance workouts, endurance, and exercises to improve athletes' velocity and agility (Steinacker et al., 2000b). Elite rowers train between 10 and 14 times per week (approximately 20–28 h), with a further increased frequency of sessions in training camps. Even at junior levels (age 16–18 years), training camps for the World Championships are more than double the training time than at "home training" (Kellmann & Altenburg, 2000). Athletes adapt differently to increased training loads; some are able to cope and others are not. The impact of an increased training load is exacerbated if sufficient recovery does not occur, for example, due to a lack of sleep. Consequently, the intense nature of rowing training makes these athletes especially prone to experiencing underrecovery (similar to swimmers) and highlights the need for adequate recovery monitoring tools.

Monitoring instruments

Monitoring instruments are important to assess the individual's mood, their need for recovery, and current life circumstances (e.g., Kenttä et al., 2006).

The advantage of psychometric instruments is that they provide information quickly. While common physiological monitoring (e.g., blood analysis and/or specific medical/physiological diagnostics) may take hours or up to days for feedback, psychological data can be available within minutes. The following discussed monitoring instruments can be applied across sports and gender.

The Profile of Mood States (POMS, McNair et al., 1971/1992) provides a self-assessment for mood and affective states, and is frequently used in psychological monitoring of training/overtraining/underrecovery. The POMS is a 65-item questionnaire in which responses are rated on a Likert scale of 1 (not at all) to 4 (extremely). The POMS provides a measure of total mood disturbances and six mood states (Tension, Depression, Anger, Vigour, Fatigue, Confusion). The POMS is useful in detecting mood fluctuations in exercise and appears to measure mood subcomponents, which are differentially responsive to diverse characteristics of exercise settings. It also provides an easy assessment of the early indicators of overtraining in athletes. However, the POMS does not provide information about the causes of overtraining.

The Borg's Rating of Perceived Exertion (RPE, Borg, 1975, 1998) has also been used in a variety of sport and exercise settings to measure the level of exertion perceived by an individual (Noble & Robertson, 1996). There is a well-established relationship between training load and perceived exertion (see Borg, 1998, for a summary of the research), and the RPE provides an accurate estimate of the intensity of exercise stimulus (Morgan, 1994). More specifically, ratings of perceived exertion have been found to be a sound indicator of adaptation to training programs involving normal populations and cardiac and hypertensive patients (Noble & Roberston, 1996).

More recently, Kenttä and Hassmén (1998, 2002) (see also Richardson et al., 2008) have introduced Total Quality Recovery, which attempts to highlight the relationship between training and recovery. Structured similar to RPE, this new approach is an effective means of addressing the problem of assessing both recovery and underrecovery. Another approach established by Hanin (2000, 2002), proposes that athletes have a zone of optimal functioning in which performance is maximized when an individual's subjective, emotional experience falls within this zone. Consequently, the Individual Zones of Optimal Functioning (IZOF) provides an individually tailored framework and toolset that attempts to describe, predict, and explain the way in which optimal and dysfunctional states can influence an athlete's performance. IZOF has been further extended to include idiosyncratic emotion markers of optimal and dysfunctional performance states. These markers are argued to provide a criterion of optimal (sufficient) recovery processes. Furthermore, IZOF also recommend that individual optimal recover strategies used by athletes must be identified.

The Recovery–Stress Questionnaire for Athletes (RESTQ-Sport)

Description

The RESTQ-Sport (Kellmann & Kallus, 2001) systematically assesses the recovery–stress state of an athlete. The recovery–stress state indicates the extent to which an individual is physically and/or mentally stressed, and whether or not the person is capable of using individual strategies for recovery. The RESTQ-Sport also assesses the extent to which these strategies are currently being used with a Likert-type scale measuring to what extent the respondent took part in different activities within the past 3 days/nights.

The RESTQ-Sport consists of 77 items (19 scales with four items each plus one warm-up item), which the participants answer retrospectively. A Likert-type scale is used with values ranging from 0 (never) to 6 (always) indicating how often the respondent participated in various activities during the past 3 days/nights. High scores in the stress-associated activity scales reflect intense subjective stress, whereas high scores in the recovery-oriented scales indicate good recovery activities.

The RESTQ-Sport consists of seven general stress scales (General Stress, Emotional Stress, Social Stress, Conflicts/Pressure, Fatigue, Lack of Energy, Physical Complaints), five general recovery scales (Success, Social Recovery, Physical Recovery, General Well-being, Sleep Quality), three sport-specific stress scales (Disturbed Breaks, Emotional Exhaustion, Injury), and four sport-specific recovery scales (Being in Shape, Personal Accomplishment, Self-Efficacy, Self-Regulation). Examples of items would be: ''In the past (3) days/nights ... my body felt strong'' (for the scale Being in Shape) or ''In the past (3) days/nights ... I had a satisfying sleep'' (for the scale Sleep Quality). The questionnaire has well-established internal consistency (Cronbach's $\alpha = 0.67$–0.89). It also acknowledges that the recovery–stress condition is a temporary state that comprises emotional, physical, and behavioral features with a determined persistence (Bradburn, 1969).

Kallus (1995) demonstrated that after 24 h, the test–retest reliability of all general scales is high ($r > 0.79$), which indicates that intra-individual variances in the recovery–stress states can be measured. High test–retest consistency displays firm results in connection with short-term shifts of recovery–stress state and functionary fluctuations. Stress and recov-

ery, according to Intercorrelations and Principle Component Analysis of the scales, must be viewed to some extent, as independent components. This permits data analysis based on individual scales and on the factors of stress and recovery (for a detailed description see Kellmann & Kallus, 2001).

Monitoring of the recovery–stress state

The RESTQ-Sport has been used in various sports (e.g., triathlon, swimming, soccer, rugby) and nations (e.g., Brazil, Canada, Germany, Estonia, France) to monitor athletes and the impact of training during the preparation camp for World Championships and Olympic Games (Kellmann & Günther, 2000; Bouget et al., 2006; Mäestu et al., 2006; Coutts et al., 2007; Filaire et al., 2009). Evaluation of the use of the instrument has found that changes in training volume were reflected by significant changes in RESTQ-Sport scales. Specifically in rowing, it was found that increases in training volume were reflected in elevated stress and reduced recovery scores measured by the RESTQ-Sport. Kellmann and Günther (2000) and Kellmann et al. (2001) reported significant increases in stress and decreases in recovery when training load expands, and vice versa. Changes in mood, creatine kinase (CK), and ergometer performance reflected the alteration and success of training. In addition to this data, Kellmann (2002b) reported the parallel development over time of some RESTQ-Sport and POMS scales over the testing period, which also suggests that the both questionnaires appear to be sensitive to events in the life of athletes that affect the recovery–stress state and mood, respectively. A group of Estonian researchers published a series of studies in rowing (Jürimäe et al., 2004; Purge et al., 2004, 2005, 2006) confirming the above described relationship.

For rowers, Steinacker et al. (1999) and Steinacker et al. (2000a) reported a relationship between hormone characteristics and RESTQ-Sport results. Physical Complaints, as reported in the RESTQ-Sport, are highest during the phase of most intensive training and correlate with increased cortisol and CK. If Physical Complaints decrease, the distribution of cortisol and CK also declines. In the same way, the peak amount of norepinephrine corresponds to Fatigue.

As Fig. 2 illustrates, the RESTQ-Sport data can also be used to evaluate training programs in the off-season (Kellmann & Altenburg, 2000; Kellmann & Kallus, 2001) to determine if the training had the intended effects on the athletes. Furthermore, in relation to training programs that span several years, RESTQ-Sport data can provide feedback to evaluate whether training outcomes met previously established goals. Figure 2 shows changes in male rowers

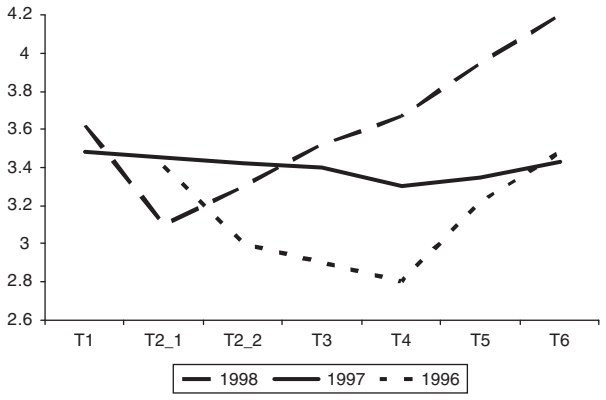

Fig. 2. Arithmetic mean of the Recovery–Stress Questionnaire for Athletes scale Being in Shape (0 = never; 6 = always) over 3 years for male rowers during the training camp before the Junior World Championships in Rowing. Whereas five measurements were taken in 1996 (T2_1, T2_2, T4, T5, T6) and 1997 (T1, T3, T4, T5, T6), six were used in 1998 (T1, T2_1, T3, T4, T5, T6). To compare the data, the assessments were adapted to the time schedule that describes the development over 3 years.

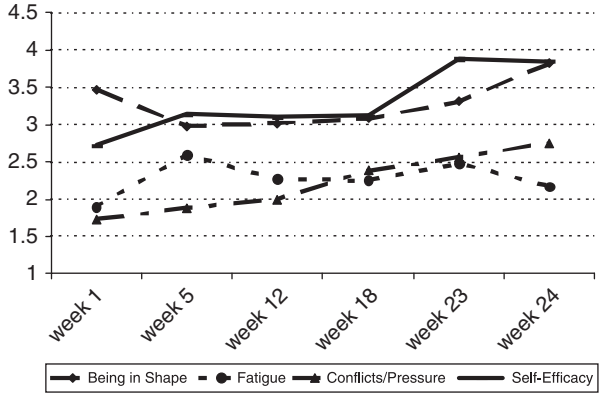

Fig. 3. Comparison of the Recovery–Stress Questionnaire for Athletes scales Being in Shape, Fatigue, Conflicts/Pressure, and Self-Efficacy (0 = never; 6 = always) in the course of the season 2000 of German Junior Rowers (mean of 17 rowers).

on the scale Being in Shape during a training camp that spanned 3 years. It can be seen that the RESTQ-Sport scores were sensitive to modifications in the training schedule throughout the course of the program. For example, changes to the 1998 training camp to include high-impact weight lifting training were reflected in changes in the RESTQ-Sport scores.

Figure 3 also provides evidence that the RESTQ-Sport is sensitive to changes throughout the training period. It shows changes in scale scores for 17 males and females German Junior rowers (mean age = 17 years) who completed the RESTQ-Sport over the course of the season in 2000. Specifically, they completed the RESTQ-Sport six times throughout an interval of 24 weeks. As expected, scores on

Conflicts/Pressure increased over the preparation phase and throughout the season, peaking before the German Junior Championships, whereas scores on Fatigue declined again from week 23 to week 24. While Conflicts/Pressure increased over the season peaking before the German Championships, so too did Self-Efficacy. Athletes felt psychologically and physically best at the end of the regular season, which was reflected by the scores of Being in Shape. These results underline the importance of assessing the multiple components of recovery and stress (see also Steinacker et al., 1999). Because recovery is a process that is based upon individual preferences and capabilities, stress and recovery should be continuously monitored during the training process to determine which aspect of the process (i.e. which scale) is most sensitive to the individual situation of the athlete.

Individual assessment

The following case illustrates further the applied utility of the RESTQ-Sport. The main purpose of individual assessment is to identify athletes whose recovery–stress states do not correspond with the training schedule. Through early intervention, individual training can be adapted in order to help the athlete deal with training stress, optimize recovery, and subsequently prevent overtraining. In general, it should be noted that low scores in the stress-related areas and high scores in the recovery-related areas are "positively" labeled, and vice versa. However, in this context, terms such as *good*/*bad* or *positive*/*negative* do not exist. It must always be kept in mind that the RESTQ-Sport profile reflects just *one short period in a person's life*, which may change drastically within a few days. In addition, because the recovery–stress state is affected by the current training schedule the interpretation of the RESTQ-Sport scores should always consider the current phase of training (see Kellmann & Kallus, 2001).

Figure 4 shows two RESTQ-Sport profiles of a 26-year-old rower. He completed the RESTQ-Sport 2 days before and 3 days after a regular season regatta. At the first measurement (Trail 1, bold line), the pattern can be described generally as high on stress and low on recovery, as well as in the sport-specific scales. High scores in Fatigue, Lack of Energy, Physical Complaints, and Injury are accompanied by low scores for Physical Recovery and Being in Shape, indicating a poorly balanced physical recovery–stress state phase due to a high-training load or high-training intensity. In addition, elevated scores on the stress-related scales General Stress, Emotional Stress, Social Stress, and Conflicts/Pressure plus low scores on Success, Social Recovery, and General Well-being indicate that it was not

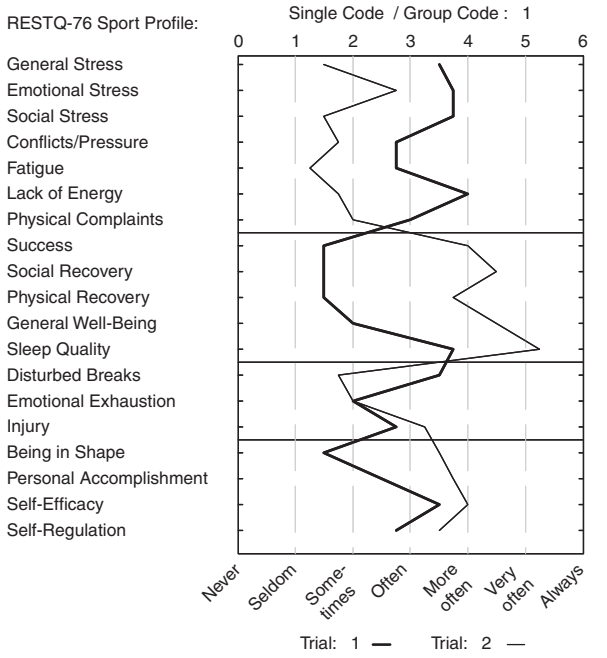

Fig. 4. Recovery–Stress Questionnaire for Athletes profile for a male rower at two times of measurement.

only training that was affecting this athlete when the questionnaire was completed. The coach approached the rower and provided feedback on the RESTQ-Sport profile. During this feedback and communication, the athlete disclosed the occurrence of a problematic personal situation to the coach. Talking to the coach helped him to address the problem and deal with his personal issues. Subsequently, at the second measurement, the RESTQ-Sport profile changed clearly (Trail 2, thin line). General and sport-specific recovery increased, while the other stress-related scales decreased, except for Conflicts/Pressure. This dramatic change in scores provides support that the RESTQ-Sport profile reflects a person's life momentarily, and has the potential to change drastically within a short period of time.

While the RESTQ-Sport provides an indication of whether the athlete is progressing according to the training plan, it does not provide the final diagnosis that someone is overtrained. As overtraining is due to underrecovery over a longer period of time, the RESTQ-Sport profile is better suited to identifying people at risk of overtraining. To diagnose overtraining, other indicators need to occur, such as a chronic performance plateau that cannot be influenced positively by short amounts of rest and recovery periods and/or of depression, general apathy, decreased self-esteem, emotional instability, impaired performance, lack of supercompensation, restlessness, irritability, disturbed sleep, weight loss, loss of appetite, increased resting heart rate, increased vul-

nerability to injuries, increased susceptibility to infections, and/or hormonal changes.

Perspectives on recovery

When talking to coaches, it appears easier to frame the current topic as underrecovery rather than overtraining. It is the coaches' job to train athletes at the optimal level (which is often at the limit); however, they should also avoid overtraining. Coaches may be much more receptive to working with the concept of underrecovery because it acknowledges that underrecovery can also be due to factors, which are outside of their control. The diagnosis of overtraining and underrecovery, should be determined only by an interdisciplinary team that is able and willing to share the data to allow for a comprehensive assessment of the athlete. To optimize this process, the consultation of athletes should be conducted in consultation with coaches, sport physicians, and sport psychologists. Consequently, all physiological and psychological data, as well as training and performance data should be shared on an interdisciplinary basis (Kellmann, 2002a; Smith & Norris, 2002). Assessment should include a complete training documentation, the assessment of subjective and objective physiological and psychological data, and the integration of an athletes' perspective. It is important that psychological testing like lactate testing, also be part of the regular training routine. Furthermore, research in sport psychology should systematically focus on psychological interventions, which help to optimize the recovery process, ideally in combination with physiological interventions.

Key words: recovery, rowing, RESTQ-Sport.

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