Changes in Perceived Stress and Recovery During Heavy Training in Highly Trained Male Rowers

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The aims were to assess (a) the usefulness of RESTQ-Sport in the process of training monitoring and (b) whether a change in psychological parameters is reflected by similar changes in specific biochemical parameters. The high volume training period, in general, caused increases in stress scales and decreases in recovery scales of the RESTQ-Sport, while during recovery period, stress levels declined. Cortisol was not changed during the study period, but significant increases in creatine kinase activity were found during the high training period compared to reference period. The results of the present study demonstrate that changes in training volume were reflected by changes in the RESTQ-Sport scales. A close relationship was found between cortisol and creatine kinase activity and subjective ratings of stress and recovery.

The relationship between stress and sport performance is well documented in athletes (Kellmann & Günther, 2000; Steinacker et al., 2000). Although there are different models of stress, in this investigation stress is defined as an unspecific reaction-oriented syndrome that is characterized by a deviation from the norm of the biological/psychological state of the organism (Janke & Wolffgramm, 1995). Stress is accompanied by emotional symptoms like anxiety and anger, elevated activation in the central and autonomic nervous system, humoral responses, changes in immune functions, and behavioral changes (Kellmann & Günther, 2000). Stress sends processes of adaptation and coping into action (Kallus & Kellmann, 2000).

The recovery process is too often overlooked as an essential aspect of any training regimen (Kellmann & Kallus, 2001). According to Kallus and Kellmann (2000), recovery is not just the elimination of stress, but the processes of reestablishing psychological and physical resources and states that allow taxing these resources again. Furthermore, Kallus (1995) postulated recovery to be an individual specific process that occurs over time and depends on the type and duration of stress. In
addition, it has been suggested that recovery is a sensitive process that can easily be disturbed or prevented (Kallus & Krauth, 1995), and it has physiological, subjective, as well as action-oriented components, and it ends with a psychophysiological state of restored efficacy and homeostatic balance (Kellmann & Günther, 2000).

Increase in sport performance is achievable when athletes optimally balance high training stress with adequate recovery (Rowbottom, Keast, & Morton, 1998). Therefore, the condition of an athlete depends on the balance/imbalance of these two aspects. The recovery-stress state indicates the extent to which someone is physically or mentally stressed as well as whether or not the person is capable of using individual strategies for recovery and which strategies are used (Kellmann & Kallus, 2001). Further, within the training camp or high load training phases, it is important to monitor the athletes’ subjective view of stress and recovery, because inadequate recovery (deficit and/or disturbances of recovery) may take place, and therefore, athletes may suffer from overtraining syndrome. It is known that during training camps and high load training phases, the amount of training increases that can cause an imbalance between stress and recovery. Morgan, Brown, Raglin, O’Connor, and Ellickson (1987) recommend that the symptoms associated with overtraining should be monitored continuously during the course of athletic training so that training volumes can be adjusted as soon as negative symptoms begin to appear. Overtraining syndrome, as an unwanted result of athletic training regimen is characterized by a loss in performance and increased fatigue, which is caused by imbalance between stress and recovery (Steinacker & Lehmann, 2002). The first phase of overtraining is called overreaching, which is reversible within a short term recovery period and can be awarded with supercompensation (the recovery of performance to a higher level compared to the prestress value). As the improvement in performance is the main goal of the training in elite athletes, the overreaching state is regularly used in top sport training. However, it is a complicated situation, because it is not known from which moment the overreaching turns into overtraining syndrome. Therefore, it is of great interest to identify markers that can help us to avoid the negative consequences of training (i.e., overtraining syndrome).

The research previously concerning training monitoring and mood states has been based so far mostly on the Profile of Mood States (POMS; McNair, Lorr, & Dropppelmann, 1992). Morgan and colleagues (1987) have indicated a positive mental health to appear during enhanced performance (iceberg-profile) and that the mood of the athletes worsened during overtraining. O’Connor, Morgan, and Raglin (1991) reported significant increase in the POMS total mood disturbance score after high volume training cycle in swimmers. Contrary to this, Hooper, Mackinnon, and Hanråhan (1997) demonstrated that the POMS may not reliably differentiate between overtrained and not overtrained athletes under all circumstances. However, two swimmers, classified as “stale” showed higher scores of the POMS than “non-stale” swimmers, but the third “stale” swimmer showed values similar to “non-stale” swimmers during the season. Moreover, decreases in training load during tapering did not show any changes in the POMS scores. The authors argued that one reason might have been that the decreased physiological stress might have coincided with an increase in psychological stress (Hooper et al., 1997). Therefore it remained unclear what had caused high POMS scores during tapering.

Indicating this problem, Kellmann (2002) argued that if the POMS can identify overtrained athletes, we do not know which kind of intervention should be taken.
As the items of the POMS are in the adjective form (e.g., annoyed, tense, confused), the POMS does not provide information about the cause of the mood. In their review, Berger and Motl (2000) discussed that from the six scales of the POMS, only one scale (Vigor) measures positive mood and the other five (Depression, Anger, Confusion, Fatigue, and Tension) measure negative moods and a decrease in negative mood may not indicate mood benefits. Furthermore, the POMS was initially developed for clinical populations in order to have an economical method of identifying and assessing transient, fluctuating affective states (Berger & Motl, 2000), while Kellmann and Kallus (2001) describe recovery as an individual multilevel process (e.g., psychological, physiological, social) in time for reestablishment of performance abilities. Therefore, the POMS only vaguely reflects recovery processes and does not lead to the application of appropriate recovery strategies (Kellmann, 2002) and a more sport specific measure would be benefit in order to better understand the complexities of top sport training.

Concerning the perspective of a biopsychological stress model from Janke and Wolffgramm (1995), recovery and stress should be treated using a multilevel approach, dealing with psychological, emotional, cognitive-behavioral performance, and social aspects of the problem (Kellmann & Günther, 2000). The Recovery-Stress Questionnaire for Athletes (RESTQ-Sport; Kellmann & Kallus, 2001) has been reported as one of the few questionnaires with which one may address the full complexities of stress and recovery (Kenttä & Hassmen, 1998). Contrary to the POMS, the RESTQ-Sport assesses mood oriented stress and recovery-associated activities. The main advantage of RESTQ in POMS is that it allows specific intervention strategies, which are complicated with the POMS (Kellmann & Kallus, 2001). Specifically, RESTQ-Sport asks the question, “What happened in the past 3 days/night?” while the POMS just measures the mood state itself (Kellmann & Günther, 2000). The RESTQ-Sport has been successfully used to monitor changes in stress and recovery over different training periods in athletes (Jürimäe, Mäestu, Purge, Jürimäe, & Sööt, 2002; Kellmann, Altenburg, Lormes, & Steinacker, 2001; Kellmann & Günther, 2000; Steinacker et al., 2000). It has also been shown that using RESTQ-Sport, the diagnosis and intervention could be done quickly and effectively by the coach himself or with the help of the assistance (Kellmann & Kallus, 2001). Kellmann and colleagues (2001) also suggested a dose-response relationship between training load, creatine kinase (CK) activity, and the subjective assessment of stress and recovery. However, different scales of RESTQ-Sport have different time courses reflecting the current psychophysiological state. For example, Steinacker and colleagues (1999) found Somatic Complaints to be highest with the highest training load and elevated cortisol levels as well as CK activity. However, to our knowledge, no studies have investigated the usefulness of this questionnaire for monitoring training during heavy increase in training volume and the following recovery period.

One limitation of the use of psychological questionnaires could be their subjectivity. For example, athletes may manipulate if they feel to be substituted with another due to their “bad” condition. Therefore, more reliable markers of training stress are also frequently used. Examinations of the response of the different hormonal axis have increased the knowledge about hormonal regulation in training, also for overreaching and overtraining (Hackney, Sinning, & Bruor, 1990; Steinacker et al., 1999). A downregulation of hypothalamic-pituitary-adrenocortical axis will
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result in lower basal cortisol levels during high load training periods (Steinacker et al., 2000). Therefore, cortisol as one of the stress hormones could be used to distinguish the training status of the athletes. Cortisol level in blood increases sharply in various stress situations (environmental influences, emotional strain, exercise, trauma, infection, poisons, intoxications) and contributes to adaptive metabolic arrangements; it is justifiably called the adaptation or stress hormone (Viru & Viru, 2001). The behavioral alterations are obviously related to cortisol-induced changes in neuronal activity. Serum CK activity can be used to study training effects at muscular level and mirrors high muscular strain. High CK activity values represent muscle cell damage, while the normalization of CK activity reflects the muscular adaptation to training load (Steinacker et al., 1999). It can be speculated that if biochemical values change during stressful trainings, it will cause a change also in the subjective assessment of athletes’ condition. However, it has to be stated that the use of biochemical markers for training monitoring is quite expensive and time consuming while analyzing and needs qualified specialists. Therefore, biochemical markers are not very suitable for frequent monitoring.

In summary, it is suggested that athletes’ performance should be monitored incorporating both stress and recovery components. The aims of this study were to assess the usefulness of the RESTQ-Sport questionnaire in the process of training monitoring and whether a change in psychological parameters is reflected by similar changes in specific biochemical parameters in 12 national level male rowers. CK activity and cortisol were chosen to represent the local and more central training effects, respectively. We hypothesize that there is a relation in subjectively perceived stress and recovery parameters and selected biochemical parameters.

Method

Participants

Twelve national level male rowers volunteered to participate in this investigation. Their mean age was 20.5 yrs (SD = 3.0 yrs), mean height was 187.9 cm (SD = 6.1 cm), and mean weight was 87.1 kg (SD = 2.5 kg). All participants completed the study. The participants represented all available athletes who train at this level in Estonia (also qualifiers for the Olympic Games). The study was conducted at the beginning of the preparation period (i.e., in November), where the main goal of training was to build up a base for the next season through high load, low intensity trainings. No feedback about their training status was given to subjects during the study period. The participants were informed about the procedures before providing their written consent to participate in the experiment as approved by the Medical Ethics Committee of the University of Tartu.

Instrument

The RESTQ-Sport was developed to measure the frequency of current stress along with the frequency of recovery-associated activities and is based on the hypothesis that an accumulation of stress in different areas of life, at least with insufficient recovery possibilities, leads to a changed psychophysical state (Kellman & Kallus, 2001). As a multidimensional questionnaire, the RESTQ-Sport is suitable for clari-
Characterization of the interdependencies of stress and recovery activities. Therefore, the frequency of stress and recovery is recorded. The RESTQ-Sport is constructed in a modular way, including 12 scales of the general Recovery-Stress Questionnaire and additional seven sport-specific scales (Kellmann & Kallus, 2001). The English version as well as the Estonian version (Jürimäe et al., 2002) of RESTQ-Sport have 77 items (19 scales with four items each plus one warm-up item), and the 24 h test-retest repeatability has been reported to be above .74 (Table 1; Jürimäe et al., 2002). The estimation of the reliability of the Estonian version of RESTQ-Sport was satisfactory (Cronbach α ranging from .71 to .94) and was similar in present study. A Likert-type scale is used with the values ranging from 0 (never) to 6 (always) indicating the frequency of their stress- and recovery-related mood states, social activities, performance, and specific physical states during the past three days/nights. The mean of each scale can range from 0 to 6, with high scores in the stress-associated activity scales reflecting intense subjective stress, whereas high scores in the recovery-oriented scales mirror plenty recovery activities (e.g., social activities, vacation, sauna, etc.).

The stress and the recovery scales correlate positively with the scales of the related areas, but they have a negative relationship with the scales of the opposite areas. The intercorrelations among scale scores indicate that stress and recovery can be considered as two partly independent factors, which allow analysis of the data on the basis of single scales as well as on the factors of stress and recovery. All factor analyses (Kellmann & Kallus, 2001) suggested one stress-related and one recovery-related factor for the general RESTQ-Sport scales and also for the sport-specific scales of the Estonian version of the questionnaire. The first seven scales of the questionnaire cover different aspects of subjective stress (General Stress, Emotional Stress, Social Stress, Conflicts/Pressure, Fatigue, Lack of Energy, and Somatic Complaints) as well as the resulting consequences. Success is the only resulting recovery-oriented scale concerned with performance in general but not in a sport-specific context and related to pleasure at work, having lots of ideas and achievement. Social Relaxation, Somatic Relaxation, General Well-Being, and Sleep Quality are the basic scales for the recovery area. To address more details of stress and recovery in sports, Kellmann and Kallus (2001) developed additional scales for the RESTQ-Sport that extend the basic scales mentioned before. Sport specific scales of stress (Disturbed Breaks, Emotional Exhaustion, and Fitness/Injury) and recovery (Being in Shape, Burnout/Personal Accomplishment, Self-Efficacy, and Self-Regulation) are examined in scales 13 to 19, for further explanation of the scales of the RESTQ-Sport see Kellmann and Kallus (2001). High test-retest reliability of the scales of the questionnaire (Table 1) shows that intraindividual differences in the recovery-stress state can be consistently reproduced, and the results of the RESTQ-Sport are stable regarding short-term (24 hour) functionary fluctuations and minor short-term changes in recovery-stress state (Kellmann & Kallus, 2001).

Kellmann and Günther (2000) also studied the relationships between the RESTQ-Sport and the Profile of Mood States (POMS) and reported a positive correlation between the POMS Vigor and the recovery scales of the RESTQ-Sport, while Tension, Depression, Anger, Fatigue, and Confusion are negatively correlated with recovery, and vice versa a positive correlation between the stress scales and Tension, Depression, Anger, Fatigue, and Confusion, whereas Vigor is negatively
Table 1  The Scales of the RESTQ-Sport, Their Orientation (O) and Cronbach $\alpha$, and Test-Retest Repeatability of the Estonian Version of RESTQ-Sport

<table>
<thead>
<tr>
<th>RESTQ-Sport Scale</th>
<th>O</th>
<th>Sample question</th>
<th>$\alpha$</th>
<th>Test-retest</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Stress</td>
<td>S</td>
<td>I felt depressed</td>
<td>.91</td>
<td>.75</td>
</tr>
<tr>
<td>Emotional Stress</td>
<td>S</td>
<td>Everything bothered me</td>
<td>.91</td>
<td>.74</td>
</tr>
<tr>
<td>Social Stress</td>
<td>S</td>
<td>I was annoyed by others</td>
<td>.95</td>
<td>.79</td>
</tr>
<tr>
<td>Conflicts/Pressure</td>
<td>S</td>
<td>I felt under pressure</td>
<td>.72</td>
<td>.84</td>
</tr>
<tr>
<td>Fatigue</td>
<td>S</td>
<td>I was tired from work</td>
<td>.75</td>
<td>.75</td>
</tr>
<tr>
<td>Lack of Energy</td>
<td>S</td>
<td>I put off making decisions</td>
<td>.81</td>
<td>.76</td>
</tr>
<tr>
<td>Somatic Complaints</td>
<td>S</td>
<td>I felt physically bad</td>
<td>.74</td>
<td>.81</td>
</tr>
<tr>
<td>Success</td>
<td>R</td>
<td>I was successful in what I did</td>
<td>.77</td>
<td>.79</td>
</tr>
<tr>
<td>Social Relaxation</td>
<td>R</td>
<td>I visited some close friends</td>
<td>.93</td>
<td>.75</td>
</tr>
<tr>
<td>Somatic Relaxation</td>
<td>R</td>
<td>I felt physically fit</td>
<td>.78</td>
<td>.82</td>
</tr>
<tr>
<td>General Well-Being</td>
<td>R</td>
<td>I was in good spirits</td>
<td>.91</td>
<td>.80</td>
</tr>
<tr>
<td>Sleep Quality</td>
<td>R</td>
<td>I slept restlessly</td>
<td>.83</td>
<td>.76</td>
</tr>
<tr>
<td>Disturbed Breaks</td>
<td>S</td>
<td>I could not get rest during breaks</td>
<td>.81</td>
<td>.63</td>
</tr>
<tr>
<td>Emotional Exhaustion</td>
<td>S</td>
<td>I felt burned out by my sport</td>
<td>.87</td>
<td>.75</td>
</tr>
<tr>
<td>Fitness/Injury</td>
<td>S</td>
<td>I felt vulnerable to injuries</td>
<td>.73</td>
<td>.83</td>
</tr>
<tr>
<td>Being in Shape</td>
<td>R</td>
<td>My body felt strong</td>
<td>.93</td>
<td>.81</td>
</tr>
<tr>
<td>Personal Accomplishment</td>
<td>R</td>
<td>I accomplished many worthwhile things in my sport</td>
<td>.87</td>
<td>.76</td>
</tr>
<tr>
<td>Self-Efficacy</td>
<td>R</td>
<td>I was convinced that I performed well</td>
<td>.86</td>
<td>.79</td>
</tr>
<tr>
<td>Self Regulation</td>
<td>R</td>
<td>I pushed myself during the performance</td>
<td>.78</td>
<td>.82</td>
</tr>
</tbody>
</table>

Note. O – RESTQ-Sport Scale’s orientation, that was either S – stress or R – recovery. $\alpha$ – Cronbach $\alpha$ for the respective scale, Test-retest – reliability coefficient for the respective scale. All $\alpha$’s and test-retest reliability were significant at the level of $p < .05$. 

correlated with stress (see also Introduction for differences in the construct of RESTQ-Sport and POMS).

**Procedure**

The study lasted for six weeks. The participants were told to maintain their normal diet regimen they use accordingly to the change in training volume throughout the study period and not to change their usual habits during this time. We chose to manipulate with training volume, because changing the intensity would probably cause different stress and recovery responses to athletes. The design of the training
plan was modified from Steinacker, Lormes, Lehmann, and Altenburg (1998). The reference week (Week 1) was the regular training cycle for athletes, which consisted of 6 training sessions per week. High training volume was considered to evoke a training initiated stress in athletes. During the high training volume phase (Weeks 2, 3, and 4) training volume was increased by about 25% (Week 2 compared to Week 1) and 50% (Weeks 3 and 4 compared to Week 1). During the high training volume period, the rowers completed 12 training sessions each week. During the recovery period (Weeks 5 and 6), training volume was reduced to about 90% of the reference week and 5 training sessions were completed in each week. The training regimen remained similar each week of the study; 45% of the total training time was low intensity extensive endurance training (i.e., running, swimming, or ergometer training or both, intensity below 4 mmol.l⁻¹ anaerobic threshold), 45% was high volume, low intensity resistance training (i.e., 30 repetitions per set with a load of 50-60% of one repetition maximum), and 10% of the total time was spent playing different ball games (e.g., basketball and soccer). The average time of the training was chosen as an appropriate indicator for training volume (Jüirimäe et al., 2002; Kellmann et al., 2001). Training intensity was monitored using Polar Vantage NV (Kempele, Finland) heart rate monitors, based on the subjects’ individual data. Training sessions were supervised by the coaches, who were instructed of the study design, but no information was given about the construction of the RESTQ-Sport. Monday was meant for the recovery day. Every Tuesday, during the afternoon (prior to the evening training session, about 3:00 p.m) the rowers filled out the RESTQ-Sport (Kellmann & Kallus, 2001).

Maximal 2000 meter rowing ergometer performance (W) was assessed on the Concept II rowing ergometer (Morrisville, USA) after the day of rest (i.e., on Tuesday from 10:00 to 12:00). Testing was conducted before (at the beginning of Week 2) and immediately after (at the beginning of Week 5) the high training volume period and after the tapering period (at the beginning of Week 7). Testing time was kept identical for each participant. The rowers were training regularly on this kind of apparatus and were therefore fully familiarized with the use of this apparatus. Power and stroke frequency were delivered continuously on the computer display of the rowing ergometer and were stored for later analysis. The subjects were allowed to perform the individual warm-up of 10 min and they were also verbally encouraged during 2000 meter all-out test to accomplish the best possible result (Jüirimäe et al., 2002).

In the morning after the day of rest, between 8:00 and 9:00 a.m. (to avoid circadian rhythms of cortisol concentration), the blood samples were collected. Ten milliliter blood sample was obtained from the anticubital vein while the rowers were in an upright position. The plasma was separated and frozen at −20°C for later analyses. Cortisol was analyzed in duplicate on Immunolite 2000 (DPC, Los Angeles, USA). The inter- and intra-assay coefficients of variation were less than 5%. The CK activity was measured by means of photometric method using a commercially available kit (Boehringer, Mannheim).

The RESTQ-Sport and biochemical data were analyzed after the study to ensure that the coaches or athletes do not change the designed training plan (e.g., because of increased stress scores, for example). The heart rate data were collected each day to ensure the completion of the designed training plan.
**Data Analysis.** Means and standard deviations were calculated for each 6 times. Differences in responses to every single RESTQ-Sport scales were studied by repeated measures ANOVA for three weeks with significantly different training load (i.e., Weeks 1, 4, and 6). Eleven scales (out of 19) showed considerable changes according to training phase (see Figure 3). The standardized scores for Stress and Recovery were calculated as follows. The scores of stress-related scales (scales 1 to 7, 13, 14, and 15) and the recovery-oriented scales (scales 8 to 12, 16, 17, 18, and 19) were summed and divided by the number of scales and were then converted to standardized values by subtracting the global sample mean and dividing the difference by the standard deviation (Kellmann & Kallus, 1999). Thus, a standardized recovery and stress score could be obtained on a common scale, which allowed computing a difference between stress and recovery (stress subtracted from recovery, Standardized RESTQ-Index; Kellmann & Kallus, 1999). This procedure was performed for each week. It could be speculated that higher values for the RESTQ-Index indicates that the athlete is in a more optimal recovery-stress state and it was hypothesized that RESTQ-Index would decrease during high volume training and increase during recovery period.

Two-tailed paired t-test was used to determine where differences existed. A priori alpha level was set at $p = .05$. Pearson correlation coefficients were calculated between combined data over different time points of the six week training cycle (Hooper, Mackinnon, & Hanrahan, 1997; Jürimäe, Mäestu, Jürimäe, 2003; Simsch et al., 2002). A Bonferroni correction ($0.05$ divided by the sum of Standardized Stress, Standardized Recovery and RESTQ-Index, cortisol, CK and training volume) was applied and alpha level of $p = .008$ was considered significant.

**Results**

Training volume increased significantly from the reference week (Week 1) to the high volume training period (Weeks 2, 3, 4), and during the recovery period (Weeks 5, 6) the training volume significantly decreased compared to the high volume training period (Weeks 2, 3, 4; $p < .05$; Figure 1). Throughout the 6 weeks a Time × Scale MANOVA for repeated measurements revealed a significant time effect for the stress scales $F(5, 35) = 5.90$, $p < .005$, and $F(5, 35) = 2.91$, $p < .027$ for recovery scales. RESTQ-Index decreased significantly after the high volume training period (Weeks 2, 3, 4) and increased significantly during recovery period (Weeks 5, 6) compared to the high training volume period ($p < .05$; Figure 2). The Standardized Stress score increased significantly during heavy training period (Weeks 2, 3, 4) compared to the reference week (Week 1) and then decreased significantly during recovery period (Weeks 5, 6) compared to the value at the end of heavy training period (Week 4; $p < .05$; Figure 2, dotted line). The Standardized Recovery score decreased significantly during two weeks of heavy training (Weeks 3 and 4) compared to the reference week (Week 1; $p < .05$; Figure 2, broken line). Significant changes were found in the scores of General Stress, $F(2, 14) = 5.08$, $p = .022$; Emotional Stress, $F(2, 14) = 6.89$, $p = .008$; Social Stress, $F(2, 14) = 4.99$, $p = .023$; Fatigue, $F(2, 14) = 18.62$, $p = .0001$; Physical Complaints, $F(2, 14) = 5.18$, $p = .021$; Somatic Relaxation, $F(2, 14) = 3.87$, $p = .046$; General Well-Being, $F(2, 14) = 6.37$, $p = .011$; Emotional Exhaustion, $F(2, 14) = 3.99$, $p = .043$; Injury,
F(2, 14) = 3.4, p = .063; and Being in Shape, F(2, 14) = 7.38, p = .007 after high volume training period (Week 4 vs Week LSD post hoc test, p < .05; Figure 3). Significant improvements (Week 6 vs Week 4) were found in the scales General Stress, F(2, 14) = 5.08, p = .022; Emotional Stress, F(2, 14) = 6.89, p = .008; Social Stress, F(2, 14) = 4.99, p = .023; Fatigue, F(2, 14) = 18.62, p = .0001; Physical Complaints, F(2, 14) = 5.18, p = .021; and Success, F(2, 14) = 3.13, p = .075 after two weeks of recovery (p < .05, LSD post hoc test). Cortisol remained unchanged.

**Figure 1**—Training load (means and SD) during the six week study in highly trained male rowers (N = 12). Numbers indicate significant differences (p < .05) in training load from pointed week.

**Figure 2**—Means of Standardized Stress, Standardized Recovery and RESTQ-Index during the six week study in male rowers (N = 12). ■—significantly different from Week 1; ◆—significantly different from Weeks 2, 3, 4; ▲—significantly different from Weeks 4; p < .05.
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during the six week study period, showing a tendency to decrease during high volume training period (from 561.5 ± 99.77 to 551.33 ± 94.18 ng/ml; p > .296). Significant increases in CK activity were found during high training volume period (Weeks 2, 3, 4) compared to reference period (Week 1; p < .05). During the recovery period (Weeks 5, 6), the values of CK activity decreased significantly compared to the last high volume training week (Week 4; p < .05).

The 2000 meter all-out rowing ergometer performance did not change significantly during the whole six-week study period - from 397.5 ± 42.3 to 395.59 ± 37.5 W (p = .640) during high volume training and from 395.59 ± 37.5 to 399.15 ± 38.9 W (p = .286) during recovery period.

Training load was significantly related to the RESTQ-Index (r = -.39; p < .008; n = 72). The values of cortisol were significantly related to Standardized Stress score (r = .76; p < .008; n = 72) and to RESTQ-Index (r = -.64; p < .008; n = 72). Creatine kinase activity was significantly related to Standardized Recovery score (r = -.45; p < .008; n = 72).

Figure 3 — RESTQ-Sport variables after the reference (Week 1), after the high volume training (Week 4) and recovery (Week 6) periods in male rowers (N = 12). *- Significant difference between the first and the fourth week; □ — Significant difference between the fourth and the sixth week; 1 — General Stress, 2 — Emotional Stress, 3 — Social Stress, 4 — Conflicts/Pressure, 5 — Fatigue, 6 — Lack of Energy, 7 — Physical Complaints, 8 — Success, 9 — Social Relaxation, 10 — Somatic Relaxation, 11 — General Well-Being, 12 — Sleep Quality, 13 — Disturbed Breaks, 14 — Emotional Exhaustion, 15 — Fitness/Injury, 16 — Being in Shape, 17 — Burnout/Personal Accomplishment, 18 — Self-Efficacy, 19 — Self-Regulation.

Discussion

It is well established that appropriate training is needed for improved performance. However, the extent and content of training often leads to inappropriate training responses of the athlete and in the long-term, to overtraining syndrome (Kellmann...
Steinacker et al. (2000) pointed out that peak athletic performance depends on the proper manipulation of training volume and intensity as well as providing adequate rest and recovery between practice sessions. Therefore, the reliable markers for better understanding the training effects of the athletes are in the focus of sport science in order to prevent athletes from negative consequences of training process.

The results of the present study revealed that RESTQ-Index and different scales of RESTQ-Sport demonstrated an increase in stress related scales during high volume training period and a decrease during the recovery period. An opposite effect was found in recovery scales. Additionally, a close relationship was detected in psychological and biochemical parameters in male rowers during high volume training cycle.

It is known that training stress can be caused by changes in intensity, volume, or both of these components and it can cause different responses in athletes' states; therefore, in this study, only change in training volume was used to create training induced stress and avoid different impacts, which may be caused by increases in training intensity. In the future studies, there is also a need to investigate different types of training stress (intensity, combination of intensity and volume, etc.) and the subjective assessment of athletes.

It has been reported that during stressful trainings, values of mood state decrease (Morgan et al., 1987). Thus, we were interested if RESTQ-Index is similarly reflected by changes in training volume. The results of our study indicated that RESTQ-Index was negatively correlated with training volume ($r = -.39; p < .008$). High training volume was accompanied by lowered levels of RESTQ-Index and vice versa, lowered training volume was indicated by higher RESTQ-Index. Kellmann and Kallus (1999) have recently shown that the RESTQ-Index was found to decrease dramatically before the overtraining state was diagnosed, while increased RESTQ-Index was found in an athlete who won the European Championships on a mountain bike. This index can be interpreted as a kind of athletes’ resource measure (Kellmann & Kallus, 1999) and could be used as an indicator of athletes’ recovery-stress state and it may, therefore, be more understandable to use for athletes and coaches to monitor the impact of different trainings to the athletes’ current state. However, it remains unclear, as we do not have enough data, how much the RESTQ-Index must decrease or how long the lowered RESTQ-Index can be tolerated before athlete shows the signs of overtraining; therefore, further research concerning RESTQ-Index and training stress is needed.

As the performance in this study did not change, it is difficult to say if a state of overreaching was present in our participants. However, some data suggest that some overreaching might have occurred. Hooper, Mackinnon, Howard, Gordon, and Bachmann (1995) stated that subjective ratings of sleep, fatigue, stress, and muscle soreness characterized up to 78% of the overtraining syndrome. Similar results were obtained in our study also with the significant increases in the scales of Emotional Stress, Fatigue, and Physical Complaints during the high volume period. During the transition period (period from the end of competition period to next preparation period) maximal sport-specific performance may decrease up to 14% (Hagerman & Staron, 1983); therefore, the improvement in performance could be expectable even during the preparation period. Considering also the
significant decrease in the RESTQ-Index and stagnation in performance, which has also been considered sufficient to refer on overreaching (Hooper et al., 1995), we suggest that three weeks of high volume training caused an overreaching state in our subjects, which was also reflected by changes in subjective stress and recovery components.

The changes in Standardized Stress score in the current study were similar as expected—significant increase during high volume training period and during recovery period a significant decrease was observed. However, the Standardized Recovery score decreased during high volume training period but no significant improvement was followed during recovery period. The fact that during recovery period only the scale of Success was significantly improved compared to the high training volume period indicates that the recovery activities, in general, were not enough during the recovery period. Therefore, the athletes should also focus on recovery periods as essential parts of the whole training program and using RESTQ-Sport coaches can be informed how athletes spend their time when not training and how this period may affect their state. If an athlete shows a negative recovery profile, solutions can be derived to make some intervention in order to improve athletes’ recovery potential in order to better cope with different stressors.

Cortisol remained unchanged during a six week study period ($p > .296$). Cortisol is known as a stress hormone that concentration has been shown to increase during stressful trainings (Steinacker et al., 1999) and was related to Standardized Stress score ($r = .76; p < .008$). This close relation between psychometric and stress hormone response is very intriguing from a multilevel approach of training monitoring. The hypothalamus has an important role in integrating different stress influences and the answers from the hypothalamus are expressed via the endocrine system, the autonomic nervous system, and the behavior (Barron, Noakes, Lewy, Smith, & Millar, 1985; Steinacker et al., 2000). Changes in plasma levels of cortisol reflect the metabolic stress as the endpoint of the hypothalamus-pituitary-adrenocortical axis (Steinacker et al., 2000). Lowered levels of cortisol have been found in overtrained subjects (Barron et al., 1985). In the future, the underlying mechanisms of training and stress responses should be more investigated, so that specific diagnostic tools can be used sufficiently for monitoring training (Steinacker et al., 2000).

It is interesting to note that CK activity was related to Standardized Recovery score ($r = -.45; p < .008$). Furthermore, it is well known that CK activity increases following exercise of high muscular strain because of muscle cell leakage and/or damage, and the morning levels represent mainly the CK release during the previous days, and normalization of the CK activity demonstrates a reduced muscle stress (Steinacker et al., 2000). Accordingly, the CK activity values indicate that the training protocol used in this study was that of heavily increased physical stress followed by recovery period. This was also reflected by the values of specific recovery-associated subscales of the questionnaire (see Figure 3).

We also demonstrate two different impacts of the high volume training cycle on two different subjects: Subject 1 who showed no signs of overtraining and subject 2, whose performance was even worsened after two weeks of recovery and showing signs of negative adaptation to trainings. Subject 1 was one of the successful athletes during the following year of the study. Subject 2 was one of the youngest participants in the study. After three weeks of high volume training, Subject 2 showed much more negative RESTQ-profile than did Subject 1, showing significantly
increased scores of Fatigue, sport-specific stress scales (scales 8-12), and lowered scores of recovery scales (Figure 4). However, as can be seen, there was not a big difference in the Stress scales of the general part of the RESTQ-Sport (scales 1-7) except Fatigue. This may indicate the greater general stress tolerance for athletes and also why the stress scales never exceeded the midpoint of the scale (except Fatigue). The most pronounced difference in the profile of general recovery scales indicates the importance of measurement of recovery in top athletes. By increasing the recovery associated activities the athlete can cope better with stress and also increase the stress tolerance as was seen in Subject 1 (Figure 4). Therefore, the coaches can be quickly informed about the athletes whose recovery-stress state does not correspond to what expected and make corrections in training and/or recovery. Unfortunately, the RESTQ-Sport was not analyzed during the study period. So it remains speculative what had happened if we would have decreased the training volume for Subject 2. However, as we tried to investigate different impact of high training volume on the RESTQ-profile, changing the training volume would not have allowed us to do it.

Too high training stress was also indicated by lowered levels of cortisol by the end of week 4, and cortisol was further lowered after the recovery period in Subject 2, while in Subject 1, the cortisol response was classified as a normal for stressful training cycle (Steinacker et al., 1999; Figure 5). The changes in biochemical and psychological data were in line with changes in performance, which showed a gradual decrease in Subject 2. While in Subject 1, the performance decreased after high volume training and increased after 2 weeks of recovery and showed as positive response for trainings.

In conclusion, the monitoring of training adaptation in a period of heavy training stress and the current adaptation state of an athlete appears to be a very complex task. The results of present study demonstrated that changes in training volume were reflected by changes in the RESTQ-Sport scales. Decreased scores of general recovery scales and fatigue were detected in an athlete showing signs of overtraining when compared to nonovertrained athlete. A close relationship was detected between subjective ratings of stress and recovery and specific

![Figure 4](image-url)—The RESTQ-Sport profiles of two subjects after three weeks of high volume training. For explanation of RESTQ-Sport scales, see Figure 3.
biochemical parameters. These findings suggest that the RESTQ-Sport questionnaire is a valuable instrument to evaluate the recovery-stress state during high volume and recovery cycles in male rowers.

References


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**Figure 5**—Performance (indicated with bars) and cortisol concentration (indicated with lines) in two subjects during the study period.


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