DISSERTATIONES KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

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THE PERCEIVED RECOVERY-STRESS STATE AND SELECTED HORMONAL MARKERS OF TRAINING STRESS IN HIGHLY TRAINED MALE ROWERS

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1. INTRODUCTION

In the world of sports, athletes and coaches push themselves harder and harder in order to achieve the best result during the competitions. However, by increasing either the frequency, duration or intensity of training, they risk creating excessive fatigue that may lead to functional impairment, which has been described as staleness or burnout (Hooper et al., 1995). The aim of sport training is to accustome the human body through different training loads and competitions, at the same time minimizing the risk of illness and fatigue in the period shortly before the competition. Thus, athlete's body must accustome with training loads that are intense enough to displace the homeostasis of an athlete. Once the adaptation to a certain training load has occurred, a greater load must be applied to get further improvement. Stressful high intensity training periods are necessary to obtain high performance in sports (Steinacker et al., 1998). A problem for a coach is also that athletes respond different to same training loads. A load that is too high for one athlete, may have no training effect at all to the other. It is evident, however, that underestimation or overestimation of the performance level, trainability and insufficent recovery will lead to: 1) inappropriate training response of the athlete; or 2) overreaching and in the long run staleness, burnout syndrome or overtraining (Bruin, 1994; Kuipers & Keizer, 1988; Lehmann et al., 1993).

Further increases in performance can be reached by increasing intensity and duration of exercise (Bannister et al., 1997; Steinacker, 1993). For rowers, it has been demonstrated that daily rowed kilometers are positively related to rowing performance (Hagerman & Staron, 1983; Steinacker, 1993). This makes the training process complicated, because increasing training volume and monotoneus training will increase the risk of overtraining.

The recovery of athletes from the fatigue of intense training stress has had far less attention in previous studies, although tapering (a gradual reduction of training load) has been used to allow the athlete to recover from intense training and thus optimize training process and performance prior competitions. To date, rest (physical inactivity) is the best known treatment for athletes who have reached an undesirable state because of prolonged training (Lehmann et al., 1993; Kuipers & Keizer, 1988; Raglin, 1993). Only few studies have investigated the markers for monitoring recovery processes of athletes during the taper (Hooper et al., 1995; Simsch et al., 2002; Steinacker et al., 2000). However, these studies have used different metabolical and psychological parameters and have used different types of training.

Evaluation of the overall state of an athlete and appointing appropriate training load without leading the athlete to ovrtraining syndrome has been among the most complicated tasks in the field of coaching sciences and sports medicine. Several parameters (e.g., clinical findings, hormonal, psychological, metabolic) have been studied (Barron et al., 1985; Lehmann et al., 1997;

Simsch et al., 2002; Snegovskaya & Viru, 1993; Steinacker et al., 1999, 2000; Urhausen et al., 1987; Vervoorn et al., 1991). To date, these parameters have either shown inconsistent responses, or where trends have appeared, there are too few studies to make definite conclusions. Therefore, the aim of current dissertation is to monitor simultaneously the stress and recovery processes of highly trained male rowers and to investigate the response of different hormones and athletes' subjective ratings of stress and recovery during a period of heavy training stress in highly trained male rowers.

2. REVIEW OF LITERATURE

2.1. Characteristics of rowing performance

Rowing is primarily a strength-endurance type of sport. The typical rowing competition takes place on a 2000 metre course and lasts, depending on a boat type and weather conditions 5.5–7.0 minutes. During a rowing race muscle contraction is relatively slow and about 32–38 duty cycles per minute are used. Maximal power per stroke may reach as high as 1200 W and average power per race is about 450–550 W (Steinacker, 1993). During competition, a rower depends mainly on his/her aerobic metabolism because energy stores and glycolysis are limited to cover the energy demand only for approximately 1.5–2.0 minutes (Steinacker, 1993). Aerobic power can be defined as the maximal oxygen consumption as estimated during a performance that lasts two to 10 minutes (Jensen, 1994). Aerobic and anaerobic energy contributions on a 2000 metre rowing race in different studies are presented in Table 1. According to Roth et al. (1983), the energy of the 2000 metre race was provided 67% aerobically and 33% anaerobically, 21% alactic and 12% lactic. While Secher et al. (1982) found that the aerobic energy contribution may be up to 86%.

Table 1. Mean contribution of aerobic and anaerobic energy during extensive rowing in different studies using elite heavyweight male rowers.

Studies	Number of subjects	Aerobic energy %	Anaerobic energy %
Russell et al. (1998)	19	84	16
Hagerman et al. (1978)	310	70	30
Hartmann (1987)	17	82	18
Mickelson & Hagerman (1982)	25	72	28
Roth et al. (1983)	10	67	33
Secher et al. (1982)	7	70–86	14–30
Messonnier et al. (1997)	13	86	14

Many factors affect physical performance during rowing. Power depends on aerobic and anaerobic energy supplies balanced by efficiency or technique (Jensen, 1994). Efficiency is expressed as the relationship between energy expenditure and boat velocity. Efficiency depends on the technical skill of the rower and varies as much as from 16 to 21% even during ergometer and tank rowing (Bunk & Leso, 1993; Lakomy et al., 1993). Differences in efficiency between rowers and non-rowers have been demonstrated, while no differences were observed between elite lightweights selected for World Championships team compared with those who did not make the team (Lakomy et al., 1993). This indicates that efficiency on an ergometer is only a rough estimate of technique in the boat (Jensen, 1994).

Testing an athlete is an attempt to evaluate his/her sport-specific performance. The easiest way of doing this is to measure the shortest time needed to cover a particular rowing distance. However, it is rather complicated, because external factors like wind, currents, and temperature may influence the result. Furthermore, a need may exist to evaluate the individual contribution to a boat including as many as eight rowers (Jensen, 1994). Rowing ergometers are commonly used to measure individual performance parameters in rowers and training changes. Although rowing an ergometer does not require the same skills as on-water rowing, it has been observed that the ergometer simulates the biomechanical and metabolic demands of on-water rowing (Lamb, 1989). Thus, it should also be taken into consideration that rowing ergometers are valuable tools in testing, but they should be used in care when developing endurance during the preparation period, because they may affect seriously the technique of on-water rowing.

Many researchers (Table 2) have found performance predictive parameters for rowers to predict 2000 metre rowing ergometer performance (Cosgrove et al., 1999; Ingham et al., 2002; Jürimäe et al., 1999, 2000; Perkins & Pivarnik, 2003; Riechman et al., 2002; Russell et al., 1998; Womack et al., 1996) and two of them (Jürimäe et al., 1999, 2000) also developed performance predictive parameters for 2000 metre single scull distance. These studies used rowers of different levels, classification (scullers, sweep rowers), sexes and that may be the reason why each study had different equations of performance predictive parameters. Howerver, all these studies reported either maximal oxygen consumption (VO_{2max} in $l \cdot min^{-1}$) or maximal aerobic power (P_{max} in W) to be an important parameter in predicting performance on a 2000 metre rowing ergometer distance. For example, Ingham et al. (2002) and Womack et al. (1996) found that VO_{2max}, P_{max}, oxygen consumption at 4 $mmol \cdot l^{-1}$ blood lactate level were highly correlated with 2000 metre rowing ergometer performance. Contrary to this, Riechman et al. (2002) found that 2000 metre rowing ergometer performance is best characterized by mean power of 30 second all-out ergometer test (i.e. anaerobic lactic power) and VO_{2max}. Similar results were obtained by Jürimäe et al. (2000), who reported P_{max} and mean power of 40 second work (i.e. anaerobic lactic power) to be the best predictive parameters of 2000 metre rowing ergometer performance.

Jürimäe et al. (2000) compared ergometer rowing with on-water rowing and found that from different anthropometric characteristics only muscle mass was correlated with 2000 metre single scull distance, while almost every anthropometric variable was related to 2000 metre rowing ergometer distance. In support to this, Russell et al. (1998) reported that anthropometrical parameters alone predicted the 2000 metre rowing ergometer distance best compared to metabolic parameters and combination of both categories. Thus, care should be taken when interpreting the rowing ergometer results to predict on-water rowing performance, because anthropometric variables may have too big influence of the result. In smaller and lighter rowers on-water rowing speed is usually compensated by higher physiological parameters, which is clearly indicated by the fact that in international regattas some lightweight rowers may easily compete with their heavier peers.

Table 2. Performance predictive parameters for rowers on 2000 metre ergometer distance in different studies.

Classification	Parameters	Comments	Study
13 male college level rowers	– VO_{2max} – lactate 5 minutes after 2000 ergometer all-out	May be due to homogenous group, rowing economy was not found to be an important predictor to rowing success	Cosgrove et al., 1999
41 international level male and female rowers including lightweights	– Power at VO_{2max} – VO_{2max} at 4 $mmol \cdot l^{-1}$ – Power at 4 $mmol \cdot l^{-1}$ – P_{max}	May be not specific enough, becose both male and female and also lightweights were used	Ingham et al., 2002
19 elite schoolboys	– Height – Body mass – Skinfolds	Sweep rowers were used, who are known to be taller and heavier than scullers	Russell et al., 1998
12 international female rowers	– Power of 30sec all-out – VO_{2max} – Fatigue	A 30 sec Wingate test, with fatigue measure was developed to predict 2000 metre rowing performance	Riechman et al., 2002
10 male college level rowers	– VO_{2max} – Peak velocity – Velocity at 4 $mmol \cdot l^{-1}$ – VO_{2max} at 4 $mmol \cdot l^{-1}$	The rest period during the incremental test could have too big influence on the VO_{2max} value.	Womack et al., 1996
10 male national level rowers	– Pa_{max} – La_{350W} – CSA thigh – Height – Muscle mass	Compares on-water and rowing ergometer performance parameters	Jürimäe et al., 2000

VO_{2max} – maximal oxygen consumption; P_{max} – maximal aerobic power; La_{350W} – blood lactate concentration at 350W power; CSA thigh – the cross-sectional area of a thigh

The accurate analysis and assessment of various components of performance within the training context is an important process for coaches and sport scientists to include as an integral aspect of the training and competition programme of a rower. Determinants of competitive success include various psychological attributes such as self-motivation (Raglin et al., 1990), technical skills including balance (Mester et al., 1982), coordination with other crew members (Wing & Woodburn, 1995), in addition to the physiological characteristics of muscular endurance, aerobic power, anaerobic power and strength characteristics (Shephard, 1998). Hereby, a good testing battery for a rower needs several parameters to determinate his/her performance and to make selection process more effective. A key aspect to bear in mind with physiological tests is the extent to which it is actually correlated with performance (Smith, 2002).

Changes in performance capacity can be analysed during all-out rowing tests in a rowing boat over various distances or on the rowing ergometers. Maximum performance (P_{max}) during a standardized test (2, 6 and 7 minute all-out, 500, 2000, 2500 and 6000 metre all-out, tests on anaerobic threshold, etc.) can be used for evaluation of the exercise capacity (Gullstrand, 1996; Hagerman, 2000; Hagerman & Staron, 1978; Jensen, 1994; Jürimäe et al., 1999, 2000; Mahler et al., 1984; Messonnier et al., 1997; Peltonen & Rusko, 1993; Smith et al., 2000; Snegovskaya & Viru, 1993; Vermulst et al., 1991; Womack et al., 1996). However, Steinacker et al. (1998) argued that P_{max} is subject to motivation of the rower tested and thus may not be sensitive enough to monitor a complete rowing season and raised a question of more reliable test programmes such as fast ramp tests, because they may fit into training program more easily. However, in a study of Smith et al. (2000) no changes were found in 500 metre rowing ergometer time nor power after 3 weeks of overload training with 33% increase in the frequency and 30% increase in training volume and the following tapering week in international male and female rowers. It may be explained by the fact that anaerobic energy production may have too big influence on the test results and it is well known that in successful rowers anaerobic capacity trainings are less than 10% of the whole training time.

Endurance capacity is an important result of training and regeneration (Mickelson & Hagerman, 1982; Steinaker et al., 1998). Higher performance at a fixed or individual lactate threshold means higher maximum performance, but there is a wide scattering of individual data of rowers. In successful rowers, the 4 $\text{mmol} \cdot \text{l}^{-1}$ lactate threshold is in the range of 75 to 85% of their P_{max} (Secher, 1993; Steinacker, 1993). It should be taken into account that different testing protocols and different types of ergometers used may contribute different levels of 4 $\text{mmol} \cdot \text{l}^{-1}$ blood lactate levels. For example, Lormes et al. (1993) found higher lactate levels for a given heart rate on the Gjessing than on the Concept II rowing ergometer, a possible reason of power losses in the transmission system of the Gjessing rowing ergometer. Maximal lactate values decrease with higher lactate threshold, as an indicator of increased endurance capacity (Steinacker, 1993). However, using fixed or individual lactate threshold values as guidelines for training intensity must be viewed with caution, because they do not mirror exactly the blood lactate steady-state for rowers (Bourgois & Vrijens, 1998). Lactate threshold and maximum lactate values are also influenced by preceding exercise and muscle glycogen stores (Steinacker, 1993).

Thus, all variables before testing the athlete must be standardized to avoid difficulties in interpretation of the test results. In a glycogen deficient state, maximum lactate and performance are depressed and lactate threshold virtually increased, but in the state of overreaching or overtraining without glycogen deficit, maximum lactate and performance capacity and lactate threshold are decreased or lactate threshold unchanged (Lehmann et al., 1992; Steinacker et al., 1998, 1999).

Nowadays, the blood lactate response to exercise is commonly accepted as a tool for performance assessment and training prescription (Steinacker, 1993; Tokmakidis et al., 1998). The blood lactate response has been investigated thoroughly and described using variety of terms and definitions (Bishop et al., 1998; Tokmakidis et al., 1998). The anaerobic threshold has been one of the most commonly used terms for describing the blood lactate response. Anaerobic threshold can be defined as the workload that can be performed by the oxidative metabolism and at which blood lactate production and release are balanced during continuous exercise (Bishop et al., 1998; Kindermann et al., 1979; Tokmakidis et al., 1998).

To determine anaerobic threshold, numerous concepts and definitions have been published in the last decades. A number of methods are based on the observation that blood lactate levels change suddenly at some critical work rate and thus reflect a threshold phenomenon (Brooks, 1985). For example, some authors consider the anaerobic threshold to be the work rate at which the lactate concentration first begins to increase above the resting level (Yoshida et al., 1987), whereas others have suggested an increase of 1.0 $\text{mmol} \cdot \text{l}^{-1}$ above baseline during incremental exercise (Coyle et al., 1983). To overcome the disadvantage of visual, subjective determination of anaerobic threshold, lactate parameters may also be identified by using various curve fitting procedures such as log-log transformation (LT_{LOG}) (Beaver et al., 1985), the D_{MAX} method (Cheng et al., 1992), or a modified D_{MAX} method (D_{MOD}) (Bishop et al., 1998). Other investigations have proposed a fixed lactate level to define and detect anaerobic threshold. For example, values of 2.0 $\text{mmol} \cdot \text{l}^{-1}$ (LaFontaine et al., 1981), 3.0 $\text{mmol} \cdot \text{l}^{-1}$ (Föhrenbach et al., 1987) and 4.0 $\text{mmol} \cdot \text{l}^{-1}$ (Kindermann et al., 1979) have been used. Although a number of competing models exist to fit blood lactate concentration data during incremental exercise, there has been little comparison between different concepts in rowers. However, different anaerobic threshold concepts (Table 3) and their relationships to rowing performance were studied by Jürimäe et al. (2001b). The authors concludeded that LT_{LOG} represented the rowing ergometer performance time best.

Table 3. Blood lactate values recorded during the incremental rowing ergometer test in male rowers (n = 21) (modified from Jürimäe et al., 2001b).

Parameter	LT ($\text{mmol} \cdot \text{l}^{-1}$)	LT_1 ($\text{mmol} \cdot \text{l}^{-1}$)	LT_{LOG} ($\text{mmol} \cdot \text{l}^{-1}$)	LT_D ($\text{mmol} \cdot \text{l}^{-1}$)	LT_{MOD} ($\text{mmol} \cdot \text{l}^{-1}$)
Mean±SD	2.5±0.6	3.2±0.7	3.7±0.8	4.5±1.0	5.6±0.9

LT — the power output preceding the first increase in blood lactate concentration above the resting level during an incremental exercise test; LT_1 — the power output at which blood lactate increases by 1.0 $\text{mmol} \cdot \text{l}^{-1}$ or more; LT_{LOG} — the power output at which blood lactate concentration begins to increase when the log (lactate) is plotted against the log (power output); LT_D — the lactate threshold calculated by the D_{max} method; LT_{MOD} — a modified LT_D method.

Steinacker (1993) and Wolf and Roth (1987) have reported that the submaximal aerobic capacity measured as the power which elicits a blood lactate level of 4.0 $\text{mmol} \cdot \text{l}^{-1}$ is the most predictive parameter of competition performance in trained rowers, especially in small boats such as singles and doubles, but some authors have questioned the physiological significance of a fixed blood lactate value of 4.0 $\text{mmol} \cdot \text{l}^{-1}$, which does not take into account the inividual kinetics of the lactate concentration curve (Coyle, 1995; Stegman et al., 1981). Moreover, a power at blood lactate level of 4.0 $\text{mmol} \cdot \text{l}^{-1}$ has not been reported to represent a steady state workload in rowing (Beneke, 1995; Bourgois & Vrijens, 1998). Using 21 male rowers, Jürimäe et al. (2001b) found anaerobic threshold value to be 3.7 $\text{mmol} \cdot \text{l}^{-1}$ (see, Table 3), which is lower than suggested 4 $\text{mmol} \cdot \text{l}^{-1}$ value and may therefore be better to select training intensities without accumulation of blood lactate. Moreover, a deflection point using LT_{LOG} method was very easily detected, allowing more accuracy for each athlete. Thus, LT_{LOG} value, which detects the anaerobic threshold with less subjectivity, may be a more appropriate measure of training modality in rowing, however, it must be still confirmed in future studies.

This is in contrast with the results of previous studies (Bishop et al., 1998; Tanaka & Matsura, 1984; Yoshida et al., 1987), who reported different anaerobic threshold concepts to represent steady-state in different endurance events. The results of these studies indicate that there is not one blood lactate parameter that best predicts competition performance in all endurance events. For endurance events of different intensity and duration, different blood lactate parameters may provide a simple method of estimating a pace that does not result in premature fatigue (Bishop et al., 1998).

In conclusion, aerobic and anaerobic capacities both seem to be an important parameters in competitive rowing despite the level, sex, body mass, etc., and both components are worth testing to better understand the performance of a rower. For anaerobic threshold level, a method when the power output at which blood lactate concentration begins to increase when the log (lactate) is plotted against the log (power output) may represent the threshold inensity better than commonly used 4 mmol · l^{-1} blood lactate concentration. It should also be taken into consideration that a 2000 metre rowing ergometer performance is suitable for rowers, who compete in big boats like fours and/or eights. When performance of rowers in small boats is measured, a 2500 metre ergometer distance appears to more closely reflect the metabolic effort of on-water rowing on singles and doubles (Jensen, 1994; Jürimäe et al., 2000).

2.2. Characteristics of rowing training

During a rowing race (approximately 5.5 to 7.0 minutes, average power per stroke 450–550W), anaerobic alactic and lactic as well as aerobic capacities are stressed to their maximum (Steinacker, 1993). Therefore, the training of successful rowers has to be built up on the focus of aerobic training with the proper relation with strength and anaerobic training.

Endurance training (training at blood lactate concentration of 2–4 mmol · l^{-1}) is the mainstay of success in rowing (Howald, 1988; Mahler et al., 1984; Secher, 1983,1993; Steinacker, 1988, 1993). Training of successful athletes is characterized by extensive as well as intensive endurance training with approximately 70–80% of the time spent on the water (Jensen et al., 1993; Marx, 1988; Steinacker, 1988). Intense endurance training above the anaerobic threshold may be important for improvement of VO_{2max} during the competitive season, but should not amount to more than 10% of the training volume (Steinacker, 1993). Over the year, the percentage of specific rowing training on the water is 52–55% for the 18 year old, 55–60% for the 21 year old, and up to 65% for the older athlete. Strength training is in the range 20% at the 18 year old and 16% at the adult athlete, and general athletic training is in the range from 26–23%, respectively (Altenburg, 1997). It is important to increase specific rowing training with increased training experience (Steinacker et al., 1998).

The preparation period of rowers starts usually in October, where the main goal of training is to build up a base through aerobic extensive endurance training (90% of the total training time) (Nielsen et al., 1993). It appears that during the preparation period, rowers should deemphasize strength training at low velocities and emphazise power development at higher velocities (i.e. train more specifically for the types and velocities of movements used in the rowing technique and at speeds necessary to mimic the competitive pace) (Hagerman, 2000). The main period for developing strength-endurance is from January to March (Nielsen et al., 1993). The competitive period starts in March and culminates for elite rowers in late August or in early September with World Rowing Championships. During competitive period, the aerobic training is still the most important (about 70% of total training). About 25% of the training during the competitive season is aerobic-anaerobic (blood lactate concentration 4–8 mmol · l^{-1}) training and the rest is purely anaerobic (blood lactate concentration above 8 $\mathrm{mmol} \cdot l^{-1}$) training (Nielsen et al., 1993). Steinacker et al. (1999) investigated the time course of rowing velocity and ergometer results of a coxed eight during the training camp before Junior World Championships 1995. This preparatory training programme had a duration of approximately 4 weeks: 2 weeks high-intensity / high-volume training, tapering 1 week and in the last week special preparation for the finals. The slowest boat speed of the 2000 metre distance was observed during the high-volume / high-intensity, and the fastest boat speed was observed at the time trial 4 after the tapering period and at the World Championships.

In rowing, for stuying training effects the problem is the complexity of the goals of training because different capacities (aerobic, anaerobic, power, strength, tactical skills) have to be improved (Steinacker et al., 1998). This causes timing problems, because several capacities cannot be developed at the same time. For example, endurance and sprint training are not appropriate to develop in the same training session. For rowers, one of the most important task is the maintenance of strength gains while training to enhance aerobic endurance simultaneusly (Bell et al., 1993), as strength training is one physical performance factor of a complete annual training programme (Hagerman & Staron, 1983; Secher, 1993). Research has shown that a sequence of strength training prior to endurance training may be preferred for off-season for rowing (Bell et al., 1988,1991). Bell et al. (1993) found significant strength gains with a training frequency of three times per week for 10 weeks and were maintained for at least six weeks where the main goal was to develop aerobic endurance and strength training was conducted only once or twice per week (Bell et al., 1993). Whether strength gains can be maintained beyond six weeks while performing endurance training is not known (Bell et al., 1993) and needs further research.

Most rowers use also unspecific and cross training to increase training tolerance and to avoid overtraining. During cross training, different muscle groups are recruited, which may allow partial recovery of other muscle groups and therefore, the advantages of cross training seem to be “peripheral” effects, enhancing or maintaining strength in power training and “central” effects by decreasing monotony of trainings (Steinacker et al., 1998). However, it has to be stated that in international level the relation of specific and unspecific training has to be in the range of 70% and 30%, respectively (Altenburg, 1997; Nielsen et al., 1993).

In conclusion, endurance training is the main type of training in rowing, which has to be in proper relation with strength and speed training. Over the career the percentage of specific rowing training must increase and reache 65 to 70% in elite rowers.

2.3. Psychological monitoring of training in rowing

In addition to clinical findings, the level of psychologically-related stress and recovery seems to reflect well the state of athletes (Kellmann & Kallus, 1999; Steinacker et al., 2000). Furthermore, mood state, e.g., motivation and striving for success, seems to be closely related to actual performance (Kellmann & Kallus, 1999; Morgan et al., 1987; Secher, 1993). Shephard & Shek (1994) argued that psychological testing provides both easier and more effective methods for detecting the overtraining syndrome than methods dependent on various physiological or immunulogical markers. To date, most common psychometric instruments used were the one item Borg ratio scale (Borg, 1998), which was developed to subjectively measure the intensity of the exercise; the Profile of Mood States (POMS) (McNair et al., 1992), which measures only current stress; and Recovery-Stress-Questionnaire for Athletes (RESTQ-Sport) (Kellmann & Kallus, 2001), which allowes measuring both subjectively perceived stress and recovery. It has to be considered that the Borg ratio scale, RESTQ-Sport and the POMS are not direct measures of physiological states of the organism, these instruments reflect the subjective representation of these states (Kellmann & Kallus, 1999).

During a training programme, mood state did not differ between those who adhered to the programme and the dropouts; however, those who remained in training had higher self-motivaton (Secher, 1993). During training, mood state increased, but suprisingly remained elevated in those who did not make the team, but decreased in those who were successful (Secher, 1993). Marriot & Lamb (1996) found a highly consistent relationship between Borg ratio-scale perceptions of exertion on a rowing ergometer and heart rate. When the rating of perceived exertion was used as a means of producing an appropriate training heart rate, it was satisfactory but only as the higher intensities of effort (ratings 15 and above) (Marriot & Lamb, 1996). Urhausen et al. (1998) found significantly higher ratings of subjective exertion in overtrained endurance athletes. However, the one-item construction of the Borg ratio scale cannot assess different aspects of recovery and stress (Kellmann, 2002). Moreover, it is difficult to interprete what causes the change of the scale after standardized exercise, and therefore, proper intervention is complicated. Thus, the Borg ratio-scale is not suitable for monitoring training in highly trained athletes (Kellmann, 2002).

There is convincing evidence that athletes can be distinguished on the basis of psychological skills and emotional competencies (Smith et al., 2002). The POMS was initially developed as an economical method of identifying and assessing transient, fluctuating affective state (McNair, 1992). The POMS consists of 65 items and it yields a global measure of mood, consisting of *Tension, Depression, Anger, Vigour, Confusion* and *Fatigue*. An overall score is computed by summarizing the five negative mood states and subtracting the positive mood state (*Vigor*). The POMS has also been used to measure mood state of rowers (Kellmann & Kallus, 1999), swimmers (Morgan et al., 1987) and runners (Verde et al., 1992). Verde et al. (1992) concluded that resting heart rate, sleep patterns and hormonal changes do not provide a useful early warning that the peak of the performance has been passed, but the POMS score showed a consistent pattern of loss of *Vigour* and *Fatigue* during heavy training of three weeks in runners. Morgan et al. (1987) measured mood states of swimmers throughout the season. At the beginning, the swimmers exhibited the "iceberg profile," an indicator of a mentally healthy state. In high load phase, mood disturbances increased and a profile reflected poor mental health. After reducing the intensity, the swimmers demonstrated the original "iceberg profile" again. A dose-response relation between mood disturbances and training intensity is prevalent (Raglin, 1993),

However, Kelmann (2002) argued that if we assume that the POMS can identify overtrained athletes at an early stage, the question then arises as to what kind of intervention should take place. Because the items of the POMS are in adjective form (e.g., *Confusion, Vigor, Anger*), it does not provide information of the cause of the mood (Kellmann, 2002). Furthermore, Berger & Motl (2000) noted the disadvantage that the POMS was initially developed for use with clinical populations in order to have an economical method of identifying and assessing transient, fluctuating states. In addition, five of the of the six scales of the POMS measure the negative mood characteristics of *Tension, Anger, Fatigue, Depression* and *Confusion* and a decrease in a negative mood state may not necessarily indicate mood benefits (Berger & Motl, 2000). Therefore, the POMS only vaguely reflects recovery processes and does not lead to the application of appropriate recovery strategies (Kellmann, 2002).

Restricting the analysis to the stress dimension alone is insufficient, especially in high performance areas, since the management of training intensity and volume is tightly linked to outstanding performance (Steinacker et al., 2000). A psychometrically based instrument to assess the recovery-stress state is the RESTQ-Sport. The recovery-stress state indicates the extent to which persons are physically and/or mentally stressed, whether or not they are capable of using individual strategies for recovery as well as which strategies are used (Kellmann & Günther, 2000). This questionnaire was created to get distinct answers to the question "How are You?“ (Kellmann, 2002) and addresses physical, subjective, behavioral, and social aspects using a self-report approach (Kellmann & Kallus, 1999). The theory behind the questionnaire is that an accretion of stress in everyday life, coupled with weak recovery potential, will cause a variation of the psychophysical general state (Kellmann, 2002).

Several studies have showed that POMS scales *Depression, Anger and Fatigue* are negatively correlated with recovery associated scales of RESTQ-Sport, at the same time *Vigor* is positevily correlated (Kellmann et al., 2001; Kellmann & Günther, 2000) and vice versa, a positive relationship exists between the stress related scales of RESTQ-Sport and *Depression, Anger* and *Fatigue*, while *Vigor* appears to be negatively correlated with stress scales.

Longitudinal studies in German and American athletes participating in different sports have shown that the RESTQ-Sport can sensitively monitor stress and recovery processes in training camps and throughout the season (Kallus & Kellmann, 2000; Kellmann & Günther, 2000; Kellmann & Kallus, 1999; Steinacker et al., 2000). Moreover, a dose-response relationship was demonstrated between training volume (daily rowed kilometers) and the somatic components of stress and recovery in rowers (Kellmann & Günther, 2000; Steinacker et al., 2000).

Using 11 elite rowers during their preparation for the 1996 Atlanta Olympics, Kellmann & Günther (2000) found that the alteration of extensive endurance training was well reflected in psychological measures. High duration was indicated by elevated levels of stress and simultaneuos lowered levels of recovery. Moreover, the scales *Somatic Complaints, Lack of Energy, Fitness/ Injury,* and *Fitness/Being in Shape* described the dose-response relationship with the training load. However, the different trends in the RESTQ-Sport scales may be explained by the different time courses of hormones and corresponding scales (Steinacker et al., 1999). For example, *Somatic Complaints* were highest with the highest training load and elevated cortisol concentrations as well as creatine kinase activity.

In conclusion, through utilization of the RESTQ-Sport coaches and athletes can be informed of the importance of daily activities and how these activities are related to recovery-stress state of athlete's compared to the frequently used one-item Borg scale or POMS, which in general measures the stress related behaviour and thus, could not be sufficient in high performance areas. Previous studies (Kellmann & Günther, 2000; Simsch et al., 2002; Steinacker et al., 1999, 2000) utilizing RESTQ-Sport could suggest that it is appropriate to measure recovery-stress state changes during rowing training in highly trained male athletes.

2.4. Selected blood biochemical indicies of training monitoring in rowing

In the world of training and coaching, different biochemical indicies in blood are used to prevent and to diagnose overtraining syndrome as an unwanted result of athlete's training regimen. The acute responses in the endocrine system during physical exercise may be related to the intensity and duration of the specific exercise as well as to the physical condition of the athletes (Häkkinen et al., 1989; Remes et al., 1985). Evaluation of serum hormones during prolonged physical activity and/or training has also received considerable attention due to its implications for general adaptive mechanisms and for physical conditioning (Häkkinen et al., 1989). However, to date, there is still no valid diagnostic tools that would help us to prevent overtraining. Different hormonal responses were often proposed for monitoring overreaching and overtraining situations and also for recovery period (Häkkinen et al., 1989; Kuipers & Keizer, 1998; Lehmann et al., 1991,1993; Simsch et al., 2002; Snegovskaya & Viru, 1993; Steinacker et al., 1999, 2000; Urhausen et al., 1987, 1998). Endogenous hormones are essentially involved in exercise-induced acute or chronic adaptions and influence the regeneration phase through the modulation of anabolic and catabolic processes after exercise (Urhausen et al., 1995). Hormonal mechanisms most assuredly help mediate both short-term homeostatic control and long-term cellular adaptations to any type of stress are imposed on man. For example, cortisol and growth hormone exert an essential role both in short-term (control on utilization of energy substrates, mobilization of protein resources) and prolonged stable (amplification of the translation process, supply of protein synthesis by "building materials") adaptation to exercises (Viru, 1985).

Since cortisol levels in humans show a circadian rhythm, with low levels in the late evening and high levels in the early morning, it has to be taken into account when collecting the hormone sampling (Fry et al., 1991; Hackney et al., 1988). Testosterone shows no specific pattern, but fluctuations due to nervous stimuli in response to temperature, psychological events and amount of light in the day, have been reported (Hackney et al., 1988; Hoogeveen & Zonderland, 1996).

Numerous investigations have studied the effects of different kind of prolonged physical stress has on the hormones of hypothalamus-pituitary-adreno-cortical axis (Häkkinen et al., 1989, Simsch et al., 2002; Steinacker et al., 2000; Vervoorn et al., 1991). Prolonged heavy endurance training has found to cause the increase and decrease in the morning basal levels of cortisol and testosterone, respectively (Vervoorn et al., 1991). While resting levels of cortisol have reported to be unchanged (Mackinnon et al., 1997) or decrease (Flynn et al., 1994) after endurance training in male athletes.

The exercise induced cortisol increase depends on the duration and intensity of physical exercise (Snegovskaya & Viru, 1993). A significant increase in the blood cortisol level usually requires a duration of exercise of more than 20 minutes with at least 60% of the VO_{2max} and is primarily the consequence of a higher secretion rate. In previously trained sportsmen, the further improvement of performance capacity is connected with an increased functional capacity of endocrine systems (Snegovskaya & Viru, 1993). During the post exercise phase, cortisol decreases rapidly and, within hours, reaches an initial value (Urhausen et al., 1995).

In rowers, the further improvement of performance capacity was associated with increased growth hormone and cortisol levels and elite rowers have a higher values of cortisol and growth hormone compared to national and medium performance level (Snegovskaya & Viru, 1993). These results are somewhat controversial to Steinacker et al. (1993) study, who reported higher cortisol values for rowers who were not selected to National Junior Team of Germany, indicating higher catabolic activity. At an early stage during the training camp before World Junior Championships 1996 in German Junior Team, when the training load was highest, basal cortisol levels increased by 18% and decreased slightly afterwards (Steinacker et al., 1999). Elevated basal cortisol levels are often seen as a normal stress response to high-intensity training (Steinacker et al., 1993,1998). For example, the increase in cortisol level was found in junior rowers after anaerobic training during the last days before the blood sampling (Steinacker et al., 1993). There were no changes in plasma cortisol and testosterone concentration after two hours of rowing at the intensity of 75% of 4 $\text{mmol} \cdot \text{l}^{-1}$ anaerobic threshold (Jürimäe et al., 2001a). Steinacker et al. (2000) found human growth hormone increase from baseline (0.45 ng.ml^{-1}) to 10% in high load training phase (training load approximately 180 minutes per day for two weeks), but a decrease of 30% during the tapering phase where training volume was reduced for about 30%, but the intensity was maintained.

Adlercreutz et al. (1986) and Härkonen et al. (1984) stated that a condition of overstrain might exist in an athlete if at least one of the two following criteria are fulfilled: 1) free testosterone/cortisol ratio lover than 0.35×10^{-3}; and/or 2) a decrease in free testosterone/cortisol ratio of 30% or more. During a rowing season, no significant relationships were found between free testosterone/ cortisol ratio and rowing ergometer performance parameters in highly trained male rowers (Vervoorn et al., 1991). However, a decrease in free testosterone/ cortisol ratio was observed after the training camp (range 4–40%), but these changes were not significantly related to performance parameters (Vervoorn et al., 1991). The authors concluded that the criterion of a decrease in the free testosterone/cortisol ratio of 30% or more nor the free testosterone/cortisol ratio lower than 0.35×10^{-3} cannot be regarded as a first sign of overtraining (Vervoorn et al., 1991). Therefore, the free testosterone/cortisol ratio seems to be more useful as an indicator for a status of insufficient time to recover from training, in particular when such a decrease is caused by a decrease in plasma free testosterone concentration (Vervoorn et al., 1991).

Catecholamines stimulate cardiovascular and metabolic reactions and indicate physical and psychological stress (Galbo, 1983; Kindermann et al., 1982; Lehmann et al., 1985). All-out rowing is usually associated with extremely high plasma catecholamine levels — 19 $\text{nmol} \cdot \text{l}^{-1}$ and 74 $\text{nmol} \cdot \text{l}^{-1}$ for adrenaline and noradrenaline, respectively (Holmquist et al., 1986; Jensen et al., 1984). Higher noradrenaline concentrations were noted during endurance training at similar heart rate on the Gjessing rowing ergometer compared to rowing in the boat, but adrenaline values were not statistically different (Urhausen et al., 1993). It was concluded that, because of the higher sympathoadrenergic activation when exercising on the ergometer, the intensity of ergometer rowing should be set carefully (Urhausen et al., 1993).

The plasma leptin level is identified as an adipocyte-derived hormone and its receptor has highlighted the regulation of appetite, thermogenesis and metabolism (Friedman & Halaas, 1998). Leptin is considered to be one of the physiological signals designed to prolong survival in hazardous situations like strenous exercise or starvation, mainly by reducing basal metabolic rate, increasing food seeking behaviour, increasing the secretion of glycocorticoids and decreasing reproductive function (Flier, 1998). However, it has become evident that leptin does not act only as an “adipostatic hormone” (Steinacker et al., 2003). It has also been shown that exogenous leptin is a potent stimulus of growth hormone secretion (Tannenbaum et al., 1998). Studies have shown that endurance exercise sessions decrease the plasma leptin concentration after 48 hours, in association with a preceding decrease in insulin (Essig et al., 2000), while short-term exhaustive exercise has no immediate or delayed effect on circulating leptin concentration (Hickey et al., 1996). In the literature, the responses of plasma leptin to exercise are controversial. It has been suggested that fasting plasma leptin is not regulated in a dose-response manner in competitive male swimmers (Noland et al., 2001), while it has shown to be decreased in heavy training in highly trained rowers during high load training and increased when training load was decreased (Simsch et al., 2002). These controversial results could be explained by the differences in physical stress as the training regimen of the swimmers in Noland et al. (2001) study was intensive high load interval training, while in Simsch et al. (2002) investigation was high intensity strength training. Furthermore, Simsch et al. (2002) demonstrated a positive relationship between leptin levels and rowing performance. These results are controversial to Petibois et al. (2002), who argued that plasma leptin is not sensitive to an increase in training volume for trained individuals. There is the hypothesis that leptin expression in the adipocyte is related to energy flux and triglyceride loss (Considine, 1997). Accordingly, there is not a consensus about the effect of different training regimen on plasma leptin concentrations in humans.

Recently, Urhausen & Kindermann (2002) suggested that instead of resting hormone concentrations, maximal exercise-induced hormonal responses during and after a period of training overload should be studied to assess the adaptivity of the athletes. The elevation of hormone levels after rowing exercises performed at the maximal possible rate may be an overall expression of the dependance of hormone changes on the exercise intensity (Snegovskaya & Viru, 1993). This means that there should be a wide reserve to increase the hormone responses to exercise. Only a sufficient performance capacity has to be achieved to evoke a correspondingly large rise in hormone concentrations (Snegovskaya & Viru, 1993).

Despite the episodic character of growth hormone secretion, its response during exercise is characterized by a continuous increase of blood level during the exercise (Viru & Viru, 2001). Growth hormone response to submaximal exercises has found to decrease or disappear, as a result of training (Buckler, 1973; Sutton et al., 1969). There is also a possibility that fatigue may modulate growth hormone response (Viru & Viru, 2001). For example, Urhausen et al. (1998) demonstrated a decrease in ecercise induced rise of growth hormone, while Lehmann et al. (1992) found no change in resting nor exercise induced values of growth hormone. In the state of overreaching and overtraining, an intraindividually decreased maximum rise of cortisol and insulin has also been found after a standardized exhaustive exercise test (Urhausen & Kindermann, 2002).

For several years, serum creatine kinase activity has been measured as a parameter of muscular stress in training associated studies. A particularly important consideration relating to the use and interpretation of creatine kinase values in the sports sector is the dependence of this parameter on nature of the stress (Hartmann & Mester, 2000). Creatine kinase activity reflects training intensity and muscular strain only at the beginning of a training phase, decreasing creatine kinase activity and suggesting muscular adaptation to training (Steinacker, 1993; Steinacker et al., 1998; Urhausen et al., 1987). Morning levels of creatine kinase activity represent mainly its release during the previous day and are also influenced by creatine kinase clearance (50–80% per day) (Steinacker et al., 1993). Steinacker et al. (1993) found higher creatine kinase values in the junior rowers who were not selected to the national team, indicating higher muscular strain despite their lower physical power.

In summary, it seems that at present a lack of valid biochemical markers of training stress exist in rowing. However, the study of Simsch et al. (2002) has proved the decrease of leptin in high load training phases due to hypothalamic dysfunction and, therefore, it could be a marker of training stress in rowers. It could also be suggested that the maximal exercise-induced changes in biochemical values may represent the more sensitive markers of training and possible overreaching in athletes.

2.5. Studies on monitoring training in rowing

In the literature, there are not very many longitudinal studies that deal with training monitoring of rowers. Some of them are summarized in Table 4. Most of them are three to five weeks of duration — one microcycle. Only few of them (Cosgrove et al., 1999; Snegovskaya & Viru, 1993; Vervoorn et al., 1991, Vermulst et al., 1991) are longer than one microcycle. However, these longer studies tend to monitor only one specific pattern or the time between two different testing battery is too long. There is also a lack of studies which deal with rowing performance and resistance training. Bell et al. (1988, 1989, 1991, 1993) have investigated high velocity resistance training (HVRT) relation to rowing training. However, they have compared HVRT to anaerobic power and reported no significant changes in anaerobic power after different training programs (Bell et al., 1989) High intensive resistance training was also used in the study of Simsch et al. (2002) and the stagnation in performance of incremental ergometer test was detected, but after endurance training the performance increased significantly. It is known that building up the strength-endurance capacity during off-season is one part of rowers' winter training program. The impact of low-velocity resistance training (frequency, intensity, etc.) at least during off-season on rowing performance needs some further research.

Table 4. Studies involving training monitoring in rowers.

Reference	Sub	Per	Design	Performance	Blood parameters	Mood State	Conclusions
Vervoorn et al., 1991	6 M	9 mon	Testing int. 5 w. 5'at AT_4, P_{max} 2' all-out	P_{max} almost unchanged. AT_4↑ 12% if load↑ 110%. Heavy int. AT_4↓ 8%	C, FT, FTCR almost unchanged Int training-FTCR↓ 40%, taper-FTCR↑ 60%		5 weeks of training does not induce a change in La dynamics, when comparing AT_4 with perceding test in highly trained rowers. FTCR may be a parameter of early hormonal overstrain with interpretation with training logs. Decrease of 30% is not regarded as overtraining.
Steinacker et al., 1993	35 M	26 days	P_{max}-incremental test, AT_4 and 6 min all-out 16 days Aer-119.6', Thr-6.5', An-2.3. 10days Aer-91.2',Thr – 6.5', An-3.2'.	AT_4 (W) ↑ 4.6%	Load 128 min/day FTCR↑ 24%, T↑ 20%, Urea↑ 20.8%, CK↑ 25%. Load 90 min/day C↑ 23.5%, T↑ 23.2%, FTCR↑ 7.9%, Urea↓ 10.3%, CK↓ 27%		AT4 (W) 4.1% and P_{max} 3.4% higher in national team rowers than non selected rowers.
Simsch et al., 2002	6 M	6 w	3 w RT 16.6 h/w (55% RT) 3 w ET 14.3 h/w P_{max}-incremental test	AT_4 tend to↓ in RT and tend to↑ in ET. VO_2 tend to↑. P_{max}↑ in ET.	L↓ 27%, C↓ 30%, TSH↓ 23% in RT. L tend to ↑, C tend to ↑, TSH↑ 22% in ET.		The ↓ of TSH and the peripheral thyroid hormones could be attributed to lower hypothalamus levels and is reated to ↓ L levels. L – possible director of monitoring training.
Snegovskaya & Viru, 1993	35 M	20 mon	P_{max} 7'all-out in group A Feb, June, Oct. In group B March, Jan, June.	P_{max}↑ 14.6% HR tend to increase	Post exercise levels of C and GH↑		Improvements in performance capacity was associated with increased GH and C.
Vermulst et al., 1991	6 F	9 mon	Testing int. 5 weeks. 5'at AT_4, P_{max} 2' all-out	AT_4↑if vol↑ 150% (aerobic training, submax intensity). AT_4↓ if vol↕ (70–75% aerobic, emphase on intensive distance training. P_{max}-slight 5–10% increase	Not specified		AT_4 is a useful parameter for measuring aerobic capacity of the female rowers. P_{max} does not seem to give a valid estimation of the actual maximal power in female rowers.
Steinacker et al., 2000	10 M	5 w	Vol 56% in 2 w and 40% for 2 w (90% ext rowing) P_{max}-incremental test 2000 m rowing on 8+ RESTQ	P_{max}↑ 2.7%, La_{max}↑ 3.3%, $LaAT_4$↑ 8%	In overload Hct↕, C↕, DHEAS↕, FT ↕, ALD↑, LU↓10%, FSH↓11% , GH↑10%, Ins↓ 17%. In taper Hct↕, C, DHEAS, FT↑10%, ALD↑, FSH↑ 9%, GH↓30%, Ins↑37%.	Som Comp, Gen Str, Som Rel, Self Reg, Fitness reveal a significant cubic trend of the dependant variables	Overreaching was indicated by decreases in P and increases in stress and deterioration in recovery values in RESTQ. This was also indicated by suppression of central and peripheral stress hormones.

Table 4. Studies involving training monitoring in rowers. Continued

Reference	Sub	Per	Design	Performance	Blood parameters	Mood State	Conclusions
Womack et al., 1996	10 M	12 w	Each w 5 sets of rowing (water, ergom) and 3 sets RT. P_{max}- 2000m all-out Incremental test	P_{max}↑, Velocity$_{peak}$↕, VO_2 ↕, HR↕ , Velocity$_{AT4}$ ↑, HR_{AT4}↑	Not specified		Changes inVO_2 were not significantly related to changes in P. Peak velocity during incremental testing may be a better indicator of changes in P
Urhausen et al., 1987	6 M 3 F	7 w			T, FTCR↓, C↕ Urea↑ in first 2 w and then↓		The findings suggest an increase in catabolic activity in periods of intensive physical strain, including competitions. Regenerative phases of training seem to reduce the anabolic-catabolic imbalance.
Hagerman & Staron, 1983	9 M		Changes from off-season to in-season. P_{max}- 6min all-out.	Ve ↑, VO_2 ↑, P_{max}↑ 14%, HR↕, leg strength ↑ from off-season to in-season.			Although seasonal effects were expected, the unusually large differences in metabolic and strength capacities between IS and OS reflect a high degree of training specificity
Smith, 2000	10M 8 F	4 w	3 w high load (33%↑ in frequency, 30%↑ in vol, 1 w taper (load↓ 25%). P_{max}-500 m all-out	HR↓ 30% in overload. F – 1%↓ in P_{max} during overload and 2%↑ in taper. M — P_{max}↕.	La↑ 16% in tests 3 and 4 Ammonia↓ 29% at the ent of the study		If an individuals 500 m time was monitored regularly, such a change(2% of recent time) might be noteworthy for that particular athlete.
Kelmann & Günther, 2000	9 M 2 F	3 w	RESTQ 4 times			High training volume is indicated by increased levels of stress and decreased levels of recovery	A dose-response relationship exists between the training volume and the subjective assessment of stress and recovery

M – males; mon – months; W – power in Watts; AT4 – anaerobic threshold; P_{max} – maximal performance; ↑ – significant increase; ↓ – significant decrease; ↕ – unchanged; C – cortisol; FT – free testosterone; FTCR – free testosterone cortisol ratio; Aer – aerobic training; Thr – threshold training; An – anaerobic training; T – testosterone; CK – creatine kinase; RT – resistance training; h – hours; ET – endurance training; L – leptin; TSH – thyroid stimulating hormone; GH – growth hormone; F – females; RESTQ – recovery-stress questionnaire; LaAT4 – lactate at anaerobic threshold; La – lactate, Hct – haematocrit; ALD – aldosterone; LU – luitenizing hormone; FSH – follicule stimulating hormone; Ins – insulin; Som Comp – somatic complaints; Gen Str – general stress; Self Reg – self regulation; Glyc – glycose; HR – heart rate; Ve – ventilation

Achieving the maximal result during competitions is the major purpose of athletic training. It is not always accomplished that a rower is in his/her best shape at the period of major competitions. Therefore, valuable information could be obtained from studies that deal with specific preparation for competitions at different level of rowers. However, it has to be stated that these studies have to be not case studies, but controlled ones, which are difficult to prepare because most of athletes do not want to make experiments in their trainings before competitions. Furthermore, the competition results are always difficult to analyse, because they depend on counterpants, wheather conditions, etc.

2.6. Multi-level approach of training monitoring

The evaluation of the current trainability and of the diagnosis of overload and overtraining of the athlete, is already one of the most complicated tasks in sport science (Foster, 1998; Kuipers & Keizer, 1988; Lehmann et al., 1992; Simsch et al., 2002; Steinacker et al., 1999). There is a cascade of various responses to prolonged training, which can be used to monitor an athlete. It is also evident that only a few parameters are reliable and specific enough. One should also distinguish between parameters in which the individual response is different between different subjects, like creatine kinase activity, hormonal parameters and/or mood state, and parameters that are hard to tolerate, like physical performance (Steinacker et al., 1999). The hypothalamus acts as the central integrator of all afferent signals to the brain and has an important role in the regulation of the central responses to stress and training (Steinacker et al., 2003). Such integration involves several information from autonomic nerve system afferents, direct metabolic effects, hormones and also different information from different brain centres (Steinacker et al., 1999).

There is experimental evidence that all hormones have hypothalamic receptors (Haass & Schauenstein, 1997). Leptin and insulin depress the activity of excitatory neurons in the lateral hypothalamus (Brüning et al., 2000; Withers, 2001) and have effects on energy expenditure, body mass control and sympathetic activity (Steinacker et al., 2003). High levels of leptin will inhibit activation of the hypothalamus-pituitary-adenocortical axis and cortisol release (Ahima et al., 1999). Therefore, studying the effects of leptin may have the advantage of knowing the amount of stress affecting the organism.

In the high-load training phases, which are essential to achieve improvements in performance through overreaching, decreases in steroid hormones could be observed (Hackney et al., 1990; Lehmann et al., 1992; Steinacker et al., 1993, 2002; Vervoorn et al., 1991), suggesting that hypothalamic downregulation will occur in a state of overreaching, that was also demonstrated in experimental training studies by Lehmann et al. (1996) and Barron et al. (1985). At present, the mechanism by which the hypothalamus senses metabolic imbalance and fatigue in athletes is speculative (Simsch et al., 2002).

Steinacker et al. (2000) found disturbance of the homeostasis after high-intensity and high volume training for 3.2 hours per day after 18 days in male junior rowers. This disturbance was aslo reflected in psychometric scales, performance, metabolic and hormonal parameters (depression of peripheral and steroid hormones) and was restored and supercompensated after tapering as indicated by the boat speed (Steinacker et al., 2000). Therefore, psychometric scales, which changes have known to be related to blood hormone concentration changes may be an alternative measure of athletes' current state.

For training monitoring, it is also important that mood is correlated to physical performance ability, hormonal parameters and metabolic data (Steinacker et al., 1999). Naessens et al. (1996) demonstrated a U-shaped relation between subjective fatigue-ratings and sympathietic tone (basal noradrenaline excretion). RESTQ-Sport allows to monitor mood state in athletes, but different scales of RESTQ-Sport have different time courses that have to be taken into account (Kellmann & Kallus, 1999). *Physical Complaints* and *General Stress* (Steinacker et al. 2000) were highest with highest training load, elevated cortisol concentrations and high creatine kinase activity (Steinacker et al., 1999). *Fatigue* peaks together with sympathetic activation (noradrenaline secretion) (Steinacker et al., 1999). From the perspective of a biopsychological stress model (Janke & Wolfgramm, 1995; Steinacker et al., 1999), recovery and stress should be treated using a multi-level approach dealing with psychological, emotional, cognitive behavioral/performance, and social aspects of the problem, considering these aspects both separatedly and together (Steinacker et al., 2000).

In conclusion, the training monitoring studies in rowers should become more specific in their nature. There appears to be not a single marker of training monitoring and possible overtraining in rowers. In the future, the studies should focus on different blood biochemical markers during different training periods and it is suggested that investigating physiological and psychological aspects of rowers are an advantage of more effective training monitoring in highly trained rowers.

3. AIM AND PURPOSES OF THE STUDY

The main aim of the current investigation was to find possible markers of heavy training stress in highly trained male rowers.

According to the main aim the specific purposes of the study were to:

1. investigate the response of the perceived recovery-stress state to heavy training stress;
2. investigate the response of selected fasting blood biochemical parameters to heavy training stress;
3. investigate the response of selected exercise-induced blood biochemical parameters to heavy training stress;
4. find possible markers that can characterize heavy changes in training stress.

4. METHODS

4.1. Subjects

In total, 22 highly trained male junior and senior rowers were investigated. All rowers were the members or candidates for the Estonian national junior and senior team (Table 5). All subjects were informed about the procedures and the aims of the investigation before they signed a written consent. This study was approved by the Medical Ethics Committee of the University of Tartu.

Table 5. Selected physical characteristics of the subjects.

	Age (years)	Height (cm)	Body mass (kg)	Body fat (%)
Juniors (n=10)	16.6±0.7	185.0±3.3	80.4±4.9	9.6±1.5
Seniors (n=12)	20.5±3.0	187.9±6.1	87.1±8.3	10.4±3.2

4.2. Study design

These studies were conducted during the preparatory period. The testing period for junior rowers constituted their first training camp, where the training volume was meant to increase rapidly compared to their previous training volume (Hedelin et al., 2000; Kirwan et al., 1990). In total, 12 training sessions were completed during this high volume training period compared to six training sessions a week completed during the previous four weeks. Eighty five percent of the total training volume was low-intensity endurance training (rowing or running), 5% was high intensity anaerobic training and 10% was resistance training (Nielsen et al., 1993).

The overall schematic view of the study in senior rowers is presented on Figure 1. The study period consisted of three different periods and lasted for six weeks. The study was conducted during the preparatory period, where the main aim of training program was to develop a basic strength-endurance (Nielsen et al., 1993; Simsch et al., 2002) for the next season. The week before the experimental period was a moderate standardized training for athletes to obtain the pretraining baseline measurements and six training sessions were completed during this week (Week 1). The 3-week high training volume period was aimed to maximally overload the subjects (Steinacker et al. 2000).

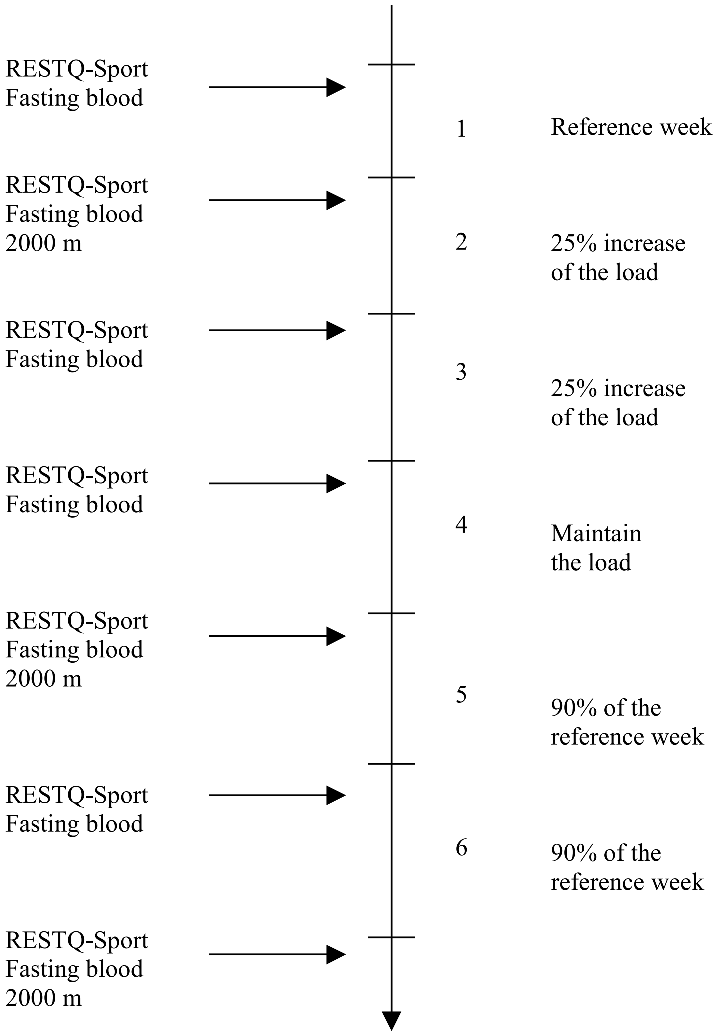


Figure 1. The schematic view of the study with senior rowers.

Training load was increased about 25% during the second week (Week 2) and further 25% increase for the next two weeks (Weeks 3 and 4). In total, 12 training sessions were completed during every week of the exhaustive training period. The athletes trained 6 days a week with one day (Monday) was meant for recovery. The high training volume period was followed by 2-week (Weeks 5 and 6) tapering period, where training load was approximately 90% compared to the reference week (Week 1). The subjects completed five training sessions during the recovery week. The training regimen of rowers was typical for this period of year (Nielsen et al., 1993; Simsch et al., 2002) and consisted of 45% high-volume, low-intensity strength training aimed to improve strength-endurance, 45% extensive endurance training (running, swimming and/or ergometer rowing) aimed to improve basic endurance and about 10% different kinds of ball games (basketball and/or soccer). The training regimen was the same for each week of the study. Training sessions were supervised by experienced coaches, who were fully instructed of the study design and the expectable outcome. Caloric intake was not measured in this study. However, during the whole study period, all athletes were asked to maintain their usual diet. Daily food intake consisted of a high carbohydrate diet with the composition remaining stable throughout the study period.

4.3. Testing schedule

Junior rowers:

Maximal performance, the perceived recovery-stress state and fasting blood were assessed before ($TEST_J$ 1) and after six day training period ($TEST_J$ 2). The subjects were only allowed to train easy or not at all on the afternoon before the final testing ($TEST_J$ 2) (Hedelin et al., 2000). Fasting blood samples were obtained at 08.00 hours. Performance testing sessions were carried out at the same time of the day, i.e. between 10.00 a.m. and 12.00 noon, and a testing time was kept identical for each subject.

Senior rowers:

The *perceived recovery-stress state* and *fasting blood samples* were obtained each week after the resting day (i.e., on Tuesday) (see Figure 1). Fasting blood samples were obtained at 08.00 hours after a resting day. *Maximal performance* time was assessed before ($TEST_S$ 1) and immediately after ($TEST_S$ 2) the high training volume period. The last performance testing ($TEST_S$ 3) was conducted after the tapering period. Exercise induced blood samples were obtained before (PRE), immediately after (POST) and 30 minutes after (POST 30’) the rowing performance test.

4.4. Procedures

4.4.1. Body composition

The height (Martin metal anthropometer) and body mass (A&D Instruments Ltd, UK) of the participants were measured to the nearest 0.1 cm and 0.05 kg, respectively. Body composition was measured using a bioelectrical impedance analyzer (Multiscan 5000, Bodystat, UK).

4.4.2. Maximal performance

Maximal 2000 metre rowing ergometer performance was assessed on the Concept II rowing ergometer (Morrisville, USA). The temperature during the testing was in the range of 20 to 22° Celsius and humidity around 50 to 60%. The rowers were training regularly on this kind of apparatus and were therefore fully familiarized with the use of the 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 minutes and they were also verbally encouraged during 2000 metre all-out test to accomplish the best possible result (Jürimäe et al., 2001).

4.4.3. The perceived recovery stress-state

The perceived recovery-stress state was assessed using the the Recovery-Stress Questionnaire for Athletes (RESTQ-Sport). With the kind written notice of permission from Dr. M. Kellmann, one of the author of RESTQ-Sport (Kellmann & Kallus, 2001), this questionnaire has been judged as a suitable tool to measure current stress of the athletes taking recovery associated activities into consideration. The RESTQ-Sport is constructed in a modular way including 12 scales of the general Recovery-Stress-Questionnaire (Kallus, 1995) and 7 additional sport-specific scales (Kellmann & Kallus, 2000). The specific characteristics of the RESTQ-Sport are that it allows systematic and direct measurement of appraised events, states, and activities regarding their frequency while simultaneously considering stress and recovery processes (Kellmann & Kallus, 2001).

Data from senior rowers were also pooled to obtain an overall average score and an estimation of the standard deviation (Kellmann & Kallus, 1999). Based on these data, a score was computed that possibly reflects the recovery-stress state for athletes (Kellmann & Kallus, 1999). The scores of stress-related scales (scales 1 to 7, 13, 14 and 15) were summed and divided by the number of scales representing the Standardized Stress. The same procedure was used for the recovery-oriented scales (scales 8 to 12, 16, 17, 18 and 19) resulting a Standardized Recovery. The Standardized Stress as well as the Standardized Recovery were 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 (Standartized RESTQ-index) (Kellmann & Kallus, 1999).

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 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 strain whereas high scores in the recovery-oriented scales mirror plenty recovery activities (social activities, vacation, sauna, etc.) (Kellmann & Günther, 2000).

4.4.4. Blood sampling

A 10-ml blood sample was obtained from an anticubital vein with the subject in the upright position. The plasma was separated and frozen at –20° C for later analysis. Leptin was determined in duplicate by radioimmunoassay (Mediagnost GMBH, Germany). This assay has a detection limit of 0.01 ng · ml^{-1}, and the intra-assay and inter-assay coefficients of variation (CV) were <5% and <7.5%, respectively (Mediagnost GMBH, Germany). Cortisol, testosterone and growth hormone were analyzed in duplicate on IMMUNOLITE 2000 (DPC, Los Angeles, USA). The inter- and intra-assay coefficients of variation were less than 5%. Creatine kinase activity was measured by means of photometric method using a commercial kit (Boehringer Mannheim, Germany). Aliquots of whole blood were also analysed in quadruplicate for haematocrit as 12,000 ren.min^{-1} for 5 minutes and for haemaglobin using a Lange (Germany) microanalyser. Post-exercise changes in plasma volume were calculated using the formulae of Dill & Costill (1974).

4.5. Statistical analysis

The results are presented as mean values ± standard deviation (SD). One-way analysis of variance (ANOVA) with repeated measures was used to determine changes in measured RESTQ-Sport scales, fasting blood and rowing performance parameters over time. The factor analysis (Stress and Recovery scales of the RESTQ-Sport questionnaire) was done via Principal Component Analysis followed by varimax rotation (Kellmann & Kallus, 2001). After the stop criterion (eigenvalue <1; Kaiser), two factors could be extracted for the general as well as for the sport-specific parts of the RESTQ-Sport. For blood data analysis obtained during rowing performance tests, the influence of blood sampling and testing times was examined by two-way ANOVA with repeated measures. Matched-paired Student's t-test was used where post-hoc analysis was relevant. The level of statistical significance was set at $p<0.05$. A Bonferroni correction was applied due to the large number of correlations among RESTQ-Sport scales, and an alpha level of 0.003 for juniors and 0.001 for seniors was considered significant. All values for correlation analysis (Pearson Correlation analysis) were determined during each training phases.

5. RESULTS

5.1. Training volume and performance

The training volume (minutes) during the study period in junior and senior rowers are presented on Figures 2 and 3, respectively. Mean training volume of junior rowers was increased 102% during the second week, while in senior rowers the mean increase was 65% compared to the first and the fourth week. Both increases were significant.

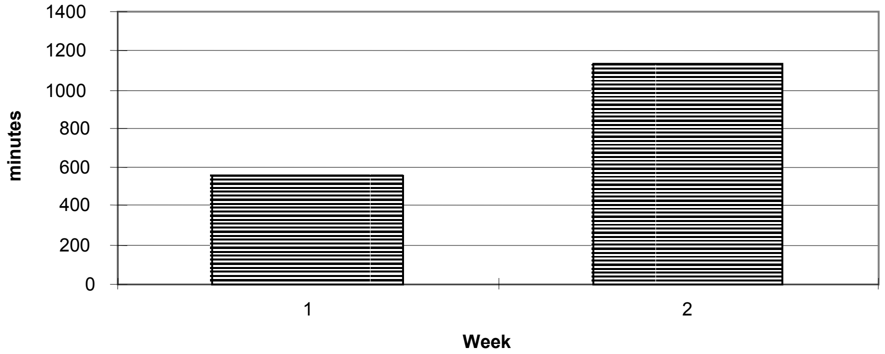


Figure 2. Training volume (minutes) during the study (2) and the average of perceding four weeks (1) in junior rowers. ($p > 0.05$)

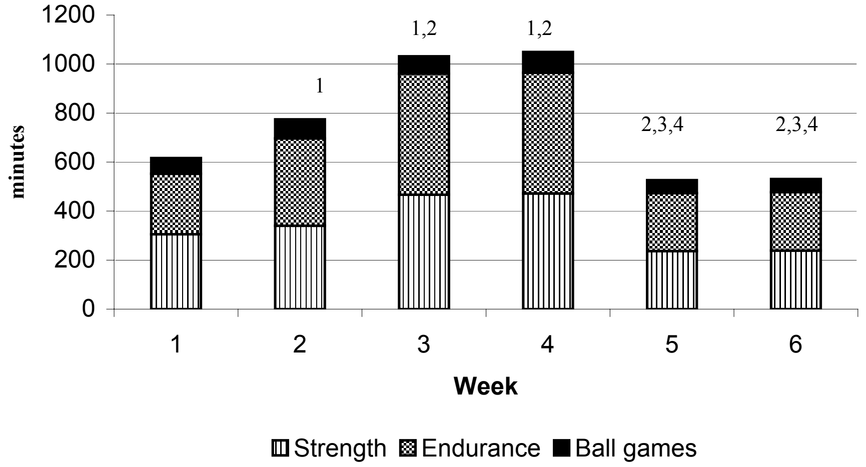


Figure 3. Training volume (minutes) during a six-week training period in senior rowers. Numbers indicate significant differences ($p < 0.05$) in training load from pointed week.

The 2000 metre all-out rowing ergometer performance decreased significantly after heavy training period in junior rowers but in senior rowers no significant changes in performance during the whole six-week study period were observed (Table 6).

Table 6. Performance parameters (mean ± SD) of 2000 metre all-out rowing ergometer test during the study period.

	TEST 1	TEST 2	TEST 3
Junior rowers			
Time (s)	406.8±9.2	410.9±8.8*	–
Power (W)	354.86±43.52	352.96±44.78*	
Senior rowers			
Time (s)	384.5±13.7	384.9± 12.0	381.6±12.2
Power (W)	397.5±42.3	395.59±37.5	399.15±38.9

* Significantly different from TEST 1; $p<0.05$

5.2. The perceived recovery-stress state

The Estonian version, the translation from the English version of RESTQ-Sport consists of 77 items (19 scales with four items plus one warm-up item), which subjects answer retrospectively. The estimation of the reliability of the Estonian version of RESTQ-Sport was satisfactory, (Cronbach α ranging from 0.71 to 0.94). The 24-hour test-retest reliability of the scales for the Estonian version of the RESTQ-Sport was also considered to be adequate ($r>0.74$). All factor analyses suggested one stress-related and one recovery-related factor for the general RESTQ-Sport scales.

In junior rowers, the recovery-stress state changed during the heavy training period (Table 7). A significant increase in *Fatigue* scores from stress-related scales and a significant decrease in scores of *Social Relaxation* from recovery-associated scales were found.

In senior rowers, the three week high volume training period increased the stress-related scores and decreased the recovery-oriented scores. During the recovery weeks, the stress and recovery scales behaved *vice versa*. Significant changes were found in the scores of *Emotional Stress*, *Fatigue*, *Somatic Relaxation*, *General Well-Being*, *Emotional Exhaustion*, *Injury*, and *Being in Shape* after heavy training period (Week 4 vs Week 1) (Figure 4). Significant improvements were found in *Emotional Stress*, *Social Stress*, *Fatigue*, *Physical Complaints* and *Success* after two weeks of recovery (Week 6 vs Week 4). The score of *Emotional Exhaustion* remained significantly elevated also after recovery period (Week 6 vs Week 1).

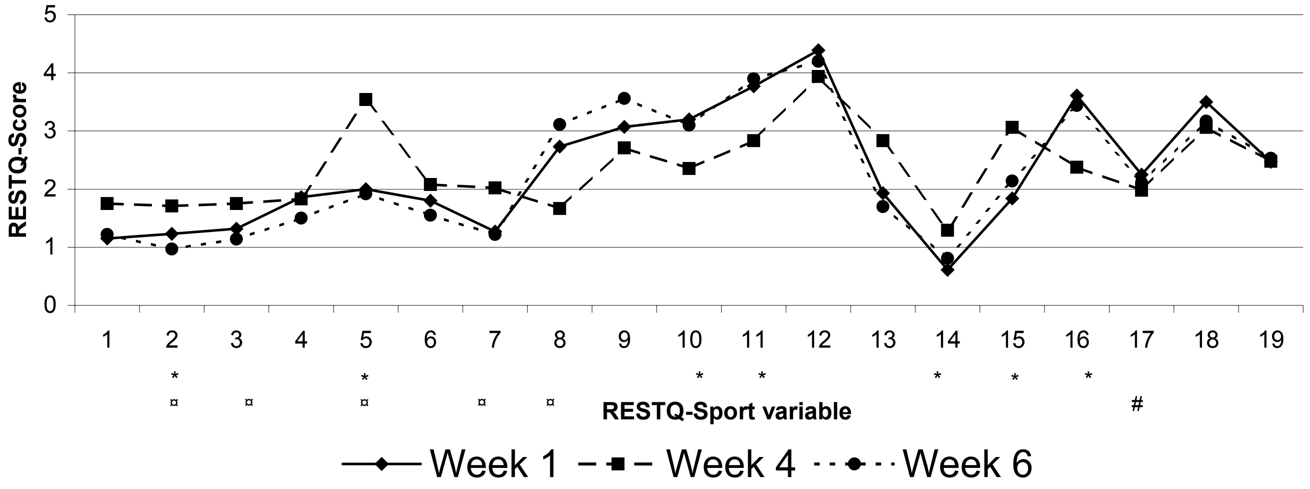


Figure 4. The RESTQ-Sport variables after the reference (Week 1), heavy training (Week 4) and recovery (Week 6) periods in senior rowers.

* – Significant difference between Week 1 and Week 4; ¤ — significant difference between Week 4 and Week 6; # — significant difference between Week 1 and Week 6.

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.

Table 7. Changes in the RESTQ-Sport scale over the high load period in junior rowers.

RESTQ-Sport Scale	Orientation	TEST 1	TEST 2
General Stress	S	1.8±1.0	2.0±0.7
Emotional Stress	S	1.8±0.8	1.6±0.9
Social Stress	S	1.9±0.9	1.9±1.0
Conflicts/Pressure	S	1.8±1.1	1.8±0.9
Fatigue	S	2.1±0.6	3.5±0.8*
Lack of Energy	S	1.9±0.7	1.9±0.8
Somatic Complaints	S	1.6±0.7	2.7±0.8
Success	R	3.2±0.9	2.6±0.6
Social Relaxation	R	3.7±0.9	2.5±0.8*
Somatic Relaxation	R	2.9±1.3	2.5±1.2
General Well-Being	R	3.4±1.4	3.3±1.1
Sleep Quality	R	4.1±1.1	3.4±0.8
Disturbed Breaks	S	2.1±0.8	3.0±1.0
Emotional Exhaustion	S	1.3±0.8	1.7±1.7
Fitness/Injury	S	2.8±1.3	3.3±1.2
Being in Shape	R	3.3±1.2	2.8±1.4
Burnout/Personal Accomplishment	R	2.8±1.0	2.5±0.7
Self-Efficacy	R	2.8±1.4	3.4±1.1
Self Regulation	R	2.9±1.3	3.1±1.0

* – Significantly different from TEST 1; $p<0.05$; S – stress; R – recovery

The Standardized Stress and Standardized Recovery scores changed significantly during a six week training period (Table 8). The Standardized Stress score increased significantly during the heavy training period (Weeks 2, 3, 4) compared to the reference week (Week 1) and decreased significantly during recovery period (Weeks 5, 6) compared to the value at the end of heavy training period (Week 4). The Standardized Recovery score decreased significantly during two weeks of heavy training (Weeks 3, 4) compared to the reference week (Week 1). The Standardized RESTQ-Index decreased significantly after heavy training period (Weeks 2, 3, 4) and increased significantly during recovery period (Weeks 5, 6) ($p<0.05$) (Figure. 5).

Table 8. The Standardized Stress and Standardized Recovery scores (mean ±SD) during a six week study in senior rowers.

	Standardized Stress	**Standardized Recovery**
Week 0	1.65±0.5	3.30±0.7
Week 1	1.49±0.5	3.30±0.4
Week 2	1.89±0.8 ^{2}	2.92±0.6
Week 3	2.09±0.6 ^{2}	2.83±0.6 ^{1}
Week 4	2.18±0.7 ^{2}	2.62±0.6 ^{1}
Week 5	1.53±0.6 ^{4}	3.10±0.7
Week 6	1.42±0.4 ^{4}	3.22±0.7

Number indicates significant differences ($p<0.05$) from pointed week.

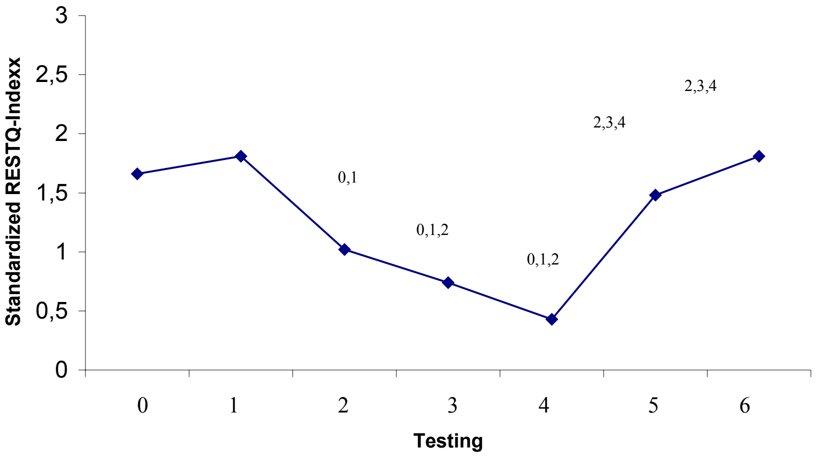
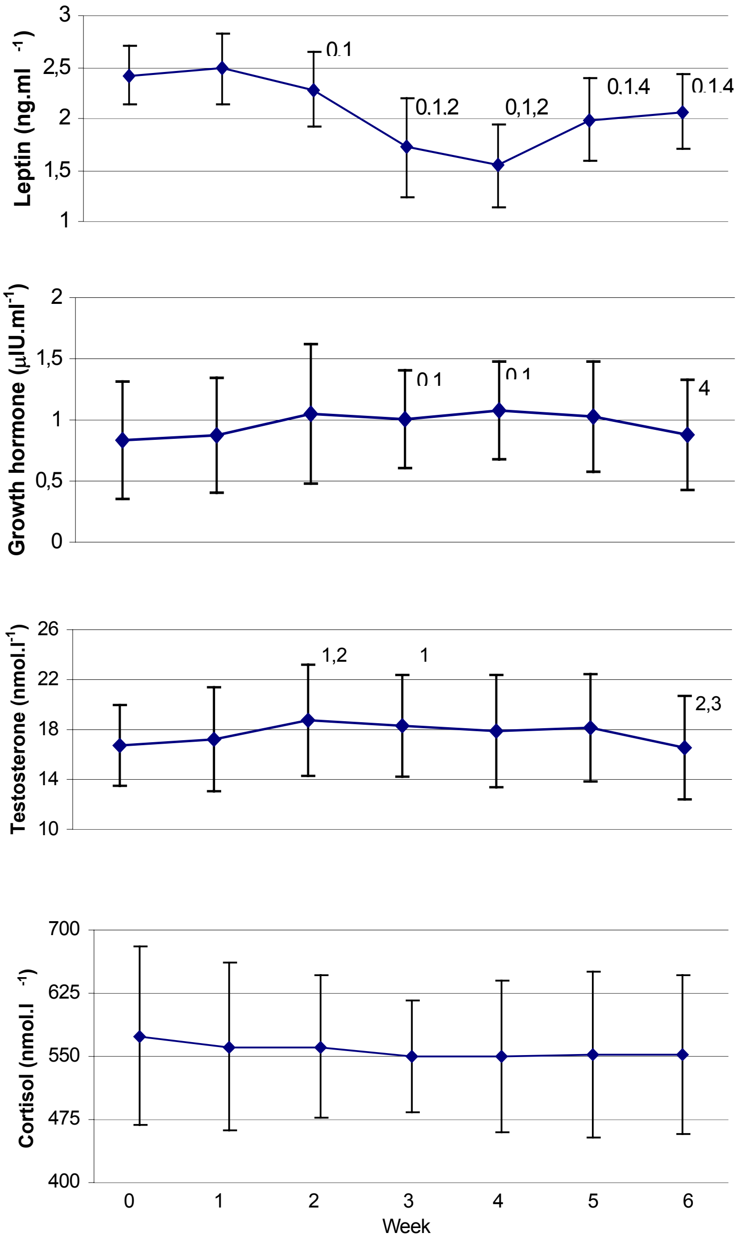


Figure 5. Standardized RESTQ-Index during a six week study in senior rowers. Numbers indicate significant differences (p<0.05) from pointed week.

5.3. Changes in fasting blood biochemical values

In junior rowers, fasting cortisol values increased significantly from $TEST_J$ 1 (479.4±42.1 $nmol \cdot l^{-1}$) to $TEST_J$ 2 (529.6±34.2 $nmol \cdot l^{-1}$). In senior rowers, fasting plasma leptin, cortisol, testosterone and growth hormone values were not altered after the first week of the study (Week 1) when the training stress was not changed (Figure 6). Plasma cortisol remained relatively constant (p>0.05) during the whole study period however, showing only a tend to decrease. A 22% increase (p<0.05) in training volume (Week 2) caused a significant decrease (by 8%) and increase (by 9%) in plasma leptin and testosterone concentrations, respectively. A further significant increase in training volume by 25% (Weeks 3 and 4) significantly reduced plasma leptin values by 25% and 10%, respectively. At the same time, no further changes (p>0.05) were observed for plasma testosterone concentration. The pattern of changes (p>0.05) in growth hormone concentrations were 20% increase during Week 2 followed by a mean 4% decrease and 7% increase after Weeks 3 and 4, respectively. However, plasma growth hormone was significantly elevated during the two week period of maximally increased training volume (Weeks 3 and 4) compared to the pretraining level (Week 0). First tapering week (Week 5), where the training stress was rapidly reduced (p<0.05) by approximately 50%, significantly influenced only plasma leptin value (increase in mean value by 29%). Growth hormone and testosterone values were significantly reduced to almost pretraining levels after the second tapering week (Week 6). Plasma leptin increased further (p<0.05) during the second tapering week but remained significantly lower compared to the pretraining value (Week 0). Creatine kinase activity was significantly increased during maximally increased training volume (Weeks 2,3,4). During tapering (Weeks 5,6) creatine kinase activity was significantly decreased.



Numbers indicate significant differences from pointed week

Figure 6. Fasting leptin, growth hormone, testosterone and cortisol concentrations during the 6-week study period in senior rowers.

5.4. Changes in exercise induced blood biochemical values

In senior rowers, leptin concentrations did not change significantly ($p>0.05$) from their respective baselines after the 2000 metre rowing ergometer tests performed before heavy training (TEST 1) and after the tapering (TEST 3) periods. Leptin concentration was significantly decreased after the 2000 metre rowing ergometer test performed at the end of the heavy training period (TEST 2) (Table 9). The decline in leptin concentration from baseline after TEST 2 was 23.5% and leptin values after the maximal rowing ergometer test at the end of the heavy training period were also significantly lower compared to the respective leptin values measured after other maximal rowing ergometer tests. Cortisol, testosterone and growth hormone levels were significantly increased at the end of all 2000 metre rowing ergometer tests. Significant decreases in testosterone, insulin and glucose values were observed after the first 30 minutes of recovery at all testing times. Cortisol values were further significantly increased and growth hormone remained elevated during the first 30 minutes of recovery at all testing times. No significant differences were observed between respective cortisol, testosterone and growth hormone values measured at different testing times. Creatine kinase activity was significantly increased immediately after the 2000 metre rowing ergometer test and a significant decrease in creatine kinase activity occurred during the first 30 minutes of recovery at all testing times. However, creatine kinase activity was significantly higher and lower during TEST 2 and TEST 3, respectively, compared to the respective values of the previous tests.

Table 9. Leptin, cortisol, testosterone, growth hormone and creatine kinase activity (Mean±SD) before (PRE), immediately after (POST) and 30 min after (POST-30') a maximal 2000-m rowing ergometer test before (TEST 1) and after (TEST 2) 3 weeks of heavy training, and after 2 weeks of tapering (TEST 3) in senior rowers.

Parameter	**TEST 1**	**TEST 2**	**TEST 3**
Leptin (ng · ml^{-1})			
PRE	2.4±0.3	1.7±0.3$^{¤}$	2.3±0.2$^{\&}$
POST	2.4±0.4	1.3±0.4*$^{¤}$	2.3±0.2$^{\&}$
POST-30’	2.2±0.2	1.3±0.3*$^{¤}$	2.2±0.3$^{\&}$
Cortisol (nmol · l^{-1})			
PRE	405.8±132.2	423.3±79.9	398.8±108.9
POST	530.6±109.4*	500.8±134.5*	522.4±120.1*
POST-30’	661.7±127.6$^{*\#}$	655.3±108.1$^{*\#}$	659.8±124.8$^{*\#}$
Testosterone (nmol · l^{-1})			
PRE	15.16±3.35	14.51±3.99	15.38±3.22
POST	19.89±2.93*	18.02±4.22$^{*¤}$	18.60±4.11$^{*¤}$
POST-30’	16.71±3.74$^{*\#}$	15.28±3.74$^{*\#}$	15.20±3.52$^{\#¤}$
Growth hormone (μIU · ml^{-1})			
PRE	1.35±0.81	1.17±0.71	1.26±0.56
POST	74.85±52.31*	81.95±44.7*	83.87±55.83*
POST-30’	74.28±56.97*	76.49±37.21*	80.86±66.40*

Parameter	TEST 1	TEST 2	TEST 3
Creatine kinase (U l^{-1})			
PRE	467.2±219.6	663.3±404.0$^{¤}$	351.0±127.8$^{¤\&}$
POST	543.3±248.3*	775.1±489.3$^{*¤}$	423.9±155.6$^{*¤\&}$
POST-30’	497.7±228.7$^{\#}$	699.1±413.4$^{\#¤}$	369.8±143.7$^{\#¤\&}$

* Significantly different from PRE; p<0.05
$^{\#}$ Significantly different from POST; p<0.05
$^{¤}$ Significantly different from TEST 1; p<0.05
$^{\&}$ Significantly different from TEST 2; p<0.05

5.5. Relationships between training volume, performance and perceived recovery-stress state and blood biochemical values

In junior rowers, increased training volume was significantly related to the scores of *Conflicts/Pressure* (r=0.63), *Sleep Quality* (r=–0.64) and *Burnout/ Personal Accomplishment* (r=–0.66) at the end of the high volume training period. In addition, changes in resting cortisol levels as a result of heavy training stress were positively related to the following stress scales of the questionnaire: *Social Stress* (r=0.76), *Fatigue* (r=0.64, *Disturbed Breaks* (r=0.65) and *Fitness/Injury* (r=0.67).

In senior rowers, significant relationships were found between cortisol and *General Stress*, *Emotional Stress*, *Social Stress*, *Conflicts/Pressure*, *Fatigue*, *Lack of Energy*, *Physical Complaints*, *General Well-Being*, *Sleep Quality*, *Emotional Exhaustion* and *Fitness/Injury* (Table 10). The values of creatine kinase activity were significantly related to *Social Relaxation*, *General Well-Being* and *Being in Shape*. Training load was significantly related to *Fatigue*, *General Well-being* and *Disturbed Breaks*. No significant relationships were found between RESTQ-Sport scales and leptin, testosterone, cortisol and growth hormone concentrations.

Table 10. Significant relationships ($p<0.001$) between RESTQ-Sport variables and training volume, cortisol and creatine kinase activity.

RESTQ-Sport variable	**Orientation**	**Training volume**	**Cortisol**	**Creatine Kinase**
General stress	S	NS	**0.77**	NS
Emotional Stress	S	NS	**0.91**	NS
Social Stress	S	NS	**0.77**	NS
Conflicts/Pressure	S	NS	**0.58**	NS
Fatigue	S	**0.44**	**0.37**	NS
Lack of Energy	S	NS	**0.45**	NS
Somatic Complaints	S	NS	**0.63**	NS
Success	R	NS	NS	NS
Social Relaxation	R	NS	NS	**0.40**
Somatic Relaxation	R	NS	NS	NS
General Well-Being	R	**0.35**	**0.52**	**0.47**
Sleep Quality	S	NS	**0.43**	NS
Disturbed breaks	S	**0.37**	NS	NS
Emotional Exhaustion	S	NS	**0.60**	NS
Fitness/Injury	R	NS	**0.46**	NS
Being in Shape	R	NS	NS	**0.35**
Burnout/Personal Accomplishment	R	NS	NS	NS
Self Efficacy	R	NS	NS	NS
Self Regulation	R	NS	NS	NS

NS – not significant; S – stress; R – recovery

In senior rowers, training volume was significantly related to the Standardized RESTQ-Index (Table 11). The values of cortisol were significantly related to Standardized Stress and Standardized RESTQ-Index. Creatine kinase activity was significantly related to Standardized Recovery score.

Table 11. Significant relationships ($p<0.001$) between training load, leptin, cortisol, testosterone, growth hormone and creatine kinase activity and the Standardized Stress, Standardized Recovery and Standardized RESTQ-Index.

	Standardized Stress	Standardized Recovery	Standardized RESTQ-Index
Training volume	NS	NS	**–0.39**
Leptin	NS	NS	NS
Cortisol	**0.76**	NS	**–0.59**
Testosterone	NS	NS	NS
Growth hormone	NS	NS	NS
Creatine kinase	NS	**–0.45**	NS

NS – not significant

In senior rowers, fasting leptin concentration was significantly related to creatine kinase activity ($r=-0.40$) but not to cortisol ($r=0.02$) values. Furthermore, the fasting leptin concentration was significantly related to the weekly training time ($r=-0.45$) but not to the 2000 metre rowing ergometer performance time ($r=0.12$). Interestingly, there was no relationship between body mass or body fat values and leptin concentration ($r=0.28$). Fasting creatine kinase activity was significantly related to the weekly training time ($r=0.44$). From exercise-induced hormone concentrations, only post-exercise growth hormone concentration was significantly related to rowing performance time on 2000 metre distance ($r=-0.46$).

6. DISCUSSION

In these studies, highly trained and motivated rowers' training for the junior or senior World Championships was studied. Their anthropometrical and functional parameters were comparable with those previously reported in the literature (Bourgois et al., 2000; Secher, 1993; Shephard, 1998). During the season that followed the study two of our subjects were 7-th in senior World Championships, two won the bronze medal in student World Championships and one being seventh in sen-B World Championships. One junior rower was the sixth and two 13-th during the World Junior Championships. Five of our subjects participated in the 2004 Athens Olympics. Accordingly, this study is one of the few studies (Kellmann & Günther, 2000; Vervoorn et al., 1991; Simsch et al., 2002; Steinacker et al., 2000) published about the training cycles of competitive high level rowers and about functional, psychological and hormonal reactions on different training regimen.

In junior rowers, doubelling the training load for approximately100% (from 560.9 to 1134.5 minutes per week) caused a significant decrease in rowing ergometer performance. In senior rowers, the performance of rowers was relatively unchanged at the end of heavy training stress and was slightly improved by the end of the second week of tapering indicating no overtraining syndrome (Kuipers & Keizer, 1988). These results indicate that doubelling the training load that is frequently used in training camps is not advantageous when comparing with not so quick increase in training load in a longer period as seen in senior rowers. Therefore, it appears that if such one week training camps are planned the previous training loads must reach more than 50% of the expected load in training camp, otherwise the performance of rowers may detoriate too much. However, there is little consensus as to how much performance must detoriate before overtraining is diagnosed (Hooper & Mackinnon, 1995). Performance decrements which are clearly a result of overtraining syndrome range from 0.7 to 15.0% (Barron et al., 1985; Hooper et al., 1995). In the study of Jeukendrup et al. (1992), one symptom of overtraining was considered lower general sense of well-being as indicated by the psychometric questionnaire. Furthermore, several investigators have suggested that stagnancy in performance is sufficient to indicate overtraining syndrome when considered together with other symptoms (Costill, 1986; Hooper et al., 1995; Kuipers & Keizer, 1988).

6.1. Perceived recovery-stress state response to heavy training stress

It has been stated that the RESTQ-Sport questionnaire is one of the few psychometric instruments that attempts to address the full complexities of stress and recovery (Kenttä & Hassmen, 1998) and it allows the assessment of subjective stress and recovery during the all year-round training cycle and preparing for major competitions (Kellmann & Günther, 2000; Kellmann & Kallus, 1999; Kellmann et al., 1997). The study with junior rowers indicated that there might be a dose-response relationship between training volume and subjective assessments of stress and recovery. A high training volume was indicated by elevated scores on the scales of stress and simultaneously recovery scales were lowered (see Table 7). However, significant changes were found for scores *Fatigue* and *Social Relaxation*. The raised scores of *Fatigue* indicated the heavy training period response to subjects' perceived fatigue ratings and as the same time the performance was significantly dropped a state of overreaching might have been achieved. Furthermore, the increased mean of the scale *Social Relaxation* suggested that the emotional, physical and social aspects of recovery may not have been adequate during this training camp. A significant decrease of the *Social Relaxation* indicates a drop in social activities during the high volume training period.

The results of the study with senior rowers revealed that different scales of the Estonian version of RESTQ-Sport demonstrated a clear dose-response relationship with training volume (see Figure 4) during high loaded training cycle and the following recovery period. Thus, the perceived recovery-stress state as well as the mood state allow to have an economical and simple tool to monitor athletes training stress. It was expexted that high volume training during the preparation period is indicated by the elevated levels of stress scales and simultaneously lowered levels of recovery scales. Accordingly, the recovery-stress profile changed after three weeks of high volume training compared to the profile of the reference week (see Figure 4). Although the change of the profile to more negative direction was quite obvious, significant changes were found in the scales of *Emotional Stress*, *Fatigue*, *Somatic Relaxation*, *General Well-Being*, *Emotional Exhaustion, Fitness/Injury* and *Being in Shape*. This demonstrates that the Estonian version of RESTQ-Sport questionnaire is a suitable tool to assess the effect of different training stress in highly trained rowers. These results are somewhat comparable to Hooper et al. (1995), although the POMS was used, who found that ratings of *Well-Being* and *Fatigue* predicted the staleness score before the detoriation of performance, which became apparent several weeks later in highly trained swimmers.

When the RESTQ-Sport profile of the reference week (Week 1) was compared to the profile at the end of two week recovery period (Week 6), a lowered levels of stress and elevated levels of recovery were detected. However, a significant increase was observed only in the stress scale of *Emotional Exhaustion*. It was somewhat intresting as the elevated levels of *Emotional Exhaustion* are shown by athletes who feel burned out and want to quit their sport (Kellmann & Kallus, 2001). As such three week high training loads are not very often used by rowers, because of the risk of overtraining syndrome (Steinacker et al., 1998, 2000) and the subjects could not be very used to this, it could be suggested that the three week heavy training period left a mark, which was not eliminated during the two week recovery period. It could be speculated that this training period was emotionally difficult to tolerate, because it was not carried out during training camp, where it is much more easier to concentrate on trainings because other limitating factors (e.g., school, friends, homework) are eliminated.

In senior rowers, Standardized Stress and Standardized Recovery values behaved opposite — when training load increased Standardized Stress increased and Recovery decreased and *vice versa* (see Table 8). After two weeks of recovery (Weeks 5,6), Standardized Stress score decreased significantly. Although Standardized Recovery score increased, the increase was not significant. According to these results, it could be speculated that recovery associated activities, in general, were not enough during two week recovery period. Personal conversation with the athletes confirmed these findings. This is supported by the fact that only *Success* from the recovery associeted items increased significantly during the recovery period (see Figure 4), while a decrease was observed in *Emotional Stress, Social Stress, Fatigue* and *Physical Complaints* from the stress-related subscales. For example, during free time of the recovery period some athletes just laid in bed or watched TV for resting, instead of visiting some friends, going to sauna or cinema, etc., or even take some physical activity for supporting recovery processes.

The state of overreaching, caused by high load training period is necessary to obtain high performance through supercompensation (Hooper & Mackinnon, 1995; Kuipers & Keizer, 1998; Steinacker, 1993; Steinacker et al., 1998). Thus, we were interested if Standardized RESTQ-Index is similarly reflected by changes in training volume in senior rowers. The results of our study indicate that Standardized RESTQ-Index behaves opposite to training volume (see Figure 5). Thus, it was suggested that a dose-response relationship exists also between Standardized RESTQ-Index and training volume in highly trained senior rowers. High training volume is accompanied by lowered level of Standardized RESTQ-Index. Moreover, in this study a negative correlation was found between training volume and Standardized RESTQ-Index ($r=-0.59$; $p<0.001$). This index can be interpreted as a kind of athletes' resource measure (Kellmann & Kallus, 1999). Accordingly, the Standardized RESTQ-Index could be used as a more simple indicator of athletes' recovery-stress state and it may be more understandable to use for athletes and coaches to monitor their current state. Although the reliability of the self-assessment scores may be questioned, it appears that conscientous recording of athletes subjective ratings provides a coach with useful information if completed on a regular basis. Furthermore, being aware of the advantage of the questionnaire, ahletes pay more attention in filling it. Moreover, athletes learn to express themselves better in frequent use of the psychometric tests and give more reliable information.

The advantage of using the RESTQ-Sport questionnaire is that it gives us a detailed picture of athletes' state. Concrete solutions to current problems can be derived from the up-to-date recovery-stress profile (Kallus & Kellmann, 2000;

Kellmann et al., 1997). This profile might, obviously, be used to derive specific intervention strategies. In addition, RESTQ-Sport questionnaire demonstrates to coaches and athletes the importance of daily activities on their mood state and how these activities are related to their performance. This course also applies when coaches have not been in contact with athletes for a longer period of time (e.g., caused by vacation or injury). Collecting some information about the actual state based on the information from the past days is important to begin with the training proccess on adequate level meaning not to overtrain the athlete, but giving an appropriate training stimuli. Moreover, the perceptions of the coaches and athletes may differ from each other and, therefore, the coaches get more information about the subjective perception of an athlete. The studies with the German National Junior Rowing Team shows that athletes use the RESTQ-Sport to express themselves (Kellmann & Kallus, 1999). This study also revealed that before important competitions athletes become more sensitive about certain activities, and perceive environment differently, although the coaches view did not change (Kellmann & Kallus, 1999).

In conclusion, the RESTQ-Sport questionnaire allows an economical and simple tool to be used in monitoring athletes' training. In this study a dose-response relationship was detected between heavy training stress and Standardized RESTQ-Index. It is suggested that the Standardized RESTQ-Index could be used as athletes' resource measure in highly trained male rowers.

6.2. Fasting blood hormone responses to heavy training stress

During the study periods, the examinations in junior and senior rowers were carried out at the same time in the morning and under similar conditions. Therefore, circardian rhythms or environmental influences as a cause of hormonal changes could be ruled out (Häkkinen et al., 1988) and hormonal values are comparable during different time-trails.

The results of the present study with senior rowers demonstrated that leptin was the most sensitive fasting hormone measured to reflect heavy changes in training stress (i.e., an increase of 65% of the training load by the end of heavy training period). Furthermore, it appeared that fasting plasma leptin concentration demonstrated a dose-response relationship with the amount of training stress during the whole six week study period (see Figure 6). While testosterone and growth hormone values were significantly increased during the maximally increased training volume (Weeks 2 to 4) and remained elevated for the first week of tapering (Week 5) (see Figure 6). Resting cortisol value was not significantly altered during the whole study period and demonstrated only a slight decrease during the exhaustive training period in senior rowers. This was somewhat expectable, because decreased values of cortisol are known to be a late sign of overtraining (Barron et al., 1985; Lehmann et al., 1998) and our purpose was to avoid it. According to Steinacker et al. (2000) the upper limit of the sustainable training load is approximately 3.2 hours a day for 2 to 3 weeks period in adapted endurance athletes. Therefore, due to a group of high level athletes used in our study, this kind of training regimen was chosen to maximally stress the athletes, without leading them to overtraining syndrome. While in junior rowers, resting cortisol values increased significantly during the study period, which is in accordance with previous study with junior rowers (Steinacker et al., 1993) as a normal response to stressful training period.

In physical training, conditions of acute physical stress should be created interspersed with rest periods to allow some recovery from the preceding strain. It has been suggested that during prolonged training, the physical stress should be optimized with regard to rest periods leading only infrequent changes in the hormone balance (Häkkinen et al., 1989). However, to achieve further improvement in physical performance, athletes should use the periods of heavy physical stress followed by some periods of reduced physical stress to achieve specific adaptations at the cellular level (Simsch et al., 2002; Steinacker et al., 2000). Therefore, it is reasonable that some alterations in the concentrations of plasma hormones may occur during stressful training periods. Fasting testosterone concentrations are known to be decreased in high intensity training in rowers (Steinacker et al., 2000) and swimmers (Häkkinen et al., 1989). The results of senior rowers may indicate that not the exercise intensity (Mackinnon et al., 1997; Flynn et al., 1994), but the total amount of exercise is the dominant factor which induces significant increase in fasting testosterone and growth hormone concentrations during the heavy physical stress in typical rowing training. However, these hormone values returned to the pre-stress level only after the second tapering week indicating some lag period in these hormone responses as also demonstrated in other studies in athletes (Häkkinen et al., 1985). While cortisol values demonstrated a slight but statistically insignificant decrease during the whole study period in senior rowers. It may be explained by the fact that during study period training intensity was kept as identical as possible and increases only in training volume were allowed. This is contrary to other studies which have reported that cortisol levels tend to increase during periods of high volume and/or intensity in endurance trained athletes (Snegovskaya & Viru, 1993; Urhausen et al., 1995; Vervoorn et al., 1991). This was aslo the case in junior rowers where an increase in fasting cortisol concentration was observed. A decreased basal cortisol level with a prolonged drop in performance for more than three weeks is a sign of chronically exhausted adaptivity (Snyder et al., 1995), which has to be avoided. Taken together, the results of our study suggest that the hormone responses of the hypothalamus-pituitary-adrenocortical axis are not specific and do not mirror exactly the amount of physical stress, although they may reach significance in some cases during the period of usual heavy training stress and following the period of reduced training volume in highly trained male rowers.

Energy intake and expenditure are of utmost importance in competitive athletes in relation to maintaining energy stores with respect to training volume (Noland et al., 2001). A positive relationship between adiposity and fasting plasma leptin has been reported in men (Comez et al., 2002; Engeli & Sharma, 2000; Hickey & Calsbeck, 2001; Noland et al., 2001; Sudi et al., 2001). However, in contrast to the results of present study, it has been suggested that fasting plasma leptin is not regulated in a dose-response manner in competitive male athletes (Noland et al., 2001; Petibois et al., 2002). Furthermore, previous investigations have demonstrated that exercise training in sedentary men did not alter fasting plasma leptin concentration unless there was a concomitant reduction in body fat mass (Hickey et al., 1997; Pasman et al., 1998). However, despite the fact that the initially low basal leptin level decreased further as a result of the three week heavy training stress, measured parameters of body composition stayed relatively constant throughout the current study in highly trained senior rowers. Furthermore, leptin showed no relationship with the amount of body fat as also demonstrated in other studies of athletes (Simsch et al., 2002; Sudi et al., 2001). The differences in fasting leptin responses to training between the present study and that of Noland et al. (2001) investigation could be explained by the differences in physical stress and previous training history of subjects. The training stimulus of the present study was that of low-intensity high volume training, while competitive swimmers in Noland et al. (2001) investigation performed mainly high-intensity interval training. These findings together would suggest that fasting leptin response during prolonged heavy training stress may depend on the total amount of physical stress performed and the physical condition of athletes.

In conclusion, leptin levels demonstrated a dose-response relationship with the amount of physical stress and were more sensitive to training volume changes than testosterone, cortisol and growth hormone. The decreases in leptin levels were independent from body compositional changes. Studying the effects of fasting plasma leptin concentration may help to direct athletes training by monitoring the leptin status in case of high volume trainings. However, this point needs to be investigated more thoroughly in the future. Stress hormones demonstrated a lag period with the amount of physical stress, while cortisol showed an increase with doubelling training volume but a tendency of decrease when the increase of training volume was smoother but longer.

6.3. Exercise-induced blood hormone responses to heavy training stress

One objective of the study was also to investigate exercise-induced responses of blood biochemical parameters during high training load and the following tapering period in senior rowers. Despite altered fasting blood hormone levels, valuable information may also provide exercise-induced hormonal responses for monitoring athletes' training (Urhausen & Kindermann, 2002). Exercise-induced hormone concentrations should be corrected by changes in plasma volume, as a decrease in plasma volume could increase the value. However, similarly to several recent studies (Hackney et al., 1995; Jürimäe et al., 2001a; Kraemer et al., 2001), the hormone concentrations reported are uncorrected for exercise-induced plasma volume alterations. Firstly, it may be the concentration of the hormone at the target tissues that is of importance, regardless of how the change in concentration is established (Hackney et al., 1995). Secondly, moving from the standing position prior to the exercise to a seated position during rowing exercise could have caused, independently of the exercise undertaken, a change in plasma volume due to haemodynamic redistribution of fluids (Shireffs & Maugham, 1994). Thirdly, the computed reductions in plasma volume values were not significantly different among the three tests in senior rowers.

Exercise-induced leptin levels were significantly reduced as a result of the three week heavy training stress (TEST 2). In contrast, no changes in leptin concentration after 2000 metre rowing ergometer tests were observed before the heavy training (TEST 1) and after the tapering (TEST 3) periods. It could be speculated that heavy training stress for three weeks in highly trained senior rowers led to the downregulation of the basal leptin concentration and disrupted metabolic homeostasis (Simsch et al., 2002; Urhausen & Kindermann, 2002) such that energy expenditure during maximal 2000 metre ergometer rowing was enough to produce a further and significant reduction in the leptin level. To date, it has been reported that significantly decreased leptin levels can be observed immediately after prolonged exercise with an estimated energy expenditure of at least 2800 kcal (i.e., a marathon run) (Leal-Cerro et al., 1998; Zaccaria et al., 2002) or that leptin levels experience a delayed (about 9 hours) reduction after acute resistance exercise (estimated energy expenditure of about 856 kcal) (Nindl et al., 2002). We believed the athletes to be in an early over-training syndrome state at the end of this heavy training period as the decreased metabolic rate during the two week tapering period was accompanied by recovered leptin levels. It has been suggested that intensified prolonged exercise training should stimulate accelerated metabolism and stimulate changes in hormones regulating body mass (Perusse et al., 1997; Simsch et al., 2002).

The increase of testosterone, cortisol and growth hormone levels after a short bout of maximal exercise in athletes is often observed and described in the literature (Guglielmini et al., 1984; Hoogeveen & Zonderland, 1996; Kramer et al., 1991). However, during the second and third testing session, the post-exercise testosterone concentration was significantly lower compared to the first testing session, indicating lower anabolic activity. The mechanism of these acute hormonal changes due to exercise is not very clear. There are several possibilities such as decreased liver perfusion, central stimulation of the hypothalamic-pituitary axis and increased perfusion of the hypothalamus, pituitary gland, testicles or adrenals (Hoogeveen & Zonderland, 1996; Schmid et al., 1982).

Typical overtraining is not only accompanied by reduced performance and mood status, but also by the suppression of all hormonal axes (Urhausen & Kindermann, 2002). The senior rowers of this study only showed a trend towards decreased performance and suppression of fasting as well as exercise-induced changes in cortisol levels. These results are in accordance with the recent findings in elite Nordic skiers, who demonstrated that a doubelling of the training load does not alter the stress hormone responses to maximal exercise test (Ronsen et al., 2001). Low cortisol responses to standardized exercise tests have been found in athletes in advanced stages of overtraining (Fry et al., 1998; Lehmann et al., 1998). Furthermore, Urhausen et al. (1995) argued that the behaviour of cortisol and testosterone is the physiological indicator of the current training load and it does not necessarily indicate to overtraining.

In conclusion, the lowered leptin responses to the maximal rowing ergometer test at the end of the heavy training period could be attributed to early signs of overtraining. It could be argued that exercise-induced leptin responses are more sensitive to heavy changes in training stress compared to other blood biochemical and/or performance markers measured in this study and could be used as a marker of the early overtraining state, caused by high volume-low intensity training in highly trained athletes. However, this is a speculation on our part at this time and needs further research.

6.4. Multi-level monitoring of heavy training stress

The levels of fasting cortisol remained unchanged during a six week study period in senior rowers, which was expectable, because lowered levels of cortisol have been reported to be the late sign of overtraining (Barron et al., 1985; Lehmann et al., 1998), although there was a tendency of decrease in cortisol concentration (see Figure 6). Significant relationships were found between cortisol and Standardized Stress (r=0.76), Standardized RESTQ-Index (r=–0.59) and various stress and recovery subscales (r>–0.37) (see Tables 11 and 12), while in junior rowers the values of cortisol were related to various stress scales of the RESTQ-Sport. Creatine kinase Values were related to different recovery scales (r>0.35) in junior rowers. This close relation between psychometric and biochemical responses are very intriguing from a multi-level 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 behaviour (Barron et al., 1985; Steinacker et al., 2000). Changes in plasma levels of cortisol reflect the metabolic stress as the endpoint of the hypothalamus-pituitary-adenocortical axis (Steinacker et al., 1999; Viru et al., 2001). At present, it is mainly a subject of speculation how the hypothalamus senses metabolic dysbalance (Barron et al., 1985) and fatigue (Steinacker et al., 2000) in athletes. In a line with this, Viru et al. (2001) suggested that fatigue from prolonged endurance activity may introduce a resetting in the pituitary-adenocortical component of the endocrine system, expressed by changed endocrine functions. In the future, the underlying mechanisms of training and stress responses should be more investigated, so that specific diagnostic tools can be used sufficently for monitoring training (Steinacker et al., 1999).

Monitoring the current levels of both stress and recovery has the possible advantage that problems may be detected before symptoms of overtraining are likely to appear (Kellmann & Kallus, 1999). Steinacker et al. (2000) found that both performance and hormonal indicies of training were reflected by the scores of the RESTQ-Sport. One week of heavily increased training volume (approximately 100% compared to previous week) indicated the increased levels of stress and deceased levels of recovery associated activities with a significant changes in *Fatigue* and *Social Relaxation* in male junior rowers.

The interesting finding of our study was that changes in creatine kinase activity were related to changes in Standardized Recovery score ($r=-0.45$; $p<0.001$) in senior rowers. It is known that the value of creatine kinase activity increases following exercise of high muscular strain because of muscle cell leakage or damage, and the morning levels represent mainly the creatine kinase release during the previous days (Steinacker et al., 2000). The normalization of the creatine kinase activity demonstrates a reduced muscle stress (Kuipers & Keizer, 1998; Steinacker et al., 2000). Our findings further confirm the need for a multi-level approach of training monitoring in highly trained athletes.

In conclusion, according to the results of our study, it could be suggested that there is no single marker that can be used in training monitoring of rowers. The close relationships with several biochemical and psychological parameters confirm that the monitoring process is more effective when both of these factors are considered during stressful training and following recovery periods.

7. CONCLUSIONS

1. RESTQ-Sport questionnaire is sensitive to the heavy training stress taking into account the differernt components of stress and recovery;
2. Fasting plasma leptin concentration is more sensitive to the heavy training stress compared to measured stress hormones. Extensive increase in training stress within one week was accompanied by a significant increase in fasting cortisol value. While a nonsignificant decrease in fasting cortisol was seen during a heavy training stress for three weeks.
3. Exercise-induced plasma leptin is more sensitive to the heavy training stress compared to measured stress hormone values;
4. Fasting plasma leptin and RESTQ-Index demonstrated a dose-response relationship with changes in training volume. Maximal exercise-induced changes in leptin could be used as the possible first sign of overreaching in the condition of increase in training volume in highly trained male rowers.

8. REFERENCES

1. Adlercreutz H., Härkonen M., Kuoppasalmi K., Näveri H., Huhtaniemi TM., Tikkanen H., Remes K., Dessypris A., Karvonen J., Effect of training on plasma anabolic and catabolic steroid hormones and their response during physical exercise. Int J Sports Med, 1986, 7: 27–8.
2. Ahima RS, Kelly J, Elmquist JK., Flier JS. Distinct physiologic and neuronal responses to decreased leptin and mild hyperleptinemia. Endocrinol, 1999, 140: 4923–31.
3. Altenburg D. The German talent-identification and talent-development program. In: H. Perry, I. Dieterle, editors. FISA's Youth Junior Rowing and Sculling Guide. Lausanne, Switzerland, 1997.
4. Bannister EW., Morton RH., Clarke JR. Clinical dose-response effects of exercise. In: Steinacker JM, Ward SA, editors. The physiology and patophysiology of exercise tolerance. New York, London: Plenum, 1997: 297–09.
5. Beaver WL., Wasserman BJ., Whipp BJ. Improved detection of lactate threshold during exercise using a log-log transformation. J Appl Physiol 1985; 59: 1936–40.
6. Barron J.L., Noakes T.D., Lewy W., Smith C., Millar R.P. Hypothalamic dysfunction in overtrained athletes. J Clin Endocrinol Metabol, 1985, 60: 803–6.
7. Bell G., Petersen S., Quinney H., Wenger H. Sequencing of endurance and high-velocity training strength training. Can J Sport Sci, 1988, 13: 214–9.
8. Bell G., Petersen S., Wessel J., Bagnall K., Quinney H. Adaptations to endurance and low velocity resistance training performed in a sequence. Can J Sports Sci, 1991, 16: 186–92.
9. Bell G., Syrotuik DG., Attwood K., Quinney HA. Maintenace of Strength Gains While Performing Endurance Training in Oarsmen. J Appl Physiol, 1993, 18: 104–15.
10. Beneke R. Anaerobic threshold, individual anaerobic threshold, and maximal lactate steady-state in rowing. Med Sci Sports Exerc, 1995; 27: 863–7.
11. Berger BG., Motl RW. Exercise and mood: A selective review and synthesis of research employing the Profile of Mood States. J Appl Sport Psychol, 2000, 12: 46–68.
12. Bishop D, Jenkins DG, Mackinnon LT. The relationship between plasma lactate parameters, W_{peak} and 1-h cycling performance in women. Med Sci Sports Exerc, 1998, 30: 1270–5.
13. Borg, G. Perceived Exertion and Pain Rating Scales. Champain, IL: Human Kinetics, 1998.
14. Bourgois J., Vrijens J. Metabolic and cardiorespiratory responses in young oarsmen during prolonged exercise tests on a rowing ergometer at power outputs corresponding to two concepts of anaerobic threshold. Eur J Appl Physiol, 1998, 77: 164–9.
15. Bourgois J., Claessens AL., Vrijens J., Philippaerts R., van Renterghem B., Thomis M., Janssens M., Loos R., Lefevre J. Anthropometric characteristics of elite male junior rowers. Br J Sports Med, 2000, 34: 213–7.
16. Brooks GA. Anaerobic threshold: review of the concept and directions for future research. Med Sci Sports Exerc, 1985; 17: 22–31.
17. Bruin D. Adaptation and overtraining in horses subjected to increasing training loads. J App Physiol, 1994, 76: 1908–13.

18. Brüning JC, Gautam D, Burks DJ. Role of brain insulin receptor in control of body weight and reproduction. Science, 2000; 289: 2122–5.
19. Buckler JMH. The relationship between changes in plasma growth hormone levels and body temperature occuring with eercise in man. Biomedicine 1973, 19: 193–7.
20. Bunk V., Leso J. Ventilatory threshold and work efficiency during exercise on a cycle and rowing ergometer. J Sports Sci, 1993, 11: 43–8.
21. Cheng B., Kuipers AC., Snyder HA., Keizer A., Jeukendrup A., Hesselink M. A new approach for the determination of ventilatory and lactate thresholds. Int J Sports Med, 1992, 13: 518–22.
22. Considine RV. Weight regulation, leptin and growth hormone. Horm Res 1997, 48: 116–21.
23. Cosgrave MJ., Wilson J., Watt D., Grant SF. The relationship between selected physiological variables of rowers and rowing performance as determined by a 2000 m ergometer test. J Sports Sci, 1999, 17: 845–52.
24. Costill DL. Inside running. Indianapolis, Benchmark Press, 1986: 123–34.
25. Coyle EF. Integration of the physiological factors determining endurance performance ability. Exerc Sport Sci Rev 1995, 23: 25–64.
26. Coyle EF., Martin WH., Ehsani AA., Hagberg JM., Bloomfeld SA., Sincore DR., Holloszy JO. Blood lactate threshold in some well-trained ischaemic heart disease patients. J Appl Physiol, 1983, 54: 18–23.
27. Dill DB., Costill DL. Calculation of percentage changes in volumes of blood, plasma and red cells in dehydration. J Appl Physiol, 1974, 37: 247–8.
28. Engeli S., Sharma AM. Role of adipose tissue for cardiovascular-renal regulation in health and disease. Horm Metab Res, 2000, 32: 485–99.
29. Essig DA., Alderson NL., Ferguson MA., Bartoli WP, Durstine JP. Delayed effects of exercise on the plasma leptin concentration. Metabolism, 2000, 49: 395–9.
30. Flier JS. What's in a name? In search of leptin's physiologic role. J Clin Endocrinol Metab, 1998, 83: 1407–13.
31. Flynn MG., Pizza FX., Boone JM., Andres FF., Michaud TA., Rodriguez-Zayas JR. Indicies of training stress during competitive running and swimming seasons. Int J Sports Med, 1994, 15: 21–6.
32. Foster C. Monitoring training in athletes with reference to overtraining syndrome. Med Sci Sports Exerc, 1998; 30: 1164–8.
33. Friedman JM., Halaas JL. Leptin and the regulation of body weight in mammals. Nature, 1998, 395: 763–70.
34. Fry AC, Kraemer WJ, Ransay CT. Pituitary-adrenal-gonadal responses to high-intensity resistance exercise overtraining. J Appl Physiol, 1998, 85: 2352–9
35. Fry RW., Morton AR., Keast D. Cautions with the use of data from incremental work-rate tests for the prescription of work rates for interval training. Sports Med Training Rehab, 1991, 3: 131–45.
36. Föhrenbach R, Mader A, Hollmann W. Determination of endurance capacity and prediction of exercise intensities for training and competition in marathon runners. Int J Sports Med, 1987, 8: 11–8.
37. Galbo H. Hormonal and Metabolic Adaption to Exercise. Stuttgart, New York, Thieme, 1983: 2–27.
38. Gomez JM., Marvall FJ., Gomez N., Guma A., Casamitjana R., Soler J. Pituitary-thyroid axis, thyroid volume and leptin in healthy adults. Horm Metab Res, 2002, 34: 67–71.

39. Guglielmini CA., Palini AR., Conconi F. Variations of serum testosterone concentrations after physical exercise of different duration. Int J Sports Med, 1984, 5: 246–9.
40. Gullstrand L. Physiological responses to short-duration high-intensity intermittent rowing. Can J Appl Physiol, 1996, 21: 197–208.
41. Haas HS, Schauenstein K. Neuroimmunomodulation via limbic structures — the neuroanatomy of psychoimmunoology. Prog Neurobiol, 1997, 51: 193–222.
42. Hackney AC., Hodgdon JA., Hesslink R Jr., Trygg K. Thyroid hormone responses to military winter exercise in the Arctic region. Arctic Med Res, 1995, 54: 82–90.
43. Hackney AC, Sinning WE, Bruot BC. Hypothalamic-pituitary-testicular axis function in endurance trained males. Int J Sports Med, 1990, 11: 298–303.
44. Hackney AC, Sinning WE, Bruot BC. Reproductive profiles of endurance-trained and untrained males. Med Sci Sports Exerc, 1988, 20: 60–5.
45. Hagerman FC. The Physiology of Competitive Rowing. In: W. Garrett Jr., D.T. Kirkendall editors. Exercise and Sport Science, Lippincott Williams & Wilkins, Phildelphia, 2000: 843–73.
46. Hagerman F., Staron R. Seasonal variables among physiological variables in elite oarsmen. Can J Appl Sports Sci, 1983, 8: 143–8.
47. Harkonen N., Kuoppasalmi K., Naveri H.. Biochemical indicators in diagnosis of overstrain condition in athletes. In: Sports Med Exerc Sci Proceedings of Olympic Scientific Congress, Eugene, Oregon, USA, 1984.
48. Hartmann U, Mester J. Training and overraining markers in selected sport events. Med Sci Sports Exerc, 2000: 32: 209–15.
49. Hedelin R., Wiklund U., Bjerle P., Henriksson-Larsen K. Cardiac autonomic imbalance in an overtrained athlete. Med Sci Sports Exerc, 2000, 32:1531–3.
50. Hickey MS., Calsbeck DJ. Plasma leptin and exercise. Recent findings. Sports Med, 2001, 31: 583–9.
51. Hickey MS., Considine RV., Israel RG, Mahar TL., McCammon MR., Tyndall GL, Houmard JL., Caro JF. Leptin is related to body fat content in male distance runners. Am J Physiol, 1996, 271: 938–40.
52. Hickey MS., Houmard JA., Considine RV., Tyndall GL., Midgette JB., Gavigan KE., Weidner ML., McCammon ML., Israel RG., Caro JF. Gender-dependent effects of exercise training on serum leptin levels in humans. Am J Physiol, 1997, 272: 562–6.
53. Holmquist N., Secher N., Sander-Jensen K., Knigge U., Warmerg J. Sympathoadrenal and parasympathietic responses to exercise. J Sport Sci, 1986, 4: 123–8.
54. Hoogeveen AR., Zonderland ML. Relationships between testosterone, cortisol and performance in proffessional cyclists. J Sports Med, 1996, 17: 423–8.
55. Hooper SL., Mackinnon LT. Monitoring overtraining in athletes. Recommendations. Sports Med, 1995, 20: 321–7.
56. Hooper SL., Mackinnon LT., Howard A., Gordon RD., Bachmann AW. Markers for monitoring overtraining and recovery. Med Sci Sports Exerc, 1995, 27: 106–12.
57. Howald H. Leistungsphysiologiche Grundlagen des Ruderns. In: Steinacker J, editor. Rudern, Berlin, Heidelberg, Springer, 1988: 31–8
58. Häkkinen K., Keskinen KL., Alen M., Komi PV., Kauhanen H. Serum hormone concentrations during prolonged training in elite endurance trained and strength-trained athletes. Eur J Appl Physiol, 1989, 59: 233–8.

59. Häkkinen K., Pakarinen A., Alen M., Komi PV. Serum hormones during prolonged training of neuromuscular performance. Eur J Appl Physiol, 1985, 53: 287–93.
60. Häkkinen K., Pakarinen A., Alen M., Kauhanen H., Komi PV. Neuromuscular and hormonal responses in elite athletes to two successive strength training sessions in one day. Eur J Appl Physiol, 1988, 57: 133–9.
61. Ingham SA., Whyte GP., Jones K., Nevill AM. Determinants of 2,000 m rowing ergometer performance in elite rowers. Eur J Appl Physiol, 2002, 88: 243–6.
62. Janke W., Wolfgramm J. Biopsychologie von Streβ und emotionalen Reaktionen: Ansätze interdisziplinärer Kooperation von Psychologie, Biologie und Medizin. In: Debus G, Erdmann G, Kallus KW, editors. Biopsychologie von Streβ und emotionalen Reaktionen. Göttingen, Hogrefe, 1995: 293–349.
63. Jensen K. Test Procedures for Rowing. FISA Coach, 1994, 5: 1–6.
64. Jensen K., Nielsen T. High altitude training does not increase maximum oxygen uptake or work capacity at sea level in rowers. Scand J Med Sci Sport, 1993, 3: 56–62.
65. Jensen K., Secher NH., Fiskerstrand A., Christensen NJ., Lund JO. Influence of body weight on physiologic variables measured during maximal dynamic exercise. Acta Physiol Scand, 1984, 212: 39–42.
66. Jeukendrup AE., Hesselink MKC., Snyder AC., Kuipers HA. Physiological changes in male competitive cyclists after two weeks of intensified training. Int J Sports Med, 1992, 13: 534–41.
67. Jürimäe J., Mäestu J., Jürimäe T., Pihl E. Prediction of rowing performance on single sculls from metabolic and anthropometric variables. J Hum Mov Stud, 2000, 38: 123–36.
68. Jürimäe J., Mäestu J., Jürimäe T., Pihl E. Relationship between rowing performance and different metabolic parameters in male rowers. Med della Sport, 1999, 52: 119–26.
69. Jürimäe J., Jürimäe T., Purge P. Plasma testosterone and cortisol responses to prolonged sculling in male competitive rowers. J Sport Sci, 2001a, 19: 893–8.
70. Jürimäe J, Mäestu J., Jürimäe T. Blood lactate response to exercise and rowing performance: relationships in competitive rowers. J Hum Mov Stud, 2001b, 41: 287–300.
71. Kallus K.W. *Der Erholungs-Belastungs Fragebogen* (The Recovry-Stress Questionnaire). Frankfurt: Swets and Zeitllinger, 1995.
72. Kallus KW., Kellmann M. Burnout in Athletes and Coaches. In: Hanin J, editor. Emotions in Sport, Champaign IL, Human Kinetics, 2000, 209–30.
73. Kellmann M. Underrecovery and overtraining: Different concepts-similar impact? In: Kellmann M editor. Enhancing Recovery. Preventing underperformance in athletes. Champaign,IL, Human Kinetics, 2002.
74. Kellmann N., Altenburg D., Lormes W., Steinacker J. Assessing stress and recovery during preparation for the world championships in rowing. Sport Psychol, 2001, 15: 151–67.
75. Kellmann M., Günther KD. Changes in stress and recovery in elite rowers during preparation for the Olympic Games. Med Sci Sports Exerc, 2000, 32: 676–83.
76. Kellmann M., Kallus KW. Mood, Recovery-Stress State and Regeneration. In: Lehmann M, editor. Overload, Performance Incompetence, and Regeneration in Sport. Kluwer Academic/Plenum Publishers, New York, 1999: 101–17.

77. Kellmann M., Kallus KW. Recovery-Stress Questionaaire for Athletes. User Manual. Champaign, IL, Human Kinetics, 2001.
78. Kellmann M., Kallus KW., Günther KD., Lormes, W., Steinacker, JM. Psychologische Betreeung der Junioren-Nationalmannschaft des Deutchen Ruderverbandes (Psychological consultation of the German Junior National Rowing Team). Psychologie und Sport, 1997, 4: 123–34.
79. Kenntä, G., & Hassmen, P. Overtraining and recovery. Sports Med, 1998, 6, 79–92.
80. Kindermann W., Schnabel A., Schmitt WM., Biro G., Gaessens J., Weber F. Catecholamines, growth hormone, cortisol, insulin and sex hormones in anaerobic and aerobic exercise. Eur J Appl Physiol, 1982, 49: 389–99.
81. Kindermann W, Simon G, Keul J. The significance of the aerobic-anaerobic transition for the determination of workload intensities during endurance training. Eur J Appl Physiol 1979, 42: 25–34.
82. Kirwan JP, Costill DL, Flynn MG, Neufer PD, Fink WJ, Morse WM. Effects of increased training volume on the oxidative capacity, glycogen content and tension development of rat skeletal muscle. Int J Sports Med, 1990, 11:479–83.
83. Kramer RR., Acevedo EO., Synovitz LB., Hebert EP., Gimpel T., Castracane VD. Leptin and steroid hormone responses to exercise in adolescent female runners over a 7-week season. Eur J Appl Physiol, 2001, 86: 85–91.
84. Kramer JF., Leger A., Peterson DH., Morrow A. Rowing performance and selected descriptive field and laboratory variables. Can J Appl Physiol, 1994, 19: 174–84.
85. Kuipers, H., Keizer, A. Overtraining in elite athletes. Sports Medicine, 1988, 6: 79–92.
86. LaFontaine TP, Londeree BR, Spath WK. The maximal steady state versus selected running events. Med Sci Sports Exerc, 1981, 13: 190–2.
87. Lamb DH. A kinematic comparison of ergometer and on-water rowing. Am J Sports Med, 1989, 17: 367–73.
88. Lakomy HKA., Lakomy J. Estimation of maximum oxygen uptake from submaximal exercise on a Concept II rowing ergometer. J Sports Sci, 1993, 11: 227–32.
89. Leal-Cerro A., Garcia-Luna PP, Astorga R., Prejo J., Peino R., Dieguez C., Casanueva FF. Serum leptin levels in male marathon run. J Clin Endocrinol Metab, 1998, 83: 2376–9.
90. Lehmann M., Foster C., Dickhuth HH., Gastmann U. Autonomic imbalance hypothesis and overtraining syndrome. Med Sci Sports Exerc, 1998, 10: 1140–5.
91. Lehmann M., Dickhuth HH., Gendrisch G., Lazar W., Thum M., Kaminski R., Aramendi JF., Peterke E., Wieland W., Keul J. Training — overtraining. A prospective, experimental study with experienced middle- and long-distance runners. Int J Sports Med, 1991, 12: 444–52.
92. Lehmann, M., Forster, C., Keul, J. Overtraining in endurance athletes: a brief review. Med Sci Sports Exerc, 1993, 25: 854–61.
93. Lehmann M., Gastmann U., Petersen KG., Bachl N., Seidel A., Khalaf AN., Fischer S., Keul J. Training-overtraining: performance and hormone levels, after a defined increase in training volume vs. intensity in experienced middle- and long-distance runners. Br J Sports Med, 1992, 26: 233–42.
94. Lehmann M., Schmid P., Keul J. Plasma catecholamines ans blood lactate cumulation during incremental exhaustive exercise. Int J Sports Med, 1985, 6: 78–81.

95. Lehmann M., Wieland H., Gastmann U. Influence of an unaccustomed increase in training volume vs intensity on performance, hematological and blood-chemical perameters in distance runners. J Sports Med Phys Fitness, 1997, 37: 110–6.
96. Lormes W., Buckwitz R., Rehbein H., Steinacker JM. Performance and Blood Lactate on Gjessing and Concept II Rowing Ergometers. Int J Sports Med, 1993, 14: 29–31.
97. Mackinnon LT., Hooper SL., Jones S., Gordon RD., Bachman AW. Hormonal, immunological, and heatological responses to intensified training in elite swimmers. Med Sci Sports Exerc, 1997, 29: 1637–45.
98. Mahler D., Nelson W., Hagerman F. Mechanical and physiological evaluations of exercise performance in elite national rowers. JAMA, 1984, 252: 496–9.
99. Marriott HE., Lamb KL. The use of ratings of perceived exertion for regulatin exercise levels in rowing ergometry. Eur J Appl Physiol, 1996, 72: 267–71.
100. Marx U. Untersuchungen zur Trainingssteuerung im Rudern mit einem Mehrstufest und einem Zweistreckentest. Dissertation, Fakultät für theoretische Medizin, Universität Ulm, 1988.
101. McNair DN., Lorr M., Droppelman LF. Profile of Mood States. Manual. Educational and Industrial Testing Service, San Diego, 1992.
102. Messonnier L., Freund H., Bourdin M., Belli A., Lacour J. Lactate exchange and removal abilities in rowing performance. Med Sci Sports Exerc, 1997, 29: 396–401.
103. Mester J., Grabow V., de Marées H. Physiologic and anthropometric aspects of vestibular regulation in rowing. Int J Sports Med, 1982, 3: 174–6.
104. Mickelson T.C, Hagerman F.C. Anaerobic threshold measurements of elite oarsmen. Med Sci Sports Exerc, 1982, 14: 440–4.
105. Morgan WP., Brown DR., Raglin JS., O`Conner PJ., Ellicson KA. Physiological monitoring of overtraining and staleness. Br J Sports Med, 1987, 21: 107–14.
106. Naessens G, Levevre J, Priessens M. Practical and clinical relevance of urinary basal noradrenaline excretion in the followup of training processes in semiprffessional football players. Conference on Overtraining in Sports. Memphis, TN, 1996.
107. Nindl BC., Kraemer WJ., Arciero PJ., Samatallee N., Leone C., Mayo M., Hafeman D. Leptin concentrations experience a delayed reduction after resistance exercise in men. Med Sci Sports Exerc, 2002, 34: 608–13.
108. Nielsen T., Daigneault T., Smith M. FISA Coaching Development Programme Course. 1993: 13–8.
109. Noland RC., Baker JT., Boudreau SR., Kobe RW., Tanner CJ., Hickner RC., McCammon MR., Houmard JA. Effect of intense training on plasma leptin in male and female swimmers. Med Sci Sports Exerc, 2001, 33: 227–31.
110. Pasman WJ., Westertrep-Plantenga MS., Saris WHM. The effect of exercise-training on leptin levels in obese males. Am J Physiol, 1998, 37: 280–6.
111. Peltonen J, Rusko H. Interrelations between power, force production and energy metabolism in maximal leg work using a modified rowing ergometer. J Sports Sci, 1993; 11: 233–40.
112. Perkins CD, Pivarnik JM. Physiological profiles and performance predictors of a women's NCAA rowing team. J Strength Cond Res, 2003, 17:173–6.
113. Perusse L., Collier G., Gagnon J., Leon AS., Roa DC., Skinner JS., Wilmore JH., Nadeau A., Zimmet PZ, Bouchard C. Acute and chronic effects of exercise on leptin levels in humans. J Appl Physiol, 1997, 83: 5–10.

114. Petibois C., Cazorla G., Poortmans JR., Déléris G. Biochemical aspects of overtraining in endurance sports. Sports Med, 2002, 32: 867–78.
115. Raglin JS. Overtraining and staleness: Psychometric monitoring of endurance athletes. In: RB Singer, M Murphey and LK Tennant, editors. Handbook of research on sport psychology. New York, Macmillan, 1993: 840–50.
116. Raglin JS., Morgan WP., Luchsinger AE. Mood and self-motivation in successful and unsuccessful female rowers. Med Sci Sports Exerc, 1990, 22: 849–53.
117. Raglin JS., Morgan WP., O'Conner PJ. Changes in mood state responses during training in female and male college swimmers. Int J Sports Med, 1991, 12: 585–9.
118. Remes K., Kuoppasalmi K., Adlercreutz H. Effect of physical exercise and sleep derivation on plasma androgen levels: Modifying effect of physical fitness. Int J Sports Med, 1985, 6: 131–5.
119. Riechman SE, Zoeller RF, Balasekaran G, Goss FL, Robertson RJ. Prediction of 2000 m indoor rowing performance using a 30 s sprint and maximal oxygen uptake. J Sports Sci, 2002, 20: 681–7.
120. Ronsen O., Holm K., Staff H., Opstad PK., Pedersen BK., Bahr R. No effect of seasonal variation in training load on immuno-endocrine responses to acute exhaustive exercise. Scand J Med Sci Sports, 2001, 11: 141–6.
121. Roth W, Hasart E, Wolf W, Pansold B. Untersuchungen zur Dynamic der Energiebereitstellung während maximaler Mittelzeitausdauerbelastung. Med Sport, 1983, 23: 107–14.
122. Russell AP., le Rossignol PF., Sparrow WA. Prediction of elite schoolboy 2000-m rowing ergometer performance from metabolic, anthropometric and strength variables. J Sports Sci, 1998, 16: 749–54.
123. Schmid P., Pusch HH., Wolf W., Pilger E., Pessenhofer H., Schwaberger G., Pristautz H., Pürstner P. Serum FSH, LH and testosterone in humans after physical exercise. Int J Sports Med, 1982, 3: 84–9.
124. Secher N.H. The physiology of rowing. Int J Sports Med, 1983, 1: 23–45.
125. Secher N.H. The physiology of rowing. Sports Med, 1993, 15: 23–53.
126. Secher NH, Vaage O, Jackson R. Rowing performance and maximal aerobic power of oarsmen. Scand J Sports Sci, 1982; 4: 9–1.
127. Simsch C., Lormes W., Petersen KG., Baur S., Liu Y., Hackney AC., Lehmann M., Steinacker JM. Training Intensity Influences Leptin and Thyroid Hormones in Highly Trained Rowers. Int J Sports Med, 2002, 23: 422–7.
128. Shephard RJ. Science and Medicine of rowing: A review. J Sports Sci, 1998, 16: 603–20.
129. Shephard RJ., Shek PN. Potential impact of physical activity and sport on the immune system: a brief review. Br J Sports Med, 1994, 26: 1071–7.
130. Shirreffs SM, Maughan RJ. The effect of posture change on blood volume, serum potassium and whole body electrical impedance. Eur J Appl Physiol 1994, 69: 461–3.
131. Smith HK. Ergometer sprint performance and recovery with variations in training load in elite rowers. Int J Sports Med 2000, 21: 573–8.
132. Smith DJ., Norris SR., Hogg JM. Performance evaluation of swimmers. Sports Med, 2002, 32: 539–54.
133. Snegovskaya V., Viru A. Elevation of cortisol and growth hormone levels in the course of further improvement of performance capacity in trained rowers. Int J Sports Med, 14, 4: 202–6.

134. Snyder AC., Kuipers H., Cheng B., Servais R., Fransen E. Overtraining followed intensified training with normal muscle glycogen. Med Sci Sports Exerc, 1995, 27: 1063–70.

135. Stegman H, Kindermann W, Schnabel A. Lactate kinetics and the individual anaerobic threshold. Int J Sports Med 1981, 2: 160–5.

136. Steinacker JM. Methoden für die Leistungsdiagnostik und Trainingssteuerung im Rudern und ihre Anwendung. In: Steinacker J, editor. Rudern Berlin, Heidelberg, Springer, 1988: 39–54.

137. Steinacker JM. Physiological aspects of rowing. Int J Sports Med, 1993, 1: 3–10.

138. Steinacker JM., Kellmann M., Böhm BO., Liu Y., Opitz-Greiss A., Kallus KW., Lehmann M., Altenburg D., Lormes W. Clinical findings and parameters of stress and regeneration in rowers before world championships. In: Lehmann M, editor. Overload, performance incompetence, and regeneration in sport. Kluwer Academic/Plenum Publishers, New York, 1999: 71–80.

139. Steinacker JM., Laske R., Hetzel WD., Lormes W., Liu Y., Stuch M. Metabolic and hormonal reactions during training in junior oarsmen. Int J Sports Med, 1993, 14: 24–8.

140. Steinacker JM., Lehmann M. Clinical findings and mechanisms of stress and recovery in athletes. In. Kellmann M, editor. Enhancing recovery, Human Kinetics, 2002: 103–21.

141. Steinacker JM., Lormes W., Lehmann M., Altenburg D. Training of rowers before world championships. Med Sci Sports Exerc, 1998, 30: 1158–63.

142. Steinacker JM., Lormes W., Kellmann M., Liu, Y., Reisnecker A., Opitz-Greiss A., Baller B., Günther K., Petersen K., Kallus K., Lehmann M.., Altenburg D. Training of junior rowers before world championships. Effects on performance, mood state and selected hormonal and metabolic responses. J Sports Med Phys Fitness*,* 2000, 40: 327–35.

143. Steinacker JM., Lormes W., Reissnecker S., Liu Y. New aspects of the hormone and cytokine responses to training. Eur J Appl Physiol, 2004, 91: 382–391.

144. Sudi K., Jürimäe J., Payerl D., Pihl E., Möller R., Tafeit E., Jürimäe T. Relationship between subcutaneus fatness and leptin in male athletes. Med Sci Sports Exerc, 2001, 33: 1324–29.

145. Sutton JR, Coleman MJ, Casey J. The hormonal response to physical exercise. Australian Annals Med 1969; 18: 84–90.

146. Tanaka K, Matsura Y. Marathon performance, anaerobic threshold, and onset of blood lactate accumulation. J Appl Physiol, 1984; 57: 640–3.

147. Tannenbaum GS., Gurd W., Lapointe M. Leptin is a potent stimulator of spontaneous pulsatile growth hormone (GH) secretion and GH response to GH-releasing hormone. Endocrinology, 1998, 139: 3871–5.

148. Tokmakidis SP, Leger LA, Pilianidis TC. Failure to obtain a unique threshold on the blood lactate curve during exercise. Eur J Appl Physiol 1998; 77: 333–4.

149. Urhausen A., Gabriel H., Kindermann W. Blood hormones as markers of training stress and overtraining. Sports Med, 1995, 20: 251–76.

150. Urhausen A., Gabriel H., Kindermann W. Impaired pituitary hormonal response to exhaustive exercise in overtrained endurance athletes. Med Sci Sports Exerc, 1998, 30: 407–4.

151. Urhausen A., Kindermann W. Diagnosis of overtraining. What tools do we have? Sports Med, 2002, 32: 95–102.

152. Urhausen A., Kullmer T., Kindermann W. A 7-week follow-up study of the behavior of testosterone and cortisol during the competition period in rowers. Eur J Appl Physiol, 1987, 56: 528–33
153. Urhausen A., Weiler B., Kindermann W. Heart Rate, Blood Lactate, and Catecholamines During Ergometer and on Water Rowing. Int J Sports Med, 1993, 14: 20–3.
154. Verde T, Thomas S, Shephard RJ. Potential markers of heavy training in highly trained distance runners. Br J Sports Med, 1992; 26: 167–75.
155. Vermulst LJ., Vervoorn C., Boelens-Quist AM., Koppeschaar KP., Erich WB., Thijssen JH., de Vries WR. Analyses of seasonal training volume and working capacity in elite female rowers. Int J Sports Med, 1991, 12: 567–72.
156. Vervoorn C., Quist AM., Vermulst LJ., Erich WB., de Vries WR., Thijssen JH. The behaciour of the plasma free testosterone/cortisol ratio during a season of elite rowing training. Int J Sports Med, 1991, 12: 257–63.
157. Viru A. Hormones in Muscular Activity. Boca Raton., CRC Press, 1985.
158. Viru AM., Hackney AC., Välja E., Karelson K., Janson T., Viru, M. Influence of prolonged continuous exercise on hormone responses to subsequent exercise in humans. Eur J Appl Physiol, 2001, 85: 578–85.
159. Viru A., Viru M. Biochemical monitoring of sport training. Human Kinetics, 2001
160. Wing AM., Woodburn C. The coordination and consistency of rowers in a racing eight. J Sports Sci, 1995, 13: 187–97.
161. Withers DJ. Insulin receptor substrate proteins and neuroendocrine function. Biochem Soc Trans, 2001, 29: 5252–9.
162. Wolf WV, Roth W. Validät Spiroergometricher Parameter für die Weltkampfleistung im Rudern. Med Sport, 1987; 27: 162–6.
163. Womack C.J., Davis S.E., Wood C.M., Sauer K., Alvarez J., Weltman A., Gaesser G. A. Effects of training on physiological correlates of rowing ergometry performance. J Strength Cond Res, 1996, 10: 234–8.
164. Yoshida T., Chida M., Ichioka M., Suda Y. Blood lactate parameters related to aerobic capacity and endurance performance. Eur J Appl Physiol, 1987, 56: 7–11.
165. Zaccaria M., Ermolao A., Roi GS., Englaro P., Tegon G., Varnier M. Leptin reduction after endurance races differing in duration and energy expenditure. Eur J Appl Physiol, 2002, 7: 108–11.

SUMMARY IN ESTONIAN

Stressi- ja taastumisnäitajad ning hormonaalsed markerid suuremahulise treeningperioodi jooksul meessõudjatel

Sissejuhatus

Sportliku treeningu peamiseks eesmärgiks on sportliku saavutusvõime parandamine. Teada on, et sportlase organism kohaneb etteantud koormustega ja saavutusvõime kasvule järgneb platoo. Et saavutada uut töövõime tõusu tuleb suurendada treenigute mahtu ja/või intensiivsust. Mahu ja intensiivsuse suurendamine aga omakorda nõuab pikemat taastumisaega, millele aga sageli pööratakse vähem tähelepanu. Ebaõige stressi ja taastumise vahekord võivad aga viia sportlase kohanemise treeningutega mitte sobivaks ning luua võimaluse ületäsimuse avaldumisele, mis pikas perspektiivis võib viia ületreenitussündroomi tekkeni, mida aga tuleks sportlastel vältida.

Käesoleva töö eesmärgiks oli uurida erinevaid biokeemilisi ja psühholoogilisi muutusi suuremahulise treeningperioodi ja sellele järgneva taastumisperioodi jooksul kõrge tasemega meessõudjatel.

Uurimustöö ülesanded:

1. Uurida muutusi sportlaste stressi- ja taastumisnäitajates suuremahulise treeningperioodi jooksul;
2. Uurida muutusi sportlaste vere biokeemilistes näitajates suuremahulise treeningperioodi jooksul;
3. Uurida muutusi sportlaste koormusjärgsetes biokeemilistes näitajates suuremahulise treeningperioodi jooksul;
4. Leida võimalik markerite kompleks, mis iseloomustaks järsku treeningmahu muutust meessõudjatel.

Uuritavad ja metoodika

Uuringus osales 22 kõrgetasemelist meessõudjat (sealhulgas 10 juuniorit).

Treeningmahtu suurendati juunioridel 100% ühe nädala jooksul jättes muutmata intensiivsuse. Seeniorite uurimisperiood koosnes kuuest nädalast. Nädal 1 oli keskmise mahuga ettevalmistava perioodi mikrotsükkel. Nädalal 2 tõsteti koormuse mahtu 25%, nädalal 3 veel 25% ja nädalal 4 säilitati koormust. Nädalad 5 ja 6 olid nn. taastumisperiood, mille jooksul koormuse maht oli 90% esimesest nädalast. Iga nädala algul, peale puhkepäeva, määrati vaatlusalustel: 1) puhkeoleku vere biokeemilised näitajad (testosteroon, kasvuhormoon, kortisool, leptiin ja kreatiini kinaas); 2) Stressi- ja taastumisfaktorite vahekord RESTQ-Sport küsimustikku kasutades. Vaatlusaluste töövõime määrati enne ja pärast suuremahulist teeningperioodi, samuti peale taastumisperioodi 2000 meetri distantsil sõudeergomeetril Concept II. Töövõime testi käigus määrati ka vaatlusaluste koormusjärgsed vere biokeemilised näitajad.

Järeldused

1. RESTQ-Sport küsimustik kajastab sportlase meeleolude muutusi koormuse mahu muutuste puhul võttes arvesse stressi ja taastumise faktorid;
2. Puhkeoleku leptiini kontsentratisoon on tundlikum treeningkoormuse suurte muutuste puhul võrreldes teiste vere biokeemiliste näitajatega; Treeningmahu kahekordne suurenemine ühe nädala jooksul põhjustas kortisooli taseme tõusu veres, samas treeningmahu sujuvam suurendamine kortisooli tasemes muutust ei põhjustanud.
3. Koormusjärgse leptiini kontsentratsioon on tundlikum treeningkoormuse suurte muutuste puhul võrreldes teiste vere biokeemiliste näitajatega;
4. Vereplasma leptiin ja RESTQ-Indeks kajastasid nn. dose-response suhet treeningkoormuse muutustega. Koormusjärgse leptiini kontsentratsioon võib olla esimeseks märgiks ülemäärase koormuse puhul.

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