HEAVY TRAINING STRESS IN MALE ROWERS: EFFECTS ON CIRCULATORY RESPONSES AND MOOD STATE PROFILES

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Abstract:

The effects of short-term overreaching on the circulatory responses and mood state parameters were investigated in male rowers. Fourteen national team level rowers (18.6 ± 2.0 yrs; 186.9 ± 5.7 cm; 82.4 ± 6.9 kg) were monitored during a six-day training camp. The training regimen consisted mainly of low-intensity on-water rowing and resistance training, for 19.2 ± 3.9 h, corresponding to an approximate 100% increase in the training load. The 2,000 m rowing ergometer performance time increased from 395.9 ± 10.8 to 404.2 ± 11.9 s corresponding to a mean power of 361.9 ± 28.5 and 349.0 ± 32.8 W, respectively. Blood lactate concentration measured five minutes after the test (from 19.2 ± 2.9 to 16.2 ± 2.3 $mmol \cdot l^{-1}$) and mean heart rate (from 184.6 ± 7.5 to 179.2 ± 7.4 $beats \cdot min^{-1}$) decreased. Maximal oxygen consumption remained unchanged. The subjective ratings of fatigue and muscle soreness increased and were related to the training volume ($r>0.52$). The blood parameters of the red blood cell count, hemoglobin concentration and hematocrit were decreased, while blood and plasma volumes were increased after the training period. The blood variables were not correlated with the training volume ($r<-0.44$; $p>0.05$). The change between tests in the corresponding heart rate demonstrated correlation to the changes in blood ($r=-0.48$) and plasma ($r=-0.55$) volumes. It is concluded that the most appropriate and simple tool for monitoring a short-term overload training period is the self-reported ratings of well-being on a daily basis.

Key words: *overreaching, fatigue, rowing performance, mood state parameters*

HOHE TRAININGSBELASTUNG BEI RUDERERN: AUSWIRKUNGEN AUF KREISLAUFWERTE UND GEMÜTSZUSTANDPARAMETER

Zusammenfassung:

Die Auswirkungen einer kurzfristigen Überbelastung bei Ruderern auf die Blutkreislaufwerte und Gemütszustandparameter wurden geforscht. Vierzehn leistungsstärkste estonische Ruderer (18,6 ± 2,0 Jahre alt; 186,9 ± 5,7 cm; 82,4 ± 6,9 kg) wurden während eines sechstägigen Trainingslagers beobachtet. Das Trainingsprogramm bestand überwiegend aus dem Rudern niedriger Intensität auf Gewässern und Krafttraining, durchschnittlich 19,2 ± 3,9 Stunden der Dauer, was einer fast 100% Erhöhung der Trainingsbelastung entspricht. Die Dauer des 2000m Ruderns steigte von 395,9 ± 10,8 bis auf 404,2 ± 11,9 Sekunden, was einer durchschnittlichen Kraftaufwand von 361,9 ± 28,5 und 349,0 ± 32,8 W entspricht. Die Konzentration von Blutlaktaten (von 19,2 ± 2,9 bis 16,2 ± 2,3 $mmol \cdot l^{-1}$) wurde fünf Minuten nach dem Test gemessen und die durchschnittliche Herzfrequenz nahm ab (von 184,6 ± 7,5 bis 179,2 ± 7,4 $Herzschläge \cdot min^{-1}$). Der maximale Sauerstoffverbrauch blieb unverändert. Die subjektive Einschätzungswerte von Erschöpfung und Muskelschmerz nahmen zu, was mit dem Trainingsumfang zusammenhängt ($r>0,52$). Die Blutparameter, wie z. B. die Anzahl von roten Blutzellen, die Hämoglobinkonzentration und Hämatokrit nahmen ab, während das Blut- und Plasmavolumen nach der Trainingsperiode zunahm. Die Blutvariablen korrelierten nicht mit dem Trainingsumfang ($r<-0,44$; $p>0,05$). Der Unterschied zwischen den Tests der durchschnittlichen Herzfrequenz zeigte die Korrelationen mit den Unterschieden im Blut- ($r=-,48$) und Plasmavolumen ($r=-0,55$) auf. Daraus lässt sich folgern, dass das meist geeignete und einfachste Mittel zur Beobachtung einer kurzfristigen Trainingsperiode mit Überbelastung die tägliche persönliche Auffasungsweise des Sportlers über seinem Wohlbefinden ist.

Schlüsselwörter: *Überbelastung, Erschöpfung, Rudern, Gemütszustandparameter*

Introduction

The overtraining syndrome has been defined as a long-term decrement in performance capacity induced by the accumulation of training and non-training stress (Hooper & Mackinnon, 1995; Kreider, Fry, & O'Toole, 1998). Overtraining is considered to occur in response to large volumes and/or high intensities of training with inadequate recovery periods between training sessions. Many indicators of overreaching and overtraining have been proposed using different physiological and psychological parameters. Currently, there is no single marker that allows for the diagnosis of the condition (Flynn, 1998). In fact, many physiological markers may vary similarly during training and overtraining (Bosquet, Leger, & Legros, 2001). Athletes have been classified as either overtrained or not overtrained when in fact the condition is on a continuum (Hooper, Mackinnon, Howard, Gordon, & Bachmann, 1995). While the overtraining syndrome requires a recovery period of several months up to a year (Lehmann, Foster, & Keul, 1993), overreaching, the result of short-term overtraining, can be reversed with a resting period of a few days (Hedelin, Kennta, Wiklund, Bjerle, & Henriksson-Larsen, 2000).

Although there is a variety of symptoms reported on overreached and overtrained athletes, the main symptoms are reduced performance and pronounced fatigue (Lehmann et al., 1993; Hooper et al.,1995). Other parameters that have been studied as possible markers of overreaching and overtraining include various blood circulatory indices at rest and/or during exercise (Lehmann, Dickhuth, Gendrisch, Lazar, Thum, Kaminski, Aramendi, Peterke, Wieland, & Keul, 1991; Hedelin et al., 2000), resting and/or exercise heart rate (HR) and oxygen consumption (Hedelin et al., 2000), and different mood state indices (Lehmann et al., 1991; Hooper et al., 1995). However, special equipment is needed to record many of the above mentioned parameters, and the procedure can be time-consuming and expensive (Hedelin et al., 2000; Bosquet, Leger, & Legros, 2001). The identification of easily monitored, reliable indicators of overreaching may aid in monitoring the adaptive process during intensive training and recovery periods in athletes.

Rowing training is performed mainly as an extensive endurance type (Jürimäe, Jürimäe, & Purge, 2001). For rowers, it has been demonstrated that the kilometers trained are positively related to the success in championships (Steinacker, 1993). However, the risk of overtraining increases with increasing daily training time and insufficient regeneration (Steinacker, Lormes, Lehmann, & Altenburg, 1998). This means that it is important to identify the specific parameters which could be used to monitor everyday training in order to avoid the overtraining syndrome in rowers. Therefore, the purpose of this investigation was to investigate whether a short-term overreaching state in rowers, as indicated by a decrease in performance parameters, is reflected in different circulatory and/or mood state parameters.

Methods

Subjects

Fourteen national-team-level male rowers (18.6 ± 2.0 yrs; 186.9 ± 5.7 cm; 82.4 ± 6.9 kg) volunteered to participate in this study. The rowers had trained regularly for the last 4.1±1.8 years. The training period and tests constituted their first training camp on water after the winter training period and at the prospect of the coming season. The subjects were informed about the procedures and the aims of the investigation, and their written consent was obtained. This study was approved by the Medical Ethics Committee of the University of Tartu.

Procedures

The volume of training during the six-day training period amounted to 19.2 ± 3.9 h, which was equivalent to an average increase in the training volume by approximately 100% compared with their average weekly training during the preceding four weeks. In total, 12 training sessions were completed during the overreaching training period compared to six training sessions 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 (rowing) and 10% was resistance training. The maximal 2,000 m rowing ergometer test was performed before (Test 1) and after (Test 2) the six-day training period. The subjects were only allowed to train easily or not at all on the afternoon before the final test day. Blood samples were collected in the morning of each performance session. Early morning body mass and heart rate (HR) were recorded daily. In addition, the rowers were asked to record daily their subjective ratings of their quality of sleep, fatigue, stress and muscle soreness on a scale of one to seven from very, very low (point 1) to very, very high (point 7) (Hooper et al., 1995).

Performance testing

The maximal 2,000 m rowing ergometer test was performed on a wind resistance braked rowing ergometer (Concept II, Morrisville, USA). The rowers were fully familiarized with the use of this apparatus. Power and stroke frequency were delivered continuously by the computer display of the rowing ergometer. HR was measured continuously and stored at 5 s intervals during exercise tests by a sporttester Polar Vantage NV (Kempele, Finland). Expired gas was sampled continuously for the measurement of maximal oxygen consumption (VO_2max; TrueMax 2400 Metabolic Measurement System, Parvo Medics, USA) (Russell, LeRossignol, & Sparrow, 1998; Jürimäe, Mäestu, Jürimäe, & Pihl, 2000). The analyzers were calibrated prior to the test using commercial gases of known concentration. Fingertip capillary blood (20 μl) was sampled five minutes after the completion of the test. Blood lactate concentration was determined from these samples enzymatically (Lange, Germany) (Greiling & Gressner, 1987). Two parameters were considered to represent the rowing performance: the time (T_{2000} in s) and the average workload (P_{2000} in W) (Jürimäe et al., 2000).

Blood analysis

A five milliliter blood sample was obtained from the antecubital vein with the subjects in an upright position (Jürimäe, Jürimäe & Purge, 2001). Red blood cell count (RBC), hemoglobin concentration (Hgb), hematocrit (Hct) and mean corpuscular volume (MCV) were measured on Sysmex SE9000 (TOA Medical Electronics, Kobe, Japan). The coefficients of variation for those analyses were < 3%. Concentrations in the lower normal range were accompanied by higher coefficients of variation values. Relative changes in blood volume (BV) and plasma volume (PV) were calculated from Hgb and Hct in each subject using the formula of Dill and Costill (1974).

Statistical analysis

Descriptive statistics (mean ± standard deviation, SD) for each of the dependent variables were determined. The Wilcoxon matched-pairs signed-ranks test was used to compare the results from Test 1 with Test 2. Spearman correlation coefficients were calculated for correlation analysis. For all tests, the level of significance was set at 0.05.

Results

Performance data

The 2,000 metre rowing ergometer performance time was significantly increased from Test 1 to Test 2 (Table 1). While mean power, mean HR and blood lactate concentration measured five minutes after the test were significantly lower in Test 2 compared to Test 1. VO_2max values remained unchanged between the tests.

Table 1. 2,000 metre rowing ergometer performance before and after the training period (Mean ± SD).

	Test 1	Test 2
Time (s)	395.9 ± 10.8	404.2 ± 11.9*
Power (W)	361.9 ± 28.5	349.0 ± 32.8*
VO_2max ($l \cdot min^{-1}$)	4.85 ± 0.70	4.83 ± 0.61
VO_2max/kg ($ml \cdot min^{-1} kg^{-1}$)	60.4 ± 6.1	60.3 ± 5.0
La 5' recovery ($mmol \cdot l^{-1}$)	19.2 ± 2.9	16.2 ± 2.3*
Mean HR ($beats \cdot min^{-1}$)	184.6 ± 7.5	179.2 ± 7.4*

VO_2max, maximal oxygen consumption; La, blood lactate concentration; HR, heart rate
* Significantly different from Test 1; p<0.05.

Resting data

Morning HR and body mass values were not significantly changed after the training period (Table 2). The subjective ratings of fatigue and muscle soreness increased significantly from Test 1 to Test 2 (Table 2). The blood parameters of RBC, Hgb and Hct were significantly decreased after the training period (Table 3). Changes in BV and PV values were calculated to be +4.9 ± 4.6% ($p<0.05$) and +6.4 ± 8.0% ($p<0.05$), respectively. Only one of the 14 subjects showed reduced volumes.

Correlation analysis

The training volume (19.2 ± 3.9 h) of the six-day training period was significantly related to the following parameters measured in Test 2: T_{2000} (r=0.63), P_{2000} (r=-0.62), VO_2max (r=-0.65), body mass (r=-0.70), and subjective ratings of fatigue (r=0.52) and muscle soreness (r=0.53). The measured blood parameters were not significantly correlated with the training volume ($r<-0.44$; $p>0.05$). The change between tests in the mean HR demonstrated significant

Table 2. Morning HR, body mass and subjective ratings of quality of sleep, fatigue, stress, and muscle soreness before and after the training period (Mean ± SD).

	Test 1	Test 2
HR (beats·min^{-1})	56.8 ± 9.9	57.6 ± 10.4
Body mass (kg)	81.6 ± 9.6	81.5 ± 9.6
Sleep	3.3 ± 1.4	3.4 ± 1.6
Fatigue	3.1 ± 1.2	3.9 ± 1.3*
Stress	3.1 ± 1.7	3.3 ± 1.7
Muscle soreness	3.1 ± 1.5	3.8 ± 1.4*

HR, heart rate
* Significantly different from Test 1; p<0.05.

Table 3. Morning blood parameters before and after the training period (Mean ± SD).

	Test 1	Test 2
RBC (10^{12} l^{-1})	4.9 ± 0.2	4.7 ± 0.2*
Hgb (g dl^{-1})	14.9 ± 0.6	14.3 ± 0.6*
Hct (%)	43.4 ± 1.7	42.3 ± 1.8*
MCV (fl)	88.8 ± 2.9	89.7 ± 3.1

RBC, red blood cell count; Hgb, hemoglobin; Hct, hematocrit; MCV, mean corpuscular volume
* Significantly different from Test 1; p<0.05.

correlations to the changes in BV (r=-0.48) and PV (r=-0.55). In addition, the change in the mean HR correlated significantly to the changes in blood parameters of Hct, Hgb, RBC and MCV (r>0.48). The change in mean HR was also significantly related to the changes in subjective ratings of fatigue (r=-0.57) and muscle soreness (r=-0.49).

Discussion and conclusions

The main diagnostic criterion of overtraining has been reported to be a significant decrease in performance capacity, without a return to baseline after a sufficient period of rest (Lehmann et al., 1993; Hooper et al., 1995). The decrease in rowing performance as illustrated by the significant increases in T_{2000} and decreases in P_{2000}, mean HR and blood lactate concentration values (see Table 1) was thought to reflect a state of fatigue or maybe overreaching in our subjects. However, it has to be considered that success in rowing is characterized by the amount of time spent on water as low-intensity endurance training (Steinacker et al., 1998; Jürimäe et al., 2000).

The results of our study indicate that self-reported mood state indices can be used for the diagnosis and monitoring of overreaching in rowers. However, only few investigations have focused on self-assessment by the athletes themselves for monitoring overreaching and overtraining (Lehmann et al., 1991; Hooper et al., 1995; Bosquet, Leger, & Legros, 2001). In addition, different questionnaires have also been used to assess training stress in athletes (Kellmann & Günther, 2000; Bosquet, Leger, & Legros, 2001). However, questionnaires cannot be used on a daily basis to monitor the effect and recovery of high volume training loads. This study aimed at identifying the specific inquiries that could be used on a daily basis to monitor training stress during a period of dramatically increased training volume in rowers. The self-rated inquiries of fatigue and muscle soreness demonstrated a close association with the increased training time (r>0.52; p<0.05). However, it must be considered that the capacity of such measures to identify potentially overtrained athletes is very much dependent on the data interpretation by the reviewer (e.g. coach) (Hooper & Mackinnon, 1995; Hooper et al., 1995). Although the reliability of the self-assessment scores is questioned, it appears that the daily recording of mood state may provide useful information for the coach.

Similarly to our results, body mass has been reported to remain unchanged in cases of presumed overreaching in endurance events (Dressendorfer, Wade, & Scaff, 1985; Kuipers & Keizer, 1988; Lehmann et al., 1991; Hooper & Mackinnon, 1995). An increase in the morning resting HR may be absent (Kuipers & Keizer, 1988; Lehmann et al., 1991) or only slight (Dressendorfer, Wade, & Scaff, 1985) during overreaching in endurance athletes. Morning resting HR values in our group of rowers were also not affected by a short-term overreaching training period (see Table 2). Loss of body mass and increase in morning resting HR have been reported to be symptoms of overreaching mainly in speed and power athletes (Hooper & Mackinnon, 1995).

Another important finding of this study was that the measured blood parameters and HR values were not significantly correlated with the increased training time, although changes were significant at the end of the six-day overreaching training period (see Tables 2 and 3). In agreement with our results, it has been suggested that such blood variables as Hgb, Hct and RBC values have a smaller diagnostic capacity in short overexertion periods (Lehmann et al., 1991; Hedelin et al., 2000). The decrease in Hgb, Hct and RBC in 13 of the 14 athletes is likely to be a consequence of an increased PV as demonstrated in other studies (Kirwan, Costill, Houmard, Mitchell, Flynn, & Fink, 1990; Sawka, Convertino, Eichner, Schneider, & Young, 2000). Thus, it appears difficult to distinguish normal changes occurring during training from the abnormal changes associated with the syndrome of overtraining by using different physiological parameters. Similarly to our results, it has been reported that many physiological parameters change in the normal response to intensive training (Hooper et al., 1995; Sawka et al., 2000).

The reduced mean HR values (by 2 to 10 beats·min^{-1}) during maximal 2,000 metre ergometer rowing in Test 2 could be attributed to an exercise-induced hypervolemia leading to an increased stroke volume and maintenance of cardiac output with lower HRs (Hedelin et al., 2000). In turn, the increased stroke volume compensates for the reduced arteriovenous oxygen difference due to dilution (Kanstrup & Ekblom, 1984). Furthermore, the reduced HR values can also be attributed to an increase in the stroke volume as a significant relationship was observed between changes in HR and BV values as a result of the six-day training period ($r=-0.48$; $p<0.05$). This demonstrates that changes in HR values during maximal exercise might be a good tool for the evaluation of intraindividual performance changes on a weekly basis during intense training periods in rowers.

Reduced blood lactate concentrations after maximal exercise have been reported previously and attributed to the depleted glycogen stores in overtrained athletes (Hooper & Mackinnon, 1995). This was also the case in our study (see Table 1). Maximal blood lactate values have been suggested as markers that can distinguish between overtraining and overreaching in long endurance events (Bosquet, Leger, & Legros, 2001). In contrast, it has been reported that factors unrelated to overtraining may influence maximal blood lactate levels (e.g. diet) and inconsistent changes have been found in overtrained athletes (Hooper et al., 1995). In this study, an increased training volume was not related to the measured maximal blood lactate level after the maximal 2,000 metre rowing ergometer test in Test 2. Further studies using sufficient rest periods after an overreaching training period are necessary to evaluate the suitability of maximal blood lactate as a marker of overreaching in rowers.

The reduced maximal performance in rowers was interpreted to reflect a state of fatigue or maybe overreaching. According to the results of the present study, the most appropriate and simple method for monitoring a short-term overreaching training period is self-analysis of mood states using daily training logs. Comprehensive physiological testing is less sensitive to the dramatic increase in the training volume of rowers. At present, it appears that self-analysis by the athlete who trains with high training loads is the most efficient method of monitoring any possible short-term overreaching. Long term daily records of self-analysis can be kept with relative ease and compared with the more sophisticated physiological methods when necessary.

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STRES KAO POSLJEDICA NAPORNOG TRENINGA VESLAČA - UTJECAJ NA CIRKULACIJSKE ODGOVORE I PROFILE RASPOLOŽENJA

Sažetak

Uvod

Sindrom pretreniranosti definira se kao dugoročno sniženje kapaciteta za sportske rezultate uzrokovano nakupljanjem trenažnog i izvantrenažnog stresa. Pretreniranost se javlja kao odgovor na velike volumene trenažnih opterećenja i/ili visoke intenzitete treninga uz neadekvatne periode oporavka između pojedinačnih treninga. Brojni pokazatelji pretreniranosti i preopterećenosti (overreaching) izdvojeni su na temelju različitih fizioloških i psiholoških parametara. Svrha ovog istraživanja bila je istražiti učinke kratkotrajne preopterećenosti na cirkulacijske odgovore i parametre raspoloženja kod veslača.

Metoda

Uzorak ispitanika činilo je 14 veslača, natjecatelja na nacionalnoj kvalitetnoj razini (18.6±2.0 godina, 186±5.7 cm, 82.4±6.9 kg) koji su praćeni za vrijeme šestodnevnih priprema. Volumen treninga tijekom šest dana narastao je do 19.2±3.9 sati, što odgovara povećanju trenažnog volumena za otprilike 100% u usporedbi s njihovim prosječnim tjednim trenažnim opterećenjem u prethodna četiri tjedna. Ukupno, provedeno je 12 pojedinačnih treninga u eksperimentalnom periodu s preopterećenjem, za razliku od 6 takvih pojedinačnih treninga u četiri tjedna koja su prethodila pripremama. Osamdeset i pet posto ukupnog trenažnog volumena otpadalo je na trening izdržljivosti nižeg intenziteta (veslanje ili trčanje), 5% na anaerobni trening visokog intenziteta (veslanje) i 10% na treninge s otporom. Maksimalni test veslanja 2000 m na veslačkom ergometru proveden je prije (test 1) i nakon (test 2) šestodnevnog perioda treninga. Ispitanicima je bilo dozvoljeno da lagano treniraju ili da ne treniraju uopće to popodne kada se provodilo finalno testiranje. Uzorci krvi prikupljali su se na svakom jutarnjem treningu. Ranojutarnja tjelesna težina i frekvencija srca pratili su se svakog dana. Osim toga, od veslača se tražilo da svaki dan sami procijene kvalitetu spavanja, umor, stres i bol u mišićima na skali od 1 do 7 (1-vrlo, vrlo malo, 7 - vrlo, vrlo jako).

Rezultati

Wilcoxonov test ekvivalentnih parova korišten je za usporedbu rezultata prvog i drugog testiranja. Izračunat je Spearmanov koeficijent korelacije. Za sve testove utvrđena je razina značajnosti od 0.05. Vrijeme veslanja na ergometru na 2000 m poraslo je sa 395.9±10.8s na 404.2±11.9 sekundi zajedno s opadanjem snage sa 361.9±28.5W na 349.0±32.8 W. Koncentracija laktata u krvi, mjerena pet minuta nakon provedenog testa, smanjila se (sa 19.2±2.9 na 16.2±2.3mmol $\cdot l^{-1}$), kao i frekvencija srca (sa 184.6±7.5 na 179.2±7.4 otk $\cdot min^{-1}$). Maksimalni primitak kisika ostao je nepromijenjen. Subjektivna ocjena umora i boli u mišićima povećala se, a i pokazalo se da je povezana s razinom trenažnog volumena (r>.52). Parametri iz krvi, kao što su broj crvenih krvnih stanica, koncentracija hemoglobina i hematokrita, smanjili su svoje vrijednosti, dok su volumen krvne plazme i volumen krvi bili povećani nakon trenažnog perioda. Varijable krvnih parametara nisu pokazale povezanost s trenažnim volumenom (r<-0.44, p>0.05). Promjene u testovima prosječnih vrijednosti frekvencije srca pokazale su povezanost s promjenama u volumenima krvi (r = -0.48) i plazme (r = -0.55).

Rasprava i zaključak

Smanjenje maksimalnih rezultata kod veslača interpretiralo se kao odraz premorenosti, možda i preopterećenosti. Prema rezultatima ovog istraživanja mogli bismo reći da je najprikladnija metoda za praćenje kratkotrajnog trenažnog perioda preopterećenosti samoanaliza raspoloženja uz korištenje dnevnčkih bilježaka o treninzima. Sveobuhvatno fiziološko testiranje manje je osjetljivo na dramatično povećanje trenažnog volumena kod veslača.

Za sada se čini da je samoanaliza sportaša, koji je podvrgnut visokim trenažnim opterećenjima, najučinkovitija metoda za praćenje moguće kratkotrajne preopterećenosti. Dugoročno vođene dnevničke samoanalitičke bilješke mogu se jednostavno čuvati i uspoređivati sa sostificiranijim fiziološkim metodama za za procjenu pretreniranosti kada je to potrebno.