Ergometric and Psychological Findings During Overtraining: A Long-Term Follow-Up Study in Endurance Athletes

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In the present prospective longitudinal study 17 male endurance trained athletes (cyclists and triathletes; age 23.4 ± 6.7 years, VO2max 61.2 ± 7.5 ml·min⁻¹·kg⁻¹; means ± SD) were investigated both during a state of overtraining syndrome (OT: N = 15), mainly induced by an increase of exercise intensity, as well as several times in a state of regular physical ability (NS: N = 62). Cycle-ergometric and psychological data were compared for a period of approximately 19 months. On 2 separate days, each subject performed a maximum incremental graded exercise, two anaerobic tests (10 s and 30 s) as well as a short-endurance “stress test” with the intensity of 110% of the individual anaerobic threshold until volitional exhaustion. The mood state was recorded by a psychological questionnaire including 40 basic items. During OT the submaximal lactate concentrations were slightly decreased. The performance of the 10 s- and 30 s-tests was unaffected. In contrast, the duration of the “stress test” decreased significantly by approximately 27% during OT compared to the individual NS. The submaximal oxygen uptake measured during the incremental graded exercise was slightly higher during OT as compared to NS, whereas the submaximal and maximal respiratory exchange ratio, maximal heart rate and maximal lactate concentrations were decreased. At the 10th minute of the “stress test”, ammonia tended to be increased during OT (P = 0.048). The parameters of mood state at rest as well as the subjective rating of perceived exertion during exercise were significantly impaired during OT. In conclusion, the results indicate a decreased intramuscular utilization of carbohydrates with diminished maximal anaerobic lactacid energy supply during OT. Neither the lactate-performance relationship during incremental graded exercise nor the anaerobic lactacid performance showed alterations. The duration of the short-endurance “stress test”, the maximal lactate concentration of the incremental graded exercise as well as the altered mood profile turned out to be the most sensitive parameters for the diagnosis of OT.

Key words: Anaerobic threshold, heart rate, lactate, mood profile, staleness.

Introduction

A sustained imbalance between actual load and resistance to exercise training and other stressors leads to an overtraining syndrome (OT). It is attended by reduced physical performance and early fatigue in comparison to the usual individual situation. At the same time more or less severe vegetative complaints are reported (16,18). OT represents a rather frequent and severe, but reversible problem in the monitoring of top athletes, however, valid diagnostic tools are not available. Many parameters are supposed to be altered during OT (11, 14, 18, 24, 30, 35, 37), but base more on anecdotal and single reports, respectively, than on experimentally controlled investigations (31).

Primarily the monitoring of performance data and parameters of the mood state are supposed to help in the diagnostic of an OT (11, 14, 18). Israel (16) distinguished between a sympathicotonic and parasympathicotonic form of an OT. This was due to the observation of increased vegetative excitability or rather depressive mood state, respectively. The latter, parasympathicotonic and probably more chronic form of OT is dominating in endurance athletes and leads to a relatively bad prognosis because it often requires prolonged recovery periods, while the vegetative symptoms are rather discrete, which makes an early diagnosis particularly difficult and important. If the decreased performance as a cardinal symptom during OT has to be objectified, sport specific and standardized methods are necessary. These methods have to be based on knowledge about energy delivering pathways limiting performance during OT. Only few studies deal with endurance athletes and use more than one standardized test protocol. Incremental graded or submaximal constant load protocols and anaerobic tests were preferred investigating less than 10 overtrained athletes (7, 10, 12, 17, 18). Usually at the onset of the study the not-overtrained normal condition has been characterized using one initial test, which, afterwards, was compared to the results obtained during and after a following intensive training period lasting a few
days or weeks (7,12,17,19,21,23). In endurance athletes intra-
individual comparisons between different seasonal points in
time by using longer periods of observation during training and
competition periods are an exception (10).

During a follow-up lasting approximately 1.5 years the present
prospectively designed study monitored various ergonomic
and psychological parameters during training and competition
periods in a group of endurance athletes. Results during over-
training periods were intra-individually compared to results of
not-overtrained state (NS).

Methods

Subjects

Initially 23 male endurance athletes (cyclists, triathletes) par-
 participated in this investigation. Seventeen of these individuals
 completed the investigation (for anthropometrical data see Ta-
 bles 1). Drop-outs were due to long-lasting illness or injuries
 (independent of OT), new professional arrangements and lack
 of compliance with the time schedule of the study. Each indi-
 vidual gave informed written consent prior to the start of the
 study, which was approved by the Faculty of Medicine of the
 University of Saarland.

Study design

Within a time of 19 ± 3 months per subject, each individual
was investigated five times. These investigations were ap-
proximately 3–5 months apart, and each investigation includ-
ed a sequence of standardized testings on 2 separate days
(Fig. 1). In agreement with the individual training and compe-
tition program of the athlete, a period opportune for the induc-
tion of an OT was chosen, while the detailed procedure of in-
duction was not strictly defined. If a subject was suspected to
be overtrained, he was enabled to consult our institute within
a few days. All investigations were performed at the same time
of the day after an overnight fast (8.00–11.00 a.m.). Prior to la-
boratory testings training sessions were protocolled for 2
weeks and most of the training sessions were monitored for
heart rates. The day before each testing only regenerative
training sessions were allowed. The last intensive or longer
lasting (> 90 min) training was at least 36 h before the testing
day.

The first day of each investigation comprised the following
tests: clinical and training history, physical examination in-
cluding routine blood analysis, anthropometric measurements
including skin caliper (41), resting ECG, incremental graded
spiroergometry with ECG and indirect measurement of blood
pressure, two anaerobic all-out exercise tests for 10 s and 30 s.
In addition, on the first day of the first investigation heart vol-
ume was measured by combined one- and two-dimensional
echocardiography (modified Simpson rule (8); Vingmed CFM
700, Sonotron Inc., Norway). On the second day of each inves-
tigation, three to seven days later, present history was taken
again, a standardized psychological questionnaire was filled
in and a high-intensive short-endurance exercise (“stress test”) was performed to exhaustion.

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>Body fat (%)</th>
<th>Heart volume (ml·kg⁻¹)</th>
<th>VO₂max (ml·kg⁻¹·min⁻¹)</th>
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<td>23.4</td>
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<td>68.9</td>
<td>12.5</td>
<td>61.2</td>
<td>± 6.7</td>
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<td>± 7</td>
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<td>± 2.1</td>
<td>± 7.5</td>
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Study: (5 investigations) 19±3 months

<table>
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<th>study:</th>
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<th>day 2</th>
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<td>NS</td>
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<td>OT</td>
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<td>- all-out 10s-test</td>
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<td>NS</td>
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<tr>
<td>- all-out 30s-test</td>
<td>NS</td>
<td>NS</td>
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<td>- psychological questionnaire</td>
<td>NS</td>
<td>NS</td>
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Fig. 1 Study design (NS = not-overtrained state, OT = overtraining; inves-
vestigations #1, 2, 3 or 4; IAT = individual anaerobic threshold).

Two experienced physicians independently diagnosed OT by
exclusion of other reasons, i.e. organic diseases, classical
symptoms such as decrease of performance (decline in results
at recent competitions, premature interruption of effort or im-
n possibility to keep the usual training pace), decreased sub-
 jective tolerance of effort and early fatigue together with more or
less severe vegetative symptoms (14,16,18,24). At the time of
diagnosis no subject suffered from infectious disease or dimin-
ished iron stores, objectified by clinical examination and rou-
tine laboratory parameters.

Ergometry

All exercises were performed on electrically braked cycle
ergometers in an upright position (incremental graded exercise
and “stress test”: Jäger Inc., Würzburg, Germany; anaerobic
tests: Kiper-Dynavit Inc., Kaiserslautern, Germany).

Incremental graded exercise started at 100 W and the work-
load (rpm-independent modus) was increased by 50 W every
3 min to subjective exhaustion. Each athlete was motivated to
complete the test scheme maximally. Parameters of gas ex-
change were measured with an open system for every 30 s
(Oxycon, Hellige Inc., Freiburg, Germany). Heart rates were
monitored after 10 min of rest in supine position, during the
last 15 s of each step of exercise, 15 s before end of exercise
and at the end of the 3 rd and 5 th min after finishing exercise
by using outprints of the ECG. Blood pressure measurements
were made by the indirect method of Riva-Rocci after 10 min
of rest in supine position as well as during the 3rd min of each
step of exercise up to 250 W. Before, at the end of each step of
exercise 50μl blood samples from the hyperemized ear lobe
were taken for measurements of lactate concentrations. The
kinetic of lactate during exercise and the recovery phase was used to determine the individual anaerobic threshold (34).

After a recovery of 90 min and a warm-up (100–150 W) of 5 min followed by 3 min of rest in upright position the subject exercised a maximal 10 s test (rpm-dependent modus). Thirty min after the 10 s test another all-out test lasting 30 s was performed, again after warming up following an identical protocol as prior to 10 s tests. Capillary blood samples were taken for measurements of lactate concentrations before each test as well as 5 and 6 times during the first 10 and 12 min following the 10 and 30 s tests, respectively.

The so-called "stress test" consisted in an endurance exercise above the maximal lactate steady state. This time-to-exhaustion test is performed with an intensity of 110% of the individual anaerobic threshold. During each test the subject was maximally motivated by an experienced co-worker to continue until subjective exhaustion. Previous studies have shown that the individual anaerobic threshold can be regarded as an indicator for the maximum lactate steady state at endurance exercise lasting 30 min on a cycle ergometer (39).

The Sport-Tester PW 3000 (Polar Electro Inc., Finland) served for measurements of heart rates before, at the end of 10 min intervals during the "stress test", 15 s before the end of exercise as well as 5 and 10 min post-exercise. Capillary blood samples were taken from both hyperemized ear lobes before, at the end of 10 min intervals during exercise immediately and 5 min after the end of exercise for measurements of lactate, glucose and ammonia.

Laboratory methods

Lactate was measured in whole capillary blood enzymatically (Testomer-Laktat Mono Kit, Behring Inc., Marburg, Germany; (15). Glucose was determined enzymatically (UV-test) and ammonia reflectometrically (Ammoniak Checker, HEK Inc., Hamburg, Germany; [13]).

Psychological parameters

The athletes were asked about vegetative complaints (mainly disorders of sleep, appetite, capacity to concentrate mentally) on each examination day. The psychological profile was assessed by using a standardized scale of self-condition according to Nitsch (27). By using a specialized software the ratings (on a scale from 1 to 6) of 40 items are transformed into 14 binary factors, which describe the present readiness to act (motivation) and capacity to act (strain) on a scale from 1 to 9. In 10 min intervals during the "stress test" the athletes estimated their grade of subjective rating of exertion by using the Borg-scale (from 6 to 20; [2]).

Statistics

Data are shown as means and standard deviations. Medians were calculated for each individual in case of not-overtrained normal state (NS). Statistical comparisons between NS and OT were made using the Wilcoxon test for matched pairs. The level of significance was set at 5% (P < 0.05) and adjusted by using a Bonferroni-correction if repeated measurements (rest/exercise) were considered. Possible differences between NS conditions were calculated with an ANOVA for repeated measures and post-hoc analysis with Newman-Keuls tests (level of significance 5%). Relationships between two variables were calculated with linear regression analysis. CSS-software (Stat. Soft, Tulsa, Oklahoma, USA) was used for all statistical calculations.

Results

At 15 of 85 examinations OT was diagnosed. An OT could be excluded 62 times. Within these 15 cases 6 appeared during the competition period, in 10 cases at the 4th individual investigation. Each subject had at least one examination in NS during the competition period and also at least one examination in NS after OT. Nine OT’s were induced during autumn, 1 to 3 during the other seasons. OT was experimentally induced in 13 cases by a substantial increase of high-intensive training during approximately 2–3 weeks without the usual regenerative days, by increasing the frequency of competitions or by prolonging the competition period. OT spontaneously appeared twice accompanied by occupational stress. The athletes had significantly increased the amount of training at an intensity above or within the range of the individual anaerobic threshold before OT (approximately 4.5 h per week) in comparison to NS (approximately 1.5 h per week). Weekly total training volume before OT was not different from NS (approximately 10 and 9 h, respectively). From the athletes completing the study two failed to induce an OT despite repeated intensive training sessions.

Complaints and psychological parameters

The athletes complained about typical OT symptoms: the feeling of heavy muscles in the lower limbs at unusually modest exercise intensities was clearly predominant in all subjects. Thirteen athletes complained about intense daily fatigue and lack of mental concentration, 11 reported about sleeping disorders (difficulties to get to sleep and/or to sleep through), 4 a diminished appetite and 3 an increased sweating rate over- and/or during exercise. These complaints had started 13 ± 4 days before the date of the “stress test” and lasted 24 ± 10 days in total despite exclusively regenerative training after the day of the “stress test”.

Borg scale values (rating of subjective exertion) were significantly higher after 10 min of the “stress test” during OT, without differences to NS at the end of the exercise (Fig. 2). The following factors of the self-condition scale according to Nitsch (27) were altered significantly during OT: mean of all 14 binary factors as a measure for the global mood profile, fatigue, recovery, strain, sleepiness, satisfaction (Fig. 2), as well as readiness for effort, motivation and sociability (P < 0.05, respectively; data not shown). Results of ANOVA showed no significant differences of the psychological parameters between the different investigations in NS.

Anthropometric measurements and parameters of the cardiorespiratory system

Body mass increased by 2.6 kg (not significant) during the study. In case of OT body weight, percentage of body fat and fat-free body mass were the same as in NS.
Performance capacity on ergometer

Substrates

Blood pressure (at rest: NS: systolic 129 ± 8 mmHg/diastolic 73 ± 8 mmHg; OT: 132 ± 10/73 ± 8 mmHg; exercise data not shown), ECG at rest and during the incremental graded exercise as well as heart rates at rest (NS: 50 ± 7 beats·min⁻¹; OT: 49 ± 8) were not affected by OT. In contrast, maximal heart rates at the incremental graded exercise and at the end of the "stress test" were significantly reduced during OT by approximately 5 beats·min⁻¹ (Fig. 3, Table 3).

At the 5th (P < 0.01) and 10th min (P = 0.033, not significant) of the post-exercise period of the "stress test" heart rates were lower during OT in comparison to NS. At the submaximal intensity of 250 W of the incremental graded exercise oxygen uptake was slightly, but significantly higher during OT compared to NS, but no differences were seen at rest and at the maximal exercise intensity (Table 2). At submaximal (Table 2) and maximal (NS: 1.11 ± 0.06, OT: 1.02 ± 0.06; P < 0.01) exercise intensities of the incremental graded test the respiratory exchange ratio was significantly lower during OT. Minute ventilation, respiratory rate and ventilation equivalent did not show significant differences between both conditions. There were no significant changes of the heart rate measurements between the different investigations in NS.

Performance capacity on ergometer

The mean intensity of the "stress test" was 83% of the VO₂max during both OT and NS. The individual anaerobic threshold as well as the power-output at 4 mmol·l⁻¹ lactate were slightly but significantly higher (about +10 W) during OT compared to NS. Maximal power of the incremental graded exercise and mean power at the anaerobic 10 s- and 30 s-tests were not different (Fig. 4). In contrast, time to exhaustion of the "stress test" was significantly lower by 27% during OT in comparison to NS (Fig. 4). The results of a regression equation comparing the performance at the individual anaerobic threshold to the time to exhaustion of the "stress test" during NS shows that a reduction of the time to exhaustion by 6% would have been expected, if the somewhat higher mean calculated individual anaerobic threshold during OT was taken into account. Results of ANOVA showed a small, but significant improvement of the maximal ergometrical performance of the incremental graded test by approximately 10 W (P < 0.05) in NS during the study, the duration of the "stress test" was unchanged.

Substrates

The maximal lactate concentration during the incremental graded exercise test was significantly decreased in OT (Fig. 3).
No differences were found for the lactate increase after the anaerobic 10-s- and 30-s-tests (approximately 4–5 and 8–9 mmol·l⁻¹, respectively). During the “stress test” the concentrations of lactate and glucose were similar for OT and NS, while ammonia was tendentially increased at the 10th min in OT (Table 3). Results of ANOVA revealed that from the different investigations in NS the highest maximal lactate concentrations after the incremental graded exercise were measured at the first investigation (by approximately 1.5 mmol·l⁻¹, P < 0.05), however, the differences were significantly smaller in comparison to the changes in OT.

Combination of parameters for diagnosis of overtraining

In 11 subjects in OT (out of 15) the mean of the 14 binary factors of the self-condition scale according to Nitsch was measured lower than the lowest value in NS. Eight athletes in OT showed their lowest exercise time to exhaustion at the 10th min of the “stress test,” 8 subjects their lowest maximal lactate concentration at the incremental graded test, respectively. In 7 cases of OT, the maximal heart rate at the incremental graded test was decreased in comparison to the lowest value in NS. The best predictor was obtained by using a combination of parameters as follows: maximal lactate concentration and/or maximal heart rate at the incremental graded exercise (criterion 1), time to exhaustion during the “stress test” (criterion 2) and mean of the 14 binary factors of the self-condition scale (criterion 3). In this investigation 13 out of 15 OT conditions could be recognized if at least 2 of these criteria were significantly lower than the individually lowest value during NS. The two spontaneous cases of OT did not show essential differences to the other states of OT and also fulfilled two of the above-mentioned criteria: each presented its lowest value of self-condition scale as well as the lowest duration of “stress test” or the lowest measurement of maximal heart rate during the graded exercise test.

Discussion

In the present prospective and longitudinal study of 1.5 years an early stage of OT or overreaching was induced mainly by an individual increase of the frequency of highly intensive training sessions (exercise intensities above the individual anaerobic threshold) or competitions. Similar investigations using a comparable follow-up period and a comparable number of athletes in OT have not yet been published.

The predominant symptom during OT was the feeling of heavy legs. These muscular complaints appeared at unusually low exercise intensities during training, but also were observed in daily routine activities as found in prior studies as well (12,26,31,32). The increased subjective strain during the “stress test” fit to this symptom. Athletes also frequently complained about chronic fatigue and sleeping disturbances. Disturbances of sleep and appetite as well as vegetative lability combined with loss of motivation to work and enhanced irritability were already described in the earliest references about OT (29).

During OT, the self-condition scale according to Nitsch (27) especially revealed altered indices of capacity to act and fatigue. At the same time the mood state (degree of satisfaction) already declined. The very small overlap of psychological parameters between OT and non-overtrained status in this study is remarkable. Impaired parameters of global mood and depression were also described in swimmers classified as stale (28,30). A differentiation into sympathicotonic or parasympathicotonic type of OT, however, was not possible in the present study. This might be explained by the fact, that endurance athletes were investigated, described as more susceptible to develop a parasympathiotocotic type of OT (16,18), while the OT was not induced by an increase of volume but of intensity of training. However, the clinical relevance of this differentiation might be questioned.

A reduction of total and active body mass is described as an early indicator of OT occasionally (11,31,35), but was not observed in this and other prospective studies (12,17). In the literature speculations about altered ECG and blood pressure exist (35). Increased resting heart rates were supposed to contribute to the diagnosis of OT (9,16,31), but these findings cannot be confirmed neither by the present study or the data of other authors (5,10,12).

The increased oxygen uptake at submaximal exercise intensities during OT might be interpreted as an altered economy of neuromuscular coordination or a reduced degree of efficiency (20,33,35). But it should be kept in mind, that the absolute differences were only small, and heart rate and lactate concentrations at submaximal exercise intensities were not increased in OT. The significant reduction of the respiratory exchange ratio can be explained by a shift of the energy delivering processes to an enhanced metabolisation of fat subsequent to a declined supply of carbohydrates. This argumentation follows earlier reports (6,33). In addition, a tendency towards increased submaximal levels of ammonia was found. This effect might be explained by an impaired mobilization of carbohydrates leading to a deficit of energy supply and increased activation of the purine nucleotide cycle, maybe with an enhanced recruitment of additional (FT) muscle fibres (3,25,36). There are reports about central or peripheral effects of increased ammonia levels leading to a reduction of performance (1), but the small differences measured in this study seem to be of minor – if any – clinical relevance. Furthermore it should be considered that the 10th min of the “stress test” where the submaximal amo-
nia concentrations have been measured, reflects a higher percentage of total exercise time in OT than in NS. Occasionally increased ammonia concentrations at rest were described during periods of largely increased training volume of weight lifters (35,40). Others found reduced ammonia levels in periods of OT (23).

The present data show a slight shift of the lactate curve to the right during OT, which has also been described by others (4,17,35). This can be related to the previously discussed shift of the energy supplying mechanism combined with a reduced utilization of carbohydrates. It should be noticed that during OT an unchanged or even increased anaerobic threshold may pretend a false high performance capacity. Although a carbohydrate depletion caused by intense training of 2–3 weeks cannot be completely ruled out (7), it should be emphasized that neither significantly increased ammonia concentrations and heart rate measurements nor elevated concentrations of glycolytic hormones (data not shown; publication in preparation) typical for exercising under conditions of reduced muscle glycogen stores were measured in the present study.

In contrast to earlier reports (17,18), maximal oxygen uptake of the incremental graded exercise was unchanged in the present study. At first sight this result seems to be unexpected, but it should be considered that the athletes were in an early phase of OT, particularly important to prevent a long-term form of OT. Other follow-up studies investigating relatively short induction periods of OT also showed unchanged (5,7,12) or slightly, but not significantly, reduced maximal oxygen uptake (23).

In overtrained athletes the impairment of the maximal anaerobic lactacid capacity combined with a reduced tolerance of acidosis seems to be of primary importance. During maximal anaerobic tests lasting 1–2 min on a treadmill (18), repeated high-intensive bouts of speed-endurance runs (3–300 m; 5) or maximal swims over 365.8 m performance and/or increase of lactate concentrations were also reported to decline. In the present study maximal lactate concentrations and maximal heart rates of the incremental graded exercise were significantly reduced in OT. Both were described earlier as well (7) and a reduced sensitivity for catecholamines has been put forward to explain the effects (24). It seems, however, that the reduction of the maximal lactate concentrations seems to be more sensitive to indicate an OT in comparison to maximal heart rates, because the relative differences in comparison to NS are greater (lactate: approximately 18% lower, heart rate only 3%). The power output of the 10 s- and 30 s-test was unaffected during OT. Although the maximal 30 s-test also requires significant anaerobic lactacid energy supply, the duration of exercise is too short to reach a higher lactacidosis. In a prior study we had reported about an unchanged anaerobic lactacid capacity of middle-distance runners (18). Other working groups found an increased performance in 5 × 50 m sprint tests of overloaded judoka (5), or decreased performance over 22.9 m in overloaded swimmers (10). These findings could be different in non-endurance athletes such as sprinters.

The duration of the “stress test” – an all-out short-term endurance exercise test performed at the intensity of 110% of the individual anaerobic threshold – turned out to be the most sensitive single objectifiable criterion to diagnose an OT. In comparison to the not-overtrained state the time to exhaustion was reduced by 27%. Decreased performances by 0.7–15% were reported before in overloaded athletes (14). To guarantee higher demands on carbohydrate metabolism the exercise intensity for the “stress test” was defined slightly above the maximal lactate steady state (39). A reduced performance at short maximal endurance exercise tests was also reported in the early phase of OT (12,40).

The combination of 3 criteria (maximal lactate concentration and/or heart rate of the incremental graded exercise, time to exhaustion of the “stress test”, psychological profile) resulted in a relatively high accordance with the “clinical” diagnosis of OT. These criteria exclusively require intraindividual comparative data. It was not possible to define absolute values of parameters to provide a valid differentiation between OT and normal state. The usefulness of the recently proposed relation between subjective rating of exertion and lactate concentrations during exercise for the diagnosis of OT (32) may be confirmed.

The interpretation of the present results requires some methodical restrictions. A “golden standard” to diagnose OT does not exist. The underlying “clinical” definition of an OT had to remain a diagnosis by exclusion, but experience from sportsmedical practice and recommendations from the literature were taken into consideration (11,18,22). The “stress test” itself represents an open-end test until subjective exhaustion and thus can be influenced by the knowledge of former test results; it may be speculated if a time-trial protocol would be more appropriate. In addition, training intensities were evaluated by using training protocols and monitoring of heart rates, but this can only lead to orientating data. Evidence about the carbohydrate mobilization may only be achieved by more sensitive methods including magnetic resonance technique and metabolic tracers. It would have been useful to include detailed protocols of nutrition in our study, but their interpretation would be problematical without considering the energy output of the training and competitions performed. Although it was not the aim of the present study to assess data from the recovery period after OT, this interesting phase should be especially considered in future studies. Finally, the present results are valid for endurance athletes, but cannot necessarily be transposed to speed- and strength-trained athletes.

In summary, it can be concluded that the diagnosis of OT requires carefully chosen standardized exercise tests performed to exhaustion as shown by the presented “stress test”. The comparison of the test results with pre-existing individual data is indispensable. Obviously the intramuscular mobilization of carbohydrates is impaired and attended by a reduced maximal anaerobic lactacid energy supply. The submaximal relation of lactate and performance including the calculations of anaerobic thresholds are not altered during periods of OT. Performance capacity achieved in short exercise tests without maximal lactacidosis also remains unchanged. To diagnose an OT it is necessary to consider the altered psychological profile and typical vegetative complaints presented in this study.

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References


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