Is plasma viscosity a predictor of overtraining in athletes?

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1. Abstract

There is a lack of consensus about the biological diagnosis of the overtraining syndrome (OTS). Recently, efforts have been made to standardize its clinical diagnosis (e.g., standardized questionnaires like that of the French consensus group on overtraining of the Société Française de Médecine du Sport - SFMS). We previously reported that the early signs of overtraining (= « overreaching ») in elite sportsmen are associated with a hemorheologic pattern (raised hematocrit and plasma viscosity $\eta_p$) that suggests some degree of reversal of the 'autohemodilution' which characterizes fitness, and that the feeling of heavy legs in overtrained athletes is related to higher $\eta_p$ and higher red cell aggregation. We thus investigated on a sample of 48 athletes (age 24±1 yr), referred for possible diagnosis of overtraining to what extent plasma viscosity is a predictor of OTS. From those 48 athletes 10 had a value of $\eta_p$ in the highest quartile ($\eta_p >1.44$ mPa.s) and 8 of them had a diagnosis of overreaching, while in the 38 whose $\eta_p$ was <1.44 mPa.s there were 20 cases of overreachings. Overt cases of OTS were found in 1 subject of the highest quintile and two in the lowest. Thus the predictive value of $\eta_p$ for early stages (overreaching) or chronicized stages (overtraining syndrome) is as follows: a) prediction of overreaching: sensitivity 28.57%; specificity 90 % ; positive predictive value 80 %; negative predictive value 47.37% ; b) prediction of chronicized overtraining: sensitivity 2.70%; specificity 18.18% ; positive predictive value; 10.00% ; negative predictive value 5.26%. These results show that $\eta_p$ is a rather specific, although poorly sensitive predictor of overreaching but has no interest in the diagnosis of the overtraining syndrome itself.

Key words: overtraining, overreaching, plasma viscosity, hemorheology

2. Introduction

In athletes, when prolonged, excessive training stresses are applied concurrent with inadequate recovery, and even more if nutrition is not adequate and if there is a mild inflammation, performance decrements and chronic maladaptations occur. Known as the overtraining syndrome this complex condition afflicts a large percentage of athletes at least once during their careers. The multitude of publications regarding this syndrome and the severity of consequences for the athlete are in sharp contrast with the limited availability of valid diagnostic tools [1]. While some ergometric and biologic tests appear promising, there is a lack of consensus about this diagnosis [2]. Recently, efforts have been made to standardize its clinical approach. Standardized questionnaires like that of the French consensus group on
overtraining of the Société Française de Médecine du Sport (SFMS) seem to be helpful for classifying the subjects on the basis of subjective complaints [3-4]. On the other hand, we previously reported that the early signs of overtraining (= « overreaching ») in elite sportsmen are associated with a hemorheologic pattern (raised hematocrit and plasma viscosity \( \eta_p \)) [5] that suggests some degree of reversal of the 'autohemodilution' which characterizes fitness, and that the feeling of heavy legs in overtrained athletes is related to higher \( \eta_p \) and higher red cell aggregation [6]. We thus investigated on a sample of athletes referred for possible diagnosis of overtraining to what extent plasma viscosity \( \eta_p \) is a predictor of OTS.

3. Material and Methods

Sudy subjects are a sample of 48 athletes (age 24±1 yr), referred for possible diagnosis of overtraining. Their characteristics are given on table 1. The clinical evaluation included a careful anamnesis, and the standardized questionnaire of the French Society of Sports Medicine (SFMS). On the basis of this approach patients were divided into 3 categories: healthy, overreaching (ie early reversible stage of the OTS), and overtraining, ie a chronicized situation. The occurrence of a decrease in performance despite maintained or increased training volumes was required for the diagnosis of overreaching or overtraining. Besides, ergometric and biological approaches, although none of them is specific [2], were employed to improve the accuracy of the diagnosis. This work was a part of the multicentric study on overtraining carried on by the Consensus group on Overtraining of the French Society of Sports Medicine (SFMS).

Body composition was assessed with a multifrequency bioelectrical impedancemeter Dietosystem Human IM Scan that uses low intensity (100-800µA) at the following frequencies: 1, 5, 10, 50, and 100 kHz [8]. Analysis was performed with the software Master 1.0 that gives the choice among 25 published equations for body composition calculations.

The subject's VO\(_{2}\)\(_{\text{max}}\) was measured during 8-12 min of exercise performed on an electronically-braked cycle ergometer (550 ERG, Bosch, Germany). Fractions of oxygen and carbon dioxide in the expired air were measured by a mass spectrometer (Marquette MGA 1100, Blagnac, France). Heart rate was monitored throughout the exercise test. Exercise testing was started with a 3-min warm-up at 40 W. The workload was increased by steps of 20 W for the sedentary group and 30 W for the trained group every minute until maximal exercise was reached. This was evaluated in terms of maximal heart rate, RER values (>1.15) and O\(_2\) consumption (VO\(_2\)) stability.

Blood samples for hemorheological measurements (7 ml) were drawn with potassium EDTA as the anticoagulant in a vacuum tube (Vacutainer). Viscometric measurements were done at high shear rate (1000 s\(^{-1}\)) with a falling ball viscometer (MT 90 Medicat test, F-86280 Saint Benoit) [9-10]. Accuracy of the measurements was regularly controlled with the Carrimed Rheometer 'CS' (purchased from Rhéo, 91120 Palaiseau, France) [7]. The coefficient of variation of this method ranged between 0.6 and 0.8% [7].

The distribution of the values of plasma viscosity in our laboratory and the limits of quartiles have been defined in a previous paper [8]. Mean plasma viscosity values are 1.381 ± 0.015 mPa.s (mean ± SEM) so that the limit of the upper quartile is 1.448 mPa.s.
Table 1
General characteristics of study subjects (mean±SEM). Abbreviations: BMI: body mass index (=weight/height^2); VO_{2max}: maximal oxygen consumption.

<table>
<thead>
<tr>
<th>AGE (years)</th>
<th>WEIGHT (kg)</th>
<th>HEIGHT (m)</th>
<th>BMI (kg/m^2)</th>
<th>FAT MASS (%)</th>
<th>VO_{2max} (ml^-1.kg^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.01 ±0.95</td>
<td>77.1 ±1.09</td>
<td>1.80 ±0.01</td>
<td>23.7 ±0.25</td>
<td>13.24 ±0.4</td>
<td>49.3 ±1.9</td>
</tr>
</tbody>
</table>

Statistics

Sensitivity was calculated as the number of truly positive subjects divided by the sum of true positive and false negative, that sum representing the total number of insulin resistant patients in the sample of subjects. The specificity was calculated as the number of truly negative subjects divided by the sum of false positive and true negative. The positive predictive value was calculated as the number of truly positive subjects divided by the sum of true positive and false positive. The negative predictive value value was calculated as the number of truly negative subjects divided by the sum of true negative and false negative ones. All these four indexes were expressed as percentages.

4. Results

Table 2
Comparison of the two subgroups: high plasma viscosity η_p > 1.44 vs low plasma viscosity η_p <1.44 mPa.s (mean±SEM). Abbreviations: BMI: body mass index (=weight/height^2); VO_{2max}: maximal oxygen consumption.

<table>
<thead>
<tr>
<th>AGE (years)</th>
<th>WEIGHT (kg)</th>
<th>HEIGHT (m)</th>
<th>BMI (kg/m^2)</th>
<th>FAT (%)</th>
<th>VO_{2max} (ml^-1.kg^-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>η_p &gt; 1.44</td>
<td>25.70 ±0.95</td>
<td>78.85 ±1.09</td>
<td>1.80 ±0.01</td>
<td>24.23 ±0.25</td>
<td>13.24 ±0.4</td>
</tr>
<tr>
<td>η_p &gt; 1.44</td>
<td>23.6 ±0.95</td>
<td>76.6 ±1.09</td>
<td>1.80 ±0.01</td>
<td>23.6 ±0.25</td>
<td>13.24 ±0.4</td>
</tr>
</tbody>
</table>

From those 48 athletes 10 had a value of η_p in the highest quartile (η_p >1.44 pPa.s). Their comparison with athletes in the other quartiles is indicated on Table 2. They had a mean overtraining score of 9.3±2.04 vs 7.10 ± 1.08 in the other quartiles. They were training 12.4±3.6 hr/wk vs 11.1±2.6 hr/wk. Thus on the whole the training volume and the mean overtraining score were not significantly different. We also compared dietary assessment which exhibited no differences (data not shown). However, in the group of the 10 athletes whole plasma
viscosity exceeded 1.44 mPa.s, 8 of them had a diagnosis of overreaching, while in the 38 whose $\eta_p$ was <1.44 there were 20 cases of overreachings. Overt cases of OTS were found in 1 subject of the highest quintile and two in the lowest. Thus the predictive value of $\eta_p$ for early stages (overreaching) or chronicized stages (overtraining syndrome) is shown on Table 3.

**Table 3**
Diagnostic value of a $\eta_p > 1.44$ pPa.s for overtraining and overreaching.

<table>
<thead>
<tr>
<th>prediction of $\eta_p &gt; 1.44$ pPa.s for overtraining</th>
<th>overreaching</th>
<th>overtraining</th>
</tr>
</thead>
<tbody>
<tr>
<td>sensitivity</td>
<td>28.57%</td>
<td>2.70%</td>
</tr>
<tr>
<td>specificity</td>
<td>90.00%</td>
<td>18.18%</td>
</tr>
<tr>
<td>positive predictive value</td>
<td>80.00%</td>
<td>10.00%</td>
</tr>
<tr>
<td>negative predictive value</td>
<td>47.37%</td>
<td>5.26%</td>
</tr>
</tbody>
</table>

5. Discussion

These results show that $\eta_p$ is a rather specific, although poorly sensitive predictor of overreaching but has no interest in the diagnosis of the overtraining syndrome itself.

This diagnostic value was interesting to assess, since a new attractive hypothesis describes the overtraining syndrome as a mild inflammatory reaction due to an imbalance between work load and recovery [9]. This “Smith’s cytokine hypothesis” provides a unifying paradigm integrating all the symptoms of the syndrome. It is argued that high volume/intensity training, with insufficient rest, will produce muscle and/or skeletal and/or joint trauma, resulting in turn in activation of circulating monocytes by injury-related cytokines. This activation produces large quantities of proinflammatory IL-1beta, and/or IL-6, and/or TNF-alpha. There is thus a mild systemic inflammation, and this inflammation induces a cytokine-mediated whole-body response including psychoneuroendocrinological signs (referred to as "sickness" behavior), up-regulation of hepatic gluconeogenesis, hypercatabolic state, and slightly depressed immune function [9].

Our previous report of a mild hyperviscosity in the overtraining syndrome fits with this unifying hypothesis. Like in many other inflammatory disorders [10], hyperviscosity seems to be usual in overtrained athletes.

Even more interestingly, we have observed that this hyperviscosity is in close connection with one of the most usual symptoms of overtraining, the “feeling of heavy legs” [11]. Unfortunately, the evaluation of plasma viscosity as a diagnostic tool is rather deceiving. Although quite specific of overreaching, it appears to be poorly sensitive. Even more, in the cases of chronicized overtraining, it seems to be devoid of any diagnostic relevance.

We think, however, that further studies are needed in order to evaluate the usefulness and the pathophysiological involvement of hemorheologic disturbances in the context of this syndrome which still lacks reliable diagnostic tools.

6. References


