Is the feeling of heavy legs in overtrained athletes related to impaired hemorheology?

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Abstract. The feeling of having “heavy legs” (FHL) is commonly reported in the overtraining syndrome (OTS), i.e., the condition wherein an athlete is training excessively, yet performance deteriorates. Since FHL is also a sign of chronic venous insufficiency where it can be corrected by rheo-active drugs, and given the fact that OTS is also a hemorheologic disease associated with mild hemoconcentration, we investigated whether the FHL is associated with a hemorheologic profile. 37 athletes training 13.05 ± 0.97 hr/week completed the French questionnaire of Overtraining (mean score: 11.66 ± 1.96) and underwent a medical check-up including hemorheological measurements. 14 subjects quote the item: “I have the FHL”. Although well matched with the 23 others for age and body composition, FHL subjects had higher plasma viscosity (1.44 ± 0.05 vs 1.32 ± 0.02 mPa.s; p < 0.05) and a higher red cell aggregation as measured with laser backscattering (Affibio indices: final aggregation time “TF”: 36.77 ± 1.88 vs 44.26 ± 2.37; p < 0.05; aggregation index at 10 s “S10”: 26.31 ± 1.14 vs 21.92 ± 1.19; p < 0.05). The OTS score was correlated positively with plasma viscosity (r = 0.549; p = 0.008), whole blood viscosity (r = 0.4458; p = 0.03), and the following aggregability parameters: “S10” (r = 0.4818; p = 0.0232) and the aggregation index at 60 s “S60” (r = 0.4601; p = 0.0312). The OTS score was also correlated negatively with the aggregability parameters “TF” (r = −0.4432; p = 0.0389) and the initial aggregation time “TA” (exponential relationship r = −0.458; p = 0.03). These findings suggest that the feeling of heavy legs in overtrained athletes is related to OTS-related hemorheologic disturbances, namely mild plasma hyperviscosity and mild erythrocyte hyperaggregability.

Keywords: Athletes, overtraining, heavy legs, blood viscosity, plasma viscosity, aggregability

1. Introduction

Elite sport requires high training volumes. The relationship between training volume and performance appears to have an inverted U-shape. Accordingly, beyond fitness, at its top, the overtraining syndrome (OTS) is a condition wherein an athlete is training excessively, yet performance deteriorates. This is usually accompanied by mood/behaviour changes and a variety of biochemical and physiological alterations. Short-term “overtraining” or “overreaching” is probably associated with insufficient metabolic recovery, resulting in a decline in ATP levels. Chronic, systemic overtraining or staleness is attributed to failure of the hypothalamus to cope with the total amount of stress [1]. The French consensus group on overtraining of the “Société Française de Médecine du Sport” (SFMS) proposed a standardized questionnaire of early clinical symptoms of overreaching, allowing the calculation of a “score” that may help to classify on a clinical basis athletes submitted to a heavy training program [2,3]. This score appears...
to be correlated with markers of muscular damage (creatine kinase, myosin) or neuroendocrine dysfunction (somatotropic axis), but also with some haematological markers like ferritin [4,5]. Despite these advances, no specific, simple, and reliable parameters are known to diagnose overreaching and overtraining in the earliest stage. However, we have reported [6] a specific hemorheologic profile of athletes complaining of OTS symptoms as assessed with the SFMS questionnaire. Interestingly, these patients exhibit a reversal of the “autohemodilution” pattern [7–9] typically found in trained subjects, with mildly raised plasma viscosity and hematocrit.

Among the numerous signs of OTS that are reported in the literature, one of the most classical is the feeling of heavy legs (FHL). This symptom is also classical in chronic venous insufficiency [10] and has been reported to be corrected by rheo-active drugs such as troxerutine [11]. Therefore, it was interesting to analyse to what extent it was also associated to hemorheological disturbances in the OTS.

We made the hypothesis that the FHL may also reflect the hemorheologic profile and we investigated to what extent FHL is associated with hemorheologic disturbances.

2. Subjects and methods

37 elite sportsmen (national level in football and volleyball, international level in basketball and triathlon) submitted everyday to a physical training program (13.05 ± 0.97 hr/week). Their characteristic are shown in Table 1. All subjects were on good health and free from medication. Subjects’ characteristics were as follows (mean ± SEM): age 23.8 ± 0.65 yr; weight 75.21 ± 1.42 kg; height was 177.97 ± 0.98 cm; body mass index 23.69 ± 0.29 kg/m².

2.1. Laboratory measurements

Blood samples for hemorheological measurements (7 ml) were drawn with potassium EDTA as the anticoagulant in a vacuum tube (Vacutainer) as specified by the International Committee for Standardization in Haematology [12]. Measurements were performed within 2 h after venepuncture. Blood viscosity and plasma viscosity were measured at very high shear rate (1000 s⁻¹) with a micro-method. Measurements were performed on the MT 90 falling ball viscometer (Medicatest, F-86280 Saint Benoit) [13,14]. Accuracy of the measurements was regularly controlled with the Carrimed Rheometer “CS” (purchased from Rhéo, 91120 Palaiseau, France) [15]. The coefficient of variation of this method ranges between 0.6 and 0.8%. The results of viscometric measurements were expressed as apparent viscosity of whole blood at

| Table 1 |
|------------------|---|---|---|
| Number of subjects | Overall | Yes | No |
| 37 | 14 | 23 |
| Age (yr) | 23.81 ± 0.65 | 22.29 ± 1.08 | 24.74 ± 0.77 |
| Weight (kg) | 75.21 ± 1.42 | 75.54 ± 2.23 | 75.02 ± 1.88 |
| Height (cm) | 177.97 ± 0.98 | 178.18 ± 1.15 | 177.85 ± 1.44 |
| Body mass index (kg/m²) | 23.69 ± 0.29 | 23.75 ± 0.56 | 23.65 ± 0.33 |
| Training (hr/week) | 13.05 ± 0.97 | 20.53 ± 0.47* | 13.45 ± 0.88* |
| Overtraining score | 11.65 ± 1.96 | 21.31 ± 2.86* | 5.05 ± 1.21* |

*p < 0.05.
native hematocrit $\eta_b$, plasma viscosity $\eta_{pl}$, blood viscosity at corrected hematocrit (45%) $\eta_{45}$ according to the equation of Quemada [16], and RBC rigidity index “Tk". Hematocrit (packed cell volume) was evaluated by a microhematocrit technique on a Hellige autocrit centrifuge.

RBC aggregation was assessed with the Myrenne aggregometer [17] which gives two indices of RBC aggregation: “M" (aggregation during stasis after shearing at 600 s$^{-1}$) and “M1” (facilitated aggregation at low shear rate after shearing at 600 s$^{-1}$). We could also employ a more quantitative technique which requires more blood, the AFFIBIO-SEFAM aggregometer which could thus provide a more precise assessment of RBC aggregation. This device is based upon the experiments of Mills [18] on cell disaggregation behavior in shear flow. This device measures the changes in backscattered light which are observed when sheared RBC suspensions are abruptly brought to a full stop. The decrease in the optical signal reflects the formation of RBC aggregates. Some parameters are derived from the curve of light intensity as a function of time. The aggregation times “TA” and “TF” (respectively primary and final aggregation times) are the reciprocal of the initial slope (calculated between 0.5 and 2 sec after the shear has stopped). The aggregation index at 10 s “$S_{10}$” is a measurement of the extent of erythrocyte aggregation and is the relative surface area above the curve calculated over the first 10 seconds, the aggregation index at 60 s “$S_{60}$” is the relative surface area above the curve calculated over the first 60 seconds. This device measures also disaggregation thresholds, by submitting blood to a succession of shear rates from 600 s$^{-1}$ to 7 s$^{-1}$. The total disaggregation threshold “$\gamma_d$” is the shear rate below which the backscattered light intensity starts to decrease, indicating that the shear stress applied to aggregates is no longer sufficient for allowing complete dispersion of RBC aggregates. The partial disaggregation shear rate “$\gamma_s$” is defined as the shear rate corresponding to the intersection point of the two asymptotes drawn from the extremes (maximum and minimum shear rate).

2.2. Study protocol

The check-up included clinical examination and body composition evaluation by bioelectrical impedanceometry. The psychological scale for overtraining proposed by the consensus group on overtraining of the French Society of Sports Medicine was used [2,3]. This scale consist of a list of 54 items selected among the reported clinical manifestations of the syndrome and that have to be quoted “yes” or “no” by the subject. The number of positive items (quoted “yes”) is used as a score in this study [5].

2.3. Statistics

Values are presented as mean ± standard error (SE) of the mean. Comparison were made with Student’s $t$ test after comparison of variances and verification of the normality of the sample with the Kolmogorov–Smirnov test. Correlations were tested by least square fitting for linear, exponential, logarithmic and power relationships. Significance level was defined as $p < 0.05$ [19].

3. Results

Mean values of hemorheologic and aggregation parameters are shown on Tables 2 and 3. 14 subjects quote the item: “I have the FHL”. 
3.2. OTS and hemorheological parameters

The OTS score was correlated with plasma viscosity \( (r = 0.549; p = 0.008) \) (Fig. 3), whole blood viscosity \( (r = 0.4458; p = 0.03) \) (Fig. 4), and the following aggregability parameters: “TF” \( (r = 0.4432; p = 0.0389) \) and “TA” \( (r = -0.3706; p = 0.0896) \); “S_{10}” \( (r = 0.4818; p = 0.0232) \) (Fig. 5); “S_{60}” \( (r = 0.4601; p = 0.0312) \). Correlations of the OTS with TA and S_{60} were found to fit better with an exponential than a linear relationship (respectively \( r = 0.458; p < 0.03 \) and \( r = 0.461; p < 0.03 \)).

4. Discussion

This study follows a preceding one [20] in which we reported a mild reversal of the training-induced blood hypoviscosity in athletes in whom the OTS score suggested some degree of overtraining. We focused here on one of the most common symptoms of overtraining, i.e., the feeling of heavy legs. As shown in Tables 2 and 3, athletes complaining of this feeling, when compared to a control group of other athletes matched for age and body mass index, have higher plasma viscosity (Fig. 1) and their red
Fig. 1. Comparison of plasma viscosity values between athletes complaining of the feeling of heavy legs (FHL) and controls. *$p < 0.05$.

Fig. 2. Comparison of red cell aggregability index measured by laser backscattering between athletes complaining of the feeling of heavy legs (FHL) and controls. *$p < 0.05$.
Fig. 3. Correlation between the overtraining syndrome (OTS) score and plasma viscosity ($r = 0.549$, $p = 0.008$).

Fig. 4. Correlation between the overtraining syndrome (OTS) score and whole blood viscosity ($r = 0.4458$, $p = 0.03$).

Fig. 5. Correlation between the overtraining syndrome (OTS) score and the aggregation index at 10 s “$S_{10}$” ($r = 0.4818$, $p = 0.0232$).
cells aggregate faster (Fig. 2). By contrast there is no difference in systemic hematocrit between the two groups.

These findings are thus in agreement with our initial working hypothesis of a link between the hemorheological signs of overtraining and the feeling of heavy legs in athletes. Accordingly, this feeling, which is also reported in patients suffering from venous insufficiency and appears rather early in this disease [21–28], may be hypothesized to be induced in some case by the increase in plasma viscosity and red cell aggregability. By contrast, although a moderate rise in hematocrit can also frequently be found during overtraining [6], hematocrit does not appear, in our study, to be associated with the feeling of heavy legs.

One could argue that we evidence in the OTS only very moderate alterations of blood viscosity which are unlikely to have measurable effects on hemodynamic. However, if we analyse the influence of hemorheology on hemodynamics under the light of the percolation theory, as proposed by Schmid-Schönbein [29] it appears that, at rest, in low flow, low shear rate conditions such as those of veins and venules, such hemorheological alterations are actually able to promote a self-potentiating blood viscosity which can result in local stasis. This local stasis will, in turn, impede fluid exchanges at the capillary level, resulting in local edema which can trigger nervous afferent messages and provide thus the pathophysiological basis of the feeling of heavy legs.

In venous insufficiency, such an explanation of this feeling may also be hypothesized and is even more supported by the efficiency of rheo-active drugs on this symptom [11,30,31].

Concerning the more general questions of overtraining, this study provides also some interesting informations. First, we confirm our previous report [6] of a moderate increase in blood viscosity in athletes quoting signs of overtraining on the standardized questionnaire of the French Society for Sports Medicine. While whole blood viscosity at high shear rate exhibits a correlation with the overtraining score, this correlation appears to be explained by only one viscosity factor, which is plasma viscosity. Plasma viscosity, although there is a paucity of studies investigating it in the context of overtraining, appears to be a logic marker for overtraining, since it may reflect both the hydration status and the occurrence of an inflammatory syndrome [32,33], two obvious consequences of an increased release of cytokines which is one of the most likely current explanations of overtraining [34].

Besides, the sophisticated analysis of red cell aggregability and disaggregability with the laser backscattering technique evidences also some subtle changes in this hemorheological parameter. Since the disaggregability threshold does not appear in this study to be related to the overtraining score, this finding is likely to reflect the plasma protein pattern rather than an intrinsic red cell alteration. Thus, on the whole, our findings suggest that the most typical hemorheological sign of mild overtraining (i.e., the situation most often referred as “overreaching”) is a change in the plasma protein pattern resulting in both plasma hyperviscosity and erythrocyte hyperaggregation. Both of these hemorheological alterations are statistically related to the finding of heavy legs and it is theoretically conceivable that they are involved in its pathophysiology in overtrained athletes.

References


