ORIGINAL ARTICLE

IGFBP-3, a sensitive marker of physical training and overtraining

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Objective: To investigate the response of the somatotrope axis (insulin-like growth factor-1 (IGF-1), insulin-like growth factor binding protein-3 (IGFBP-3)) to intense exercise in relation to tiredness.
Methods: The study involved 11 rugby players who completed a questionnaire intended to evaluate fitness or, conversely, overtraining and who agreed to plasma samples being taken before and after an international rugby match.
Results: The main finding of our study is that we observed strong negative correlations between IGF-1 ($r = 0.652$) and IGFBP-3 ($r = 0.824$) levels and the overtraining state estimated using the French Society of Sport Medicine questionnaire. In particular, there was a fall (of up to 25%) in IGFBP-3 levels after the match in the more fatigued subjects compared to an increase (of up to 40%) in fit subjects.
Conclusions: A fall in IGFBP-3 in response to an intense bout of exercise may represent an index of tiredness in highly trained sportsmen, as indicated by the scores obtained from the overtraining questionnaire.

Physical exercise is a powerful stimulus for growth hormone (GH) secretion, certain actions of which take place by way of growth factors called somatomedins, the principal one being somatomedin-C or insulin-like growth factor-1 (IGF-1). IGF-1 plays a role in many physiological processes,[1] particularly in organism anabolism, related to bone and muscular growth.[2] About 80% of IGF-1 occur in a ternary 150 kDa complex including insulin-like growth factor binding protein-3 (IGFBP-3) and a protein called acid-labile subunit; less than 1% of IGF-1 are free.[3–5] The IGFBPs prolong the half life of the IGFs, serve as IGF carriers in the circulation, and act as autocrine and/or paracrine regulators of their biological actions.[6 7] IGFBP-3, which is synthesised in many tissues, is considered the major IGF-1 carrier.[7] It is well documented that circulating levels of IGF-1 and IGFBP-3 are regulated by nutrition, age, pregnancy, chronic diseases, insulin, and GH.[5 7 8] A reduction in IGF-1 concentration is commonly associated with nutritional deficiency.[8] Several studies have shown that intensive training stimulates both circulating IGF-1 and IGFBP-3, since positive significant correlations exist between these factors and physical fitness levels.[9–13] In contrast, an associated fall in IGFBP-3 related to overtraining was observed.[14] These correlations indicate that fitness in healthy subjects is related to increased activity of the IGF system, favouring an anabolic state;[15] thus, it can be confirmed that physical exercise affects tissue anabolism and may provide general health benefits. The evaluation of possible changes in concentrations of total IGF-1 and its binding proteins (mainly IGFBP-3) may be of interest because it is thought that they affect performance, and probably reflect the physical overload state of athletes.[9 16]

However, data reviewed in the literature concerning the variation of IGF-1 and IGFBP-3 after exercise, that is to say in a dynamic situation, present conflicting opinions, depending on the type of exercise and the degree of training.[4 17–22] To our knowledge, no study to date has investigated the responses of these factors to exercise in relation to overtraining.

In this investigation, we report the concentrations of total IGF-1 and total IGFBP-3 in rugby players during a rest day and after an international rugby competition. Rugby is a physical activity characterised by mixed physiological demands, but essentially comprising of anaerobic lactic type physiological responses.[23 24] At a high level, this sport requires intensive training (10 h per week), and during the championship season a match occurs typically every week. The duration of a rugby match (90 min including a 10 min half time) pushes players to exhaustion, particularly in an exercise situation of maximal activity levels as reflected during an international contest. Therefore, the aim of our study was to examine if changes in IGF-1 and IGFBP-3 were associated so that fitness or overtraining could be measured; overtraining was estimated by using the overtraining questionnaire of the French Society of Sport Medicine (SFMS).[25] An English translation of this questionnaire is given in the appendix.

METHODS

This study was conducted in a realistic situation of international competition on 11 international rugby players who belonged to the 17 member national team of Tunisia. These 11 athletes gave their consent to participate in the study following an explanation of experimental procedures and purpose and agreed to be sampled on two occasions by sport physicians. The study was carried out in compliance with ethical rules currently applied in Tunisia. No subject was taking any drugs or medication or reported a history of endocrine disorders before or during any stage of the study. None of these 11 players was substituted during the match. The players, aged 26.6 (1.4) years, had all participated actively in rugby for 16.5 (1.3) years, and trained in their clubs 3–4 days a week (8–12 h/week) in addition to their weekly 1.5 h match.

Anthropometric measurements

Anthropometric measurements included height, body mass, body mass index (BMI: weight in kg/height in m^2) and

Abbreviations: AFC, after the competition; BMI, body mass index; CV, coefficient of variability; G1, group 1; G2, group 2; GH, growth hormone; IGF-1, insulin-like growth factor-1; IGFBP-3, insulin-like growth factor binding protein-3; SD, standard deviation; SFMS, French Society of Sport Medicine percent body fat, estimated from skin fold thickness at the biceps, triceps, and subcapsular and subiliac sampling sites.[26] Height was measured using a Harpenden anthropometer (Holtain, Crosswell, Pembrokeshire, UK) to the nearest 0.1 cm. Weight was recorded to the nearest 0.1 kg with a portable digital metric scale, which was calibrated prior to data collection using standard weights. Skin folds were measured on each subject with a Harpenden skin fold calliper (Holtain). All the data were collected by the authors who were experienced in taking skin fold thicknesses.

For the assessment of Vo_{2max}, subjects performed a continuous incremental test to exhaustion on an athletic track according to the protocol of Léger and Boucher.[27]

Food intake

To assess the adequacy of nutrient intake, a 7 day consecutive dietary record was completed. All players received a detailed verbal explanation and written instructions on data collection procedures. Subjects were asked to continue with their usual dietary habits during the period of diet recording, and to be as accurate as possible in recording the amount and type of food and fluid consumed. A list of common household measures, such as cups and tablespoons, and specific information about the quantity in each measurement (grams, etc) was given to each participant. Each individual's diet was calculated using the Bilnut 4 software package (SCDA Nutrisoft, Cerelles, France), a computerised database that calculates food intake and composition from French standard references.

Psychometric assessment

The subjects were asked to complete a standardised overtraining questionnaire proposed by the French consensus group on overtraining (French Society for Sports Medicine, SFMS). This questionnaire was self administered 48 h before the match. It allows the calculation of a score that helps to classify, on a clinical basis, the demands of sportsmen submitted to a heavy training program.[25] This questionnaire consists of a list of 54 items requiring an answered response of "Yes" or "No" by the subject and selected from the reported clinical manifestations of the syndrome. The total of positive items (quoted "Yes") is used as a score of overtraining (see appendix).

Blood sampling and analytical methods

Blood samples for each subject were collected from a forearm vein during a rest day, 48 h before the competition (Rest) and 5–15 min after the competition (AFC). Rest sampling was performed at 8 am after an overnight fast and 9 h of sleep. Sampling after the match occurred at 3 pm, 5 h after the last meal. Each subject was instructed to maintain a supine position on a clinical couch during blood collection. The blood was centrifuged and serum was stored immediately at –30℃ until analysis.

Table 1 Anthropometric characteristics of the subjects

	Whole group	G1 (n = 6)	G2 (n = 5)
Age, year	26.6 (1.4)	28.3 (2.0)	24.6 (1.6)
Weight, kg	91.1 (3.5)	93.5 (5.6)	88.2 (3.8)
Height, cm	180.9 (1.6)	179.7 (1.8)	182.4 (2.8)
BMI, kg/m^2	27.56 (1.0)	28.42 (1.5)	26.5 (1.2)
% Fat mass	19.5 (1.0)	20.5 (1.6)	18.2 (1.2)
Lean mass, kg	72.4 (2.4)	72.8 (4.0)	72.0 (2.7)

Data are means (SE).

IGF-1

Serum concentrations of total IGF-1 were estimated using the Non-Extraction Insulin-Like Growth Factor-I IRMA Kit (Diagnostic Systems Laboratories, Webster, TX, USA). The theoretical sensibility, or minimum detection limit, calculated by interpolation of the mean plus 2 SD of 20 replicates of the 0 ng/ml IGF-1 standard, is 2 ng/ml. The inter-assay coefficients of variability (CVs) were 7.4 and 4.2, respectively, for the concentrations 32.54 and 383.86 ng/ml. The intra-assay CVs were 7 and 3.9, respectively, for the mean concentrations 34.03 and 373.86 ng/ml.

IGFBP-3

Serum concentrations of total IGFBP-3 were estimated using the Non-Extraction Insulin-Like Growth Factor Binding Protein-3 (IGFBP-3) Immunoradiometric Assay Kit (Diagnostic Systems Laboratories). The minimum detection limit, calculated as 2 SD from the mean of 22 replicates of the 0 ng/ml IGFBP-3 standard, is approximately 0.5 ng/ml. The intra-assay CVs were 1.8 and 3.9, respectively, for the mean concentrations 82.72 and 7.35 ng/ml. The inter-assay CVs were 1.9 and 0.6, respectively, for the mean concentrations 76.9 and 8.03 ng/ml.

Statistical analysis

Subjects were divided a posteriori into group G1 (n = 6) and group G2 (n = 5) following the response (positive or negative) of IGFBP-3 to the match.

Results are expressed as means (SE). The non-parametric Mann-Whitney test was used to test differences between variables within groups G1 and G2. Wilcoxon's test was used to test differences between variables within subjects (Rest *v* AFC). Simple correlations were performed to analyse relationships between biological, physical, and psychological variables. Analysis was performed using StatView software and the significance threshold was set at $p<0.05$.

RESULTS

All data are presented as results for the whole group (11 subjects) and for specific subjects presenting an increase (G1), or conversely, a decrease (G2), in IGFBP-3 levels.

The subjects' age and anthropometric characteristics are reported in table 1. Whatever the variable, there was no difference between G1 and G2.

Table 2 shows the data for Vo_{2max} results, overtraining score, and food intake. There was no difference in Vo_{2max} between G1 and G2. The mean overtraining score was 15.3 for the whole group. This score was higher ($p<0.01$) in G2 (21) than in G1 (10.5).

Nutritional assessment showed similar values for G1 and G2 for mean food intake. This intake is lower (−6%) than recommended (3373 kcal) for subjects with corresponding

Table 2 Aerobic capacity, overtraining score, and mean food intake of the subjects

	Whole group (n = 11)	G1 (n = 6)	G2 (n = 5)
Vo_{2max}, ml/min per kg	58.4 (0.9)	56.9 (1.1)	60.1 (1.2)
Overtraining score	15.3 (2.3)	10.5 (0.6)	21.0 (3.5)**
Food intake			
kcal	3148 (56)	3174 (66)	3116 (130)
MJ	13.16 (0.24)	13.27 (0.28)	13.03 (0.54)
Protein intake, g/kg per day	1.27 (0.04)	1.31 (0.03)	1.23 (0.09)

Data are means (SE).
**$p<0.01$ G1 *v* G2.

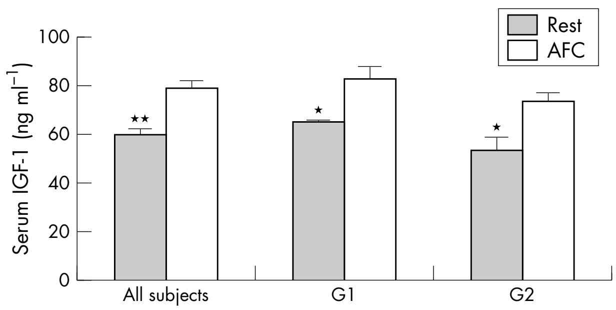

Figure 1 Concentration of serum total IGF-1 on the rest day (Rest) and just after competition (AFC). *p<0.05, **p<0.01, rest day *v* after competition values.

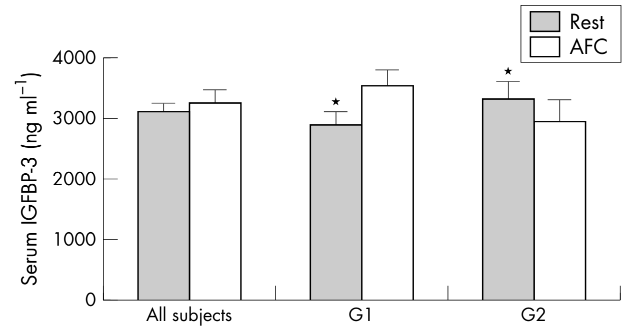

Figure 2 Concentrations of serum total IGFBP-3 on the rest day (Rest) and just after competition (AFC). *p<0.05, rest day *v* after competition values.

weights and activity levels.[28] The same is true for the protein intake.

The values of total serum IGF-1 (fig 1) during the rest day and just after the match are lower than the norms for adults of the same age. Compared to baseline levels, a significant increase of 42% in total IGF-1 serum concentrations was observed at the end of the match in all subjects ($p<0.01$).

In contrast, total serum IGFBP-3 values (fig 2) registered at the end of competition were not significantly different from the reference values when the whole group was considered. In fact, these values corresponded, in the first instance, to a significant increase in total serum IGFBP-3 levels recorded in six athletes (from 2911.66 (SE 170.9) ng/ml to 3540 (246.77) ng/ml, $p<0.05$), and in contrast, to a significant decrease in total serum IGFBP-3 levels observed in the other five athletes (from 3339 (641.35) ng/ml to 2932 (770.71) ng/ml, $p<0.05$). For this reason, we classified our subjects into the two subgroups outlined above.

The IGF-1/IGFBP-3 ratio increased significantly ($p<0.05$) when considering the whole group, but this variation resulted only from an increase in G2 (fig 3). The baseline ratio was also significantly lower in G2 than in G1.

Significant correlations (summarised in table 3) were found between the overtraining score and the resting IGF-1 levels, the IGFBP-3 levels measured after the match, and the ΔIGFBP-3 (difference between resting and after match IGFBP-3 levels) (figs 4–6).

Considering figs 4–6, it appears that three subjects among the 11 presented a score >20. These three subjects had IGFBP-3 levels lower than 3000 ng/ml, while only one of them presented an IGF-1 level lower than 40 ng/ml. A non-tired subject also had a similar low level of IGFBP-3. The three tired subjects only presented a >10% decrease in IGFBP-3 (ΔIGFBP-3) between baseline and after competition values.

DISCUSSION

This study was intended to investigate the response to a competition of the somatotrope axis (IGF-1, IGFBP-3) in relation to states of tiredness. The subjects involved in the study were high level rugby players in the Tunisian national team and had the anthropometric and energetic characteristics required to participate in this type of activity at this level.[29] The competition was an international contest which required the participants to produce maximal efforts. When confronted with a maximal intensity task incorporating both physiological and psychological demands, the organism presents a global physiological response corresponding to the stress. The pituitary adrenal axis response to stress has been well documented,[30 31] but other pituitary hormones may also respond to the imposed stress, in particular GH. This hormone is important in relation to metabolic supply when energetic demand is increased, as in sports performance. GH secretion is characterised by pulses and by a short half life (½ h), so that a single dosage is of little significance. For that reason, it is better to assay IGF-1 which is a hepatic relay of GH action (agreed that it may originate from other places) having a linear production and a longer half life (6 h), representing an integration of the changes in GH levels. In plasma, IGF-1 is linked to carrier proteins (IGFBP-1 to IGFBP-6). The biologically active fraction is the free fraction; thus, the level of free plasmatic IGF-1 depends not only on GH production, but also on the degree of linking to its carrier proteins, particularly to IGFBP-3 which has been shown to demonstrate some changes in response to exercise.[32]

It was reported that stress related cortisol secretion is associated with low IGF-1[33] and that total IGF-1 does not present a circadian rhythm.[34] Therefore, we determined resting values from morning samples collected 48 h before the match in order to avoid the precompetitive stress due to cognitive anticipation leading to increased cortisol levels.[31]

Similarly, the SFMS questionnaire was self administered 48 h before the match, since it aims to evaluate a general state of tiredness and not reaction to the competition. The score of 20 is only suggestive and not absolutely indicative of overtraining, like many other indexes (comportmental or biological), when taken alone.[25]

Although not significantly different, G1 and G2 were not perfectly matched: G1 was a little bit older and heavier than G2; the difference in body weight was accounted for by a higher percentage of fat mass in G1. Effectively, the two groups had very similar lean body masses. As they also had very similar food intakes, this difference in fat mass may be related to a natural trend linked to age. Whatever the cause, this did not seem to introduce a bias in the general conclusions.

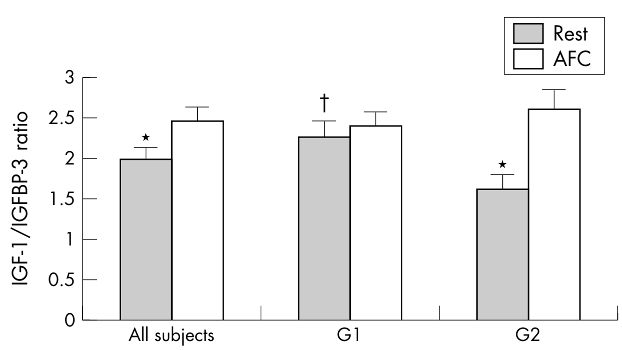

Figure 3 Ratio of total IGF-1 to IGFBP-3 in rest day (Rest) and just after competition (AFC). *p<0.05, rest day *v* after competition values. †p<0.05, G1 rest *v* G2 rest.

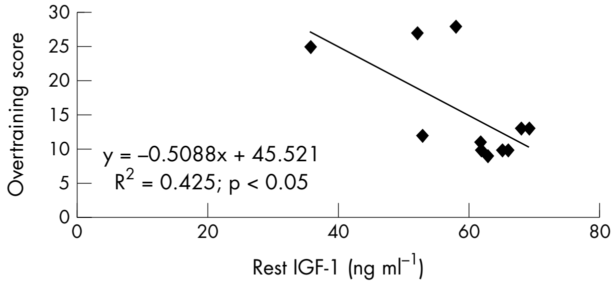

Figure 4 Relationships between the overtraining score and the resting serum total IGF-1 level.

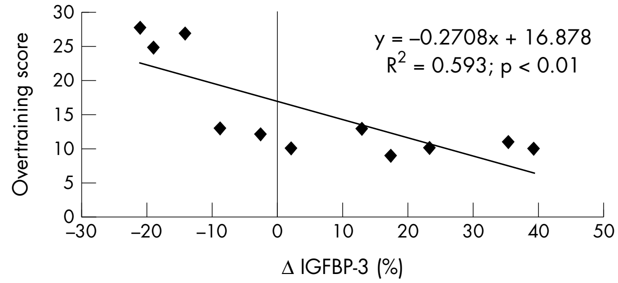

Figure 6 Relationships between the overtraining score and IGFBP-3 level changes from baseline to after competition.

The main finding of our study is that we observed strong correlations between IGF-1, IGFBP-3, and the overtraining state as estimated by the scores of the SFMS questionnaire completed at the same time, and more particularly, that the more tired subjects presented a fall in IGFBP-3 after the match compared to resting values.

Participation in regular physical exercise generally increases serum concentrations of IGF-1.[11–13] Conversely, it has been observed that high intensity training or prolonged endurance activities provoke a long term decrease in IGF-1 levels.[9 10 17 18 35] It has also been established that reduced energy intake, or, more generally, when the energetic cost exceeds energy consumption, a fall in free IGF-1 levels occurs.[36 37]

We observed similar results since, in all subjects, both at rest and after the match, the total IGF-1 levels were lower (range: 100–310 ng/ml) than adult norms. This may be related to the food intake of these sportsmen which was lower (6%) than recommended.[28] Similar observations are frequently reported in sportsmen who probably limit their food intake to avoid overweight.[38] More particularly, the mean protein intake (1.27 (SE 0.04) g/kg per day) was slightly lower than recommended (1.5–2 g/kg per day) which may partly account for the low IGF-1 level.[39]

We also found, using the SFMS overtraining questionnaire, that the mean overtraining score was rather high at 15.3 (range: 6–25). A score higher than 20 strongly suggests excessive exercise load or overtraining.[25] Below this value, the score is correlated with training volume and intensity.[40] This intensive physical training combined with low energy intake may explain the low IGF-1 levels. This is illustrated by the negative significant correlation found between the resting total IGF-1 and the overtraining score.

The total IGF-1 values recorded immediately after competition were significantly higher than baseline. This increase in serum total IGF-1 is in agreement with previous findings,[4 17 19 22] activation of the GH/IGF-1 axis being a potentially favourable hormonal response promoting anabolic actions.[4] The great intensity and duration of exercise (during the rugby match) performed by the subjects in this study may explain the significant rise in serum total IGF-1. Physical exertion stimulates GH release into the circulation,[17 41] which induces short term increases in tissue IGF-1 production and leads to increased serum levels.[17]

In contrast to the findings of our study, other authors have shown unaltered[4 21] or decreased levels[18 42] of total serum IGF-1. This variability in exercise induced IGF-1 changes may be explained by the very different exercise protocols examined and by variation in individual subject profiles. Results from Nguyen *et al*[20] further illustrate the variability in IGF-1 response after exercise, as they reported a 12% increase, a 15% decrease, and no change in an incremental ergometer cycling exercise, in a long distance Nordic ski race, and in a treadmill simulated soccer game, respectively.

Free IGF-1 may be affected by the decrease in IGFBP-3 level, which is a compensatory mechanism allowing an increase in free IGF-1. It has been proposed that exercise induced IGFBP-3 proteolysis contributes significantly to the anabolic effects of exercise.[15] It has been documented that there was no change in IGFBP-3 after short (4–5 min) intense exercise,[4] but a decrease in IGFBP-3 was found after longer exercise.[15 22]

These low levels of IGFBP-3 seem to indicate excess training, suggesting a risk of overtraining. Some studies found a decrease in IGFBP-3 after 1 year of gymnastic training[9 10 14] and negative correlations were found between IGFBP-3 and overtraining states in high level soccer and volleyball players, suggesting that a lowered IGFBP-3 level may reflect a reversal of the neuroendocrine adaptation to training.[16] This is in agreement with the results from this study since we also found a strong negative correlation between the overtraining score and the serum levels of IGFBP-3 recorded just after the match. These low levels of IGFBP-3 may exert a protective mechanism against catabolism through an increase in the free IGF-1 fraction. Effectively, it was suggested that a high IGF-1 to IGFBP-3 ratio, as was the case in G2 after the competition, leads to a greater disponibility of IGF-1.[43]

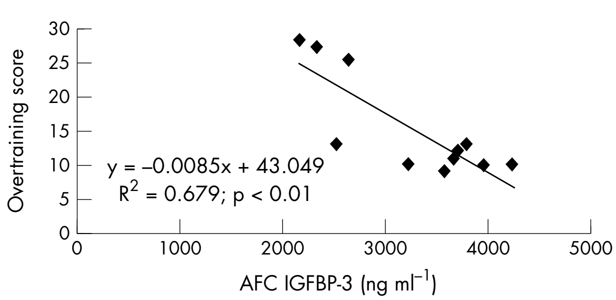

Figure 5 Relationships between the overtraining score and the after competition serum total IGFBP-3 level.

Table 3 Relationships between the resting IGF-1 level, after competition IGFBP-3 level, IGFBP-3 changes, and overtraining score

	Equation	r	p
Rest level of IGF-1 *v* OS	$y = 45.52 - 0.5088x$; $r^2 = 0.425$	r = 0.652	<0.05
AFC level of IGFBP-3 *v* OS	$y = 43.05 - 0.0085x$; $r^2 = 0.679$	r = 0.824	<0.01
ΔIGFBP-3 *v* OS	$y = 16.88 - 0.2708x$; $r^2 = 0.593$	r = 0.767	<0.01

AFC, after competition; OS, overtraining score.

What is already known on this topic

Several studies have shown that intensive training stimulates both circulating IGF-1 and IGFBP-3. However, an associated fall in IGFBP-3 related to overtraining has been observed.

What this study adds

A strong negative correlations was found between IGF-1 and IGFBP-3 levels and overtraining as estimated by the SFMS questionnaire. In particular, levels of IGFBP-3 after exercise decreased in the fatigued subjects but were increased in fit subjects.

The more salient finding of the present study was that the IGFBP-3 levels increased in six rugby players and decreased in the five others after the match. This led us to classify our subjects into two subgroups. The first group (G1) included the six subjects who presented both elevated total serum IGF-1 and elevated IGFBP-3; these subjects exhibited low scores of overtraining (mean 10.5). The second group (G2) included the subjects whose IGFBP-3 levels decreased and who presented high scores (mean 21). Another approach was to consider the subjects whose score was >20 (overtrained subjects according to the SFMS guideline) and to examine the corresponding values of IGF-1, IGFBP-3, and ΔIGFBP-3 from baseline for after competition values. From this, it follows that ΔIGFBP-3 is a very reliable index of overtraining. However, considering that the overtrained subgroup is rather small (only three subjects), it is not possible to calculate a reliable sensitivity. In spite of this, we strongly suggest the use of this index in further surveys to confirm our finding.

Thus, the results of our study suggest that low levels of IGFBP-3 are linked to a state of tiredness. Moreover, in a dynamic situation such as a rugby match, IGFBP-3 level decreases in the more fatigued subjects. Therefore, we conclude that a fall of IGFBP-3 in response to an intense bout of exercise may represent an index of tiredness in highly trained sportsmen, as indicated by the scores obtained from the overtraining questionnaire.

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APPENDIX

English translation of the SFMS questionnaire

Sex	M	F	
Date of birth			
What is your profession?			
If you are a student, are you doing examinations?	Yes	No	
What is your main sport or game?			
How many hours do you practise per week?	6–8.	8–10	More than 10
If you play other sports or games, write them:			
This month, has there been any significant event which may have disturbed your private or professional life?	Yes	No	
This month			
1–My level of sports performance/my general form has decreased	Yes	No	
2–I am not as attentive as before	Yes	No	
3–My close friends think that my behaviour has changed	Yes	No	
4–I have a sensation of pressure in my chest	Yes	No	
5 –My heart seems to beat faster	Yes	No	
6–I have a lump in my throat	Yes	No	
7–I have less appetite than before	Yes	No	
8–I eat more	Yes	No	
9–I do not sleep as well as before	Yes	No	
10–I drowse and yawn in the daytime	Yes	No	
11–The time between training sessions seems to me too short	Yes	No	
12–My sexual libido has decreased	Yes	No	
13–My performances are poor	Yes	No	
14–I frequently catch a cold	Yes	No	
15–I have put on weight	Yes	No	
16–I have memory problems	Yes	No	
17–I often feel tired	Yes	No	
18–I underestimate myself	Yes	No	
19–I often have cramps, muscular pain	Yes	No	
20–I suffer from headaches more frequently	Yes	No	
21–I do not feel fit	Yes	No	
22–I sometimes feel dizzy, on the point of fainting	Yes	No	
23–I do not confide in others so easily	Yes	No	
24–I often feel seedy	Yes	No	
25–I have a sore throat more often	Yes	No	
26–I feel nervous, insecure, anxious	Yes	No	
27–I do not bear training so well	Yes	No	
28–At rest, my heart rate is faster than before	Yes	No	
29–During exercise, my heart rate is faster than before	Yes	No	
30–I often feel rotten	Yes	No	
31–I get tired more easily	Yes	No	
32–I often have digestive disorders	Yes	No	
33–I feel like staying in bed	Yes	No	
34–I am not so confident in myself	Yes	No	
35–I get injured more easily	Yes	No	
36–I have more difficulties in organising my thoughts	Yes	No	
37–I have more difficulties in concentrating in my sports activity	Yes	No	
38–My sporting gestures are less precise, less skilful	Yes	No	
39–I have lost force and aggressiveness	Yes	No	
40–I feel as if I have no one to talk to	Yes	No	
41–I sleep longer	Yes	No	
42–I cough more often	Yes	No	
43–I do not enjoy practising my sports as much	Yes	No	
44–I do not enjoy my leisure activities as much	Yes	No	
45–I get irritated more easily	Yes	No	
46–I am less efficient in my school or professional activity	Yes	No	
47–People around me think that I have become less pleasant	Yes	No	
48–Training seems harder and harder	Yes	No	
49–It is my fault if my results are worse	Yes	No	
50–My legs feel heavy	Yes	No	
51–I lose my personal things more easily (wallet, keys, etc)	Yes	No	
52–I am pessimistic, I have the blues	Yes	No	
53–I have lost weight	Yes	No	
54–My motivation, will and tenacity are weaker	Yes	No	

Put a cross to range between these two opposite states

My physical level

Great form--Bad form

I feel fatigued

More slowly---More quickly

Continued

I recover from my state of tiredness
More quickly---More slowly
I feel
Very relaxed---Very anxious
I feel that my muscular strength has
Increased---Decreased
I feel that my endurance has
Increased---Decreased
Have you had any difficulties in understanding some of the questions? Yes No
If Yes, which questions did you find difficult to understand (write the numbers)

Each "Yes" answer receives one point, giving a score of between 0 and 54. According to the French multicentric study (F Maso, in press) scores >20 are highly suggestive of overtraining and are constantly found in overtly overtrained individuals.