Serum Hormone Concentrations and Body Composition in Brazilian Air Force Cadets During Rainforest Survival Training

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ABSTRACT

Background: Physiological adaptations in military jungle survival training have not yet been studied. Knowledge about the relationship between the insulin-like growth factor type I (IGF-I)/insulin-like growth factor binding protein type 3 (IGFBP-3) system and survival activities in a jungle environment can improve readiness and prepare Brazilian Air Force cadets for this kind of battlefield. Our goal was to assess changes in body composition and serum concentrations of the IGF-I/IGFBP-3 system in Brazilian Air Force cadets during five-day Amazon rainforest survival training and whether differences in sex influence these variations.

Methods: In the five-day survival training, variations in body composition and serum levels of IGF-I and IGFBP-3 were observed. The sample consisted of 14 male cadets (21.71 ± 1.64 years) and 6 female cadets (22.00 ± 1.41 years). Changes were assessed before and immediately after the survival training.

Results: The male cadets’ body mass (pre: 73.89 ± 8.79 kg; post: 69.57 ± 8.44 kg), body fat (pre: 11.43 ± 4.15%; post: 10.16 ± 4.19%), IGF-I serum concentrations (pre: 252 ± 72 ng/mL; post: 140 ± 42 ng/mL), and IGFBP-3 serum concentrations (pre: 4.90 ± 0.67 ng/mL; post: 4.22 ± 0.73 ng/mL) were significantly reduced (P < .01). In the female cadets, the mean body mass values (pre: 60.98 ± 8.82 kg; post: 57.91 ± 9.01 kg), body fat (pre: 19.20 ± 5.03%; post: 17.19 ± 4.77%), and IGF-I serum concentrations (pre: 202 ± 50 ng/mL; post: 108 ± 29 ng/mL) also decreased significantly (P < .01) after survival training. Finally, the cadet’s sex does not affect the variations of IGF-I (P = .46) and IGFBP-3 (P = .205) serum concentrations.

Conclusions: These findings all suggest that changes in body mass and body fat, as well as variations in the IGF-I/IGFBP-3 system, corroborate the need for military readiness preparation. Equivalent changes in both sexes indicate probable equal recovery intervals after survival training.

INTRODUCTION

Success in military operations is, in many cases, due to the physical/technical preparation and maintenance of troop readiness levels for the use of their skills in far from ideal conditions. This physical preparation, when appropriate, can be an effective way to improve the capabilities inherent to war operations, increasing combat efficiency rates, developing psychological attributes, and positively acting on physiological adaptations. Thus, the specifics of the environment, the objectives, and the military personnel involved in the mission should guide the planning and organization of the operational training sessions. In this sense, during basic training, military academies apply several specific trainings to improve the cognitive, psychomotor, and affective skills needed for battlefields. This correct preparation plays a crucial role in combat efficiency and operational lifespan.

However, even if this preparation is adequate, the practice of operational training generates a homeostatic imbalance that triggers several endocrine responses capable of producing effects on muscle maintenance and compromising the readiness of the troops. Physical and psychological exhaustion of soldiers in combat operations can manifest in different ways and in combinations of physical weariness, psychic overload, sleep deprivation, energy deficit, emotional crises, and hormonal changes. Thus, the measurement of serum concentration biomarkers can help understand physiological adaptations to military training.
Recent studies have shown that insulin growth factor type I (IGF-I) and its binding protein insulin growth factor binding protein type 3 (IGFBP-3) are relevant biomarkers in military operations. Insulin growth factor type I is a hormone that promotes amino acid absorption, potentiates synthesis, and mitigates protein degradation, which are necessary for the development and regulation of normal tissues, increasing cell proliferation and blocking apoptosis. The application of IGF-I as a biomarker of metabolic status and a parameter of individual health status justifies several kinds of research about changes in IGF-I/IGFBP-3 serum levels. Caloric or protein restriction situations foment reduced IGF-I serum concentrations, and reestablished baseline levels only occur following refeeding. In addition, short-term military operational field training (three days) has been shown to cause a reduction in IGF-I serum levels (−24% and −42%; total and free IGF-I, respectively). The acute responses of this hormone to nutritional limitations and physical exhaustion highlight the importance of monitoring this metabolic data in military training activities.

The Brazilian Air Force Academy (AFA), the institution responsible for training future aviation officers in Brazil, annually performs training that prepares its cadets for the adversities of battlefields. One of these training exercises is jungle survival training (JST), carried out in the Amazon rainforest, in which the cadets must apply survival techniques to build shelters, make fires, and obtain water and food to survive over five days. Physiological adaptations in military Amazon survival training have not been well studied, and the relationship between the IGF-I/IGFBP-3 system and survival activities in a jungle environment is unknown. However, the physical overload generated by the tasks proposed in the exercise and the nutritional status of the military personnel can affect the circulating concentrations of the IGF-I/IGFBP-3 system, decrease physical performance, and may be related to differences in sex. In addition, the regular day-to-day military training schedule does not allow recovery time after field exercises. Most routine AFA activities do not account for field exercises in their planning schedule, which increases the risk of musculoskeletal injuries and decreases readiness levels. Thus, knowledge of the changes in serum concentrations of the IGF-I/IGFBP-3 system can provide a scientific basis for planning metabolic recovery after JST and avoiding concurrent training in the cadets’ military training routine.

The purpose of this study was to assess changes in serum concentrations of the IGF-I/IGFBP-3 system in Brazilian Air Force cadets during five-day Amazon rainforest survival training and whether differences in sex influence these variations. It was hypothesized that IGF-I and IGFBP-3 serum levels would decrease after JST and that differences in sex influence these variations, suggesting different physiological recovery intervals after JST.

**METHODS**

**Subjects**

A total of 20 cadets, 14 men (21.71 ± 1.64 years; 175.43 ± 5.15 cm; 73.89 ± 8.79 kg; 11.43 ± 4.15% body fat) and 6 women (22.00 ± 1.41 years; 163.33 ± 6.02 cm; 60.98 ± 8.82 kg; 19.20 ± 5.03% body fat), volunteered for the current study. The sample size was determined by convenience, based on the cadets’ availability and acceptance to participate in the study. Due to the logistics involved in JST, the time available for data collection did not allow a larger sample.

**Ethical Considerations**

The study protocol is in accordance with the ethical guidelines of the 1975 Declaration of Helsinki and was approved by the local Ethics Committee (n. 3.230.057) and by the Brazilian AFA. All the volunteers were informed of the experimental design, the benefits, and possible risks that could be associated with the study before signing an informed consent form to participate in the study.

**Experimental Design**

Initial blood collection was carried out before the beginning of the activity, preceded by a 10-minute rest and 12-hour fasting (due to flight time). Afterward, the participants began the five-day survival activity. At the end of the JST, there were new anthropometric measurements and blood collection.

Figure 1 shows the collection steps performed during the survival training in the Amazon jungle.

**Jungle Survival Training**

First, there is theoretical–practical preparation in the AFA. Over five days, there are classes on the basic skills needed by a survivor of an aeronautical accident in the Amazon rainforest (general aspects of survival, traveling in the jungle, protection in the jungle, and food in the jungle). During the JST, the cadets were divided into groups of 10 and taken on boats for the survival simulation activity. For five days and four nights, the groups of cadets remained isolated in jungle areas and had to build a survival base (make shelters, clean the area, collect firewood, and build a rescue port and traps) using only the survival kit provided by the instruction team, the knowledge acquired in military training, and environmental resources. The survival areas designated by the AFA Military Instruct Section are located on the banks of the Braço Norte River, which prevents the cadets from becoming dehydrated and simulates realistic conditions of a survival situation: cold, rain, heat, humidity, insects, and the need to obtain food by hunting, fishing, and identifying edible fruits, seeds, and roots. The cadets were instructed to complete a dietary recall for the group. On the penultimate day, the instruction team went to...
the survival areas to assess the application of knowledge of survival techniques and check the physical and psychological conditions of the cadets. Finally, on the morning of the last day, the instructor team removed the cadets from the survival areas and the researchers began the second stage of the data collection.

**Serum Hormone Concentrations**

Morning fasted blood was obtained by venipuncture between 7:00 AM and 8:00 AM at the baseline and after the five-day JST. Blood samples were collected using approved standardized procedures and processed in accordance with laboratory guidance. Serum concentrations of IGF-I and IGFBP-3 were determined by specific immunoassays using commercial kits (Immulite 2000, Siemens, Los Angeles, CA). All the study samples were assayed in duplicate in the same assay. The intra-assay coefficients of variation were 2.77% for IGF-I and 2.60% for IGFBP-3.

**Anthropometric Assessments**

The anthropometric assessments (body mass and height) were carried out using a 2098pp Toledo electronic scale (0.1 kg and 0.1 cm accuracy). The average of three measurements was used in the calculations. During the measurements, the subjects wore light clothing and the same investigator carried out all the measurements.

**Body Composition**

All body composition measurements were performed and analyzed by the same investigator throughout the study period. Skinfold measurements were performed in millimeters using a Cescorf skinfold caliper, with 0.1 mm accuracy. The male cadets’ body fat was calculated using the equation proposed by Jackson and Pollock\(^{16}\), for the female cadets, the calculation was performed using the formula proposed by Jackson and Pollock.\(^{17}\) Subsequently, the percentage of body fat was obtained using the Siri equation.\(^{16,17}\) The average of three measurements was used in the calculations.

**Statistical Analysis**

The study data were analyzed using the SPSS software (Statistical Package for the Social Sciences for Windows), version 20.0. The Shapiro–Wilk test was used to check all data normality, and all measured variables showed normal distributions for both sexes. Descriptive statistics were used to calculate means, 95% CIs, and ±SD. Changes in serum concentrations of the IGF-I/IGFBP-3 system were evaluated using two parametric statistical methods. Variations between the phases (pre- and post-JST) in both sexes were analyzed by the Student’s \(t\)-test for paired samples. The Student’s \(t\)-test for independent variables was used to assess the influences of sex on the changes in IGF-I and IGFBP-3 serum levels. The significance level adopted was \(P < .05\).

**RESULTS**

Table I shows the sample’s descriptive data, anthropometric variations, and the changes in the serum concentrations of IGF-I and IGFBP-3.

The Student’s \(t\)-test for paired samples showed that the mean IGF-I (pre: 273 ± 69 ng/mL; post: 131 ± 41 ng/mL) and IGFBP-3 (pre: 4.98 ± 0.63 ng/mL; post: 4.42 ± 0.85 ng/mL) concentrations of the entire sample were significantly reduced \((P < .01; P < .05, respectively) after the JST.

Figure 2 shows the variations in the serum levels of IGF-I and IGFBP-3 in all the military personnel involved in the study.

The Student’s \(t\)-test for paired samples showed that the male cadets’ mean body mass (pre: 73.89 ± 8.79 kg; post: 69.57 ± 8.44 kg), body fat (pre: 11.43 ± 4.15%; post: 10.16 ± 4.19%), serum IGF-I concentrations (pre: 252 ± 72 ng/mL; post: 140 ± 42 ng/mL), and IGFBP-3 (pre: 4.90 ± 0.67 ng/mL; post: 4.22 ± 0.73 ng/mL) were significantly reduced \((P < .01) after the survival training. As for the female cadets, their mean body mass values (pre: 60.98 ± 8.82 kg; post: 57.91 ± 9.01 kg), body fat (pre: 19.20 ± 5.03%; post: 17.19 ± 4.77%), and IGF-I concentrations (pre: 202 ± 50 ng/mL; post: 108 ± 29 ng/mL) also decreased significantly \((P < .01) after the survival training. Although a significant variation was not observed, the serum concentrations of IGFBP-3 also decreased (pre: 5.17 ± 0.50 ng/mL; post: 4.91 ± 0.98 ng/mL, \(P = .59\)). Figure 3 shows the variations of IGF-I and IGFBP-3, in both sexes, before and after the five-day survival training.

Finally, the relationship between variations in serum IGF-I and IGFBP-3 concentrations and their relationship with the participant’s sex was analyzed using the Student’s \(t\)-test for independent samples. The independent \(t\)-test demonstrated that the null hypothesis is valid and that the participants’ sex does not impact on the variations of IGF-I \((P = .46) and IGFBP-3 \((P = .205)\).
TABLE I. Effects of JST on Body Composition and Serum Concentrations of IGF-I and IGFBP-3

<table>
<thead>
<tr>
<th>Sex</th>
<th>Variable</th>
<th>Baseline Mean ± SD</th>
<th>95% CI</th>
<th>Immediately after Mean ± SD</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male (n = 14)</td>
<td>Body weight (kg)*</td>
<td>73.89 ± 8.79</td>
<td>68.82–78.97</td>
<td>69.57 ± 8.44</td>
<td>64.70–74.45</td>
</tr>
<tr>
<td></td>
<td>% body fat</td>
<td>11.43 ± 4.15</td>
<td>9.03–13.83</td>
<td>10.16 ± 4.19</td>
<td>7.74–12.58</td>
</tr>
<tr>
<td></td>
<td>IGF-I (ng/mL)*</td>
<td>252 ± 72</td>
<td>211–294</td>
<td>140 ± 42</td>
<td>115.66–164.74</td>
</tr>
<tr>
<td></td>
<td>IGFBP-3 (ng/mL)*</td>
<td>4.9 ± 0.67</td>
<td>4.51–5.29</td>
<td>4.22 ± 0.73</td>
<td>3.79–4.64</td>
</tr>
<tr>
<td>Female (n = 6)</td>
<td>Body weight (kg)*</td>
<td>60.91 ± 8.82</td>
<td>51.73–70.24</td>
<td>57.91 ± 9.01</td>
<td>48.45–67.37</td>
</tr>
<tr>
<td></td>
<td>% body fat</td>
<td>19.2 ± 5.03</td>
<td>13.92–24.48</td>
<td>17.19 ± 4.77</td>
<td>12.18–22.20</td>
</tr>
<tr>
<td></td>
<td>IGF-I (ng/mL)*</td>
<td>202 ± 50</td>
<td>149–255</td>
<td>108 ± 29</td>
<td>77.93–138.23</td>
</tr>
<tr>
<td></td>
<td>IGFBP-3 (ng/mL)*</td>
<td>5.17 ± 0.5</td>
<td>4.64–5.69</td>
<td>4.91 ± 0.98</td>
<td>3.88–5.95</td>
</tr>
</tbody>
</table>

The results are presented as means, 95% CIs, and ±SD. Abbreviations: IGFBP-3, insulin growth factor binding protein type 3; IGF-I, insulin growth factor type I. *P < .01.

**DISCUSSION**

The current study showed no difference between sexes in the changes of the IGF-I/IGFBP-3 system and that short-term JST can affect these biomarkers. Our study was the first to examine these physiological changes in the Amazon environment and supports our initial hypothesis of the need for recovery after JST to improve readiness and avoid physiological risks in the Brazilian military.

According to the dietary recall, the JST resulted in a higher daily caloric deficit (∼3,000 kcal for males and ∼2,300 kcal for female cadets), which is a significant factor for reduced IGF-I serum levels. Similarly, physiological responses during the training of U.S. Army Rangers, with high daily caloric expenditure (∼4,000 kcal/d) and low food consumption (∼1,000 kcal/d), also negatively influenced the IGF-I/IGFBP-3 system, with IGF-I varying around 62% from the initial values. Short-term operational activities (three to eight days) have been shown to cause a reduction in IGF-I serum levels, which might occur after at least three days of operations. In this case, the authors suggested that the caloric restrictions (∼1,600 kcal/d) and the high energy expenditure (∼4,500 kcal/d) may be the main reasons for these variations (∼24% and −42%; total and free IGF-I, respectively).

In another study, which involved 62-day U.S. Army Rangers operational training, Nindl et al. showed that high energy expenditure and low caloric intake reduce the ability to lift weight and vertical jump, accompanied by loss of body mass (−12.6%) and fat (−6%). In addition, the authors suggested that changes in total IGF-I levels are also related to reduced body mass and body fat after operational training, with adaptation/survival training in different kinds of biomes. Other studies found similar results, where changes in IGF-I/IGFBP-3 serum levels were related to the muscular endurance and aerobic conditioning test results, and physical performance decreased after military training. Similarly, decreases in IGF-I serum levels, body mass, and body fat during the JST suggested that physical skills may have been affected after the survival training. However, due
to logistical limitations, changes in physical performance and physical capabilities could not be assessed in our study.

During four months of basic military training, female soldiers from the Israeli Defense Forces were divided into injured and uninjured. In this study, the authors observed that changes in IGF-I levels are directly related to the incidence of musculoskeletal injuries in military training. The negative variations were related to the injured soldiers and the positive ones to the uninjured ones. In the AFA, cadets return to their military training routine a day after the JST. Thus, due to the negative variations observed in the IGF-I/IGFBP-3 system after the JST, it is possible to suggest that the absence of adequate rest may facilitate the incidence of this kind of injury.

Another male sample similar to the one in the present study (23 ± 2.8 years; 177.6 ± 7.9 cm; 81.0 ± 9.6 kg; 16.8 ± 3.9% BF) showed changes after military operational training. In this case, the recovery of the catabolic phase—characterized by a decrease in IGF-I levels after training—was completed within eight weeks after operational activity. In addition, as in the present study, there was a decrease in IGF-I serum levels, body mass (~8.4%), and body fat (~53.6%) immediately after the military training. When assessing the IGF-I serum levels in Finnish army soldiers during a campaign exercise, Ojanen et al. verified significant changes in serum levels of IGF-I after training and observed that four resting days were enough for recovery. Similar conclusions have also been found in other studies, confirming the sensitivity of this biomarker to military training. Unfortunately, the JST logistics and the academic routine of the volunteers did not allow for another blood collection to verify physiological recovery a few days after the JST.

According to the present study hypothesis, there could be differences in the serum changes of the IGF-I/IGFBP-3 system between the sexes. These differences could suggest different physiological recovery intervals after JST. In a previous study, Nindl et al. observed that variations in body composition and the somatotropic influences of IGF-I and leptin established direct relationships between IGF-I and the body composition of each sex. However, the present study showed that the mean variations resulting from the female cadets' body mass (5.04%) and body fat (~10.42%) did not differ from those of the male cadets (~5.84% and ~11.11%, respectively) during the survival activity. Likewise, as for hormonal signaling in response to military training, both sexes showed equivalent IGF-I mean variations (men: ~44%; women: ~46%).

The present study was limited by the small number of subjects in the JST, which may have reduced the generalizability of the findings. Additionally, the regular day-to-day military training schedule did not allow for the recovery time assessment of physiological changes and the impact on physical capabilities after the survival training. Finally, JST seeks to optimize military adaptation to survive in Amazon rainforest. Due to the changes in the serum concentrations of IGF-I and IGFBP-3 during the activity, the physiologic variations in the changes in serum concentrations of IGF-I and IGFBP-3 could be investigated when experienced soldiers undergo such activity, proving the effectiveness of military training in physiological adaptations and readiness. The lack of articles related to the IGF-I/IGFBP-3 system in survival training and the use of a sample with cadets of both sexes both lead to several other doubts related to physiological changes in JST. Therefore, several other studies related...
CONCLUSION

Survival skills are indispensable for the training of future officers, and, in an emergency, they can mean the difference between success and failure. In this study, JST was shown to be strenuous military training with food restrictions and different stressors. The cadets’ changes in body mass and body fat, as well as variations in the IGF-I/IGFBP-3 system, corroborate the need for military readiness. The IGF-I/IGFBP-3 system showed similar changes in both sexes, which suggested equal recovery intervals after survival training. The significant changes in this hormonal signaling increase its consideration as a training state biomarker and as an aid in training periodization for cadets’ academic routines, which can affect physical performance and the state of readiness. Furthermore, in the future, it is important to study the effects of the IGF-I/IGFBP-3 system on changes in physical fitness after JST and the recovery time needed before this training. Study other biomarkers—such as cortisol, testosterone, sex-hormone binding globulin, and others IGFBPs—may be necessary to understand better the physiological adaptations to JST.\(^9,10,23\) In the future, a specific periodization between JST and the military training routine is needed to achieve better physical performance and avoid injuries in Brazilian cadets. With this data, the Brazilian military could improve its readiness and better prepare for an Amazon rainforest battlefield.

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CONFLICT OF INTEREST STATEMENT

None declared.

AUTHORS’ CONTRIBUTIONS

JMPDSM collected and analyzed the data and drafted the original manuscript. JMPDSM, TTN, HCHJ, CEMJ, and HTF designed this research and reviewed and edited the manuscript. JMPDSM, TTN, and HCHJ supported data collection. All authors read and approved the final manuscript.

AVAILABILITY OF DATA AND MATERIALS

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving human subjects were approved by the ethics and research committee of the School of Physical Education and Sport of Ribeirão Preto EEFERP/USP. The corresponding ethics code is 3.230.057.

CONSENT FOR PUBLICATION

The authors affirm that human research participants provided informed consent for the publication of their data.

REFERENCES


