Hormonal Responses in Strenuous Jumping Effort

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Abstract: In order to test the possibility for rapid responses of blood hormone levels in short-term supramaximal exercises, serum concentrations of corticotropin (ACTH), cortisol (C), total testosterone (tT), free testosterone (fT), growth hormone (GH), thyrotropin (TSH), free thyroxine (fT₄), free triiodothyronine (fT₃), prolactin (PRL), insulin-like growth factor (IGF-I), and sex hormone-binding globulin (SHBG) were determined by RIA procedures in blood samples obtained before and immediately after a 60-s period of consecutive vertical jumps (Bosco test). The study subjects were 16 Italian professional soccer players. Immediately after exercise, significant increases ($p < 0.05$) were found in the concentrations of ACTH (by 39%), C (by 14%), TSH (by 20%), fT₃ (by 28%), fT₄ (by 30%), tT (by 12%), fT (by 13%), and SHBG (by 21%). Signifi-

cant changes were not detected in the blood levels of GH, IGF-I and PRL. Most pronounced testosterone responses were typical for persons of high jumping performance (the increase of serum fT correlated with average power output, $r = 0.61$ and jumping height, $r = 0.66$). The larger the drop in power output during 60-s jumping, the higher was the thyroid response: the difference in jumping height between the first and last 15-s period correlated with increases in TSH ($r = 0.52$) and in fT₄, ($r = 0.55$). In conclusion, the obtained results indicate that in intense exercise, causing the rapid development of fatigue, rapid increases in serum levels of hormones of the pituitary-adrenocortical, pituitary-gonadal and pituitary-thyroid systems occur. [Japanese Journal of Physiology, 46, 93–98, 1996]

Key words: cortisol, corticotropin, growth hormone, jumping exercise, testosterone, thyroid hormones.

Immediately after supramaximal exercises (intensity over the level of maximal oxygen uptake) the increased blood levels of catecholamines [1–5], corticotropin [6–8], and β -endorphin [3, 7, 8] have been found. A rapid cortisol response has been detected mainly in trained persons [8, 9]. Rapid blood testosterone responses have been found by some authors after short-term anaerobic cycle [1] or weight lifting [10] exercises. In another study, an immediate increase in the blood lutropin but not the testosterone concentration was detected after running for 3×300 m [11]. It has been indicated that plasma volume change accounted for the increase in the testosterone concen-

tration during a short-term period of high resistance exercises for improved strength [12].

Short-term anaerobic exercise may evoke also a rapid increase in blood growth hormone [11] and glucagon [2] concentrations, although in prolonged exercises the responses of these hormones appear after an initial lag period of 10–20 min or more [13, 14]. Results have been obtained pointing to a lag period of somatotropin response also in high resistance exercise, intermittent high intensity cycling [15], or a high-intense anaerobic exercise bout [16].

The study was performed in order to verify the possibility that highly intensive exercise, causing rapid

Received on October 31, 1995; accepted on January 16, 1996

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development of fatigue, results in rapid changes in the blood concentrations of the pituitary-adrenocortical, pituitary-gonadal, pituitary-thyroid and somatotropin-somatomedin systems. Serum levels of corticotropin, cortisol, testosterone, thyrotropin, triiodothyronine, thyroxine, growth hormone, and somatomedin C were measured in blood samples obtained before and immediately after a supramaximal exercise, consisting of one-minute continuous maximal jumping.

MATERIALS AND METHODS

Subjects. Sixteen Italian professional soccer players volunteered for the study. Their mean ($\pm$ SD) age, height, and body mass were 24.3 ± 4.5 years, 178.4 ± 3.7 cm and 73.7 ± 3.9 kg, respectively. All the subjects were familiarised with the test procedure and gave their informed consent.

Measurements. The exercise consisted in performing maximal consecutive vertical jumps during a 60-s period. The test was performed in the morning, and blood samples were collected before and immediately after the jumping exercises for hormonal analysis. Maximal consecutive vertical jumps were performed on a resistive platform [17]. The athletes were instructed to jump as high as possible. The flight time of a single jump was recorded with a micro-processor (Psion[®] CM, ± 0.001 s) connected to the platform (Ergo Jump[®], MAGICA, Rome, Italy). The rise of the center of gravity above the ground was calculated from flight time (t_f) applying the ballistic law:

$$h = t_f^2 \cdot g \cdot 8^{-1} \quad (\text{m}) \quad (1)$$

where g is the acceleration due to gravity $9.81 \text{ m} \times \text{s}^{-1}$. The t_f of each jump recorded by the Psion[®] gave the basis for calculation of average mechanical power, using the equation introduced by Bosco *et al.* [17]:

$$P = T_f \times g \times [(4 \times n_j \times (45 - T_f))] \quad (\text{W} \times \text{kg}^{-1}) \quad (2)$$

where P is the mechanical power per kilogram of body mass, T_f the sum of the total flight time, and n_j the number of jumps performed during 60 s of exercise. Average height and average mechanical power for the total period of work (60 s) and for the separate 15-s intervals (0–15 s, 15–30 s, 30–45 s, and 45–60 s) were also computed. To minimize unmeasurable work, the subject was asked to avoid horizontal and lateral displacements, hands were kept on the hips throughout the test. Knee angular displacement was standardized so that the subjects were required to bend their knees to around 90° . The reproducibility of the continuous jumping test has been reported to be very

high: correlation between test-retest values is $r = 0.95$ [17].

Analytic methods. Following 12 h of fasting, blood samples were drawn at 7:30 a.m. from the antecubital vein before and immediately (within a few seconds) after the execution of 60 s of continuous jumping. Serum samples were frozen at -20°C until analyzed. Serum free thyroxine (fT_4), and free triiodothyronine (fT_3), cortisol (C), total testosterone (tT), free testosterone (fT), and corticotropin (ACTH) concentrations were analyzed by radioimmunoassay (RIA) reagent kits from Diagnostic Products Corporation (Los Angeles, CA, USA). Serum prolactin (PRL), thyroid stimulating hormone (TSH) and growth hormone (GH) were measured using RIA reagent kits obtained from Radium (Pomezia, Italy). Serum insulin-like growth factor I (IGF-I) was analyzed using reagent kits from Diagnostic System Laboratories Inc. (Webster, USA), and sex hormone-binding globulin (SHBG) was analysed using reagent kits from Techland (Liege, Belgium). All samples were analyzed in the RIA counter (COBRA 5005, Packard Instruments Co, Meriden, USA). The intra-assay coefficients of variation for duplicate samples were determined to be 1.8% for GH; 2.3% for ACTH; 2.8% for fT_4 ; 3.51% for tT, fT, and PRL; 4.81% for TSH; 5.31% for SC; and 6.51% for SHBG.

Statistical methods. Means standard deviations and standard errors of the parameters were calculated. Two-tailed Student's t -test was used to test the significance between the values before and after the strenuous jumping performance. Coefficients of correlation between performance parameters and changes produced by the jumping exercises on hormonal parameters were tested using Pearson's product moment technique.

RESULTS

Both the average power and work output decreased drastically over the course of the 60 s of continuous maximal jumping (Fig. 1). A statistically significant difference ($p < 0.01$) was found between the work and power outputs performed during the first (0–15 s) and the last (45–60 s) 15 s of the test. This strenuous supramaximal exercise resulted in pronounced increases in the serum levels of hormones of the pituitary-adrenocortical systems, pituitary-thyroid system, and pituitary-gonadal systems (Table 1). Serum samples collected immediately after the end of performance showed significantly higher concentrations of ACTH, TSH, fT_3 , fT_4 , tT, fT ($p < 0.01$), and C ($p < 0.05$). The level of SHBG was also enhanced

($p < 0.01$). No changes were noted in the levels of GH and PRL. The IGF-I concentration increased insignificantly (by 10%).

No correlation was found between the changes of individual hormone levels. However, a positive correlation ($r = 0.61$, $p < 0.02$) was found between the average power output during jumping and the increase in serum tT (Fig. 2a). A similar correlation ($r = 0.66$, $p < 0.01$) was also observed between the average jumping height and serum tT (Fig. 2b). The decrease in jumping height during the 60 s exercises (difference between the first and the last 15 s) correlated significantly with increases in TSH and fT_4 at $r = 0.52$ and $r = 0.55$ ($p < 0.05$), respectively (Fig. 3a, b). The changes in serum TSH during 60 s jumping indicated a negative relationship ($r = 0.55$, $p < 0.05$) to the average mechanical power developed in jumping (Fig. 4).

Fig. 1 Dynamics of power output during 1-min continuous maximal jumping, analyzed by 15-s periods (mean $\pm$ SE). Number above the column indicates the mean values in $W \cdot kg^{-1}$.

DISCUSSION

In agreement with the results of previous studies, a drastic reduction of average power and work output was induced by the 60-s continuous jumping exercise [17–19]. These findings demonstrate the rapid development of fatigue during this exercise. Immediately after the performed short-term supramaximal exercise, the serum levels of ACTH, C, T, TSH, T_3 , and T_4 were increased. During exercises exceeding the so-

Table 1. Hormone levels before and after jumping exercise.

	Before exercise	After exercise	<i>p</i> value
Corticotropin ($pg \cdot ml^{-1}$)	31.8 $\pm$ 18.1	44.3 $\pm$ 20.9	<0.01
Cortisol ($ng \cdot ml^{-1}$)	181 $\pm$ 31	206 $\pm$ 41	<0.05
Thyrotropin ($\mu U \cdot ml^{-1}$)	1.07 $\pm$ 0.37	1.28 $\pm$ 0.43	<0.01
Free triiodothyronine ($pg \cdot ml^{-1}$)	2.85 $\pm$ 0.68	3.66 $\pm$ 0.75	<0.01
Free thyroxine ($ng \cdot ml^{-1}$)	12.2 $\pm$ 1.7	15.9 $\pm$ 2.1	<0.01
Testosterone total ($ng \cdot ml^{-1}$)	5.8 $\pm$ 0.97	6.5 $\pm$ 1.18	<0.01
Testosterone free ($pg \cdot ml^{-1}$)	16.5 $\pm$ 3.3	18.6 $\pm$ 3.2	<0.01
SHBG ($nmol \cdot ml^{-1}$)	22.2 $\pm$ 16.3	26.8 $\pm$ 16.0	<0.01
Growth hormone ($ng \cdot ml^{-1}$)	2.4 $\pm$ 0.30	2.7 $\pm$ 0.61	N. S.
Somatomedin C ($ng \cdot ml^{-1}$)	106.4 $\pm$ 42.5	117.5 $\pm$ 59.4	N. S.
Prolactin ($ng \cdot ml^{-1}$)	6.18 $\pm$ 1.63	6.12 $\pm$ 1.69	N. S.

Mean $\pm$ SD are indicated.

Fig. 2 Correlation of change in serum testosterone levels with average power output (A) and average jumping height (B) during continuous jumping for 60 s.

Fig. 3 Correlation of decrease in jumping height between the first and last 15 s with TSH (A) and fT_4 (B) levels.

Fig. 4 Correlation of change in TSH level with the average power output in jumping.

called intensity threshold [20] fast activation of the pituitary-adrenocortical system has been demonstrated [6, 7, 9]. Rather rapid responses have also been found in the serum testosterone in short-term weight lifting effort [10] and in the thyroxine level in anaerobic exercise [21]. The fast activation of hormonal systems may be related to stimulation of hypothalamic neurosecretory cells by the neural discharges from the brain cortex (collateral pathway of the central motor command) and from the proprio- and metaboreceptors of working muscles [22, 23].

It may be argued whether the studied endocrine systems are capable of increasing the hormone levels in the blood within one minute. It has been indicated that the peak level of thyrotropin in the blood appeared 20 min after intravenous injection of TRH. GRH increases the plasma ACTH concentration within 15 min following injection. ACTH stimulates the release of cortisol from the adrenals within 2 to 3 min [24]. Therefore, within 1 min after the short-term exercise, the increased hormone levels might not be re-

lated to increased secretion but to a possible extravasation of blood plasma and/or to a "wash-out" of hormones from the gland caused by the increased rate of blood flow. However, the increases of serum concentrations of ACTH, fT_3 , and fT_4 were within 28 to 39%. It is difficult to assume that these changes were related solely to changes in plasma volume because the decrease in plasma volume reached only 15 to 20% in 1-min bouts of exhaustive exercise [25]. The lack of correlation between the observed hormonal changes also makes it doubtful that any general cause resulted in the increased hormone levels.

The anterior pituitary response to CRH is potentiated by catecholamines [26]. Obviously, in this relation the magnitude of the ACTH rise induced by CRH is less than that seen under stressful situations [24]. Therefore, it seems likely that the situations for stimulation of endocrine function are different when stimulation is caused by injection of exogenous hormones or by the endogenous mechanism triggered by exercise. In addition to the fast catecholamine response (see [20]), the rapid metabolic and circulatory alteration in supramaximal exercises may influence the sensitivity of endocrine glands to stimulating influences.

The present results demonstrate that short-term supramaximal exercises results in fast increases in the blood levels of various hormones. Further studies are necessary to clarify the factors contributing to these hormonal changes. Anyway, one must suggest that at least some of them are related to fast stimulation of endocrine function in supramaximal exercise, although the actual magnitude of the responses depends on the sum of various influences, including extravasation of plasma and circulatory changes.

Changes were not found in serum GH and PRL lev-

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els. In fact, an initial delay of 10–20 min preceeds the onset of the increase of serum GH in aerobic exercises [27–29]. An increase in the GH level was found 10 min after, but not immediately and 5 min after a high intensity anaerobic effort [16]. It is also likely that a longer period for blood sampling was required to observe the PRL response after the short-term strenuous exercises. A significant increase in the prolactin concentration has been found in prolonged exercises [30, 31] as well as in intense interval exercise [32].

The tT changes were positively correlated with the power output and average jumping height (Fig. 2a, b). However, the duration of the exercise (60 s) was too short to believe that the effort could be substantially supported by the influence of tT response. It is suggested that individual characteristics influence simultaneously both the power output and the changes in the blood level of testosterone. A positive relationship of explosive jumping performance with both the percentage of fast twitch (FT) fibers in the musculus vastus lateralis [18, 33] and the level of testosterone in boys [34] and adults [35] has been found. Therefore, it is likely that athletes whose physical activities are of the explosive type possess both a high percentage of FT fibers and a high level of testosterone. At the same time, the function of testosterone in training-induced muscular hypertrophy has been well demonstrated [36, 37].

The more pronounced thyroid response was inversely related to the capacity to sustain a high power output in the jumping exercise (Figs. 3a, b, and 4).

Similarly to testosterone, the metabolic actions of thyroid hormones and cortisol appear after a prolonged latent period necessary for synthesis of the concerned enzymes. Therefore, the physiological significance of these hormones will be actualized in the postexercise recovery period but not during the 1-min exercise. The permissive action of cortisol for certain catecholamine and glucagon effects (for review see [38]) may appear only within a couple of minutes or even during the first minute of exercise. During the 1-min supramaximal exercise, the hormonal regulation of metabolism may be exerted mainly by catecholamines and to some extent also by the insulin/glucagon ratio (for review see [37]).

In conclusion, the obtained results indicate that a short-term supramaximal exercise, causing the fast development of fatigue, induces rapid increases in hormone levels of the pituitary-adrenocortical, pituitary-gonadal and pituitary-thyroid systems.

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