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REPRODUCTIVE HORMONES AND CORTISOL RESPONSES TO PLYOMETRIC TRAINING IN MALES

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AUTHOR: Ozen S.V.

Abant Izzet Baysal Universitesi Besyo, Golkoy Kampusu, Bolu, Turkey

Reprint request to:
Serife Vatansever Ozen
Abant Izzet Baysal Universitesi
Besyo, Golkoy kampusu
14000 Bolu, Turkey
E-mail: serifevatansever@yahoo.com

ABSTRACT: Plyometric training activities are commonly used by a wide range of athletes to increase jump performance and improve explosive power and muscular activation patterns. The purpose of the study was to evaluate the effects of plyometric training on male reproductive hormones. Nineteen recreationally active males volunteered to participate in this study and were randomly assigned to plyometrically trained (n=10, 21.2 ±2.3 years) and control groups (n=9, 21.4± 2.1). The plyometric training group performed in a six-week plyometric training programme and the control group did not perform any plyometric training techniques. Resting serum levels of testosterone, prolactin, follicle stimulating hormone (FSH), luteinising hormone (LH), and cortisol were measured in each subject at t0 (before the training), t1 (end of third week) and t2 (end of training). Two-way ANOVA revealed significant ($P<0.05$) interaction effects for testosterone, prolactin, FSH and cortisol. Six-week plyometric training decreased serum levels of testosterone, cortisol and FSH and increased serum levels of prolactin. These results suggest the presence of alterations in anabolic and catabolic hormonal responses to resistance exercise in men.

KEY WORDS: plyometric training, gonadotrophins, testosterone, cortisol, prolactin

INTRODUCTION

Exercise training results in physiological changes and adaptations that are highly beneficial to the human organism. However, a high volume of training can also place a tremendous amount of stress on the organism and result in physiological maladaptations or other detrimental effects. One physiological system that is extremely sensitive to the stress of exercise training is the reproductive endocrine system.

The hormonal response to exercise is dependent on several factors including the intensity, duration, mode of exercise, and training status of the subject [20]. But most authors have focused only on the effects of endurance training on the responses and adaptations of male reproductive hormones. In this regard, it is well documented that endurance training can maximally stimulate the hypothalamic-pituitary-adrenal (HPA) axis [24], but it is not clear whether the different modes of exercise can affect the hormone response. More research is, however, needed on the influence of different modes of exercise and training on the reproductive hormones.

Plyometric training activities, involving a rapid stretch, followed by fast concentric contraction of the involved muscles, are commonly used by a wide range of athletes to increase jump performance and improve explosive power and muscular activation patterns [30]. The majority of the research suggests that plyometric training (PT) improves maximal strength performance and might reduce the risk of injury by enhancing functional joint stability in the lower extremities [19].

A large number of studies have investigated the effects of plyometric training on biomechanical and physical performance [6,8,23]. However, to date, only one study has examined the effects of strength training combined with plyometric training on reproductive hormone levels [12].

To the best of our knowledge, no study has been performed to specifically determine changes in reproductive hormones after plyometric training. Thus, the aim of this investigation was to evaluate the response of reproductive hormones of recreationally active males during and after six weeks of plyometric training.

MATERIALS AND METHODS

Subjects. Nineteen recreationally active males volunteered to participate in this study and were randomly assigned to plyometrically

trained (n=9, 21.2 ± 2.3 years) and control groups (n=10, 21.4± 2.1). Their physical characteristics are presented in Table 2. All measurements were made in triplicate on the right side of the body by the same investigator. To be eligible to participate in the study, subjects were required to meet the following criteria: 1) 18-25 years of age; 2) no injury history for the lower extremities that caused a subject to seek medical help within 1 year before recruitment; 3) no history of use of medications that could alter the hypothalamic-pituitary-gonadal (HPG) axis, such as anabolic steroids; 4) no history of chronic disease, including reproductive disorders; 5) regular eating patterns and no history of depressive illness. Written informed consent was obtained from all subjects after they had received a full explanation of the study procedures. Subjects did not change their usual activity during the period of the study. The study was performed in accordance with the Helsinki Declaration of 1975, and was approved by the Ethical Committee of the University of Abant Izzet Baysal.

Study design

After pre-testing, the subjects in the training group performed 6 weeks of plyometric training (Table 1) modified from that of Spurrs et al. [27], designed for the lower extremity, while the control group did not participate in any plyometric exercises. The plyometric programme involved two sessions per week for the first 3 weeks and three sessions per week for the final 3 weeks. Exercises consisted of various bounds, hops, and jumps in both horizontal and vertical planes. Prior to each session, all subjects underwent a 15-min dynamic warm-up including run throughs, leg swings, skips, ankle bounces, as well as static stretching. Progressive overload principles were incorporated into the programme by increasing the number of foot contacts and varying the complexity of the exercises. For all exercises subjects were instructed to give maximal efforts with minimal ground contact times. The plyometric training group trained at the same time of day, throughout the study. During the training, all subjects were under direct supervision and were instructed on how to perform each exercise.

Three resting blood samples were drawn at baseline (t0: before the plyometric training; control), midpoint (t1: end of third week) and at the end of the study (t2: end of sixth week), 48–72 h after the last training session. All subjects reported to the laboratory at the same time of day (between 08.30 and 09.00) after an overnight fast, having consumed no alcohol or caffeine for at least 24 h nor exercised within the previous 24 h. Subjects were made comfortable for at least 10 minutes before blood collection. A blood sample was then withdrawn by clean venepuncture from each subject for the determination of resting levels of the following hormones: luteinizing hormone (LH), follicle stimulating hormone (FSH), testosterone, prolactin and cortisol. The blood samples were allowed to clot at 4°C and then centrifuged at the same temperature. The serum obtained was separated and frozen at -70°C for later analysis and all samples were assayed on the same day in duplicate.

Anthropometric measurements

Height was measured to the nearest 0.1 cm using a Holtain fixed wall stadiometer. Body mass was measured to the nearest 0.01 kg using a beam balance. BMI was calculated as weight in kilograms divided by the square of height in metres. Skinfold thickness was measured at four sites (triceps, biceps, subscapular and suprailiac) on the right-hand side of the body using calipers (Skinfold Caliper Baseline MM, Fabrication Enterprise Incorporated, New York, US). Several trials were repeated until three tests yielded a difference of less than 0.5%. Body density was calculated using a four-site formula and percent body fat was then estimated using the Siri equation [7,25]. All body weight measurements were obtained with subjects wearing shorts and a tee shirt, without shoes.

TABLE I. THE TRAINING PROTOCOLS FOR THE PLYOMETRIC TRAINING GROUPS. THE EXERCISES ARE PRESCRIBED AS SETS X FOOT CONTACTS. THE PLATFORMS USED IN ALL PLYOMETRIC DRILLS WERE 0.4 M IN HEIGHT

Week/ session	Squat jump	Split scissor jump	Double leg bound	Alternate leg bound	Single leg forward hop	Depth jump	Double leg hurdle jump	Single leg hurdle hop	Total
1/1	2x15	2x15	2x15						90
1/2	2x15	2x15	2x15						90
2/1	2x15	2x15	2x15	2x15					120
2/2	2x15	2x15	2x15	2x15					120
3/1	2x15	2x15	2x15	2x15	2x15				150
3/2	2x15	2x15	2x15	2x15	2x15				150
4/1		3x13	3x13	3x13	2x13	2x10			163
4/2		3x13	3x13	3x13	2x13	2x10			163
4/3		3x13	3x13	2x20	3x13	2x12			171
5/1				3x10	3x10	3x10	3x10	3x10	150
5/2				3x20		3x15	3x12	3x12	177
5/3				3x20		3x15	3x12	3x12	177
6/1					4x12	4x15	4x12	3x12	192
6/2					4x12	4x15	4x12	4x12	195
6/3					4x12	4x15	4x12	4x12	195

Hormone measurements

Hormone levels were measured by the University of Abant İzzet Baysal biochemistry laboratory. Testosterone, cortisol, prolactin, LH and FSH were assayed using the IMMULITE 2000 immunoassay system (Siemens Healthcare Diagnostics, IL, USA), which uses a solid-phase, two-site chemiluminescent immunometric assay. Inter assay and intra assay coefficients of variation (CVs) were as follows: total testosterone 7.3 and 9.4%; cortisol 9.6 and 10.2%; LH 6.4 and 6.1%; FSH 3.1 and 4.5%; prolactin 5.6 and 6.3%.

Statistical analysis

Statistical analysis was carried out using SPSS version 15.0 (SPSS, Inc., Chicago, IL, USA). All the variables were checked regarding their normal distribution using the Shapiro–Wilk test. Data are presented as means ±SD and significance was set at $P<0.05$. Independent t-tests were used to assess differences between baseline values and paired simple t-tests were used to assess differences between pre-test and post-test values. Repeated-measures, two-factor ANOVA was used to examine differences between the two groups over time for testosterone, prolactin, cortisol, LH and FSH. Where significant interactions were found, between-trial differences at each time point were examined using one-way ANOVA and Bonferroni post hoc tests. For correlation analysis, the Pearson coefficient was calculated.

RESULTS

Body composition. Total body mass and percentage of body fat were not significantly changed either in the control or in the plyometric training group (Table 2).

Hormone changes over time

Baseline total testosterone (control 846.20 ± 174.91 ng·dL^{-1}, exercise 859.77 ± 184.94 ng·dL^{-1}), FSH (control 3.07 ± 0.90 mIU·mL^{-1}, exercise 3.16 ± 1.08 mIU·mL^{-1}), prolactin (control 7.34 ± 3.45 ng·mL^{-1}, exercise 7.53 ± 3.80 ng·mL^{-1}), LH (control 3.12 ± 0.89 mIU·mL^{-1}, exercise 3.11 ± 0.89 mIU·mL^{-1}) and cortisol (control 13.95 ± 4.09 μg·dL^{-1}, exercise 14.34 ± 4.50 μg·dL^{-1}) concentrations did not differ significantly (independent t-test, $P>0.05$) (Table 3) between groups.

Two-factor ANOVA revealed a main effect of time and group and time interaction for testosterone, FSH, prolactin and cortisol concentrations (effect of time and time and group interaction respectively: $P=0.000$, $P=0.000$ for testosterone, $P= 0.042$, $P=0.021$ for FSH, $P=0.010$, $P=0.003$ for prolactin and $P=0.003$, $P=0.006$ for cortisol). Post hoc analysis indicated significant differences ($P<0.05$) between exercise and control groups at t1 and t2 for testosterone and at t2 for prolactin, FSH and cortisol (Table 3). Two-factor ANOVA did not reveal a main effect of time ($P=0.896$) or group and time interaction ($P=0.906$) for LH (Table 3).

TABLE 2. DESCRIPTIVE CHARACTERISTICS OF SUBJECTS BEFORE AND AFTER 6 WEEKS OF PLYOMETRIC TRAINING (MEAN±SD)

	Plyometric Exercise		Control	
Variable	Pretraining	Posttraining	Pretraining	Posttraining
Age (years)	21.2 ± 2.3		21.4 ± 2.1	
Height (m)	175.1 ± 6.3		174.0 ± 6.7	
Body weight(kg)	69.2 ± 5.2	68.7 ± 3.4	70.8 ± 2.0	71.2 ± 3.1
Body fat (%)	16.9 ± 2.8	16.5 ± 1.9	17.6 ± 3.2	17.7 ± 2.4

TABLE 3. SERUM HORMONES BEFORE PLYOMETRIC TRAINING/CONTROL (t0), AND AT THE END OF THE THIRD (t1), AND SIXTH (t2) WEEK

	Exercise Group				Control Group				Interaction effect: group x time
	t0	t1	t2	Δ%	t0	t1	t2	Δ%	
Total Testesterone (ng·dL^{-1})	859.7 ± 184.9	779.4±179.1^{b}	664.0±217.5^{b}	-23.9 ^{a}	846.2±174.9	842.3±172.8^{b}	845.5±171.8^{b}	-0.0	P= 0.000*
Cortisol ug·dL^{-1}	14.3±4.5	12.9±3.6	11.6±2.3^{b}	-13.3 ^{a}	13.9±4.0	13.7±3.9	13.8±4.1^{b}	-0.5	P= 0.006*
FSH mIU·mL^{-1}	3.1±1.0	3.0±0.8	2.7±0.7^{b}	-12.0 ^{a}	3.0±0.9	3.1±0.8	3.2±0.9^{b}	1.0	P= 0.021*
LH mIU·mL^{-1}	3.1±0.8	3.1±0.9	3.2±1.2	6.6	3.1±0.6	3.1±0.4	3.2±0.5	0.9	P= 0.906
Prolactin ng·mL^{-1}	7.5±3.8	8.3±4.6	9.2±3.5^{b}	19.9 ^{a}	7.3±3.4	7.2±3.5	7.2±3.4^{b}	-1.6	P= 0.003*

Note: Values are means ± SB, FSH, follicle stimulating hormone; LH, luteinising hormone; *There was an effect of group x time interaction ($P<0.05$) for testosterone, cortisol, prolactin and FSH. ^{a} $P<0.05$, t0 vs. t2 comparison; ^{b} $P<0.05$, exercise group vs. control group comparison (same time point)

We observed a significant decline in total testosterone (-23.99%), FSH (-12.09%) and cortisol (-13.39%) levels and a significant increase in serum prolactin (19.93%) level after the six-week plyometric training compared to the baseline level in the training group. All of these results were statistically significant (paired sample t-test, $P<0.05$). Serum LH levels showed a trend to increase (6.61%) after the six-week plyometric training, but this did not reach statistical significance (paired sample t-test, $P>0.05$) (Table 3).

Correlation

When the correlation coefficients were calculated to examine the relationships among the various changes, there were no significant results.

DISCUSSION

To the best of our knowledge, this is the first study to specifically evaluate the endocrine response to plyometric training in recreationally active males. The results of this study demonstrate that strenuous six-week plyometric exercise training decreased serum levels of testosterone, cortisol and FSH and increased serum levels of prolactin.

The decrease in resting testosterone found in our subjects is in agreement with previous research [2, 21, 24]. At present, the cause of the decrease in testosterone after six-week plyometric training is still unclear. It is possible that exercise training has an affect on the hypothalamus or a direct influence on the testicular secretion of testosterone. Several pathophysiological mechanisms have been proposed to explain the perturbation of the HPG axis including loss of body mass and body fat, impairment of central stimulation of the gonads and peripheral factors [17].

Effects of body mass and body fat on testosterone can be reasonably ruled out given that the body mass and percent body fat of the subjects remained stable during the study. Although some authors have reported changes in basal pulsatile LH release in cross-sectional studies [10], we observed the present decline in serum testosterone levels without change in measures of LH release in this investigation. The lack of changes observed in basal LH is in line with several previous studies [2,13].

Altered central stimulation of the gonads through suppression at the hypothalamic or pituitary level by other hormonal systems such as cortisol or prolactin can also produce lowered testosterone levels. Small amounts of prolactin seem necessary to work synergistically at the testicle with LH, while excessive levels disrupt both central and peripheral aspects of the HPG axis [3]. In the present study the serum prolactin level was increased after plyometric training and the decrease in testosterone may be mediated by the inhibitory effect of hyperprolactinaemia on the HPG axis [1]. The exact mechanism for this lower testosterone effect is uncertain, but may be due to interference with Leydig cell receptors and/or direct inhibition of the steroidogenic synthesis pathway.

In addition, our results also may be explained by peripheral mechanisms, such as greater use of testosterone by muscle tissue and/or greater hepatic clearance of the hormone throughout strenuous physical activity [5]. The concentration of testosterone in the circulation is a function of the amount of hormone entering (testicular production and secretion) and the amount leaving (metabolic clearance) the blood pool [13]. Although this area is in need of much further investigation, one could expect exhaustion of testosterone production to a certain extent as the result of these peripheral factors.

Wheeler et al. [29] suggested that catecholamine may have an inhibitory effect on testosterone production or release under conditions of extreme stress. In agreement with previous research [9,15,17,18,22] a decrease in resting cortisol was found in our subjects. The finding that cortisol is decreased after six-week plyometric training contrasts with previous studies that found increased cortisol after long-term strenuous physical training [4,11,14,26]. The lack of agreement between their findings and our results may be explained by the different mode of exercise conducted in the majority of their studies on endurance training.

At present, the cause of the decrease in cortisol after six-week plyometric training is still unclear. It is possible that a decrease in cortisol concentration is caused by adrenal exhaustion. The decrease in catecholamine levels reported during maximal exercise in over trained athletes is attributable to adrenal exhaustion or the so-called parasympathetic form of overtraining [28].

Although our investigation is limited by the fact that we did not measure adrenocorticotropic hormone (ACTH), from the findings of other investigations it could be expected that an inhibitory and/or exhausting mechanism was responsible for the decrease in cortisol found in our subjects – that is, decreased sensitivity of the HPA axis to cortisol negative feedback in a prolonged stressful situation, and/or decreased responsiveness of cortisol to ACTH stimulation [16].

CONCLUSIONS

Plyometric exercise training would seem to have significant effects upon the major male reproductive hormone, testosterone. The data from the present study, therefore, support the studies of the effects of exercise on reproductive hormones in men. The reduced testosterone levels are not attributable to reduced gonadotrophin secretion or excessive cortisol levels. The findings suggest that increased serum FSH levels, hyperprolactinaemia and peripheral mechanisms, such as increased tissue utilization or hepatic clearance, are responsible for the changes in serum testosterone levels. If this is the case, such mechanisms appear to reduce serum testosterone levels without triggering any change in LH and cortisol release.

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