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Studying changes of testosterone to cortisol ratio in response to aerobic activity by different movement patterns

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ABSTRACT

The effect of movement pattern and intensity of physical activity on hormonal responses have been studied; but, the pure effect of each one while precisely controlling intensity and duration of physical activity on changes of testosterone to cortisol ratio has not been defined yet. Thus, 9 young active men participated in 6 physical activity sessions including 25 min of sub maximal activity with two intensities of 70 and 85% MHR and three different movement patterns (elliptical, cycle ergometer and treadmill). Their blood samples were collected before and immediately after every physical activity session. Testosterone concentration significantly increased after most of the physical activity sessions; this increase was different in different sessions ($F_{5,40}$=7.827, P=0.0001). Serum cortisol concentration decreased after most of the sessions and these variations were different in the six sessions ($F_{5,40}$=2.905, P=0.025). The ratio of testosterone to cortisol increased in most of the exercise sessions and a significant change was observed for the ratio of testosterone to cortisol in the six sessions ($F_{5,40}$=4.206, P=0.004). Although blood concentration increased in most of the activity sessions, no significant difference was reported for the amounts of blood concentration in the six sessions. In spite of the increase in blood concentration which was an important factor for the emergence of hormonal changes, the findings of this study proposed that sub maximal activity in the range of 70 to 85% MHR does not produce physiological pressure in young active men since, in this study, short term and moderate intensity exercising increased testosterone secretion and activated catabolic pathways in young active men. Although, the results of this study was influenced by the increase of blood concentration similar to some of the previous studies, treadmill exercise led to increased testosterone concentration, decreased cortisol concentration and consequently increased testosterone to cortisol ratio due to the weight tolerance characteristic and exercising on the elliptical that requires utilizing both upper and lower organs. This indicates that, while exercising at sub maximal pressure, weight tolerance and volume of the muscles involved in the activity are the main factors in response to steroid hormones.

Keywords: Aerobic Activity, Cortisol, Testosterone

INTRODUCTION

Sub maximal aerobic exercises are those exercises which should be done by all people to protect their cardiovascular performance and obtain a healthy life style. Additionally, growing spread of sports devices has made it necessary to evaluate the amount of physiological pressure caused by exercising with each of these devices. In fact, this study attempted to reevaluate the principle of exercise characteristic. According to the principle of exercise characteristic, promoting physical fitness and movement skill requires using exercises similar to the conditions which govern the activity.

Several researchers have demonstrated that applying different training protocols causes the appearance of physiological changes and improvement of physiological indicators in a physical activity does not necessarily deliver such indicators in other conditions [1,2].

Each one of these studies has used different protocols and movement patterns; also, most studies have investigated cardiovascular responses. But, in this field, changes in testosterone to cotrisol ratio in response to different movement patterns have been less considered. It should be considered that, if there are no hormonal changes, the potential force of human body will remain hidden.

Cortisol is an important hormone for determining physiological stress level and investigating its changes provides appropriate information on the amount of physical activity pressure. Testosterone to cortisol ratio is also considered as the indicator of anabolic–catabolic balance. It has been imagined that cortisol has a negative effect on body; but, catabolic effects of cortisol only show their influences on inactive muscles [3] and increase the amount of available amino acid in this way. Moreover, increase of cortisol is necessary for obtaining sports efficiency [4]. Nazar et al. (1989) represented that exercising with 30% of muscle contraction force did not change cortisol concentration [5]. In contrast, Kraemer et al. (1989) demonstrated that maximum aerobic power of corticotrophin increased in response to exercising for 3 min at the intensity of 36% and, 15 min later, cortisol also increased [6]. In order to define the effect of movement pattern, Few et al. showed that exercising with one leg for 30 min led to more response of cortisol relative to exercising with two legs [7].

Changes of testosterone concentration should be studied more. Testosterone analysis decreases during physical activity, which may increase the blood values of this hormone [8,9]. Additionally, some changes of testosterone are caused by the decrease of plasma volumes [10]. For example, testosterone concentration increases by only 13% after an activity with the intensity of 100% of aerobic power, which is caused by the decrease of plasma volume [11]. While, in one study, testosterone increased significantly in response to a moderate activity [12], in most of the above studies, lotropin concentration had no significant increase. In the previous study of the authors, free concentration of testosterone and cortisol was used in saliva to decrease the stated interventions and it was shown that testosterone concentration increased significantly in response to the 3 different movement patterns during moderate activity in which there was weight tolerance [13]. Anyway, testosterone concentration along with cortisol is used to measure changes of testosterone to cortisol ratio. Considering all the controversial current issues, testosterone to cortisol ratio has been identified as an indicator of anabolic-catabolic balance [14,15].

Investigation of different studies represents some contradictions in their results. For example, Astrand et al. (1965) showed that exercising with hand caused more clear response of catecholamine's [1] while Davies et al. observed the highest response of catecholamine's during exercising with one and two legs [16]. One of the reasons for such contradictions is the use of various training methods. Selection of each method for physical activity requires applying a certain amount of intensity, duration or the muscles involved in the activity. So, one of the objectives of this study was to use controlled movement pattern and intensity for perceiving the pure effect of the selected physical activities on changes of testosterone to cortisol ratio.

Different studies have shown that changes in the rate of organs such as increasing or decreasing number of RPM during the activity has no significant effect on the hormonal response pattern on an ergometer and the training intensity is the factor which causes the emergence of physiological changes [17,18]. Therefore, some percentage of the maximal heart rate was used to control intensity. These percents were considered in accordance with the beginning threshold of hormonal changes that were equal to the percentage of aerobic power [19,20].

Additionally, the present study examined the response of the selected biomarkers to the activity on the devices which found expansion among the general population; this question was raised for the users that whether using these machines would be safe from physiological perspective in addition to biomechanics and kinesiology issues. The effect of activity on the elliptical has been less studied thus far. Despite some limitations such as no repeated measurement, this research evaluated changes of testosterone to cortisol ratio in response to sub maximal activity by controlling intensity and duration of physical activity, daily cycles and changes of blood concentration and focusing on the examination of the effect of movement pattern.

MATERIALS AND METHODS

9 young active men who had regular physical activity 3 sessions per week volunteered to participate in this study (Table 1).

Table 1: Characteristics of the participants according to mean and standard deviation

Age (year)	24.67 ± 3.21
Height (cm)	178.67 ± 6.49
Weight (kg)	73.12 ± 9.96
BMI (kg/h^2 (m))	22.81 ± 1.89
Maximum oxygen consumption (ml/kg/min)	46.12 ± 4.12

Exercises included 7 separate sessions of physical activity with 48 h of resting time between the sessions. The aerobic power of the participants was measured by Bruce test in the first session (Maud and Foster, 1995). Before implementing Bruce test, a warm-up program was designed for 5 min which included walking for 4 min at the speed of 6 km/h on treadmill with the slope of 3% followed by an activity for 1 min at the speed of 8 km/h and the same slope.

Then, the participants performed the physical activity for 6 sessions which included activity on the ergometer, elliptical and treadmill with intensities of 70 to 85% maximum heart rate (Tanaka et al, 2001). The first to third sessions included activity on elliptical (Techno gym Wellness in motion, Italy), ergometer (Techno gym, Bike Race HC 600, Italy) and treadmill (Techno gym run race HC 1200, Italy) in the range of 70% of maximum heart rate; the forth to sixth sessions included activity on the elliptical, ergometer and treadmill in order with the range of 85% of maximum heart rate. Every session was performed in the laboratory environment and top at 2 to 4 pm in order to control the effect of environmental stimuli and routine cycles.

Table 2: The participants' mean of heart rate per activity session (rate/min) according to mean and standard deviation with respect to the order of activity sessions

Elliptical with 70% MHR	134.12 ± 3.92
Bicycle with 70% MHR	138.45 ± 4.28
Treadmill with 70% MHR	134.12 ± 1.84
Elliptical with 85% MHR	159 ± 4.72
Bicycle with 85% MHR	163.34 ± 2.13
Treadmill with 85% MHR	160.34 ± 3065

Blood samples were collected before and immediately after every session of physical activity in the sitting form from the cephalic vein of anterior forearm. The samples were poured into the pipes containing clot activator to remain for some minutes in the ambient temperature; then, serum was separated from the plasma by centrifuge for 10 min with 3500 RPM. Immediately after collecting, the samples were maintained at -20º C to get to the laboratory. Concentration of serum testosterone was tested by chemiluminescence method using American Diasorin kit with 0.05 ng/dl sensitivity and 0.26 ng/dl accuracy; concentration of cortisol serum was also evaluated by radioimmunoassay method using French Immunotec method with 20 mg/dl sensitivity and 10 mg/dl accuracy. The samples were measured in 10 equal periods in order to investigate their intra assay. The sample's coefficient of variation (transformation change) was 5.8%. The samples were measured in two different copies each containing 17 in order to evaluate their inter assay. Coefficient of variation found in the samples was equal to 9.2%.

Statistical Methods

Kolmogorov-Smirnov test was used to assure normalization of data distribution. Paired t test for identical groups was used to understand the difference between hormone's concentration before and after physical activity. Pretest and posttest values were calculated for each biochemical variable to test the effect of movement pattern and activity intensity; then, Analysis of Variance with repeated measures was used for their analyses. Data sphericity was confirmed by Mauchly's test along with the execution of Analysis of Variance. Bonferroni correction was used to understand the location of difference. Significance level of the calculations was $p \leq 0.05$ and all the statistical tests were done in SPSS software (PASW Statistics 18).

RESULTS

Testosterone concentration increased significantly in 4 sessions (Figure 2-A). Changes of testosterone concentration was different in these 6 sessions ($F_{5,40}$=7.827, P=0.0001). There was such a difference before physical activity between the sessions ($F_{5,40}$=3.951, P=0.005). But, significance levels of Analysis of Variance tests showed that these changes were considerable after the physical activity. Bonferroni correction represented that testosterone concentration decreased significantly after the activity on ergometer with the intensity of 70% MHR in comparison with the sessions they worked with elliptical (70% MHR), treadmill (70% MHR) and ergometer (85% MHR). However, less concentration of testosterone was also evident at the basic levels (Figure 2-A). Moreover, there was significant difference between testosterone concentration after activity on treadmill and ergometer devices with intensity of 85% MHR, which was due to the significant increase of testosterone concentration after activity on the ergometer.

Cortisol concentration decreased in most sessions of the physical activity. The paired t test showed that such decrease was significant after training with the treadmill (t=2.874, p=0.021) and elliptical (t=2.898, p=0.02) at the intensity of 70 and 85% MHR, respectively. Cortisol changes were different only after physical activity in the 6 training sessions. Bonferroni correction showed that cortisol concentration had more decrease after training on the treadmill relative to activity on ergometer at the intensity of 70% MHR.

Testosterone to cortisone ratio increased in most of the sessions, which were significant after physical activity with treadmill (t=6.241, p=0.0001) and elliptical (t=2.993, p=0.017) at the intensity of 70 and 85%, respectively. Changes of testosterone concentration had significant difference in the 6 sessions ($F_{5,40}$ = 3.461, P=0.011). There was such a difference before physical activity between the training sessions ($F_{5,40}$ = 4.206, P=0.004). However, Analysis of Variance tests demonstrated that such changes were significant after the physical training. Bonferroni correction represented that testosterone to cortisol ratio was significantly less after training on ergometer at the intensity of 70% MHR in comparison with the activity sessions on elliptical (85% MHR), treadmill (70% MHR) and ergometer (85% MHR). But, there was such decrease at basic levels, as well.

Table 3: Calculating changes of blood concentration with respect to the six physical activity sessions

Activity session	Elliptical 70% MHR	Ergometer 70% MHR	Treadmill 70% MHR	Elliptical 85% MHR	Ergometer 85% MHR	Treadmill 85% MHR
Changes of Plasma volume	-0.58119	-0.53079	0.243314	-5.15368	-4.3597	-2.16592

Table 4: Change of the selected biomarkers between concentrations of pre and post tests
** indicates the significant difference between pre and post exercises*

		Elliptical 70% MHR	Cycle ergometer 70% MHR	Treadmill 70% MHR	Elliptical 85% MHR	Cycle ergometer 85% MHR	Treadmill 85% MHR
Testosterone (nmol/l)	pre	18.99± 4.68	11.89± 5.014	12.64± 3.79	13.77± 4.89	17.82± 5.12	15.88± 4.57
	post	21.55± 5.78*	11.33± 3.29	15.22± 4.82*	16.45± 4.29*	19.97± 4.82*	15.54± 4.55
Cortisol (nmol/l)	pre	400.2± 71.79	470.74± 184.89	420.75±157.93	423.2±118.22	340.09±112.95	405.1±126.26
	post	375.67±70.05	425.35±103.72	320.16±95.23*	320.16±132.78*	405.41±126.84	323.54±161.69
Testosterone to Cortisol Ratio (nmol/l)	pre	0.05±0.02	0.03±0.014	0.034±0.017	0.037±0.021	0.058±0.025	0.043±0.021
	post	0.059±0.019	0.027±0.007	0.049±0.015*	0.059±0.025*	0.053±0.017	0.059±0.029
RBC(10^3/µl)	pre	6.17±0.78	6.65±1.79	6.16±1.35	6.34±1.035	6.64±0.74	6.29±1.15
	post	7.59±1.89*	7.09±2.05	6.64±1.34*	7.78±1.33*	7.78±1.23*	7.19±1.22*
WBC(10^6/µl)	pre	5.41±0.25	5.44±0.27	5.45±.23	5.49±0.52	5.35±.27	5.42±0.21
	post	5.45 ± 0.28	5.45 ± 0.28	5.45 ± 0.24	5.67 ± 0.45*	5.48 ± 0.34*	10.5 ± 1.93
HGB(g/dl)	pre	16.12 ± 0.67	16.19 ± 0.72015	16.15 ± 0.49	16.01 ± 1.005	15.69 ± 0.69	15.95 ± 0.36
	post	16.2 ± 0.7	16.25 ± 0.74	16.18 ± 0.51	16.58 ± 0.87*	16.12 ± 0.85*	16.17 ± 0.38
HCT(percent)	pre	46.08 ± 2.57	46.58 ± 2.55	46.9 ± 1.63	46.32 ± 3.15	45.97 ± 2.32	45.83 ± 1.6
	post	46.14±2.72	46.69±2.64	46.61±1.39	47.53±2.68*	47.16 ± 3.02*	46.39 ± 1.79

Table 5: The result of repeated measured Analysis of Variance (ANOVA) considering the effect size and observed power
*** indicates significant difference**

		F	P	Effect size	Observed power
Testosterone (nmol/l)	pre	3.951	0.005*	0.331	0.914
	post	7.827	0.0001*	0.415	0.998
Cortisol (nmol/l)	pre	1.558	0.194	0.163	0.485
	post	2.905	0.025*	0.266	0.794
FTCR (nmol/l)	pre	3.461	0.011*	0.302	0.869
	post	4.206	0.004*	0.345	0.932

Paired t test showed that changes in red blood cells significantly increased (P=0.04) only after training on elliptical (P=0.04) and treadmill (P=0.022) which was in the range of 70% MHR. However, almost all indicators of red blood cells, white cells, hemoglobin and percent of blood hematocrit increased significantly in response to physical activity with the intensity of 85% MHR. Nevertheless, Analysis of Variance tests did not show any significant changes for blood concentration between the three movement patterns after or before training (Table 4).

The considerable point on changes of blood concentration was the significant increase of the measured indicators after activity on elliptical and ergometer with the intensity of 85% MHR (Table 4). Moreover, variations of plasma volume was calculated in each stage in order to study this point that whether hormonal changes are caused by the pure effect of exercise or are affected by the decreased plasma volumes [21].

$$PV=100*\{(Hb1/Hb2)*[100-(Hct2*0.874)]/[100-(Hct1*0.874)-1]\}$$

DISCUSSION AND CONCLUSION

In summary, none of the applied activities in this study created physiological stress caused by physical activity in young active men. Its reason was the increase of testosterone to cortisol ratio in the all physical activity sessions. Considering the increase of testosterone and decrease of cortisol–almost in all the sessions, testosterone to cortisol ratio changed in the same way as testosterone. Despite the increase of blood concentration in almost all the sessions, Analysis of Variance tests showed that changes of blood concentration were not significant between the training sessions; however, testosterone concentration values were different between the six sessions. So, the observed changes between the six sessions– not after or before the training- was the result of the effect of movement pattern on the hormones and endocrine organs, not the effect of blood concentration and hemodynamic factors.

Various physiological factors such as changes of blood concentration [10] and decrease of removing testosterone from blood under the effect of physical activity [8,9] and the competition between cortisol and testosterone on hormone receptors [22] influenced the creation of such changes. Intensity, duration, hormonal daily cycles, tissue consumption of hormones along with low compatibility of the participants affected changes of the present study [23]. Since the duration of all the sessions was selected to be equal and the participants had almost similar aerobic fitness, this factor was controlled in the present study. Furthermore, short period of training also decreased the effect of this factor. Therefore, the most important factors which could cause hormonal changes in the present work were the applied movement pattern.

According to the results of the present research, testosterone concentration increased significantly after the training sessions with two different intensities. In response to the activity with elliptical device, testosterone concentration significantly increased regardless of the physical training. Compared with this result, training with ergometer caused testosterone increase only at the intensity of 85% MHR. And, treadmill changes caused significant increases only at the intensity of 70%. Comparison of these results proposed this finding that testosterone was affected by movement pattern. Weight tolerance and using more volume of the muscles involved in activity on the elliptical device led to the increase of testosterone at both intensities; however, this point was only true in response to running movement pattern only at sub maximal intensities and for short duration (25 min).

Despite testosterone increase in response to activity on treadmill, activity changes were significant with the intensity of 70% MHR. Probably, running pattern caused more pressure due to weight tolerance on one leg at different times of the activity with moderate intensity so that higher intensities do not strengthen anabolic processes. But, weight tolerance factor and using muscular forces with moderate intensity still prevent the generation of catabolic changes [3]. Its reason is the non-significant decrease of cortisol and non-significant increase of testosterone to cortisol ratio in response to the activity on treadmill with the intensity of 85% MHR. Although stimulating the secretion of cortisol requires using the intensity and duration levels beyond the ones used in this protocol in the present study, efficacy of the volume of involved muscles in the activity and body weight tolerance would be considered when it is know that no significant changes were observed for testosterone in response to the activity on egometer with the intensity of 70% MHR. But, the increase of testosterone in response to the activity on ergometer with the intensity of 85% MHR indicated the main effect of intensity during the absence of weight tolerance and the muscles involved in the activity.

Since controlling intensity was fulfilled by some percent of heart rate in the present study, another main point was that how these different movement patterns affected heart function in order for the participants to obtain the considered ranges. Each movement pattern could affect blood pressure and cardiac output, which is due to the beaten volume and number of heart rate.

Astrand et al. (1965) showed that training with hands caused higher blood pressure than training with legs [1]. This might be due to less vascular network of the hands and more stimulation of epinephrine. There were probably similar mechanisms for increasing testosterone since activity on elliptical, which required the application of lower and upper organs in the present study, caused significant increase of testosterone. Nevertheless, Davies et al. (1974) represented that practicing with hands caused more catecholamine response than practicing with legs and indicated that the most evident response of catecholamines was observed during exercising with two legs. They said that the response of catecholamine's had an inverse relationship with the volume of the involved muscles [16]. It should be considered that cortisol's response strengthened the function of catecholamine's [24].

Another main factor was training states which were in standing, sitting or sleeping positions. When practicing in the standing position with sub maximal intensity, the increase of the last diastolic volume is the most important factor of the increase in vascular output. So, the athlete makes more effort to get into the considered range of heart rate [11]. There is a suitable venous return during swimming; but, activity with hands probably cause increase heart rate. Muscular pumps' functioning during standing training and non-resistance of blood to the gravity during sleeping exercises are the most important factors of blood's venous return and increase of the last diastolic volume. In contrast, the increase of heart rate supplies the cardiac output during the activity on ergometer due to the aggregation of blood in the lower organ. One of the reasons that cortisol and testosterone did not change significantly after the activity on the ergometer in the present study was that heart rate increased before supplying suitable cardiac output.
Finally, the results of the present study proposed that sub maximal activity in the range of 70 to 85% MHR did not generate physiological pressure in young active men. Weight tolerance and volume of the muscles involved in the activity were the main factors in response to steroid hormones during the activity with sub maximal intensity. Considering various mechanisms which affect hormonal responses, the future studies should investigate the schemes which encompass more features of testosterone to cortisol ratio and focus on the effect of movement pattern.

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