EFFECT OF PROLONGED EXERCISE ON SERUM TESTOSTERONE LEVELS IN ADULT MEN

R. J. YOUNG,* Ph.D., A. H. ISMAIL,* H.S.D., A. BRADLEY,* Ph.D., and D. L. CORRIGAN,* Ph.D.

**Department of Physical Education for Men, Purdue University, West Lafayette, Indiana, 47907, U.S.A.*

***Damon Medical Laboratory, Inc., Philadelphia, Pennsylvania, 19047, U.S.A.*

ABSTRACT

The purpose of the study was to: 1) identify the differences in serum testosterone levels among four groups of adult men differentiated on the basis of physical fitness and age, and 2) determine the effect of a four-month physical fitness programme consisting of running, calisthenics and recreational activities on the serum testosterone levels of the four groups. The groups were designated: high-fit, young aged about 32 ($n = 7$); high-fit, old aged about 52 ($n = 7$); low-fit, young ($n = 7$), and low-fit, old ($n = 7$). The subjects were selected and grouped according to physical fitness scores obtained using the regression equation of Ismail *et al.* Serum testosterone was determined by a radioimmunoassay method. The pre-test ANOVA revealed that the high-fit groups had a significantly ($p < .01$) higher testosterone level (754.29 ng/100 ml) than the low-fit groups (548.07 ng/100 ml) and the high-fit, young group (925.01 ng/100 ml) was significantly ($p < .01$) higher than the other three groups. Post-test values were adjusted using pre-test testosterone values as covariates. No significant differences among the groups were found indicating that the serum testosterone levels were the same regardless of different ages and fitness levels. The findings were discussed in light of physiological, biochemical and psychological factors.

INTRODUCTION

Testosterone is produced by the Leydig cells of the testes (Judd *et al.*, 1974) and plasma concentrations in adult human males average from 200 to 1000 ng/100 ml (Kent and Ancone, 1966; Starka *et al.*, 1971; Tanda, 1971). Circulating levels are known to rise sharply during adolescence, peak in the twenties and gradually decrease thereafter (Tanda, 1971). The most potent biological effect of testosterone is its stimulation of growth of sexual tissues (Turner, 1966), however, it is also thought to increase: appetite, lean body weight; red cell production; bone density; sugar uptake by muscle; muscle glycogen storage, and protein synthesis associated with gains in muscle strength (Lamb, 1975). In addition, testosterone has been related to aggression in both animals (Lee and Griffo, 1973; Payne and Swanson, 1972; Rose *et al.*, 1969) and man (Kreuz and Rose, 1971; Meyer-Bahlburg *et al.*, 1974; Persky *et al.*, 1971).

Circulating levels of testosterone inhibit the pituitary gland through a feedback control mechanism effective on gonadotropins (interstitial cell stimulating hormone). Moreover, through monoaminergic neurons, the hypothalamus exerts primary control of gonadotropin release (Davidson, 1966; Kordon and Glowinski, 1970). Stressful environmental stimuli are thought to influence testosterone production rate and to reduce androgency (Levin *et al.*, 1967). In fact, a reduced secretion has been associated with surgical stress (Carstensen *et al.*, 1969; Matsumoto *et al.*, 1970), electrical shock (Mason *et al.*, 1968) and psychological stress (Kreuz *et al.*, 1972; Rose, 1969).

The literature dealing with the effects of exercise on testosterone levels is extremely limited and inconclusive. Sutton *et al.* 1973, investigated the androgen response during acute physical exercise in highly trained rowers and swimmers and in normal male medical students. They found that plasma levels rose in response to maximal exercise but not to submaximal exercise. In contrast, Bliss *et al.* 1972, found that rats, when exercised by swimming for one hour, demonstrated a depletion of testosterone both in the plasma and testes. Similar decrements were observed in animals given electrical shock stress.

Vermeulen 1973, in a study to determine the effect of physical exhaustion on plasma testosterone in six normal males, determined plasma levels before and after a three day mountain-climbing tour. Plasma testosterone levels were greatly decreased after the tour compared to pre-exercise values.

From all indications, the effect of different kinds of exercise on testosterone is still controversial and unclear. Consequently, the present study was designed to examine the effect of physical fitness and age on testosterone levels in serum of adult males. More specifically: 1) to identify the differences in serum testosterone concentration among four groups of adult men which were differentiated on the basis of physical fitness and age,

FOOTNOTE:

Address correspondence to Dr. R. John Young,
Department of Physical Education for Men, Purdue University,
West Lafayette, Indiana 47907

and 2) to determine the effect of a four-month physical fitness programme on the serum testosterone concentrations of the four groups.

METHODS

Subjects

Subjects in this study were 28 Purdue University faculty and staff members and local businessmen, 21 to 61 years of age, selected from 58 individuals who participated in a four-month physical fitness programme. Each participant was required to pass a physical examination by his family physician before being accepted into the programme. Four groups of seven subjects each were established using age and physical fitness scores obtained on each individual according to the physical fitness criterion of Ismail *et al.* 1965. These groups were designated high-fit, young; high-fit, old; low-fit, young, and low-fit, old, the "young" subjects having an average age of about 32, and the "old" 52.

Physical Fitness Programme

The physical fitness programme consisted of three 90 minute sessions weekly during the lunch period for four months. At each session subjects took part in: jogging for warm-up (10 minutes maximum), calisthenics (25 minutes maximum), running (25 minutes maximum), and self-selected recreational activities (30 minutes maximum). Attendance was recorded at each meeting and the running and calisthenics were progressively intensified during the four month period. While the distance ran varied according to the ability of the individual it was between one half and five miles. The recreational activities consisted of basketball, volleyball, squash, handball and swimming.

Physical Fitness Assessment

For classificatory purposes relevant physiological data were collected before and after the programme and physical fitness scores were obtained for each subject using the fitness criterion of Ismail *et al.* 1965. The criterion consists of a regression equation containing six variables which have a high predictive value when assessing physical fitness ($R^2 = .88$; $R = .94$). They are as follows:

Item	Beta Weight
1. Submaximal exercise heart rate	-1.33
2. Percent lean body weight	4.88
3. Max $\dot{V}O_2$ ml/kg lean body mass	2.50
4. Submaximal minute volume ventilation/kg body weight	-119.02
5. Resting diastolic blood pressure	-1.36
6. Resting pulse pressure	1.31
Constant	61.90

Each subject was required to rest for 10 minutes in the supine position during which time electrodes were attached to his chest to permit accurate monitoring, via an electrocardiograph, of his heart rate during exercise. At the end of the 10 minute rest, heart rate, systolic blood pressure and diastolic blood pressure were recorded. Percentage of lean body weight was estimated using the anthropometric method of Wilmore and Behnke 1969.

The subject then walked on a treadmill for 10 minutes at 3 mph (a distance of one half mile) with the grade being increased by two degrees every two minutes to a maximum of eight degrees. During the last 30 seconds of the walk a submaximal respiratory gas sample and heart rate were collected.

Without stopping, the subject then commenced running at a speed of 6 mph with the grade being increased each two minutes from zero to a maximum of 10 degrees if exercise was not terminated beforehand. The heart rate was monitored continuously and the subject indicated when he wanted to terminate the run, whereupon the expired air and heart rate were collected. Submaximal and maximal $\dot{V}O_2$ were determined using a Beckman OM-11 oxygen analyzer and a Beckman B1-1 medical gas analyzer. The percentage of O_2 and CO_2 obtained were applied to a nomogram (5) to obtain the true O_2 percentage. Oxygen consumption in litres was then calculated using the true O_2 percentage and the expired air volume (STPD). This volume was converted into litres per minute and divided by lean body weight in kilograms to obtain the desired unit of measurement.

On the post-programme test the subject performed a second run during which a new maximum was attained. The same measures were taken at the end of the second run as were collected at the end of the first.

Serum Testosterone

Venous blood samples were drawn, following a 10 minute bed rest, from the antecubital vein using a standard plain Vacutainer tube system. Two 10cc Vacutainers of blood were collected and allowed to stand for 15 minutes after which they were centrifuged at 3,000 rpm for 10 minutes and the serum separated. All samples were obtained between 0700 and 1000 hours, stored at $-20^\circ C$ and assayed within two months from the time of collection. Serum testosterone was determined by a modification of the radioimmunoassay technique described by Chen *et al.* 1971 using reagents supplied by Wien Laboratories, Inc., Succasunna, New Jersey.

Statistical Analysis

The analysis of variance technique was employed to determine the differences in serum testosterone con-

centrations between the four groups before the fitness programme. Whenever significance at the 0.05 level was found the means representing the levels of each effect were analyzed by the Newman-Keuls procedure to determine the mean or means responsible for contributing to the significant results obtained.

At the post-test an analysis of covariance was performed using the pre-test testosterone values as co-variates.

RESULTS

The pre- and post-test means and standard errors for age, weight, percent lean and physical fitness score are presented in Table I. The pre- and post-test testosterone levels and the adjusted post-test testosterone level for each group are presented in Table II.

TABLE I

Means and standard errors of the physiological data

	High-fit		Low-fit	
	Young (n = 7)	Old (n = 7)	Young (n = 7)	Old (n = 7)
Pre-test				
Age (years)	31.9 ± 2.0	51.4 ± 1.8	31.7 ± 1.5	52.4 ± 1.6
Weight (kg)	73.1 ± 4.4	71.8 ± 4.2	94.4 ± 7.8	83.5 ± 2.9
Percent Lean	85.2 ± 1.5	87.7 ± 1.8	78.8 ± 1.9	77.3 ± .9
Physical Fitness Score	402.5 ± 18.4	389.2 ± 6.9	280.7 ± 11.1	272.5 ± 10.0
Post-test				
Weight (kg)	72.8 ± 3.9	71.7 ± 4.0	93.0 ± 7.6	83.6 ± 3.0
Percent Lean	85.7 ± 1.4	88.8 ± 1.6	78.9 ± 2.1	78.9 ± .7
Physical Fitness Score	392.3 ± 14.9	414.1 ± 4.8	334.7 ± 19.4	313.3 ± 18.0

The results obtained from the pre-test analysis of variance are presented in Table III. The main effect of fitness (F) and the fitness x age (FA) interaction were found to be significant at the .01 level. The pooled pre-test mean of the high-fit group (754.29 ng/100 ml) was significantly higher than the pooled mean of the low-fit group (548.07 ng/100 ml). When the means representing the levels of each effect in the FA interaction were analysed by the Newman-Keuls procedure, the mean for the high-fit young group (925.01 ng/100 ml)

TABLE II

Means and standard errors of the serum testosterone data

	Serum Testosterone (ng/100 ml)		
	Pre-test	Post-test	Post-test (adjusted)
High-fit Young (n = 7)	925 ± 60	787 ± 117	602 ± 91
High-fit Old (n = 7)	584 ± 46	629 ± 54	674 ± 35
Low-fit Young (n = 7)	445 ± 48	590 ± 75	729 ± 100
Low-fit Old (n = 7)	651 ± 88	625 ± 72	625 ± 26

was found to differ significantly ($p < .01$) from the mean for the low-fit, young (445.30 ng/100 ml); the high-fit, old (583.56 ng/100 ml), and the low-fit, old (650.84 ng/100 ml) groups.

The results obtained from the analysis of covariance on the post-test data revealed that no significant differences existed between the four groups (Table IV).

TABLE III

Analysis of variance of serum testosterone at the pre-test

Source	d.f.	M.S.	F
F (high vs. low)	1	297670	10.77**
A (young vs. old)	1	32327	1.17
FA	1	523616	18.94**
P (FA)	24	27641	

****Significant at the .01 level.**

TABLE IV

Analysis of covariance of serum testosterone at the post-test

Source	d.f.	M.S.	F
F (high vs. low)	1	7332	.20
A (young vs. old)	1	1666	.05
FA	1	30327	.83
P (FA)*	23	36759	

***Since 1 d.f. was lost for the covariate only 23 remain for the error term in contrast with the 24 d.f. in the analysis of variance (Table III).**

DISCUSSION

Subjects in this study were observed to undergo beneficial physiological changes as evidenced by generally higher physical fitness scores at the end of the physical fitness programme. The serum testosterone values obtained for each group were similar to reported averages of normal male subjects of comparable ages determined by a variety of techniques (Kent and Acone, 1966; Starka *et al.* 1971; Tanda, 1971).

At the pre-test, the mean testosterone level of the high-fit groups (754.29 ng/100 ml) was significantly ($p < .01$) higher than the mean of the low-fit groups (548.07 ng/100 ml) due primarily to the above average testosterone level of the high-fit, young group (925.01 ng/100 ml) and the relative low level of the low-fit, young group (445.30 ng/100 ml). When the post-test values were adjusted using pre-test values as covariates no significant differences were observed between the four groups (Table IV).

In this study, slight nonsignificant reductions in weight and increases in percent lean body weight were observed for each group (Table I). In light of the fact that androgen insufficiency has been related to obesity in males (Tapperman, 1973) it is interesting to speculate that even a slight increase in percentage of lean body weight may be reflected in serum testosterone level particularly since no control for diet was made during this study other than to request participants to keep their caloric intake constant.

Testosterone is known to stimulate growth hormone secretion (Martin *et al.* 1968) resulting in an increased production of protein matrix and an increased retention of calcium by bones. White 1973, in a study using subjects from the same population as those in this study found that regularly active subjects (similar to the high-fit subjects in this study) had slightly higher resting mean growth hormone levels both before and after the

exercise programme. Since there are apparently three pools of testosterone in men which have mean half lives of 6.6 min., 33 min. and 3.4 hours, respectively (Bailleau and Robel, 1970), there is reason to believe that either acute or chronic exercise is likely to be associated with higher production of testosterone.

The response patterns of serum insulin and growth hormone during exercise are known to be opposite. A rise in growth hormone level tends to follow a decline in insulin production. During prolonged steady state exercise lipid substrates are the preferred source of energy. Their availability is mainly dependent on growth hormone which in turn increases glucose and glycogen storage due to a lack of utilization. Interestingly, testosterone has been implicated in the mechanism responsible for glycogen supercompensation following acute exercise (Gillespie and Edgerton, 1970).

It would appear from the data in this study that serum testosterone levels are not purely a function of age. More important may be its relationship with hormones involved in energy metabolism particularly during exercise. Furthermore, there is strong evidence to suggest that testosterone secretion is highly related, not only to physiological but also, to psychological and environmental factors such as aggression, emotionality and social status. Perhaps the psychological characteristics associated with the poor physical condition of the low-fit, young group in this study prior to participation in the physical fitness programme resulted in a suppression of testosterone secretion. The secretion rate may have been subsequently elevated when the physical fitness condition of the group improved.

FOOTNOTE

The experiments described in this paper were approved by the Committee on the Use of Human Subjects in Research at Purdue University.

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