ORIGINAL ARTICLES

VARIABILITY OF CORTICOSTEROID RESPONSES DURING EXERCISE STRESS IN ACTIVE AND SEDENTARY MIDDLE-AGED MALES

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ABSTRACT

Two groups of middle-aged male subjects (both N=11), one active (mean age 44.6 years) and one sedentary (mean age 43.7 years), undertook a graded exercise stress test on a bicycle ergometer in the post-absorptive state. Blood serum corticosteroid levels were measured at the following stages of metabolism; at rest, under conditions of submaximal and "maximal" exercise and during recovery. The active group showed no significant change in mean serum corticosteroid levels from resting values, during exercise and recovery. However the sedentary group displayed a significant increase in mean serum corticosteroid levels from a resting value of 5.81 ± 0.41 µg/100 ml. (mean ± S.E.) to 7.83 ± 0.71 µg/100 ml. during "maximal" exercise ($p < 0.05$), which was maintained throughout recovery 7.82 ± 0.70 ug/100 ml ($p < 0.05$). Furthermore the active group demonstrated significantly lower mean serum corticosteroid levels compared with the sedentary group under conditions of submaximal ($p < 0.05$) and "maximal" ($p < 0.01$) exercise and during recovery ($p < 0.01$). It was concluded that the variability in the response patterns of serum corticosteroids during exercise stress in active and sedentary middle-aged males, reflected the physiological differences observed between the two groups of subjects.

Introduction

Studies concerning the effects of physical activity upon the structure and function of the adrenals in animals are well documented. Adrenal hypertrophy associated with chronic conditioning (2) and increased levels of circulating adrenal secretions resulting from acute exercise have been demonstrated (2, 3, 22, 23). Furthermore specific relationships have been observed between corticosteroid activity, facilitated carbohydrate metabolism (6, 17, 21) and muscular work performance (10, 12). It is now generally accepted that the corticosteroids play a vital role in the mechanism of adaptation of the organism to exercise stress.

However research in humans has not been characterised by agreement upon the precise pattern of the adrenocortical response to exercise stress. Several investigations have demonstrated a reduction in serum corticosteroids resulting from exercise (4, 5, 14, 18) whereas other work has failed to find any significant changes in the circulatory levels of these hormones (19). Alternatively, much evidence exists to support an increase in corticosteroid levels during or after exercise (5, 7, 13, 14, 15, 20, 24). These differences in findings may be indicative of variability both in the experimental protocol utilised and the nature of subjects studied. Moreover, relatively few studies have taken into account the influence of previous physical conditioning when attempting to explain experimental findings.

Review of Literature

Staehelin et al. (20) found that exercise consisting of a 2 hour bicycle ergometer ride at 100 Watts produced an increase in plasma corticosteroids at 15 and 30 minutes followed by a decline to 40% of starting values by the end of the work period. In contrast Cornil et al. (4) found that bicycle ergometer exercise of 20 minutes duration at 100 Watts in sedentary subjects resulted in a fall in plasma cortisol levels. Alternatively Raymond and co-workers (18) demonstrated a 37% reduction in baseline values of serum corticosteroids in subjects who exercised on a treadmill for 30 minutes at 3 mph on a 5% positive grade.

A study by Rose et al. (19) showed no significant difference between control levels of plasma cortisol and those obtained upon completion of a mile run in conditioned subjects. However Wenzkat et al. (24) using trained sportsmen found elevated plasma cortisol levels when subjects were exercised to exhaustion. Lehnert, Lieber and Schaller (13) reported an immediate rise in plasma corticosteroids during graduated exercise of 100 to 150 Watts for 9 to 15 minutes of bicycle ergometer work.

A number of studies provide evidence that corticosteroid secretions in exercise may be dependent upon the degree of work load in relation to the subject's maximal work output rather than the absolute amount of work performed. Métivier et al. (15) found similar increases in plasma cortisol levels in trained individuals who exercised at 50% and 60% of their $V0_2$ max. Harley and co-workers (7) determined the effect of graded exercise involving work loads of 42%, 75% and 98% of $V0_2$ max on plasma cortisol levels and observed no increase above resting values except during the heaviest work load. Davies and Few (5) found that during 60 minutes of treadmill exercise, a work load of approximately 60% $\dot{V}0_2$ max appeared to be the critical level above which a rise in plasma cortisol occurred.

The effect of physical conditioning on plasma cortisol levels during 30 minutes of bicycle ergometer work at 750 kpm and 60 rpm was investigated by Métivier et al. (14). Untrained individuals demonstrated progressive increases in plasma cortisol whereas trained individuals showed an initial increase followed by no change during the work period. Alternatively, Hartly and co-workers (8) assessed the effect of a 7 week training programme on the plasma cortisol response to exhaustive bicycle ergometer exercise of moderate intensity but found no significant differences between pre- and post-test training response patterns.

In the present study we have determined the serum corticosteroid level in active and sedentary groups of middle-aged male subjects during consecutive periods of rest, submaximal and "maximal" exercise, and during recovery, in order to measure the variability of response patterns associated with physical conditioning.

Methods

Subjects. Twenty two male subjects, ages 27-57 years, were used in the study. All were faculty members of Purdue University and participants in an adult physical fitness programme. Each subject gave his written consent and had undergone a complete medical examination before participating in the study. Two groups were established, one active and one sedentary (both N=11) using physical fitness scores obtained on each individual according to the fitness criterion of Ismail et al. (11). The criterion consists of a regression equation containing six variables which have a high predictive value when assessing physical fitness (R^2 = .881; R = .939). These are as follows:

	Item	Beta Weight
1.	Exercise heart rate	-1.329
2.	Percent lean body weight	4.880
3.	Maximum oxygen uptake ml/kg lean body mass	2.502
4.	Submaximal minute volume ventilation/kg body weight	-119.017
5.	Resting diastolic blood pressure	1.310
6.	Resting pulse pressure	1.310
	Constant	61.9

The physical characteristics of the two groups of subjects are presented in TABLE I.

Table I. Physical characteristics of the two groups of subjects who participated in the study.

	Active Group Mean ± S.E.	P (Act – Sed)	Sedentary Group Mean ± S.E.
Age yr.	44.6 ± 2.5	N.S.	43.7 ± 2.5
Height cm.	181.3 ± 1.6	N.S.	182.9 ± 2.2
Weight kg.	82.9 ± 3.4	0.01	102.3 ± 7.8
% lean	84.2 ± 1.6	0.01	77.1 ± 1.2

The Physical Fitness Test. On reporting to the laboratory each subject was allowed to rest for 10 minutes in the supine position after which cardiac frequency, blood pressure, height, weight and percent lean body weight were recorded. The subject then performed a submaximal ride of 10 minutes duration on a bicycle ergometer (Monark, Sweden) at a work load of 600 kpm and pedalling frequency of 50 rpm. This was followed immediately by a bout of "maximal" exercise which involved an increase in the work load of 150 kpm min^{-1}. In order to establish a "maximal" response, a safety criterion cardiac frequency value of 160 beats min^{-1}. was employed (1), or prior to this, if the subject indicated that he was exhausted and could no longer maintain the required pedalling frequency. After the exercise had been completed, the subject spent 15 minutes in recovery in the supine position.

Venous blood samples were drawn from the antecubital vein at rest, during submaximal and maximal exercise and following recovery. Serum was separated, frozen and later analysed for corticosteroid concentration. The subject's respiratory and cardiac responses were monitored at each stage of exercise and $V0_2$ and fH were determined. The physiological responses of the two groups of subjects during the physical fitness test are presented in TABLE II.

All subjects were studied in the post-absorptive state between 0800 and 1200 hours in order to minimise the

Table II. Physiological responses of the active and sedentary groups of subjects

	Cardiac frequency (Beats min^{-1})				Oxygen intake (ml. kg^{-1} min^{-1})			Resting Blood Pressure (mmHg)		
	Rest	Submax	Max		Submax	Max		Syst.	Diast.	Pulse
Active Mean ± S.E.	58.7 ±2.4	110.0 ±4.1	157.3 ±3.8		22.6 ±1.2	45.4 ±1.6		126.4 ±4.3	77.8 ±1.7	47.7 ±2.9
P (Act – Sed)	0.05	0.01	N.S.		N.S.	0.01		N.S.	0.01	N.S.
Sedentary Mean ±S.E.	66.7 ±2.8	124.4 ±5.4	154.6 ±2.4		24.8 ±2.0	36.4 ±2.0		133.1 ±3.6	88.7 ±3.5	44.4 ±2.2

effects of diurnal variation (9). Furthermore each subject was familiarised with the bicycle ergometer test before the investigation.

Oxygen intake (VO_2). The subjects inspired through a 3-way "J" valve and expired air was collected during the last 30 seconds of each exercise bout in a 150 litre Tissot gasometer equipped with a kymograph. All volumes of expired air were corrected to STDP and duplicate samples were analysed for O_2 and CO_2 using a Beckman 777 oxygen analyser and a Beckman B1-1 medical gas analyser respectively. Both instruments were calibrated at frequent intervals using commercial gas mixtures of known concentrations which had been checked using the micro-Scholander apparatus.

Cardiac frequency (fH). Cardiac frequency was monitored at rest and throughout the exercise period using a stethoscope placed at the apex of the heart. The rate per minute was noted during the last minutes of each stage of exercise.

Percent lean body weight (% lean). The percentage of lean body weight was estimated using the method of Wilmore and Behnke (25).

Blood pressure. Blood pressure was recorded using a standard clinical sphygmomanometer and a stethoscope placed over the brachial artery. Systolic and diastolic pressures were noted and pulse pressure determined.

Serum Corticosteroids. Blood samples were centrifuged at 3,000 rpm for 10 minutes and serum was separated and kept frozen until analysed. Total serum corticosteroid concentration (cortisol and cortisone) was measured by a modification of the competitive protein-binding technique of Murphy (16).

The time course of changes in mean cardiac frequency and oxygen intake for the active and

Results

sedentary groups during different stages of exercise is shown in Figure I.

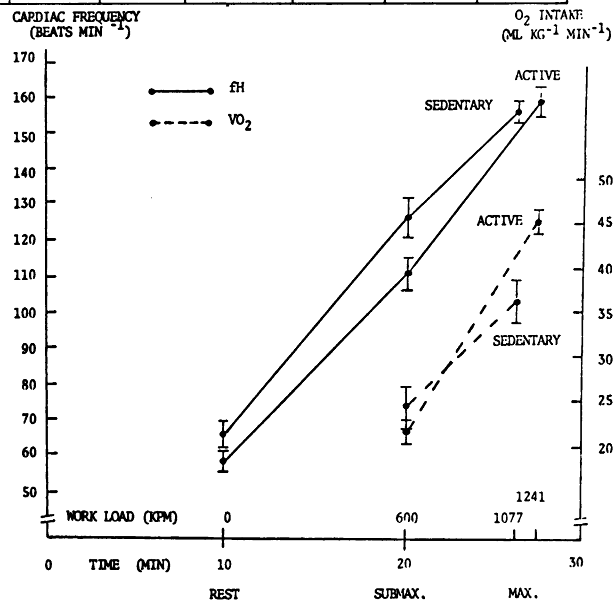

Figure 1. Mean (± S.E.) cardiac frequency and oxygen intake changes in the active and sedentary groups during different stages of exercise.

The active group had significantly lower mean cardiac frequency at rest ($p < 0.05$) and during submaximal exercise ($p < 0.01$) than the sedentary group. Furthermore the active group had significantly higher oxygen intake ($p < 0.01$) during "maximal" exercise than the sedentary group at comparable cardiac frequency and this was associated with correspondingly increased intensity and duration of the work performed.

The physiological differences between the two groups of subjects are shown in TABLE II.

The time course of changes in mean serum corticosteroid levels for the active and sedentary groups of subjects during different stages of exercise is shown in Figure 2.

The active group showed no significant change in

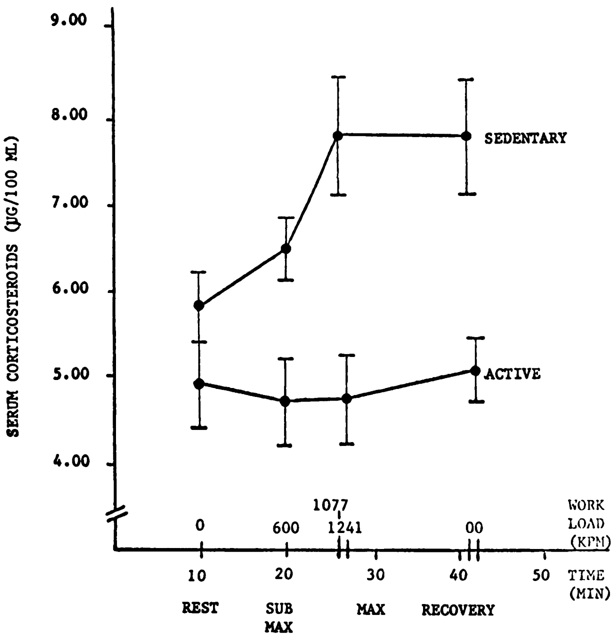

Figure 2. Mean (± S.E.) serum corticosteroid concentrations of the active and sedentary groups at different stages of exercise.

mean corticosteroids neither during exercise nor during recovery. In contrast the sedentary group displayed a significant rise in mean corticosteroids from a resting value of 5.81 ± 0.41 µg/100 ml, during maximal exercise, 7.83 ± 0.71 µg/100 ml ($p < 0.05$) which was maintained during recovery, 7.82 ± 0.70 µg/100 ml ($p < 0.05$). Furthermore the active group had significantly lower mean corticosteroids than the sedentary group during submaximal exercise ($p < 0.05$), maximal exercise ($p < 0.01$) and recovery ($p < 0.01$) as shown in TABLE III.

Table III. Comparison of serum corticosteroids (µg/100 ml) of the active and sedentary subjects during different stages of exercise

	Active Group Mean ± S.E.	P (Act – Sed)	Sedentary Group Mean ± S.E.
Rest	4.91 ± 0.51	N.S.	5.81 ± 0.41
Submax	4.73 ± 0.51	0.05	6.50 ± 0.41
Max	4.76 ± 0.52	0.01	7.83 ± 0.71
Recovery	5.11 ± 0.39	0.01	7.82 ± 0.70

Discussion

The results of this study demonstrate that the response pattern of serum corticosteroids to exercise is partly dependent upon the fitness status of the subjects tested.

In the case of the sedentary group the early rise in corticosteroids showed that graded exercise to near exhaustion resulted in physiological stress in these subjects which persisted throughout the recovery period. However since no such response was observed in the case of the active group, leads us to suggest that the active group were more able to tolerate the physiological stress imposed by the exercise. No doubt this was due in part to the fact that the exercise was not so exhaustive for the active group since the same criterion of a "maximal" response was employed for both groups of subjects, namely a cardiac frequency of 160 beats min^{-1}.

Most investigations cited in this study have been restricted to groups of subjects who were classified either as sedentary (4) or active (15, 19, 24), or more generally as "normal healthy" subjects (13, 18, 20). However a study by Métivier (14) noted lower corticosteroid levels in trained subjects compared with untrained subjects who performed steady state exercise, a finding which tends to be supported by our results. Furthermore it is suggested that the exercise stress tolerance exhibited by the active group in comparison with the sedentary group appeared to be related to their enhanced fitness status. Indeed the difference in the response patterns of corticosteroids during exercise stress between the active and sedentary groups are reflective of the physiological differences between the two groups of subjects (TABLE II). Therefore the phenomenon of exercise stress tolerance may be related to the chronic effects of physical conditioning since it was ascertained by personal interview, following fitness classification, that the groups of subjects selected had been "active" and "sedentary" since early adulthood.

The rise is corticosteroids during exercise in the sedentary group may possibly be explained in terms of findings from other investigations which suggest a relationship between increased corticosteroid secretion and the relative intensity of work performed during exercise viz. the percentage of maximal aerobic power required to perform the work load (5, 7, 8). Such studies have found that work performed toward the upper limits of maximal aerobic power is associated with increased corticosteroid secretion. Therefore the significant increases in corticosteroid levels observed in the sedentary subjects in this study, which were associated with relatively heavy work loads considered as near "maximal" for these subjects, would appear to support the above findings. However, in the case of the active subjects, the intensity and duration of work required to elicit the criterion cardiac frequency probably represented a "high steady state" of work which was not sufficiently demanding upon aerobic power to result in an adrenocortical response in this group.

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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OBITUARY

Dr. Michael J. Keating, MB, ChB, BAO, MRCGP, JP

We are distressed to learn of the sudden death of Mike Keating on December 27th 1974, in Hartlepool. He qualified at the National University of Ireland in 1940, from Cork Medical School, then went to Sunderland Royal Infirmary as House Officer in Surgery then in Orthopaedics. When I worked at that hospital in 1944, Mike Keating was already a legendary figure, and I met him soon afterwards, from whence we were lifelong friends. He served in the Burma campaign towards the end of the war, and was one of the few medical officers to penetrate deeply into enemy-held jungle for prolonged action. His fitness as a rugby football player, and boxer stood him in good stead for this type of work, and he maintained a keen interest as an active sportsman for many years, then as a doctor serving in both medical and administrative capacities in sports clubs, for the whole time he was in general practice from the end of the war until his death at the end of a surgery.

He joined B.A.S.M. in 1962, and soon afterwards organised meetings for our Association in the North East of England, being responsible for setting up the North East Area of B.A.S.M. During the past few years, however, bad health had forced him to give up much of the voluntary work he so enjoyed, and there could be no more fitting memorial that B.A.S.M could make than to see the Area Organisation resuscitated and again active under new leadership.

H. E. Robson