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SERUM INSULIN AND GLUCOSE RESPONSE TO GRADED EXERCISE IN ADULTS

PART II

THE EFFECT OF EXERCISE CONDITIONING

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ABSTRACT

The effect of conditioning to severe exercise upon serum immunoreactive insulin levels (IRI) and serum glucose concentrations (GC) was studied in active and sedentary groups of middle-aged men. The responses of serum IRI and serum GC were determined during graded cycle ergometer exercise which required similar low and high relative work intensities, before (pre) and after (post) a four month physical fitness programme. Both groups demonstrated a marked decline in serum IRI during high intensity exercise from pre to post tests, and a tendency to maintain serum, GC (sedentary group) or elevate serum GC (active group) during exercise, following the conditioning programme. The data provides evidence of a bi-directional response of serum IRI and serum GC to graded exercise, with only minor modifications in the response patterns resulting from exercise conditioning.

Index terms: Exercise conditioning; insulin; glucose.

INTRODUCTION

It has been suggested by Hartley, et al (1972) that plasma insulin levels and blood glucose concentration may be elevated during mild, moderate and heavy exercise involving work at 42%, 75% and 98% $\dot{V}O_2$ max. following a programme of physical training. Therefore to determine the effect of exercise conditioning upon serum insulin a glucose responses to graded exercise, a follow up study was carried out on the subjects used in the previous investigation (part I) after their participation in a physical fitness programme.

SUBJECTS AND METHODS

The active and sedentary groups of subjects who had taken part in the initial study underwent a four month physical fitness programme which was conducted three days a week during the lunch period (12.00-13.30 hr.) Each session consisted of a warm-up (jogging), calisthenics and progressive running, followed by self-selected recreational activities (volley ball, basketball and swimming). The intensity of subject participation was carefully matched with each individual's initial capabilities and his rate of progress during the course of the programme.

The methods used in the collection and analysis of data following the fitness programme were identical to those utilised in the previous investigations (Part I). Each subject was studied in the same post-absorptive state and the same time of day, before (pre-test) and after (post-test), the fitness programme in an attempt to minimise the effects of both diurnal and intra-individual variation in serum IRI and S.G. (Müller, Falonna and Unger, 1971).

The ergometer experimental protocol of the post-test required all subjects to perform their identical pre-test work loads. As a result low intensity exercise now involved 39% and 47% predicted $\dot{V}O_2$ max. and high intensity exercise 78% and 76% predicted $\dot{V}O_2$ max. for the active and sedentary groups, respectively. Consequently the reduction in the relative intensity of exercise performed at each level of work in the post-test was attributed to the training effects of the fitness programme which are outlined in Table I.

Furthermore, in order to accommodate the increased work capacity of the subjects after conditioning, an additional high intensity exercise level of work was introduced at the post-test, which involved exercise at 98% and 94% predicted $\dot{V}O_2$ max in the active and sedentary groups, respectively.

TABLE I

Physiological changes of the two groups of subjects who participated in the study

		Active Group			Sedentary Group		
		Pre Test ($\bar{X}$ ± S.E.)	**(P)**	**Post Test ($\bar{X}$ ± S.E.)**	**Pre Test ($\bar{X}$ ± S.E.)**	**(P)**	**Post Test ($\bar{X}$ ± S.E.)**
Weight (kg)		82.9 ± 3.4	N.S.	81.6 ± 3.2	102.3 ± 7.8	N.S.	96.7 ± 6.1
% LBW		84.2 ± 1.6	N.S.	85.4 ± 1.7	77.1 ± 1.2	N.S.	77.8 ± 1.3
Blood Pressure mm Hg	Systolic	126.4 ± 4.3	N.S.	124.8 ± 4.1	133.1 ± 3.6	< 0.01	125.3 ± 2.8
	Diastolic	77.8 ± 1.7	N.S.	79.0 ± 2.0	88.7 ± 3.5	N.S.	83.7 ± 3.0
	Pulse	47.7 ± 2.9	N.S.	46.3 ± 3.8	44.4 ± 2.2	< 0.05	41.6 ± 1.6
Heart Rate	Rest	58.7 ± 2.4	N.S.	54.0 ± 2.2	66.7 ± 2.8	< 0.01	57.6 ± 1.7
	Low Intensity	110.0 ± 4.1	N.S.	102.6 ± 3.8	124.4 ± 5.4	< 0.01	106.7 ± 6.2
	High Intensity	157.3 ± 3.8	< 0.05	145.8 ± 3.8	154.6 ± 2.4	< 0.01	136.2 ± 3.8
				166.6 ± 3.0			159.5 ± 3.6
Oxygen Intake $\dot{V}O_2$ ml kg^{-1} min^{-1}	Low Intensity	22.6 ± 1.2	N.S.	21.4 ± 1.7	24.8 ± 2.0	N.S.	23.4 ± 1.6
	High Intensity	45.4 ± 1.6	N.S.	43.8 ± 2.2	36.4 ± 2.0	N.S.	37.8 ± 1.8
				54.2 ± 2.2			45.9 ± 2.2
Respiratory Quotient	Low Intensity	0.82 ± 0.02	N.S.	0.79 ± 0.02	0.85 ± 0.02	N.S.	0.82 ± 0.01
	High Intensity	0.92 – 0.02	< 0.05	0.89 – 0.03	0.94 – 0.02	< 0.05	0.88 – 0.02
				0.96 ± 0.02			0.92 ± 0.02
% Predicted $\dot{V}O_2$ max	Low Intensity	45%		39%	59%		47%
	High Intensity	92%		78%	88%		76%
				98%			94%

Low/High = Relative intensity of exercise expressed as % predicted $\dot{V}O_2$ max

RESULTS

The physiological changes in the two groups of subjects are presented in Table I. No significant changes in body weight and % LBW were found in either group from pre- to post-tests. The improvement in cardiovascular conditioning was evident in the sedentary group by significant reductions in heart rates from pre- to post-tests at rest and during low and high intensity exercise and similarly in the active group during high intensity exercise. Both groups of subjects showed elevated oxygen uptake capacity following the fitness programme, as well as significant reductions in respiratory quotient during exercise which involved identical work loads but a reduction in the relative work intensity.

The sedentary group, while demonstrating the usual physiological changes associated with physical conditioning, will nevertheless be referred to as the "sedentary" group for the purpose of clarification.

The changes in mean serum insulin levels and mean serum glucose concentrations of the two groups of subjects are presented in Table II, while the time course of these changes are presented graphically in Figure 1.

The active and sedentary groups demonstrated similarities in the change of response patterns of serum IRI to graded exercise from pre- to post-tests. Initially the significant rise in mean serum IRI levels over resting values displayed by both groups of subjects in the pre-test was observed in the post-test where graded exercise involved the same absolute work load, although a reduced relative intensity. However this initial elevation was followed by a sharp decline in mean serum IRI values during exercise toward the upper limits of predicted $\dot{V}O_2$ max at the post-test, although this reduction was not statistically significant in either group of subjects.

In contrast, the changes in the response patterns of serum glucose to graded exercise showed more positive trends in both groups of subjects from pre- to post-tests. Mean serum glucose concentrations were significantly elevated in the active group during high intensity exercise and recovery from pre- to post-tests, whereas the sedentary group reversed a pre-test decline in mean serum glucose concentration and maintained resting values during exercise and elevated values during recovery. The magnitude of these changes however were not statistically significant. The modifications in the

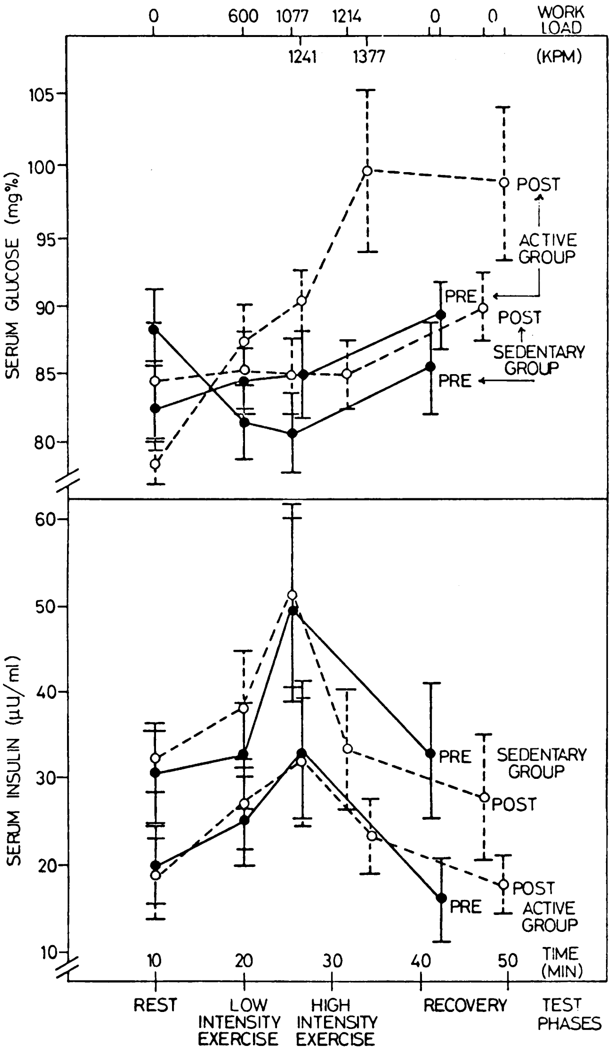

Figure 1. Mean (± S.E.) serum insulin level and glucose concentration of the active and sedentary groups at the pre- and post-programme tests.

response patterns of serum IRI and serum glucose reflected the change in experimental protocol, which necessitated an extended time course of exercise and resulted in increased work loads in order to adjust the relative work intensities from pre- to post-tests to comparable levels.

DISCUSSION

The results of this investigation demonstrate a pronounced similarity in the response patterns of serum insulin levels to graded exercise in active and sedentary subjects following exercise conditioning. However only minor modifications in the response patterns of serum insulin and serum glucose to graded exercise were observed in both groups of subjects after exercise conditioning.

The findings of this study support evidence which suggests that acute exercise may result in decreased insulin levels (Cochran, et al, 1966; Hartley et al, 1972). Thus the sharp decline in insulin levels observed in both groups of subjects in the post-test may have resulted from the inhibition of insulin secretion due to the action of adrenocorticol secretions (Perley and Kipnis, 1966) or possibly due to the actions of epinephrine (Lundquist, 1971) and norepinephrine (Porte and Williams, 1966). The influence of adrenocortical secretions appears particularly relevant since findings of a parallel study in these same subjects (White, Ismail and Bottoms, 1976) demonstrated a significant rise in serum corticosteroids in both groups of subjects under the acute stress of high intensity exercise associated with the extended time course of the exercise protocol in the post-test as shown in Fig. 2.

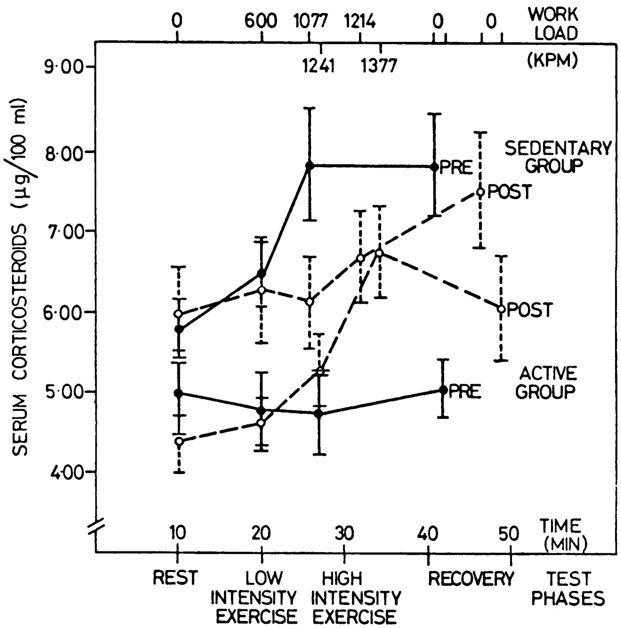

Figure 2. Mean (± S.E.) serum corticosteroid concentration of the active and sedentary groups at the pre- and post-programme tests.

In contrast to the decline in insulin levels, serum glucose concentration was maintained at resting values in the sedentary group and progressively increased in the active group during exercise in the post-test. As a result this phenomenon appears to confirm the bi-directional response of insulin and glucose during heavy exercise

TABLE II

Serum insulin and glucose values for the sedentary and active groups at the pre- and post-physical fitness programme tests

		Serum Insulin (μU/ml) Mean ± S.E.			% Predicted $\dot{V}O_2$ max		Serum Glucose (mg %) Mean ± S.E.		
Test Phase	**Sedentary**	**Sedentary Group**	**(P)**	**Active Group**	**Sed.**	**Act.**	**Sedentary Group**	**(P)**	**Active Group**
	Pre	30.0 ± 6.7	N.S.	19.2 ± 4.5	—	—	88.5 ± 3.2	N.S.	82.7 ± 3.5
Rest	(P)	N.S.		N.S.			N.S.		N.S.
	Post	30.8 ± 4.6	< 0.05	17.2 ± 4.3	—	—	84.3 ± 4.3	N.S.	77.7 ± 2.4
Low	Pre	31.8 ± 6.2	N.S.	24.5 ± 4.6	59%	45%	81.8 ± 3.0	N.S.	84.5 ± 2.4
Intensity	(P)	N.S.		N.S.			N.S.		N.S.
Exercise	Post	37.3 ± 7.5	N.S.	24.8 ± 4.9	47%	39%	85.1 ± 2.8	N.S.	87.2 ± 2.2
High	Pre	49.6 ± 10.8	N.S.	33.0 ± 8.0	88%	92%	80.8 ± 2.8	N.S.	85.4 ± 2.9
Intensity	(P)	N.S.		N.S.			N.S.		N.S.
Exercise	Post	50.1 ± 11.7	N.S.	30.4 ± 7.1	76%	78%	84.4 ± 3.2	N.S.	90.0 ± 2.4
		31.9 ± 8.0	N.S.	22.2 ± 5.7	94%	98%	84.4 ± 2.9	< 0.05	99.2 ± 6.3
	Pre	32.6 ± 8.6	< 0.05	15.9 ± 4.2	—	—	86.9 ± 2.7	N.S.	89.9 ± 2.5
Recovery	v	N.S.		N.S.			N.S.		N.S.
	Post	27.9 — 7.5	N.S.	16.1 — 3.8	—	—	89.4 — 2.9	N.S.	98.6 — 5.2

Low/High = Relative intensity of exercise expressed as % $\dot{V}O_2$ max

which has been reported in other work (Wahren, et al, 1971; Hartley, et al, 1972).

The importance of blood glucose as an energy substrate during exercise has been demonstrated in spite of a reduction in insulin availability (Wahren, et al, 1971). Nevertheless the relative contribution of carbohydrate and lipid substrates to energy production must be considered in the light of the changing demands of the work as well as the endocrine control over the availability of substrates. Therefore decline of FFA concentration accompanying low and high intensity exercise (Fig. 3) probably represents increased utilisation of these substrates (Horstman, et al, 1971). Furthermore the decrease in respiratory quotient from pre- to post-tests, which was associated with a 14% and 12% reduction in the relative work intensity in the active and sedentary groups respectively, indicated an increase in the contribution of lipid substrates toward energy production. Even so, the importance of carbohydrate substrates to energy production was evident in the RQ values which approached unity during the final phase of high intensity exercise in the post-test.

In summary, the study provides no evidence to support changes in the response of serum insulin to graded exercise following physical conditioning as reported by

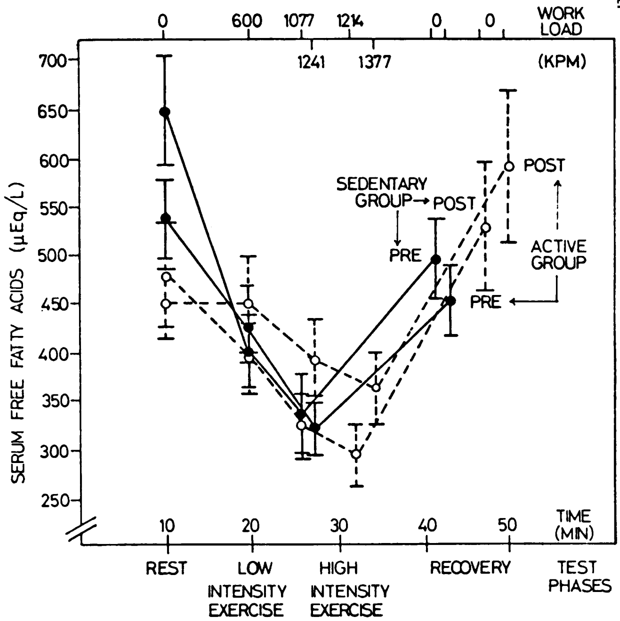

Figure 3. Mean (± S.E.) serum free fatty acid concentration of the active and sedentary groups at the pre and post-programme tests.

Hartley, et al, 1972. However this may be due in part to differences in experimental protocol which involved intermittent exercise in the Hartley, et al, study but continuous exercise in our study although each required similar relative work intensities. However, there is supportive evidence for increased serum glucose concentrations during graded exercise following training as demonstrated by Hartley, et al, 1972.

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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