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# Exercise and hormonal secretion

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**Summary**

**The effect of graded exercise on the secretion of cortisol, testosterone, prolactin, growth hormone, thyroid stimulating hormone (TSH), luteinizing hormone and follicle stimulating hormone (FSH) is reported. While cortisol, prolactin, growth hormone and testosterone rise during the period of exercise, a rise in luteinizing hormone becomes evident only after rest. Levels of FSH and TSH remained unchanged.**

## Introduction

The increased secretion of cortisol, testosterone, prolactin and growth hormone in exercise is well recognized, albeit not equally well understood. The factors that trigger hormone release in exercise are complex (Few, 1974; Sutton *et al.*, 1973) and may vary with the type, amount and length of the exercise periods. Many studies have shown increased levels of cortisol (Kozlowski *et al.*, 1972; Dessypris, Kuoppasalmi and Adlercreutz, 1976; Bloom *et al.*, 1976), but this increase occurs late in the exercise period following an initial fall. Using labelled cortisol and observing its clearance from plasma, it has been found that there is a specific point at which cortisol secretion is triggered and that, before this, cortisol is cleared more rapidly than usual (Few, 1974). Both noradrenaline and adrenaline rise markedly when graded exercise becomes intensive (Bloom *et al.*, 1976) and, although it has been suggested that noradrenaline could be the trigger, this hypothesis was not confirmed.

Exercise is the most potent stimulus to the secretion of growth hormone (GH) (Sutton and Lazarus, 1976) and, although the role of GH in the acute phase of exercise is uncertain, it has been postulated that it aids long-term stamina by mobilizing free fatty acids.

The evidence for a rise in luteinizing hormone (LH) on exercise is conflicting, since it is found during a marathon run (Dessypris *et al.*, 1976) but not following swimming or rowing (Sutton *et al.*, 1973). Testosterone falls during a marathon run (Dessypris *et al.*, 1976) and rises to a maximum during the last bout of exercise on a bicycle ergometer, falling after rest.

Prolactin has been shown to be increased on exercise as well as following surgery, orgasm and stress (Noel *et al.*, 1972). The increase on exercise is abolished when exercise is performed in cold surroundings (Shaar and Clemens, 1974).

Rises in $T_4$ and $T_3$ levels during exercise on a bicycle ergometer (Caralis, Edwards and Davis, 1977; Terjung and Tipton, 1971) are unlikely to be caused by a rise in serum-TSH level since this is unchanged during a variety of exercise protocols (Odell, Wilber and Utiger, 1967).

These data suggest that exercise is a highly effective method of stressing the pituitary–hypothalamic axis. It was therefore decided to study the effects of graded dynamic exercise on prolactin, cortisol, growth hormone, testosterone, thyroid-stimulating hormone, luteinizing hormone and follicle-stimulating hormone simultaneously in order to observe their interrelationships. A graded exercise protocol was used since it is known to produce substantial rises of noradrenaline (Bloom *et al.*, 1976) which was felt to be an important factor in the secretion of pituitary hormones.

## Materials and methods

Eleven healthy male volunteers, (mean age 28·2 ± 10 years, weight 71·2 ± 4 kg), were exercised on a Monarch bicycle ergometer at a constant tachometer speed of 20 km/hr. Each minute the workload was increased by 0·5 kPa until they could no longer proceed. This was taken to be their maximum work capacity. On a subsequent morning they were exercised, having fasted for 12 hr, at 15, 30 and 40% of their previously determined maximum load, while pedalling at 20 km/hr for successive periods of 10

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min. Blood sampling was via a Medicut cannula inserted into an antecubital vein under local anaesthetic and kept patent between samples with a bolus of normal saline. Blood was taken before beginning the exercise (sample 1) and then following each 10-min period (samples 2–4). A final sample was taken after a 10-min rest (sample 5).

On a subsequent occasion 5 of the subjects presented themselves in the laboratory under identical conditions and had samples taken at the same time intervals while they rested.

The samples were assayed as follows: HGH by radioimmunoassay, plasma cortisol fluorometrically by the method of Spencer-Peet, Daly and Smith (1965); prolactin by radioimmunoassay (CIS Biochemical products), testosterone, LH, FSH, and TSH by radioimmunoassay.

TABLE 1. Changes in prolactin levels with exercise, in mu./l (±s.d.)

| Sample | Exercise | Control |
|---|---|---|
| 1 | 268 (109) | 320 (71) |
| 2 | 251 (102) | 310 (126) |
| 3 | 263 (76) | 250 (121) |
| 4 | 364 (143) | 271 (104) |
| 5 | 420 (150) | 217 (71) |

Exercise subjects $n=11$, control $n=5$.
Results of paired $t$-test on exercise samples:
Increase from samples 1 to 5: $P=0{\cdot}05$; 2 to 5: $P=0{\cdot}02$.
Decrease from samples 1 to 2: $P=0{\cdot}05$.
Differences between control and exercise samples at sample 5: $P=0{\cdot}005$.

TABLE 2. Changes in cortisol levels with exercise, in μmol/l (±s.d.)

| Sample | Exercise | Control |
|---|---|---|
| 1 | 466 (114) | 322 (80) |
| 2 | 436 (113) | 285 (92) |
| 3 | 390 (97) | 275 (129) |
| 4 | 422 (95) | 260 (100) |
| 5 | 562 (96) | 260 (100) |

Exercise subjects $n=11$, control $n=5$.
Results of paired $t$-test on exercise samples:
Increase from samples 3 to 5: $P=0{\cdot}001$.
Difference between control and exercise: $P=0{\cdot}001$.

TABLE 3. Changes in growth hormone (GH) levels with exercise, in mu./l (±s.d.)

| Sample | GH mu./ s.d. |
|---|---|
| 1 | 2·48 (3·6519) |
| 2 | 2·15 (2·3364) |
| 3 | 10·04 (9·67) |
| 4 | 54·7 (28·4) |
| 5 | 49·6 (24·9) |

Control value = 0·5 i.u./l.
For sample 1–4 $P<0{\cdot}001$.

TABLE 4. Changes in testosterone levels with exercise in mol./l (±s.d.)

| Sample | Exercise | Control |
|---|---|---|
| 1 | 23·15 (5·4) | 21·9 (3·9) |
| 2 | 24·3 (4·5) | 22·7 (2·9) |
| 3 | 29·0 (4·0) | 22·8 (3·8) |
| 4 | 32·5 (7·2) | 21·3 (3·7) |
| 5 | 28·0 (2·9) | 24·3 (5·9) |

Results of paired $t$-test on exercise samples:
Increase from samples 1 to 4: $P<0{\cdot}01$.
Decrease from samples 4 to 5: $P<0{\cdot}01$.
Increase between control and exercise sample 4: $P<0{\cdot}025$.

TABLE 5. Changes in leuteinizing hormone (LH) levels with exercise, in i.u./l (±s.d.)

| Sample | Exercise | Control |
|---|---|---|
| 1 | 3·92 (0·81) | 5·07 (1·22) |
| 2 | 4·34 (1·05) | 5·26 (1·5) |
| 3 | 1·24 (3·85) | 4·8 (1·75) |
| 4 | 5·07 (2·39) | 4·64 (1·45) |
| 5 | 5·50 (2·23) | 4·67 (0·83) |

Results of paired $t$-test on exercise samples:
Increase from samples 1 to 5: $P<0{\cdot}05$.
Difference between controls and exercise sample 5 was not significant.

TABLE 6. Changes in follicle-stimulating hormone (FSH) and thyroid-stimulating hormone (TSH) levels with exercise

| Sample | FSH i.u./l | ±s.d. | TSH mu./l | ±s.d. |
|---|---|---|---|---|
| 1 | 2·7 | 2·175 | 3·1 | 1·28 |
| 2 | 3·01 | 2·45 | 2·5 | 1 08 |
| 3 | 3·05 | 2·7 | 2·9 | 1·28 |
| 4 | 3·04 | 3 07 | 3·1 | 1·19 |
| 5 | 2 97 | 3·05 | 2·7 | 1·30 |

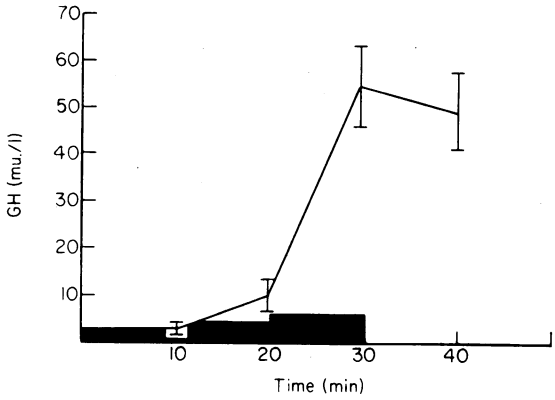


FIG. 1. Growth hormone levels during and after exercise. —— Exercise; - - - - - controls; ■ duration and grade of exercise; bars indicate standard deviation.

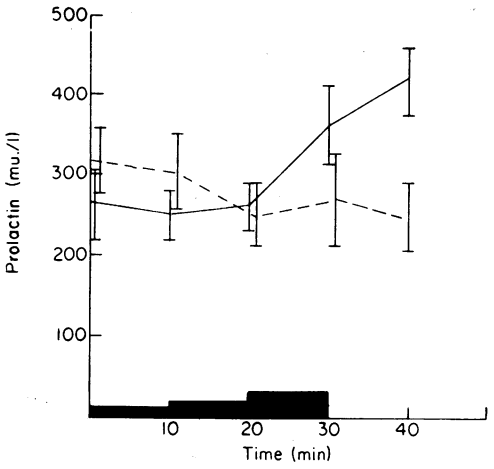


FIG. 2. Prolactin levels during and after exercise (±s.d.). —— Exercise; - - - - - controls; ■ duration and grade of exercise; bars indicate standard deviation.

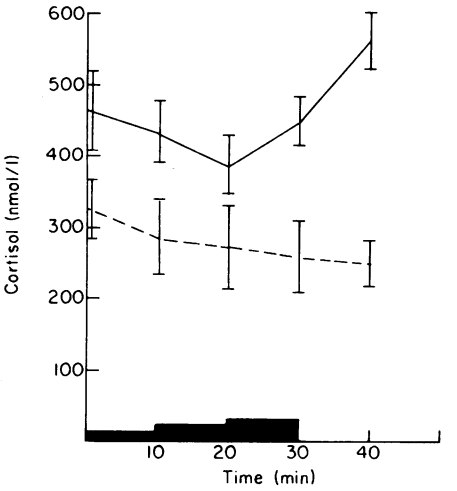


FIG. 3. Cortisol levels during and after the exercise ±s.d. —— Exercise; - - - - - controls; ■ duration and grade of exercise; bars indicate standard deviation.

## Results

There is a significant rise in prolactin and cortisol during the exercise which continues into the rest period. There is also an initial fall, significant at 10 min in the case of prolactin and at 20 min in the case of cortisol. GH increases markedly and starts to fall during the rest period. Testosterone rises independently of LH at the end of the maximal exercise and begins to fall during rest whereas the small rise in LH only becomes significant in the last sample. There is no change in the level of TSH nor in FSH.

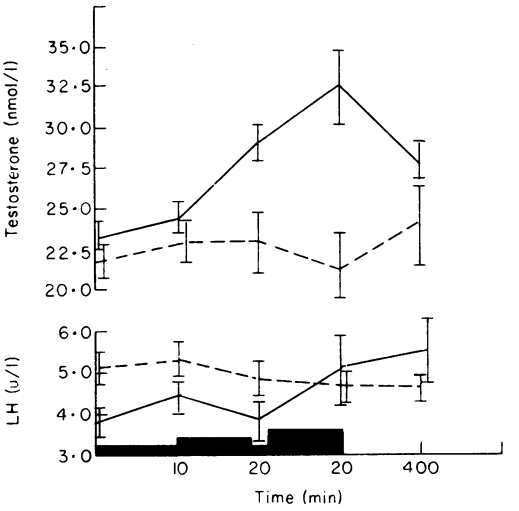


FIG. 4. Testosterone levels (upper) during and after exercise (±s.d.). —— Exercise; - - - - - controls; ■ duration grade of exercise. LH levels (lower) reach a peak 10 min after the end of exercise as testosterone levels fall; bars indicate standard deviation.

## Discussion

This study confirms previous observations on the secretion of GH, cortisol and prolactin during strenuous exercise. It has also shown that the rise in testosterone is independent of LH and confirmed the lack of response of TSH previously reported.

This study has also shown an association between prolactin and cortisol secretion. Since the triggering mechanisms for cortisol secretion in this situation are unknown (Few, 1974), and as there is no definite evidence about factors which cause prolactin release, the reason for the link between them can only be speculative. Preliminary results obtained following infusions of noradrenaline in volunteers suggest that, during the infusion, prolactin levels are markedly reduced while, within 20 min, levels return to, or exceed, the control values (Few *et al.*, 1978). This is probably too slow a change to explain the findings and possibly reflects a rebound following the inhibitory effects of noradrenaline on prolactin secretion. The lack of rise in TSH makes it unlikely that TRH plays a part in prolactin release in this situation.

Prolactin inhibits the secretion of testosterone by the Leydig cells, blocking the actions of gonadotrophins at gonadal level (Thorner and Besser,

1976). It is possible that this mechanism may cause the fall in testosterone levels in the face of a rise in LH as prolactin levels reach a maximum at this stage of the investigation. The secretion of testosterone is thought to be increased by adrenergic stimulation (Sutton *et al.*, 1973), although there is evidence that infusion of adrenaline in humans causes a fall in testosterone levels (Eik-Nes, 1969), a finding confirmed by the present authors in preliminary experiments. Isoprenaline has been shown to cause release of testosterone from dog testes owing partly to an increase in blood flow (Levin *et al.*, 1967) and it is possible that such a 'wash out' mechanism is responsible for the rise observed in this study.

It must be stated, however, that the level of hormones measured depends on the relationship between actual amount secreted and the rate of clearance. If both rise no change may be observed, thus failure to observe a rising level of a particular hormone does not necessarily mean that the rate of secretion has not changed. Indeed, as previously mentioned, in the early phase of exercise cortisol has been found to be cleared more rapidly (Few, 1974). Thus it is possible that certain exercise protocols affect clearance and secretory mechanisms in different ways having different effects on the levels measured.

The changes in hormonal secretion during exercise may be part of a complex mechanism altering metabolism to meet the different needs imposed by different activities. In this context it should be noted that, whereas testosterone has been shown to rise following swimming (Sutton *et al.*, 1973) and weightlifting (Kozlowski *et al.*, 1972), more prolonged exercise causes a fall (Dessypris *et al.*, 1976). Further studies are necessary to elucidate triggering factors and the physiological significance of the changes observed.

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