A. Biochemistry

FAT AND CARBOHYDRATE METABOLISM IN ATHLETES COMPARED WITH NON-ATHLETES:
OBSERVATIONS UPON POST EXERCISE KETOSIS

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ABSTRACT

Exercise causes major changes in metabolism and one of the indications of this is the rise in the concentration of blood ketone-bodies after severe exercise: "post-exercise ketosis". Trained athletes, running a marathon (42 km) in 2½ - 3 hrs. did not develop ketonuria whereas ketonuria occurred in unfit hill walkers after walking 20 km. in 3 - 5 hrs. One explanation may be that the degree of post-exercise ketosis depends on the extent of athletic training. Athletes and untrained subjects have been investigated during and after running 1½ hours and striking differences were observed in metabolite concentrations between the two groups. The untrained group developed post-exercise ketosis, associated with high free-fatty-acid (F.F.A.) concentration in plasma whereas the changes in the athletes were much less marked.

This could be due to differences in ketone-body utilisation or production and acetoacetate tolerance tests have been performed before, during and after exercise. In unfit subjects ketone-body production continues after exercise to a much greater extent than in athletes. During the phase of post-exercise ketosis oral glucose causes a fall in blood ketone-body and F.F.A. concentrations indicating that part of the cause of post-exercise ketosis is a shortage of carbohydrate. Metabolic studies during exercise by patients with growth hormone deficiency showed that fat mobilisation can occur during exercise in the absence of growth hormone and the hormonal controlling mechanisms are, therefore, being investigated further.

Introduction

Philippides ran into the market place of Athens and shouted the news of the Athenian victory with the words ‘Rejoice we’ve won’ and then collapsed and died. When the first modern Olympic Games was held in Greece in 1896, the arrival of the news of the battle of Marathon provoked the concept of a ‘Marathon race’. The story of Philippides was almost repeated when Jim Peters collapsed in the finishing stretch during the Commonwealth Games Marathon in Vancouver in 1956. This and other difficulties of competitors in long distance events have highlighted the fact that the success of athletes in these events depends not only upon psychological stamina, but also upon the extent to which their physiological and biochemical processes are able to match the requirements imposed by high athletic performance (Johnson, 1968). A further understanding of these changes is not only of value in the design of training programmes but also in thwarting the medical dangers of these events, particularly as Lloyd (1965) has predicted from a theoretical analysis of world records that the record marathon time will be reduced by a further 7½% by 2,000 A.D.

In our initial investigations of the changes produced by athletic training we studied two groups who differed considerably in their physical fitness. The first group were runners in good athletic training who were taking part in a Road-Runners Club Marathon meeting (Pugh, Corbett & Johnson, 1967); the second group were long distance hill walkers who were conventionally fit but not in athletic training. The runners gave a negative test for acetoacetate in the urine (‘Ketostix’ method) after competing in a race (42 km.) whereas the hill walkers, after carrying out the less strenuous exercise of walking for 3-5 hours, gave a positive test.

Absence of ketonuria has also been observed in competitors after an 85 km. ski race (Åstrand, Hallback, Hedman and Saltin, 1963). These observations suggested that post-exercise ketosis, first reported by Courrice and Douglas (1936), might depend upon the athletic training of the exercised subject.
The Effect of Running 1.5 hours upon Athletes and Non-Athletes

As a result of these initial observations we went on to study middle and long distance athletes of university and national standard as well as non-athletes during and after running for 1.5-2 hours (Corbett, Johnson, Krebs, Walton and Williamson, 1969; Johnson, Walton, Krebs and Williamson, 1969, a). Measurements were made of the weight loss, heart rate and speed of running of the two groups. Venous blood samples were also taken throughout the investigations in order to measure the changes in concentration of metabolites, including acetoacetate, 3-hydroxybutyrate, free fatty acids (F.F.A.), glycerol, lactate, pyruvate and glucose.

There were striking differences between the two groups. The weight losses were greater in the fit subjects indicating a higher rate of sweating. This suggests that the intermittent heat and temperature elevation produced during a training programme can produce heat acclimatization (Pugh, Corbett and Johnson, 1967). Heart rates measured at intervals during the running were lower in the athletes even though they ran faster.

These rose very little during exercise in the athletes compared with the non-athletic subjects (fig. 2). The untrained group also developed post-exercise ketosis whereas the athletes had relatively low ketone-body concentrations throughout (fig. 3). The amount of glycerol appearing in the venous blood can be taken as an index of the amount of adipose tissue lipolysis. This was similar in the two groups suggesting that there was no major difference in fat mobilisation. Little change was found in the glucose levels in either group suggesting that it only has a minor role in prolonged exercise. The lower F.F.A. in the athletes suggests that they can, however, oxidise them more rapidly than untrained subjects. The post-exercise ketosis found in the untrained subjects could be because they oxidise fats less rapidly than the athletes or because the rate of ketone utilization is lower.

There were also major differences in the blood metabolite changes of the two groups. The athletes did not exhibit rises in the concentrations of lactate and pyruvate during the initial period of exercise whereas there was considerable elevation of these metabolites in the subject not in athletic training (fig. 1), an observation which has been previously reported (Holmgren and Strom, 1959; Juchems and Kumper, 1968). We continued taking blood samples for an additional 1.5 hours after the end of the exercise and found striking differences in F.F.A. concentrations.
The Effect of Glucose Ingestion after Exercise upon Blood Metabolite Levels

We then studied the effect of ingestion of glucose (50g.) upon the concentrations of blood metabolites after similar periods of running by untrained subjects in order to examine the effect of carbohydrate being available (Johnson, Walton, Krebs and Williamson, 1969, b). The subjects received the glucose orally 30 minutes after running. There was depression of F.F.A. and of ketone-bodies (fig. 4) compared with the findings after control runs by similar subjects. Courtice and Douglas (1936) briefly reported depression of ketone-bodies after exercise by one subject on ingestion of sucrose.

![Graph](image)

**Fig. 4:** The effect of oral glucose (50g) on blood ketone-bodies (µmol/ml, means and S.E.M.) in twelve subjects (x-x) given glucose orally 30-60 minutes after running for 1½ hours, compared with nine otherwise similar subjects (o-o) who were not given glucose. Initial points are resting values. The availability of glucose allows the ketone levels to fall (from Johnson et al. (1969 b), by kind permission).

The observations in these and the previous investigations suggest that post-exercise ketosis develops because of the increased mobilisation of triglycerides as indicated by the rise of blood glycerol and plasma F.F.A. Ketone-body production rises as it keeps approximately proportional to the F.F.A. level in the plasma; during exercise ketones are metabolised rapidly but accumulate after the exercise in untrained subjects because the available F.F.A. is oxidized less rapidly than in athletically trained subjects. In addition the depression of ketones during glucose tolerance tests after exercise suggests that the rate of F.F.A. removal depends upon the availability of carbohydrate, which is normally only available from hepatic glycogen.

The Rate of Utilization of Acetoacetate after Exercise in Athletes and Non-Athletes

Although the explanation of post-exercise ketosis depends upon the rate of oxidation of plasma F.F.A. being slow in untrained subjects, it has been suggested earlier in this communication that a further explanation might be that subjects not in athletic training have a lower rate of utilisation of ketone-bodies compared with athletes. We have investigated this possibility by performing acetoacetate tolerance tests in the two groups before, during and after exercise (Johnson and Walton, 1970). Acetoacetate (200 ml. of 0.4M concentration) was given orally and its rate of disappearance from the blood observed by taking a series of blood samples over the next 1½ hours. There was no difference in the tolerance of athletes and non-athletes at rest and the disappearance rate was also increased equally during exercise, indicating that they were being metabolised to provide energy for muscle contraction (fig. 5). After exercise, however, the untrained individuals were found to have a lower rate of acetoacetate utilization than the athletes (fig. 6: obtained by subtraction of the levels obtained during a control run from those obtained when oral acetoacetate was given after a similar run). It thus appears that untrained subjects not only oxidize F.F.A. more slowly from the blood stream than athletes but also that they have a slower rate of utilization of ketone bodies. (Johnson and Walton, 1972)
The Relevance of Growth Hormone Levels to Post-Exercise Ketosis

A further problem is the hormonal causation of these differences. Sutton, Young, Lazarus, Hickie and Makarylis (1968) observed that exercise is accompanied by a smaller rise of hormone in subjects used to regular athletic training compared with non-athletes and we have substantiated this finding. The opportunity of further investigating the role of growth hormone in exercise is provided by studying patients with hypopituitarism in whom growth hormone levels are low and vary little with exercise. Investigation of the effects of exercise on metabolites in such patients was reported by Basu, Passmore and Strong (1960) but their patients were receiving steroid and other replacement therapy. We have now shown that patients examined before therapy is instituted nevertheless have considerable elevation of their F.F.A. and ketone-bodies after exercise (Johnson, Rennie and Duguid, 1970; Johnson, Rennie, Walton and Webster, 1971). The values were higher than in control subjects and previous evidence given in this communication would suggest that one explanation could be that the patients with hypopituitarism were less fit.

Other causes apart from growth hormone must therefore be sought for the mobilization of fat in exercise. There is a need, therefore, for further investigation of the hormonal changes which result in the development of post-exercise ketosis.

Summary

Observations have been carried out on the blood metabolite changes of middle and long distance athletes compared with less fit individuals after each group have run for about 1½ hours. The metabolite concentrations in the athletes deviate less from normal during exercise than those of untrained subjects and the untrained individuals develop more marked post-exercise ketosis. Evidence is given to indicate that post-exercise ketosis develops because of a lower rate of utilisation of fat and ketone-bodies by the unfit subjects after exercise. The differences between the two groups are not due to the lower levels of growth hormone observed in athletes during exercise and therefore other possibilities require investigation.

Acknowledgements

I wish to thank the subjects and patients who collaborated in these studies, Mr. J. L. Walton and Mr. M. J. Rennie who joined me in the investigations, Professor J. A. Simpson for encouragement and Mr. John Griffith, Jesus College, Oxford, for helpful discussion upon the classical references in the introduction. Financial support was received from the Medical Commission for Accident Prevention, the Peel Trust, the Royal Society and the Scottish Hospital Endowments Trust.
REFERENCES


PITUITARY-ADRENAL RESPONSE TO VARIOUS STRESSORS IN TRAINED AND UNTRAINED ORGANISMS

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ABSTRACT

Previous experiments have shown that trained humans as well as rats forced to swim regularly responded to well-accustomed efforts by a significantly smaller stress reaction than did untrained organisms, as indicated by the increase of plasma steroid level.

In the present study various stressors and the induced responses were investigated in trained and untrained rats. It was found that 1 mg/100 g. histamine did not raise the level of plasma steroids in trained animals whereas a significant increase was elicited by it in control animals. Though a surgical intervention (sham bilateral adrenalectomy) caused a considerable rise in the steroid content in trained animals, this increase was significantly smaller than in controls. Both groups responded to ether or endotoxin administration by an intense pituitary-adrenal reaction.

It was concluded that the organism subjected to regular swimming developed a resistance to certain neurohumoral stimuli, and the stressors in whose mechanism of action these stimuli were involved were less effective in trained animals.

Introduction

Previous work has shown that after muscular effort the increase in the plasma steroid level of trained humans and of albino rats trained by regular swimming was less great than that of untrained controls. Since ACTH administration elicited a significant increase in both trained and untrained animals, a possible hypofunction of the adrenals could be excluded. On the contrary, reduction in the response to well-accustomed re-occurrence of the stressor was considered a symptom of adaptation.

The purpose of the present experiments was to study the response of trained animals following exposure to other stressor agents in order to find out whether endocrine adaptation was specific to the familiar stressor or was elicitable also when using other agents.

Histamine, surgical intervention, ether and endotoxin were the four stressors investigated. Plasma steroid level was estimated by the fluorometric technique of Guillemin and associates.

Results

At rest (Fig. 1) there was no significant difference between the steroid level developed by trained and control animals. Swimming elicited a change which was identical with that observed in previous experiments.

1 mg of histamine (Fig. 2) failed to elevate the level of plasma steroids in trained rats while in untrained ones a significant rise was seen. 3 mg of histamine was already effective, but the level change of the swimming group was less marked than that of controls.

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Fig. 1. The effect of swimming on plasma steroid level in trained and untrained rats. C: untrained controls. SW: animals trained by swimming. Number of rats within the bars.

Fig. 2. The effect of histamine on plasma steroid level in trained and untrained rats. Saline: saline-injected control animals. C: histamine-injected controls. SW: histamine-injected animals trained by regular swimming.
Bilateral sham adrenalectomy (Fig. 3) evoked considerable steroid response even in the trained animals, but the effect of surgical intervention was significantly smaller in this group than in the untrained controls. Anaesthesia alone did not affect the level of plasma steroids.

![Graph showing the effect of surgical intervention on plasma steroid level](image)

**Fig. 3.** The effect of a surgical intervention on plasma steroid level of trained and untrained rats. R: animals restrained for operation but unoperated. C: untrained controls. SW: animals trained by swimming.

Though ether appeared (Fig. 4) to have a slighter influence on the trained group, the difference proved to be non-significant.

![Graph showing the effect of ether inhalation on plasma steroid level](image)

**Fig. 4.** The effect of ether inhalation on plasma steroid level of trained and untrained rats. R: restrained controls. C: anaesthetized controls. SW: rats trained by swimming.

The difference found in the response to endotoxin was unimportant, too (Fig. 5).

![Graph showing the effect of various doses of epinephrine](image)

**Fig. 5.** The effect of endotoxin on plasma steroid level in trained and untrained rats. R: animals restrained but not injected. C: untrained controls. SW: rats trained by swimming.

The possibility that response difference was due to unequal intensity of stimuli had to be investigated as well. In our previous work 100 microgram of epinephrine was found to cause plasma steroids rise significantly both in trained and untrained animals. In order to exclude the possibility mentioned before, 5, 10 and 20 micrograms of this agent was administered. The effect on the steroid level was of the same magnitude in the two groups in respect of all three doses (Fig. 6).

**Fig. 6.** The effect of various doses of epinephrine on the plasma steroid level of trained and untrained rats. SW: animals trained by regular swimming. C: untrained controls. Respective doses of epinephrine are shown above the bars.

Discussion

Experiments with several different stressor agents in trained and untrained animals evidenced that in the trained animals some of these agents failed to elicit the same extent of response of the hypothalamic-pituitary-adrenal system as in controls. In experiments employing different tests the trained animals were found to be less sensitive to histamine. In the present series also the hormonal response to histamine proved to be smaller. In the authors' opinion trained animals are likely to show an attenuated response to stressors whose action mechanism would mobilize such factors that participate also in the response to muscular exercise to which they became less sensitive.

Stark and associates when investigating ACTH-treated animals have found that some of the stressors employed failed to evoke a response in the pre-treated rats. They opined that among these stressors, which were known to influence ACTH secretion by different pathways, there were some whose pathway inducing ACTH liberation became blocked. In spite that regular swimming involves several other factors beyond a mere daily renewal of ACTH liberation, — and it would be an
oversimplification to reduce matters to the latter, — the suggested mechanism might be essentially similar. Thus, stressors that utilize the same or similar pathways in the hypothalamic-pituitary system as activated by muscular effort would be less effective in trained animals.

Beznák, Hajdú and Korényi have already suggested that the work hypertrophy of adrenals should be attributed to certain endocrine agents which they called hypertrophogenic. The organism may become adapted to these factors.

In addition to realizing the importance of investigating qualitative differences of stimuli, the problem of eventual quantitative differences in the stressors could not be disregarded either. That stimulus intensity controls the extent of responses is more than natural and was evidenced also by the experiments with histamine. However, the tests with various doses of epinephrine contradict an assumption that difference in the responsivity of trained and untrained animals would derive merely from a quantitative incongruity of the stressors investigated. Instead, the results seem to provide sufficient evidence that it is stimulus specificity above all that is responsible for the variability seen in the endocrine response. This piece of information is an important incentive for extending research to the study of humoral changes associated with muscular exercise. According to the observations resistance, i.e. alteration in the sensitivity to biogenic amines, is a fundamental aspect in the process of endocrine adaptation to physical effort.

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ENDOCRINE METABOLIC CHANGES DURING THE RECOVERY PERIOD IN SPORTSMEN

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ABSTRACT

During competitive sports activity body functions are involved to the physiological limit. Restoration of the biological conditions requisite for further exertion takes place during the post exertion recovery period. This poses a set of sports physiology problems which, besides their basic theoretical importance, have considerable implications for the sportsman's efficiency.

We undertook a set of research studies, in which we tested sportmen who practised handball, basketball, modern pentathlon as well as complex physiological investigation of long and middle distance racers. This latter research comprised a variety of determinations of which those concerning endocrine correlations (the pituitary-adrenal axis) and the changes in mineral metabolism (the ions Na and K in the blood, urine and sweat) are presented in this paper.

The determinations were performed on 11 runners over a 72 hour testing period. The experimental exertion consisted in running 10 times a 400 m distance with 90 sec. interval resting pauses. The dynamics of restoration of the endocrine-metabolic parameters was observed on both mineral ions and corticosteroids.

The results obtained permitted us to establish a number of individual responses in the sportmen studied, and in the same individual it was possible to observe the progress of the various factors investigated during the recovery period. In this way, besides obtaining data of theoretical importance in this field, some criteria were established of practical interest for securing the optimal biological conditions necessary to continued exertion with high sporting efficiency.

Introduction

Sports top performance strains the functions of body up to their physiological limits. Restoration of the biologic condition permitting further exertion at the same or even higher intensity takes place within the process of recovery following upon exertion. The interest of this problem is not only theoretical, as a basic problem of sports physiology but also practical by its important repercussions upon the sportman's efficiency, as emerges from a comprehensive study (18) of which the present one is part too.

Such sportive exertion as assumed by today's training standards creates a situation in which the body is systematically undergoing stress action, as expression of a "functional tension" on the high levels. Consequently sports activities involve too the activation of the neuro-endocrine axis, which plays a central part and the involvement of which has been defined in the literature (6, 7, 8, 9, 10, 11, 15). The mode in which the axis is involved is contingent upon the intensity with which stress is acting. Thus, when its action is confined to determining functional tension which elicits the general reaction of positive adjustment, there is one mode of involvement of the neuro-endocrine axis which is other than that arising when stress exceeds adjustment possibilities and leads to disadaptation (2, 6, 9, 13). Such varying intensities of demand upon the neuro-endocrine axis entails after exertion also varying modes of restoration of the body over the recovery period.

A major functional position within the neuro-endocrine axis is, as is known, that detained by the hypothalamo-pituitary-adrenal axis.

It is therefore obvious how necessary it is that the neuro-endocrine-metabolic function investigated in connection with the essential components of the motor function should become a central concern in sports biology (9). The prevalence of ergotropic conditions during exertion and of those of trophotropic type during restoration should also be taken into account, for the characteristics specific to the restoration of certain metabolic parameters will depend upon the intensity with which such conditions arise.

In our previous investigations carried out in the light of this conception (14, 15, 16) we were able to distinguish over the period of restoration some characteristics of metabolic variability as a function of the characteristics of exertion (i.e. the branch of sports, the intensity and the duration of exertion etc.).

In the present paper we set forth the results of our investigations in which the functional state of the pituitary-adrenal axis and the metabolism of electrolytes...
(sodium and potassium) under its direct control were assessed over the period of restoration after strong exertion in sportsmen.

**Experimental model**

The process of restoration including cortico-adrenal hormonal functions and electrolyte metabolism, was studied in 11 athletes, i.e. semi- and long-distance runners. The test consisted in running a flat-ground 400 m distance 10 times with 90 sec free intervals and as fast as during "tough" training.

The process of restoration was studied by evaluation of the changes in hormonal and metabolic parameters after exertion relative to the values at rest (T₀) over the 24 hours before the test. Variations in urinary excretion of cortico-adrenal hormones: total 17 ketosteroids (17 CS), of 17 hydroxisteroids (17 OH) and dehydroisoandrosterone (DHA) 24, 48 and 72 hours after exertion (denoted T₂₄, T₄₈, T₇₂) and variations in urinary excretion of sodium and potassium over the same period were studied.

**Results and discussion**

Tables 1, 2 and 3 illustrate the initial (T₀) individual values and the module (percentage) of variations in individual excretion of the hormones at T₂₄, T₄₈ and T₇₂.

| Table 1 |
| Variations in urinary 17-CS after exertion |

<table>
<thead>
<tr>
<th>Subject</th>
<th>T₀ mg/24 h</th>
<th>T₂₄</th>
<th>T₄₈ module ± %</th>
<th>T₇₂</th>
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</tr>
<tr>
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<tr>
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<td>+ 64.8</td>
<td>+ 23.0</td>
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The Tables 4 and 5 show in the same manner the results for the urinary excretion of sodium and potassium.

| Table 2 |
| Variations in 17-OH after exertion |

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<tr>
<th>Subject</th>
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| Table 3 |
| Variations in DHA excretion after exertion |

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<td>− 13.2</td>
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The Tables 4 and 5 show in the same manner the results for the urinary excretion of sodium and potassium.

| Table 4 |
| Variations in urinary excretion of sodium after exertion |

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<tr>
<th>Subject</th>
<th>T₀ mg/ % ml</th>
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</tr>
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<td>2</td>
<td>240</td>
<td>− 6.2</td>
<td>+ 15.0</td>
<td>+ 4.0</td>
</tr>
<tr>
<td>3</td>
<td>268</td>
<td>− 18.9</td>
<td>− 23.1</td>
<td>+ 40.0</td>
</tr>
<tr>
<td>4</td>
<td>248</td>
<td>+ 6.3</td>
<td>+ 6.0</td>
<td>+ 6.0</td>
</tr>
<tr>
<td>5</td>
<td>376</td>
<td>− 6.8</td>
<td>0.0</td>
<td>+ 6.0</td>
</tr>
<tr>
<td>6</td>
<td>350</td>
<td>+ 2.8</td>
<td>+ 8.4</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>425</td>
<td>− 23.0</td>
<td>− 36.2</td>
<td>− 10.0</td>
</tr>
<tr>
<td>8</td>
<td>460</td>
<td>+ 10.9</td>
<td>+ 38.0</td>
<td>− 20.0</td>
</tr>
<tr>
<td>9</td>
<td>450</td>
<td>− 5.5</td>
<td>0.0</td>
<td>− 33.8</td>
</tr>
<tr>
<td>10</td>
<td>750</td>
<td>− 20.0</td>
<td>+ 6.6</td>
<td>− 13.3</td>
</tr>
<tr>
<td>11</td>
<td>780</td>
<td>+ 3.1</td>
<td>+ 6.2</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Table 5

Variations in urinary excretion of potassium after exertion

<table>
<thead>
<tr>
<th>Subject</th>
<th>T₀</th>
<th>T₂₄</th>
<th>T₄₈</th>
<th>T₇₂</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/ % ml</td>
<td>module ± %</td>
<td>module ± %</td>
<td>module ± %</td>
</tr>
<tr>
<td>1</td>
<td>60</td>
<td>+ 108.0</td>
<td>+ 89.0</td>
<td>+ 127.0</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
<td>0.0</td>
<td>0.0</td>
<td>− 77.5</td>
</tr>
<tr>
<td>3</td>
<td>112</td>
<td>+ 16.0</td>
<td>+ 70.0</td>
<td>+ 78.5</td>
</tr>
<tr>
<td>4</td>
<td>120</td>
<td>+ 108.0</td>
<td>+ 89.0</td>
<td>+ 127.0</td>
</tr>
<tr>
<td>5</td>
<td>130</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>147</td>
<td>+ 9.6</td>
<td>− 9.0</td>
<td>+ 18.0</td>
</tr>
<tr>
<td>7</td>
<td>137</td>
<td>+ 38.8</td>
<td>+ 53.2</td>
<td>+ 86.0</td>
</tr>
<tr>
<td>8</td>
<td>180</td>
<td>+ 6.0</td>
<td>+ 11.0</td>
<td>− 6.0</td>
</tr>
<tr>
<td>9</td>
<td>220</td>
<td>+ 4.5</td>
<td>+ 9.0</td>
<td>+ 4.5</td>
</tr>
<tr>
<td>10</td>
<td>220</td>
<td>− 135</td>
<td>+ 8.0</td>
<td>− 3.5</td>
</tr>
<tr>
<td>11</td>
<td>400</td>
<td>− 22.5</td>
<td>− 35.0</td>
<td>+ 2.5</td>
</tr>
</tbody>
</table>

The graph in Fig. 1 shows, relative to the initial values, the dynamics of the excretion of total 17-CS at the above time intervals.

Fig. 1. Variations in excretion of total 17-ketosteroids after exertion.

Fig. 2 illustrates the dynamics of excretion of the hydroxisteroids, and Fig. 3 that of dehydroisoandrosterone.

Fig. 2. Variations in excretion of 17-hydroxysteroids after exertion.

Fig. 3. Variations in excretion of dehydroisoandrosterone after exertion.

The main points which emerge are the following:

Total 17-CS: the percentage of moderate-increase cases goes downward from T₂₄ to T₇₂, whereas the percentage of excretion values under the value at rest goes upward from T₂₄ to T₇₂ with an inflexion at T₄₈. One should note that in about one-third of the cases studied the excretion values tend to become twofold or even higher.

The 17-OH: the proportion of cases with moderately increased excretion is higher at T₇₂, a point of inflexion being again noted at T₄₈. Decreased excretion values relative to the initial one are more frequent at T₄₈.

The DHA: increased excretion up to twofold or even higher values prevails. Let us mention too that the proportion of decreased excretion oscillates about 25%.
Although the statistical significance of these percentages seems uncertain, a discussion of the variations of the values at the time intervals studied may, we believe, enable us to reach conclusions of physiologic dynamics with a significance from this point of view. Thus, involvement of the adrenal after exertion within our experimental model is not the same in every individual, though the subjects belonged to the same branch of athletics. Restoration of the functional state of the cortico-adrenal — as it appears from our study on the three hormonal groups — is oscillatory and not linear in character, and this in the case both of increased or, as is common, decreased (on account of exhaustion) hormonal secretion after exertion.

The inverse variation in 17-CS relative to 17-OH observed in the cases studied proves that the dynamics of adrenal secretion secures metabolic compensation over the recovery period (return to the resting tone). One should note that at 72 hrs, in about half of the sportsmen studied, the functional tone of the adrenal was still high indicating that the potential of control mechanisms was as yet not fully restored.

This obviously points to the necessity of an individualized study of the athletes.

Figs. 4 and 5

**Variation in urinary excretion of sodium after exertion**

![Graph showing variation in urinary excretion of sodium after exertion.](image)

**Fig. 4. Variations in urinary excretion of sodium after exertion.**

Graph 4 illustrates the dynamics of urinary excretion of sodium after exertion, and graph 5 that of potassium. The proportion of cases of increased excretion is higher at T48 and the proportion of cases of excretion under resting values is higher at T34. The dynamics of potassium excretion shows the greater proportion of cases of increased and evidently accentuated excretion at T72. Setting this dynamics against that of 17-OH excretion, the excretions appear to be concordant in direction, the classic mechanisms of endocrine-metabolic control being thus confirmed also along the mineral line we have studied, which has a wellknown importance in relation with the motor function (2, 3, 4, 7, 12). The increased excretion of potassium in most subjects at T72 draws attention to the potassic “budget” which is so necessary especially to the nervous regulation of muscular contraction (5, 8). Let us note that, — and this is of practical consequence too, — the supply of exogeneous potassium should be considered also in relation to the dynamics of excretion of the mineral-corticoid hormones.

**Variation in urinary excretion of potassium after exertion**

- Excretions over 100% of resting value.
- Excretions of 50-100% of resting value.
- Excretions of up to 50% of resting value.
- Excretions under resting value.

**Fig. 5. Variations in urinary excretion of potassium after exertion.**

The study of the endocrine-metabolic relationship over the process of restoration which, according to our conclusions, seems to last more than 72 hours, appears necessary at least concerning the cortico-adrenal — electrolyte metabolism relations. The data of the literature irrefutably prove that the cortico-adrenal is an essential link in the chain of neuro-endocrine-metabolic processes involved in sportive exertion (1, 2, 3, 4, 7, 9, 15, 16, 18). The dynamics of functional restoration studied in terms of the amount of hormones secreted (and, implicitly, excreted) should be considered complexly and in correlative connection with the nervous system. Neuro-endocrine control represents, in our opinion too, the essential factor in the period of recovery, and this is all the more true as the individual characteristics of these aspects underlie the sportsman’s behaviour during the course of exertion. Other studies of ours (17, 18) attested to the same point of view.

**Conclusions**

The results obtained make it possible to draw the following conclusions:
— The period of restoration or recovery at least for the cortico-adrenal axis, must be regarded as an individual characteristic in the sportsman.

— The restoration of the functional tone of the gland is contingent upon the degree of its involvement during exertion, the profile of the curve of restoration being sinusoidal.

— The endocrino-metabolic correlation, at least with respect to the cortico-adrenal axis — electrolyte metabolism displays the same dynamics.

REFERENCES


STUDIES OF PROTEIN REQUIREMENT IN SPORT

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ABSTRACT

The problem of the protein requirement in sport is controversial. As opposed to Mayer, Åstrand, Margaria, Schüsse and Kraut, a number of other authors, including Jakowlew, Grafe, Prokop and Gontea postulate the protein requirement to increase in manual work and sport. The divergence of opinion is due to differences in the methods for nitrogen balance determination. According to Consolazio, the amount of nitrogen excreted in the sweat ought to be included in the nitrogen losses.

In the present investigation, this view was confirmed in studies of athletes. Nitrogen balances were determined during training camps under natural conditions in Polish weight-lifters of the Olympic team and those of classes I and II ("Legia and Warszawa" Athletic Club). In case of high protein intake (about 200 g daily), the mean nitrogen balance was highly positive. With protein intake of 145 g daily, the mean nitrogen balance was very slightly positive, whereas in 50% of cases the balances were negative. Thus, when threshold levels of protein intake are concerned, the amount of nitrogen excreted in the sweat can be decisive of nitrogen retention in the tissues. It was demonstrated that the protein requirement of Polish weight-lifters of the Olympic team and those of the "Legia" Athletic Club remained within the range of 2.5 - 2.8 g. and 2.0 - 2.2 g./kg of body weight respectively.

It is advisable to continue the studies of the nitrogen balance in athletes, consideration being also given to nitrogen losses in the scaled epidermis.
THE EFFECTS OF TRAINING AND VITAMIN E SUPPLEMENTATION ON THE PERFORMANCE OF ADOLESCENT SWIMMERS

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² Department of Ergonomics and Cybernetics, University of Technology, Loughborough, Leicestershire

ABSTRACT

Two experimental groups of 13 adolescent boys were tested before and after a 6 week training programme by anthropometry and tests of cardio-respiratory efficiency and motor fitness.

One group was given 400 mg α-tocopheryl acetate daily, the other placebo.

No significant differences were found between these groups after the programme.

Two experimental groups, each consisting of 13 adolescent boys at boarding school, were tested before and after a six-week training period for competitive swimming. One group was given 400 mg α-tocopheryl acetate daily, the other placebo, in addition to their normal diet. A double blind procedure was employed throughout so that neither swimmers nor administrators knew which treatment was given to any individual. Effects of the experimental treatments were assessed from the results of a battery of tests which covered three different areas of investigation, viz. anthropometric status, cardio-respiratory efficiency, and motor fitness and performance.

The anthropometric measurements were height, weight and skinfold thickness recorded at five different sites. Cardio-respiratory observations were made at rest, at sub-maximal and maximal effort. Measures at maximal effort were breath-holding time, time for a mile run and time for a 400 m swim. Motor fitness tests comprised pull-ups, push-ups, sit-ups for two minutes, and a weight pressing exercise.

Training consisted of daily swims supplemented by bouts of free exercise, circuit training and general sports participation. Swimming sessions included a mixture of endurance swimming at constant speed and controlled interval training geared to individual target racing pace.

Results of the motor fitness and all-out performance tests are shown in Table 1. Significant differences in all areas were observed in both groups as the result of training at the 5% level. No significant differences were, however, found between the group given vitamin E and the one receiving placebos.

<table>
<thead>
<tr>
<th>Test</th>
<th>GROUP GIVEN VITAMIN E</th>
<th>GROUP GIVEN PLACEBES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pull-ups (No.)¹</td>
<td>Before treatment</td>
<td>After treatment</td>
</tr>
<tr>
<td></td>
<td>5.2 ± 3.1</td>
<td>6.5 ± 3.1</td>
</tr>
<tr>
<td></td>
<td>4.6 ± 2.9</td>
<td>6.1 ± 3.3</td>
</tr>
<tr>
<td>Push-ups (No.)¹</td>
<td>Before treatment</td>
<td>After treatment</td>
</tr>
<tr>
<td></td>
<td>5.0 ± 3.9</td>
<td>7.2 ± 4.0</td>
</tr>
<tr>
<td></td>
<td>5.5 ± 4.5</td>
<td>6.5 ± 4.7</td>
</tr>
<tr>
<td>Sit-ups (No. in 2 mins)¹</td>
<td>47.8 ± 9.8</td>
<td>53.0 ± 9.5</td>
</tr>
<tr>
<td></td>
<td>48.0 ± 11.3</td>
<td>53.1 ± 13.4</td>
</tr>
<tr>
<td>Presses on bench (No.)²</td>
<td>22.4 ± 9.8</td>
<td>24.9 ± 8.6</td>
</tr>
<tr>
<td></td>
<td>21.6 ± 13.0</td>
<td>24.0 ± 10.8</td>
</tr>
<tr>
<td>Breath holding(s)</td>
<td>53.4 ± 15.6</td>
<td>76.8 ± 23.7</td>
</tr>
<tr>
<td></td>
<td>69.6 ± 13.9</td>
<td>78.2 ± 22.9</td>
</tr>
<tr>
<td>Mile run(s)</td>
<td>369.5 ± 20.3</td>
<td>365.9 ± 36.3</td>
</tr>
<tr>
<td></td>
<td>369.8 ± 26.8</td>
<td>374.0 ± 27.7</td>
</tr>
<tr>
<td>400 m swim(s)</td>
<td>442.1 ± 74.8</td>
<td>418.2 ± 59.8</td>
</tr>
<tr>
<td></td>
<td>451.5 ± 60.2</td>
<td>413.1 ± 52.3</td>
</tr>
</tbody>
</table>

¹ Until subject was exhausted
² Until subject was exhausted or until the pressing rate, viz. one press every 2s was broken.
PHYSICAL TRAINING AND CHANGES IN HEPATIC FLUID SPACE

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ABSTRACT

Three of six experimental groups of 10 rats each were trained by swimming twice weekly for almost 4 months. The changes in hepatic fluid space were compared in respect of the effects of training, of acute exhaustion, and of a 24 hours regeneration period promoted by peroral glucose administration after acute exhaustion.

The dry weight of livers exsiccated to constant weight did not change significantly, though there was some slight increase in controls and some slight decrease in trained animals and in the trained ones in the regeneration period.

In the control groups fluid space of the liver showed a moderate rise whereas in the trained animals the observed decrease was both significant and considerable, following acute exhaustion.

In the regeneration period, no significant change in fluid space was observed in control animals. In trained animals, however, fluid space was considerably extended. This increase was significant even in comparison to non-exhausted trained animals.

Possible interpretation of the results is discussed.

Introduction

Little is yet known about the changes of liver volume that are elicited by the events of training and sport competitions. Wade and his associates (1956) have shown that lifting the legs alternately as an exercise brings about a decrease in hepatic circulation and splanchnic blood volume in individuals at rest. Since hepatic inflow and outflow need not be equal, the liver may act as a store of blood by pooling and thereby excluding a considerable amount of blood from the circulation temporarily and returning it into the circulation some time later again. Liver volume may accordingly undergo changes, depending on the existing extent of hepatic fluid space. Excess fluid may appear not only extracellularly, but also within the cells as vacuoles filled reversibly by fluid (Trowell 1946, Ladewig 1943).

The questions for which answers were sought by the present experiments were as follows:

Does regular training affect hepatic fluid space?

What changes may be expected in hepatic fluid space when trained and untrained animals are exposed to acute exhaustion?

What effect is elicited by glucose administered to animals exposed to acute exhaustion and allowed 24 hours of rest for regeneration?

Methods

Six groups of 10 albino rats were each used in the experiments. Three groups were regularly trained by swimming for half an hour twice weekly for four months. The groups which were not trained by swimming were used as controls. Subgroups in either groups were labelled by Latin numerals: Subgroup I was control, the animals in Subgroup II were acutely exhausted by swimming, while the animals of Subgroup III were acutely exhausted, then given 3 mls of 40% glucose in saline through a gastric tube and sacrificed after a regeneration period of 24 hours.

The animals were decapitated, the weight of the livers was measured both immediately after extirpation and after drying them to constant weight. From the difference fluid space was calculated and expressed in grammes per gramme wet liver weight.

Results were analysed by using two-tailed “t” test.

Results and Discussion

Acute exhaustion in untrained animals took 83 minutes to develop, and 126 minutes in the trained ones, on the average. Thus mean swimming time was 43 minutes longer in trained animals.

In subgroup Cl mean hepatic fluid space was 0.636 gr/gr wet liver weight (Table 1, Fig. 1). Fluid space after
acute exhaustion was significantly greater (CII). When acute exhaustion was followed by regeneration (CIII), fluid space was significantly higher than in controls, but less so than after acute exhaustion immediately.

In the swimming group S I mean fluid space was 0.6 gr/gr wet liver weight. After acute exhaustion a significantly smaller value was found (S II), while mean fluid space after regeneration (S III) was at about the same level as in controls.

Table 1.

Hepatic fluid space in gr/gr wet liver weight (mean and standard error)

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>Untrained animals (C)</th>
<th>Trained animals (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I: Control</td>
<td>0.636 ± 0.0049</td>
<td>0.643 ± 0.0036</td>
</tr>
<tr>
<td>II: Acute exhaustion</td>
<td>0.659 ± 0.0051</td>
<td>0.608 ± 0.0056</td>
</tr>
<tr>
<td>III: Acute exhaustion and regeneration</td>
<td>0.654 ± 0.0032</td>
<td>0.650 ± 0.0029</td>
</tr>
</tbody>
</table>

The comparison of trained and untrained animals shows that under control conditions hepatic fluid space was only negligibly greater in the trained rats. After acute exhaustion however a marked difference was developed, since this treatment caused an opposite effect in the two groups, each deviating significantly from its control. Thus previous training was evidenced to exert a highly significant influence on hepatic fluid space.

Fig. 2 illustrates the observed intergroup differences in per cents of liver weight. The inverse effect caused by acute exhaustion is clearly visible in the left part of this

Fig. 2. The right part of Fig. 2. shows the comparison of the respective subgroups. The difference between control animals (S I – C I) was non-significant as well as that between regenerated ones (S III – C III). In the latter condition however hepatic fluid space was slightly greater than in controls which might indicate that complete restoration of fluid space equilibrium would take longer than 24 hours.

In view of the most conspicuous difference, namely that found following acute exhaustion, the most likely suggestion would be that untrained animals develop a congestive enlargement of hepatic fluid space. Venous congestion and/or hypoxia is known to elicit hepatic intracellular fluid surplus (Riecker et al. 1957). On the other hand, well-trained athletes may increase their circulating blood volume by as much as 40% during and owing to physical exercise. This balanced increase may be a reason for a decrease in hepatic fluid space as it was observed in acutely exhausted trained animals.

The extension of the hepatic fluid space during regeneration may be attributed also to metabolic effects in the sense that circulation would depend also on local functional conditions. In order to clarify these problems further experiments are necessary.

Summary

Animals trained by swimming were found to respond to an acute exhaustion by a diminution of hepatic fluid space while untrained ones showed an increase in it when exposed to the same treatment. Glucose administration and a 24 hrs rest tended to restore resting conditions, but complete equilibrium was not attained.

Inversion of the response to acute exhaustion may be regarded as an adaptive process to the effect that hepatic circulation would grow more efficient by training and prevent the development of congestion.
REFERENCES

1. LADEWIG, P.: Anoxemic changes in liver, with regard to "high-altitude death" of airmen. Nature (London) 151, 558, 1943.


SERUM PROTEIN CHANGES IN EXERCISE

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ABSTRACT

Twelve male subjects were submitted to an intense arm exercise involving flexion and extension of the wrist while hand holding a 4 kg. dumb-bell. The exercise was carried on until the subject was exhausted. Analysis of venous blood, taken at the elbow, revealed the following:

1. during the exercise, there was an increase in the haematocrit and in serum protein concentration. The protein increase was greater than was the haematocrit.

2. during recovery, the haematocrit and protein concentration return to their initial values by nine minutes.

3. after 1.45 minute of exercise, the correlation between the increase of the haematocrit and of serum proteins was positive but low. At the end of the exercise the correlation decreased but became significant again after 3 minutes of recovery.

The increase of both the haematocrit and the serum proteins is not due exclusively to plasma concentration. The hypothesis is advanced for protein transfer to the circulation.
THE PHYSIOLOGICAL EFFECTS OF WHEAT GERM OIL* AND RELATED SUBSTANCES AS ERGOGENIC AIDS

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ABSTRACT

This controversial area has been followed for 20 years, and this report summarizes some 48 studies and reports related to the use of whole, fresh wheat Germ Oil and octacosanol, a derivative of the oil, in comparisons with various placebos, such as: cottonseed oil, corn oil, lecithin oil, devitamized (except for vitamin E) lard. Several hundred subjects have been involved. A review by W. Richard Dukelow gives supporting animal expts. (Acta Endocrin. Vol. 56).

The research methods have involved in the main parallel groups taking the same programme of physical work, under the same instructor for the same amount of time; but there have been two exceptions to this in longitudinal studies. With randomly matched samples the t test has been used for reliability at the 0.10 level or better; and with small non-random samples the differences between groups have been compared with S.E.meas, or S.E.est, based upon re-test differences within the groups at hand. The best reliability has been to repeat the work on independent samples. With skewed data non-parametric statistics were used.

A variety of physiologic parameters have been used, although 16 different experiments were conducted on endurance in the 600-yard run and All-out Treadmill Run, 7 mi/hr/8.6% grade. The mile run and muscular endurance items such as: chinning, push-ups, sitting-tucks, squat jumps have also been used, and a composite muscular endurance criterion. In addition, the highest T-wave of the ECG has been used, also pulse rate and Schneider Index and pre-ejection TP and ICP intervals of the heart beat cycle; and also metabolic rate (basal) and Max. O2 Intake; also Total Body Reaction Time. The BMR results indicate that WGO conserves oxygen. BCG (Ej.vel./time) and Amplitude and area of the brachial pulse wave were effected.

The results show that in 14 of 16 performance experiments with endurance as the criterion, the gains favoured the group on WGO or octacosanol, and these supplemented groups out did the control groups. Reliability has generally been better than 0.10 level, or the ratio of D/S.E.diff, greater than 2.0 or 3.0. Interfering activity was identified as hurting the reliability, overshadowing the effects of the oil and octacosanol. (Octacosanol = CH₃(CH₂)₆CH₂OH)

Conclusion has been reached that endurance was generally benefitted if the feeding of WGO or octacosanol was 6 weeks or more, and 20 weeks gave greater significance for the differences than 10 weeks. The effect appears to be on nervous integration rather than an effect upon the Max. O2 Intake, and in matched pairs of boys, some with the lower Max. O2 Intake ran the longest, and there were in one of these pairs boys who differed greatly in run time in the All-out Treadmill Run but who were insignificantly different in Max. O2 Intake. This idea is supported by the Total Body Reaction Time results, and by Brozek’s summary of the Russian work in this area (J. Brozek, "Soviet Studies on Nutrition and Higher Nervous Activity", Annals of the New York Academy of Sciences, 93: 665-716, 1963). The results on the T-wave of the ECG may also be mainly a nervous effect, and that on the Brachial Pulse Wave also.

It is easy to not get a significant change attributable to the supplements of WGO (fresh, capsullated, non-boiled), but when a change appears it is most likely minimized by extraneous interference and multiple causes of variability, some of which are discussed in this report. Research in this area has been discouraging to many investigators because of the difficulty of controlling humans well enough to get a significant result. Nevertheless, the effects of WGO and octacosanol are very meaningful in the practical sense, and most of the experiments meet ordinary reliability standards. The individual case, as his own control (as in Cureton’s T-wave data) are not to be discarded if continued long enough under known conditions. Differences between the experimental and controls were minimized because of some biologic action from the placebos.

*Fresh WGO, in capsules, solvent extracted with ethylene dichloride from fresh wheat germ, 20 x 3 minims per day (or 10 x 6 minims per day), 4-7 times per week. Each 6 minim capsule contained 7.54 mgs. Made by Viobin Corp., Monticello, Illinois.
Improvements in reaction time due to training with dietary supplementation.

University of Illinois Sports Fitness School — 1968

Wheat germ — Placebos — Wheat germ oil

Fig. 3

Investigation of the suitability of a salt replacement pharmaceutical ("Slow Na", CIBA)

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Abstract

Replacement of salt lost in sweat is often difficult, especially during vigorous exercise. Acceptable flavoured drinks are inefficient as they inhibit gastric emptying and so prevent rapid intestinal absorption. "Slow Na" tablets have been used by us for several years as an acceptable means of administering salt to patients during haemodialysis for chronic renal failure. We recently studied the pattern of absorption of these tablets to test their suitability for salt replacement during exercise.

Radioactive "Slow Na" tablets were given to human volunteers. Absorption was measured both by measurement of the radioactivity of plasma samples and by abdominal counting with a simple radioactivity counter, and the results compared with the absorption of trace quantities of radioactive Sodium Chloride. When taken with the stomach empty, absorption was always detectable in 30 to 60 minutes and proceeded for 4 to 7 hours. Absorption was not altered when test tablets were taken with large numbers of non-radioactive "Slow Na" tablets. A limited study of "Slow Na" in subjects performing vigorous training exercise showed no deleterious effect from 20 tablets (200 millequivalents of NaCl) taken over the previous 4 hours.
BALANCED ELECTROLYTE SOLUTIONS FOR THE PROPHYLAXIS OF HEAT ILLNESS IN ATHLETES

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ABSTRACT

Early season football deaths due to heat stroke in 1965 in the United States demonstrated the need for and gave rise to the prophylactic use of balanced electrolyte solutions for heat illness.

A case study is used to illustrate extracellular and renal electrolyte changes following a warm weather ninety minute practice session of a northern New Jersey high school football player, showing how deficits can occur. The important role of potassium in heat stress and its relationship to aldosterone is discussed. The haphazard use of irritating salt tablets and restricted water intake is eliminated.

Weight loss is used as a guide in the replacement of fluids containing adequate amounts of sodium chloride and a bland potassium salt combined in a pleasant tasting cold solution. Practical suggestions for administering such solutions to athletes are mentioned as points of interest to persons who take care of an athlete's needs.

This paper demonstrates the gradual replacement of combined fluids and electrolytes during a session in proper proportion without overloading or irritating the stomach. Such measures should help keep sweating athletes and other active people in good condition during performance and prevent the hazards of heat illness.*

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ALTERACIONES HEMOLITICAS Y FIBRINOLITICAS EN EL ESFUERZO FISICO

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CONCLUSIONES

a) Se estudian cuarenta atletas antes, inmediata y una hora despues del ejercicio, y se comparan los resultados de los valores de fibrinógeno, lisis de euglobulinas, fibrinolisis cuantitada y hemolisis, con las obtenidas en sujetos no entrenados y con deportistas despues de un periodo de descanso atlético.

b) El fibrinógeno no sufre variaciones apreciables.

c) Las euglobulinas positivizan cuando la fibrinolisis por ciento sube por encime de 40%.

d) Tanto la fibrinolisis como la hemolisis asciende de forma apreciable en aquellos que realizan un ejercicio muy activo, para no llegar a la hora postejercicio a normalizarse.

e) En aquellos deportes no tan violentos estas cifras no sufren variación.

f) En los atletas con reposo prolongado los aumentos de valores son lige — ramente mayores, pero descienden a la hora de concluir el ejercicio casi a la normalidad.

g) El factor psicógeno es muy importante en el desfasamiento de estas constantes.

h) En no atletas, la subida de cifras se aprecia a la hora postejercicio.