Effects of Continuous Long Distance Running Exercise on Plasma Enzyme Levels in Horses

Mitsuru Murakami* and Shigeyoshi Takagi*

The present investigation was undertaken to clarify the relationship between changes of some blood enzymes and physiological conditions in exercising horses. For this purpose, 3 horses were subjected to long distance running which consisted of 22,000 m per day for 5 consecutive days mainly at extended trot and partially at slow canter.

Blood samples were collected before, in the middle, immediately after, 1 and 5 hours after exercise every day in the exercise period, and 1, 2, 3, 5 and 7 days after the exercise period for observing recovery process. In this experiment, changes of creatine kinase, aspartate aminotransferase, and fructosediphosphate aldolase were observed. Moreover, erythrocyte sedimentation rate, eosinophil count and body weight were measured owing to observe the effect of exercise on horses.

As a result, creatine kinase activity elevated to a maximal level 5 hours after exercise and then rather decreased. The magnitude of increasing rate of the enzyme became larger as exercise loaded was strengthened. That is to say, the strength of the exercise closely influenced on increase of heart rate during exercise and both increase of creatine kinase and decrease of eosinophil count 5 hours after exercise in each case every day. Although aspartate aminotransferase activity failed to increase markedly with the strength of exercise, elevated activity maintained at a high level, then increased gradually during exercise period. Fructosediphosphate aldolase activity changed in an intermediate manner between the other two enzymes mentioned above.

On the other hand, it was presumed that, from the results of changes of erythrocyte sedimentation rate and body weight, the magnitude of fatigue might become larger as exercise progressed.

Therefore, these results suggest that creatine kinase may be employed as an indicator for the severity of exercise, and aspartate aminotransferase as an index for over-training. However the significance of fructosediphosphate aldolase for exercise is not so clear.

Introduction

It has been well known that some blood enzymes originated from muscular cells increase following exercise on account of the alteration of membrane permeability and/or damage of muscle cells.

With regard to horses, it has been described that creatine kinase (ATP: creatine phosphotransferase ; 2.7.3.2), fructosediphosphate aldolase (Fructose-1,
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6-diphosphate d-glyceraldehyde-3-phosphate-lyase [4.1.2.13], and aspartate aminotransferase (L-Aspartate: 2-oxoglutarate aminotransferase; 2.6.1.1) are a highly specific and very sensitive, a good, and an unspecific indicator, respectively, for muscular cell damage1-3, and that creatine kinase and aspartate aminotransferase increase with exercise, training and especially myopathies associated with exercise, such as tying-up and equine paralytic myoglobinuria2-7. Few papers, however, have dealt with fructosediphosphate aldolase in exercising horses. Also little attention has been paid to the relationship between changes of blood enzymes and physiological conditions closely reflected on the erythrocyte sedimentation rate (ESR), eosinophil count, and body weight of horses affected by exercise.

The present investigation was undertaken to clarify (1) relationship between changes of some blood enzymes mentioned above and the conditions, and (2) inter-relationship among changes of the enzymes following exercise.

Materials and Methods

Experimental horses: The subjects employed in this experiment were 3 healthy horses which had been stabled in the Equestrian Park, the Japan Racing Association, Tokyo. Case No. 1 was a 9-year-old trotter gelding. Nos. 2 and 3 were 5-year-old cross-bred geldings.

Exercise loading: The 3 subjects were put on a program of long distance running at extended trot only (No. 1), or at a combination of mainly extended trot and partially slow canter (Nos. 2 and 3). The running distance per day was uniformly 20 laps of the track at the Equestrian Park, one lap of the track being 1,100 m long. The subjects run the distance of 22,000 m without resting, except that they rested for 2–3 minutes at the 10th lap to collect blood sample. The running was performed for 5 consecutive days in all the horses.

Running speed was controlled on the basis of the heart rate so that heart rate might not exceed 170 beats per minutes by electrocardiography employed a combination of telemeter (TPE-11) and thermal stylus type direct writing recorder (SCC-1), and induction of the canter was performed when the trot failed to increase the heart rate exceeding 150.

Blood collection: Blood samples were collected from each horse 5 times a day during exercise period, that is, before exercise, in the middle of exercise (at the 10th lap), immediately after, and 1 and 5 hours after exercise. During the recovery period, blood samples were collected only once a day on 1, 2, 3, 5, and 7 days after exercise period. Blood collection was performed by venipuncture and heparinization.

Enzyme determination: Samples used for enzyme determination was heparinized blood plasma.

(1) Creatine kinase: Creatine kinase activity was determined at 30° by the CPK-Reagents Set Dade. The method employed was based on a modification of the Nuttall-Weddin method, which is the estimation of pyruvate hydrazone produced by reaction with 2,4-dinitrophenylhydrazine and pyruvate under alkalinity. The activity was indicated in terms

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1 Fukuda Denshi Co., Tokyo, Japan.
2 Dade Co. Ltd., Miami, Fla., U.S.A.
of international unit.

(2) Aspartate aminotransferase: The enzyme activity was determined at 30° by STA-Test Wako Kit\(^3\). The method used was based on a modification of the Reitman-Frankel method, which is the estimation of pyruvate hydrazone and all the same as the method of creatine kinase. The activity was indicated in terms of Karmen unit.

(3) Fructosediphosphate aldolase: The activity was measured at 30° by the Kit of Reagents for the determination of aldolase\(^4\). The method used was based on a modification of the Sibley-Lehninger method, which is the determination of hydrazone of dihydroxyacetone phosphate and glyceraldehyde-3-phosphate, and is the same as the method of creatine kinase. The activity was indicated as Sibley-Lehninger unit.

Erythrocyte sedimentation rate (ESR): ESR was determined by the method which was described by Sakurai\(^8\). That is, the value of ESR was obtained 40 minutes after the beginning of sedimentation at room temperature, and it was converted into the value at 20° with multiple characteristic factor.

Eosinophil: Eosinophils were counted by Tatai’s eosinophil counting plate employing Pilot staining solution.

Results

In the present experiment, speed and heart rate varied widely in each horse on each day. The summarized data are shown in Tables 1 and 2. As can be seen at the first glance of these tables, case No. 1 could run faster at extended trot than any other horses. Therefore, the heart rate of case No. 1 reached a high level than that of any other horses.

On the contrary, the cases of Nos. 2 and 3 were tried to run at extended trot, but failed to run fast, and their heart rate could not exceed 150. Then cases of Nos. 2 and 3 were occasionally loaded with exercise at slow canter combined with extended trot on the succeeding 3rd and 2nd day, respectively. Although these gait were combined, the distance covered by canter was restricted to 2 or 3 laps (2,200 or 3,300 m) at the longest.

In respect to the changes of the enzymes following long distance running, that of creatine kinase generally tended to increase with the strength of exercise in each case, as shown in Fig. 1. As shown in Fig. 2, when the changes of creatine kinase activity were represented as changing rate in which the values of before exercise were regarded as 100, the rates of Nos. 1, 2, and 3 determined 5 hours after exercise increased to about 140–180, 120–160, and 120–250, respectively, except that of No. 1 on the 1st and 5th days, that of No. 2 on the 4th day, and that of No. 3 on the 5th day which increased markedly to about 270, 210, 180, and 410, respectively. Thus the changes of creatine kinase activity responded relatively well to the strength of exercise, that is, speed.

Changes of aspartate aminotransferase were different from those of creatine kinase and inclined to reach maximal level immediately after exercise. Then the levels were maintained or rather decreased, as shown in Fig. 1. The changing rate of the enzyme was also different from that of creatine kinase, ranging from about 120 to 130 in each case every day, as

\(^3\) Wako Pure Chemicals, Ltd., Tokyo, Japan.
\(^4\) Sigma Chemical Co., St. Louis, Mo., U.S.A.
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Table 1. Average speed of each subject (m/sec)

<table>
<thead>
<tr>
<th>Horse</th>
<th>Day of exercise period</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>T aver.</td>
<td>6.39</td>
<td>4.70</td>
<td>4.78</td>
<td>6.24</td>
<td>6.09</td>
</tr>
<tr>
<td></td>
<td>C aver.</td>
<td>4.84</td>
<td>5.36</td>
<td>5.12</td>
<td>5.41</td>
<td>4.97</td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>3.82–5.14</td>
<td>5.08–5.57</td>
<td>4.82–5.36</td>
<td>4.23–6.29</td>
<td>4.61–5.10</td>
</tr>
<tr>
<td>No. 2</td>
<td>T aver.</td>
<td>4.97</td>
<td>5.72</td>
<td>5.53</td>
<td>5.58</td>
<td>5.71</td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>3.39–5.49</td>
<td>5.08–6.08</td>
<td>5.22–5.87</td>
<td>5.14–5.91</td>
<td>5.18–6.32</td>
</tr>
<tr>
<td></td>
<td>C aver.</td>
<td>9.20</td>
<td>8.19</td>
<td>8.28</td>
<td>9.39</td>
<td></td>
</tr>
</tbody>
</table>

Remarks: T and C mean extended trot and canter, respectively.

Table 2. Heart rate during exercise (beats/min)

<table>
<thead>
<tr>
<th>Horse</th>
<th>Day of exercise period</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>T aver.</td>
<td>187.0</td>
<td>138.3</td>
<td>131.2</td>
<td>159.8</td>
<td>153.7</td>
</tr>
<tr>
<td></td>
<td>T aver.</td>
<td>135.0</td>
<td>134.1</td>
<td>130.8</td>
<td>153.6</td>
<td>136.3</td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>105–144</td>
<td>96–144</td>
<td>96–150</td>
<td>126–182</td>
<td>96–162</td>
</tr>
<tr>
<td></td>
<td>C aver.</td>
<td>145.7</td>
<td>170.5</td>
<td>165.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>130–156</td>
<td>132–210</td>
<td>138–186</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td>T aver.</td>
<td>124.9</td>
<td>131.7</td>
<td>135.7</td>
<td>127.4</td>
<td>128.0</td>
</tr>
<tr>
<td></td>
<td>C aver.</td>
<td>149.0</td>
<td>148.1</td>
<td>147.9</td>
<td>154.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>range</td>
<td>138–162</td>
<td>129–159</td>
<td>128–164</td>
<td>141–192</td>
<td></td>
</tr>
</tbody>
</table>

Remarks: T and C mean extended trot and canter, respectively.

shown in Fig. 2. Even when the rate of creatine kinase in No. 3 on the 5th day was a maximum, that of aspartate aminotransferase was 150 at the highest, and then the rate of the enzyme began to decrease 1 hour after exercise.

Changes of fructosediphosphate aldolase somewhat resembled those of aspartate aminotransferase. The level of the enzyme tended to reach a maximum immediately after exercise. Thereafter, it became a plateau or decreased. The magnitude of
response for exercise, however, was a little greater than that of aspartate aminotransferase, as demonstrated in Fig. 2.

The effect of long distance running for 5 consecutive days on the plasma enzymes is given in Fig. 3, in which the plotted values are those estimated before exercise. The results obtained revealed that the levels of the enzymes were influenced by the exercise performed on the previous day. There were differences, however, in the manner of changes among these enzymes. The changes of creatine kinase responded relatively well to the strength of exercise. That is, when exercise was strengthened, the enzyme became higher in level than the value determined on the previous day especially as compared with
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Fig. 2. Rate of changes of plasma enzymes following exercise
Remarks. The changing rate (%) is plotted on the ordinate and the time in hours on the abscissa.
For other symbols see the remarks of Fig. 1.

Fig. 3. Changes of plasma enzymes during exercise and recovery periods
Remarks. Solid, dotted, and dot-and-dash lines indicate changes of creatine kinase, aspartate aminotransferase, and fructosephosphate aldolase, respectively.
the value at 5 hours after exercise. On the other hand, when exercise was weakened, the value of the enzyme became lower than that observed on the preceding day at the same sampling time. Consequently, the value determined on the 1st day after the exercise period (the 1st day of the recovery period) tended to increase, then the level of creatine kinase decreased rapidly thereafter.

On the contrary, a little correlation was observed between the strength of exercise and the level of the plasma enzymes of aspartate aminotransferase and fructosediphosphate aldolase. The levels of these enzymes increased gradually in the course of exercise period, then tended to decrease during the recovery period, except that aspartate aminotransferase was maintained at a high level in case
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No. 1 for 7 days after the exercise period.

PCV increased to maximal level in the middle of, or immediately after exercise, thereafter decreased rapidly then reached approximately pre-exercise value 1 hour after exercise, as shown in Fig. 4.

Changes of ESR, eosinophil count, PCV, and body weight during exercise and recovery periods are given in Fig. 5. The pre-exercise values of these items were plotted every day, and values of eosinophil count at 5 hours after exercise were also plotted.

In cases of Nos. 1 and 3, ESR was retarded in the first half of the exercise period, and was accelerated in the latter half. In case No. 2, however, ESR tended to be accelerated during exercise period. On the 7th day of recovery period, ESR returned to values of before exercise experiment. The eosinophil count decreased in all cases 5 hours after exercise, especially in case No. 1 on the 1st and 5th days and in case No. 3 on the 5th day decrease was remarkable. However the count remained unchanged in case No. 2 on the 1st and 2nd days.

Although changes of PCV were apparently irregular form, and slightly related to the strength of exercise. There was a roughly reverse relationship between changes of PCV and those of ESR.

Body weight decreased gradually with the advance in exercise. It did not return to the value weighed before beginning of the exercise experiment, even when 7th day in recovery period.

Discussion

It has been shown by many investigators that some blood enzymes increase following exercise in human beings\(^9\text{-}11\). Since creatine kinase is distributed restrictedly in skeletal and heart muscles and fructosediphosphate aldolase is also distributed largely in the skeletal muscle, it has been found that the elevations of the plasma enzymes were reflected by the conditions of exercise or training, such as amount, strength, and manner of muscular work\(^11\text{-}13\). These findings have been also demonstrated in horses, as described previously\(^1\text{-}6\). Regardless of unspecificity of aspartate aminotransferase, many investigations have been undertaken to observe changes of the enzyme with exercise in horses\(^3\text{-}14\text{-}16\), partially because the enzyme was dominant in the skeletal muscle\(^1\text{-}2\).

In order to observe changes of blood enzymes with exercise, many investigations in men were concerned with long distance running or walking, such as marathon running\(^10\text{-}17\), 16-km march\(^9\), Brighton stroll (53-mile walk)\(^18\), and 100-Km walk\(^19\). In these exercises, creatine kinase increased markedly.

Furthermore, it has been described that blood enzymes could not increase unless exercise loaded reached a certain degree of strength or amount of exercise\(^18\text{-}21\). For example, the strength of exercise caused an increase of heart rate and a subsequent increase of the plasma enzymes\(^22\), and creatine kinase increased markedly in exercise of prolonged time, but did not in short time\(^18\).

In respect to horses, some have reported changes of blood enzymes with various types of exercise, such as single training\(^15\), routine training\(^14\), and 12-mile exercise\(^3\). In single training, the training schedule consisted of dressage schooling, galloping, jumping, and roads and trials.
Gallops progressed from 1 mile in 3.5 minutes to 1 mile in 2.5 minutes plus a 1/2-mile "breeze" in 1 minute. This training schedule extended over 100 days, and aspartate aminotransferase activities decreased as training progressed, but in the latter stages of training were elevated again when exercise was restricted and food intake maintained.

In routine training, the training schedule for racing consisted of light galloping 3/8 to 1 mile for 3 successive days, galloping at full speed 3/8 to 1 mile on the 4th day, and then galloping daily until raced on the weekend. Horses undergoing strenuous daily exercise at the race track had average aspartate aminotransferase activities twice as high as horses not in training.

In the standard 12-mile exercise for 15 days, both creatine kinase and aspartate aminotransferase activities were observed. Creatine kinase increased distinctly and aspartate aminotransferase were inconsistently affected by exercise. In addition, the magnitude of creatine kinase elevation in response to exercise was greater on the 1st day than that of 8th and 15th days of exercise, while aspartate aminotransferase decreased from the 1st through the 15th days.

From these findings, the running distance for the present experiment was decided to be relatively long of 22,000 m every day so that plasma enzymes might increase. The program of exercise was designed as follows: Exercise consisted of extended trot alone or a combination of extended trot and slow canter in order to cause effective muscular work, without inducing such disturbance in the cardiovascular system as making any subject impossible to run. For this purpose, the speed was controlled by maintaining the heart rate under 170 as a rule. In addition, although it was assumed that the exercise of 22,000 m alone a day might lead to fatigue, the exercise was continued for 5 days in order to observe the conditions of horses in the state of accumulated fatigue and the occurrence of muscle cell damage.

By considering the description of Sakurai and his coworkers\(^8,^{23}\) on the training condition in racehorses, it has been known that the conditions of racehorses are judged fairly well by observing changes of ESR, eosinophil count, and body weight to determine the degree of fatigue or stress, although there was a little problem in this experiment on short time intervals for blood collection. That is, it has been considered that ESR is retarded in horses as training progressed from untrained to adapted or suitable state, and accelerated in fatigued state caused by overtraining. Since it has been found that ESR is affected readily by such factors as PCV which is represented the degree of dehydration\(^24\), observations of ESR values combined with PCV estimated 24 hours after exercise (pre-exercise value on the next day) in this experiment may make it possible to judge whether a horse was in adapted state of exercise or in fatigued state.

With regard to the eosinophil count, it was found that eosinophils decreased markedly in count as exercise was strengthened\(^23\). Although an increase or a jumping reaction in this count was observed in the course of exercise period as compared with the count made 24 hours after exercise, the eosinophil count de-
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creased to a minimum 5 hours after exercise in the present experiment. Therefore, the counting of eosinophils was performed every day to judge the strength of exercise owing to observe the difference between the count made before and that made 5 hours after exercise.

The body weights of the horses subjected to exercise were measured before exercise every day to correlate them to changes of ESR and to judge the degree of fatigue. In case No. 1, creatine kinase and fructosediphosphate aldolase increased markedly 5 hours after exercise on the 1st and 5th days. On the 1st day, speed and heart rate increased more distinctly than on any other day of exercise, and eosinophils decreased remarkably in count 5 hours after exercise. In addition, case No. 1 complained of severe pain of the left forelimb after exercise on the 1st day. From these findings, it was presumed that the exercise loaded on the 1st day might have been so strong as to induce muscular damage and a marked elevation of levels of plasma enzymes.

On the other hand, it was considered that the retardation of ESR 24 hours after exercise might have been caused by the effect of hemoconcentration. ESR was still retarded, however, 48 and 72 hours after the exercise loaded on the 1st day (pre-exercise time on the 2nd and 3rd days). On these days, exercise was weakened on account of pain, and the response of the 1st day was assumed to disappear relatively. It was considered that the exercise loaded on the 1st day might not have been so strong as to induce excessive fatigue. Although the horse still complained of pain especially at rest continuously, the subject could accomplish the exercise relatively well. In addition, it was assumed in view of changes of ESR, the subject must have had a reserve of power to run. Then the work was strengthened again thereafter. Although the decrease of eosinophils 5 hours after exercise on the 5th day was similar to that on the 1st day, it seemed that the subject might have lead to fatigue, since ESR was accelerated on the 4th or 5th day. Thus, the increasing rate of creatine kinase was relatively high, although speed and heart rate were lower than those observed on the 1st day. Then it was presumed that the subject could not have run faster than before by fatigue, and that the muscle of the subject was apt to be damaged.

Furthermore, the changing rate of creatine kinase on the 5th day and the difference in the disappearance rate of the enzyme and aspartate aminotransferase in the recovery period agreed quite well with the changes of ESR in the same period. From these point of view, it was considered that the exercise loaded on case No. 1 might have been so strong that the subject fell into fatigue in the latter half of the exercise period.

Moreover, since the subject had experienced a trotting race formerly, it got skilled at extended trot then the subject could run faster than any other experimental horse. The symptoms mentioned above might have been due to employ for only a riding horse on the experimental days. Therefore, it was assumed that the subject might be in detrained state at extended trot.

In case No. 2, magnitude of changes of enzymes were relatively small throughout the exercise period in general. From the facts that speed and heart rate were low,
and that the difference of eosinophil count between before and 5 hours after exercise was relatively small, it was thought that the strength and amount of exercise on the subject might have been rather small. When the subject was loaded at extended trot only on the 1st and 2nd days, heart rate did not increase and levels of enzymes failed to increase. Then slow canter was combined with extended trot on the 3rd day and the speed of slow canter was raised on the 4th day. As a result of the raised speed of slow canter, creatine kinase increased in changing rate more highly on the 4th day than on the previous day, and eosinophils decreased remarkably in count 5 hours after exercise. ESR was also inclined to be accelerated until it was delayed 24 hours after exercise loaded on the 4th day (or the pre-exercise time on the 5th day) at which time ESR was influenced seriously by the exercise loaded on the 4th day. It was thought that the acceleration of ESR in the first half of the exercise period might have been affected with PCV, which was considered to be reversely correlated with ESR\textsuperscript{24).} Thus the subject might have been in a well trained state by loading justified training up to the experimental days. Accordingly, it was assumed that the amount and strength of exercise for the subject might have been more reasonable than those for any other subject.

In case No. 3, increase of these enzymes were somewhat small as similar as in case No. 2, especially during exercise at extended trot alone, and then changes of ESR and eosinophil count were also small. This seemed to imply that the amount of exercise loaded might have been small in No. 3 in a similar manner as in case No. 2. As a result of the increase in speed in the subject on the 5th day, the heart rate increased and creatine kinase was elevated remarkably in changing rate 5 hours after exercise, although aspartate aminotransferase and fructosediphosphate aldolase failed to increase noticeably. The eosinophil count decreased appreciably, and the jumping reaction could not be found 24 hours after exercise loaded on the 5th day, although it was seen 24 hours after exercise loaded on any other day. Pronounced acceleration and persistence of ESR were observed in the recovery period. From these findings, it was assumed that the exercise loaded on the 5th day might have been exceedingly strong for the subject, and that the degree of fatigue might have been so high that the effect of accumulation of fatigue might have continued.

From these findings in the present experiment, changes of plasma enzymes with exercise were characterized as follows.

Generally speaking, creatine kinase tended to increase up to 5 hours after exercise and decrease thereafter, that is, elevation of the enzyme responded markedly to exercise and disappeared rapidly after exercise.

Furthermore, creatine kinase increased when exercise was strong and speed was fast, and then heart rate increased. Thus, in the case of exercise of approximately the same manner, amount, and strength, creatine kinase seemed to be a good indicator for the severity of exercise. On the other hand, when roughly the same amount of exercise was loaded on different individuals, there seemed to be an individual difference caused by state of training in response of creatine kinase to
exercise. Therefore, the enzyme may be available as an index to show the state of training of the individual.

Aspartate aminotransferase indicated a maximal value immediately after exercise. The apparent increase of the enzyme may have been caused by hemoconcentration induced by changes in PCV. Since the enzyme activity remained at a plateau or decreased small extent thereafter, the activity did not tend to decrease but maintained at a high level for 24 hours after exercise. Then the level continued to rather increase following exercise. Although the result obtained from the present experiment was differed from the findings in which aspartate aminotransferase decreased as training progressed, there was a good agreement between the results of the present experiment and the data given by CARDINET et al. in respect to the different disappearance rate of creatine kinase and aspartate aminotransferase. In fact, it has been demonstrated that elevated level of creatine kinase decreased rapidly and aspartate aminotransferase maintained at higher level for long time, and that observations of changes of aspartate aminotransferase combined with those of creatine kinase were available for the diagnosis of myopathy. From the results of the present experiment and the findings mentioned above, it is presumed that aspartate aminotransferase may not be employed as an index for the strength of exercise, but as an index for the effect of continuous exercise or training, such as over-training, or for fatigue.

The changes of fructosediphosphate aldolase in rate were regarded as intermediate ones between the responses of creatine kinase and those of aspartate aminotransferase. That is, although fructosediphosphate aldolase responded to exercise, the magnitude of the changing rate was not so high as that of creatine kinase. On the other hand, the level increased immediately after exercise and tended to decrease in a similar manner of the level of aspartate aminotransferase. Only from these results, it is difficult to determine as what indicator the enzyme is employed. Further investigation is required to solve problems on various manner, strength, and amount of exercise.

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馬の連続長距離走運動が血中酵素に及ぼす影響について

村上 穣*・高木茂美*

馬に運動を負荷した場合、運動が血中酵素の変動ならびに生理的状態にどのような影響を与えるかを明らかにするために、3頭の馬を使って次のような運動を負荷した。すなわち、1日22,000mを連続5日間、伸長速度を主体とし、一部軽い駆歩を組み合わせた。

血液試料は運動期間中は各日とも運動前、運動中、運動直後、ならびに運動後1および5時間に採取した。また回復過程を観察するために、運動実験終了後1、2、3、5、7日にそれぞれ1回ずつ採取した。測定した血中酵素は、creatine kinase, aspartate aminotransferaseおよびfructosediphosphate aldolaseである。また馬体がどのような影響を受けたかを観察するために、赤血球沈降速度、好酸球数および体重を測定した。

上記運動負荷により、creatine kinaseは運動後5時間で最高値を示し、以後はむしろ減少した。また運動が強いほど、増加率は大きかった。このように運動の強さに応じて運動中の心拍数の増加ならびに運動5時間後のcreatine kinaseの増加と好酸球数の減少がみられた。aspartate aminotransferaseの増加は顕著ではなかったが、消失速度は遅く、したがって運動期間中徐々に増加した。fructosediphosphate aldolaseは上記両酵素の変動様式の間隔を示すような変動であった。

一方、赤血球沈降速度と体重の変化から、運動の進展にともない、疲労の程度は大きくなるように考えられた。

したがってcreatine kinaseは運動の激しさを示す指標として、またaspartate aminotransferaseは疲労の程度を示す指標として有用であろうと考えられた。しかしfructosediphosphate aldolaseの運動に対する意義については本実験からは明らかにすることができなかった。