Discrimination of athletic characteristics based on exercise physiology and serum biochemistry

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ABSTRACT

The purpose of the present study is to determine whether athletic characteristics can be discriminated by changes in serum components during exercise which are considered to reflect systemic endurance capacity, muscle strength, and the energy metabolism system. Thirteen male long-distance athletes and 8 male short-distance and field athletes performed an incremental exercise test, muscle strength, and endurance test. They were also observed for changes in serum components during exercise. According to data analysis, the discriminant function thus obtained was:

$$Z = 0.8220 \times \text{peak}\dot{V}O_2 + 0.0037 \times AT + 0.0010 \times MVC + (-0.0276) \times 60\ \text{deg/sec} + 0.2629 \times \text{MVC 50\% time} + (-0.8715) \times UN + 36.1659$$

（peak$\dot{V}O_2$: measured value of peak $\dot{V}O_2$, AT: % peak$\dot{V}O_2$, MVC: measured value of the isometric muscle strength, 60 deg/sec: peak torque of the isokinetic muscle contraction at 60 deg/sec, MVC 50% time: the time for the previously determined isometric muscle strength value to become less than 50%, UN: the increase rate of UN from the value at rest to the maximum value）.

Subjects were classified into the actual group correctly, while the erroneous discriminant rate was 0.73%. In particular, weighting of the discriminant coefficient of peak$\dot{V}O_2$ and UN was large, indicating that these are useful as parameters for discriminating athletic characteristics.

INTRODUCTION

It is well known that in athletic sports the results are largely dependent on physical strength and skill (11). Ikai has demonstrated that from the standpoint of the ability to display energy, the three elements involved in physical strength are muscle strength, speed, and endurance (8). A number of reports have been made on the muscle strength and endurance of athletes (2-4,7), and a consistent relationship has been observed between slow twitch fibers and maximum oxygen consumption ($\dot{V}O_2$max). It can therefore be understood that the muscle fiber type of athletes shows a characteristic pattern according to the type of sport.

Histochemical evaluation of specimens obtained by muscle biopsy is commonly employed in evaluating muscle fiber type (14). Muscle biopsy, being an invasive procedure, constitutes a considerable burden on athletes, and thus, considerable difficulty is faced in its use in sport. From this viewpoint, Gerdle et al. (6), Moritani et al. (13), and Nagata (15) have developed non-invasive muscle fiber type evaluation procedures with the use of electromyography. It has become possible with these procedures to predict a muscle fiber type ratio, but as this muscle fiber type ratio is only one of the factors which expresses athletic characteristics, analysis from various angles is necessary to adequately ascertain athletic characteristics.

The purpose of the present study is to determine whether athletic characteristics can be discriminated by changes in serum components during exercise, which are considered to reflect systemic endurance capacity, muscle strength, and the energy metabolism system.

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SUBJECTS

In order to elucidate athletic characteristics, the subjects used in the present study were male athletes specializing in long-distance relay and long-distance track-field events of more than 5,000 meters, and male short-distance track and field athletes specializing in dash events of 100～400 meters and in throwing and jumping events. Thirteen of the professional level subjects were employed as long-distance athletes; the short-distance and field athletes were composed of two professional level and six regional university championship level athletes. The profile of the subjects is presented in Table 1. No significant difference in age, height, and weight was observed between the two groups.

Prior to the determinations, after consent and understanding were confirmed, adequate explanation was provided to the subjects.

Table 1 Profile of the subjects

	Long-distance athletes	Short-distance and field athletes
Age(yrs.)	24.7±3.7	21.9±4.3
Height(cm)	170.8±7.7	171.4±7.6
Weight(kg)	59.9±6.9	65.1±17.0

(mean±SD)

METHODS

1. Exercise test

In the determination of systemic endurance capacity, an incremental exercise test on a bicycle ergometer was employed. In the exercise protocol, 2-minute rest was first taken on the bicycle ergometer, followed by exhaustion exercise with ramp load of 30 W/min. The bicycle ergometer employed was 232C-XL (Combi Co. Ltd.), measurement of heart rate (HR) was made with a Dynascope 3140 (Fukuda Densi Co. Ltd.), and oxygen uptake ($\dot{V}O_2$) was measured using an Aeromonitor AE 280-S (Minato Medical Science Co. Ltd.). From the results of exercise tests, peak oxygen uptake (peak$\dot{V}O_2$) and anaerobic threshold (AT) were computed. Determination of AT was made by the method of Wasserman et al. (18).

Test of difference in mean of peak$\dot{V}O_2$ and AT of long-distance athletes and dash - field athletes was made with Student's t-test with the use of Stat view 4.5 J. Statistical significance was accepted as $p < 0.05$.

2. Determination of muscle strength and muscle endurance

Determination of muscle strength and muscle endurance was made with the use of an isokinetic dynamometer (Chattanooga KIN-COM AP and Cybex 770).

Muscle strength, isometric muscle strength, and isokinetic muscle strength of the right knee joint extensors were determined. Isometric muscle strength was determined by knee joint extension exercise for 5 seconds at maximum voluntary effort in a sitting position with the knee joint flexed at 90 deg. The examiner always verbally encouraged the subjects during muscle contraction. Muscle strength was expressed as N. In measurement of isokinetic muscle strength, knee joint extension exercise was performed in the sitting position with the knee joint flexion range being from 10 deg to 90 deg. Test velocities were made at 60 deg/sec and at 240 deg/sec. Isokinetic muscle strength was expressed as Nm.

Muscle endurance was measured in a sitting position with the knee joint flexed at 90 deg, with isometric maximum voluntary contraction of the knee extensors performed as long as possible, and with the time for the previously determined isometric muscle strength value to become less than 50% (regarded to be the MVC 50% time). Test of difference in mean muscle strength and muscle endurance between the two groups was made with Student's t-test with the use of Stat view 4.5 J. Statistical significance was accepted as $p < 0.05$.

3. Changes in serum components during exercise

In order to observe changes in serum components during exercise, blood was drawn.

First, from the results of the exercise test, $\dot{V}O_2$ - HR relationship formula was obtained and HR corresponding to work intensity was computed. With use of a bicycle ergometer, warming-up for 2 minutes was made at a work intensity corresponding to 40% peak$\dot{V}O_2$ and exercise was done at work intensity corresponding to 50%, 60%, 70% and 80% peak$\dot{V}O_2$ for 3 minutes at each stage and thereafter continued until reaching exhaustion (Figure 1). Establishment of work intensity was made by monitoring heart rate. Blood was drawn at rest, completion of each stage, and at 30, 60 and 120 minutes after completion of exercise. Blood was drawn during exercise using a catheter placed in the elbow vein and

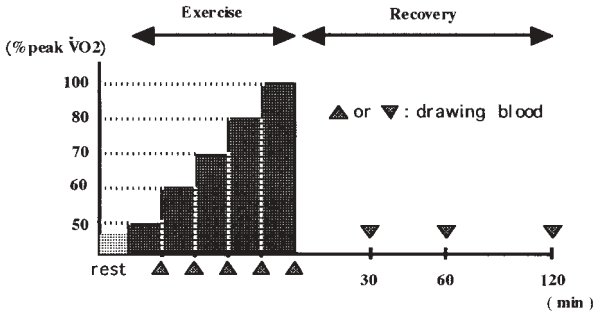

Figure1 Exercise protocol and timing of drawing blood

without clamping the upper arm.

In the determination of serum components, we selected those which in our previous studies (9) demonstrated changes during exercise and after completion of exercise. As shown in Table 2, urea nitrogen (UN), uric acid (UA), total protein, total cholesterol, enzymes released in serum creatinine kinase (CK), glutamic oxalacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT), and electrolytes P, Na, Mg, K, and Fe were determined. Analysis of serum components was conducted on request by the Department of Clinical Laboratories, Hiroshima University Medical Hospital. Each determined value was computed as a ratio to the value obtained at rest. Study of changes over time of both groups was made by two-way ANOVA with repeated measures. Statistical significance was accepted as $p < 0.05$.

Table 2 Selected serum components during exercise and after completion of exercise

biochemical	enzymes released in serum	electrolytes
urea nitrogen(UN)	creatinine kinase (CK)	P
uric acid(UA)	glutamic oxalacetic transaminase (GOT)	Na
total protein(TP)	glutamic pyruvic transaminase (GPT)	Mg
total cholesterol(T.cho.)		K
		Fe

4. Preparation of discriminant equation of athletic characteristics

Athletic characteristics were classified into two groups, that is, long-distance athletes and short-distance and field athletes. Using multivariate analysis, discriminant analysis was based on the results obtained from determinations of methods 1～3, and resulted in a discriminant function of athletic characteristics. The measured values of systemic endurance capacity, muscle strength, and muscle endurance strength were employed, and as for values of serum components, the increase rate from the value at rest to the maximum value was used. Excel TOUKEI Ver. 1.1 was used in preparation of the discriminant function.

RESULTS

1. Exercise test

Mean peak $\dot{V}O_2$ of long-distance athletes was 58.7 ml/kg/min and that of short-distance and field athletes was 49.2 ml/kg/min, while mean AT of long-distance athletes was 67.5% peak $\dot{V}O_2$ and that of short-distance and field athletes was 53.3% peak $\dot{V}O_2$. Both peak $\dot{V}O_2$ and AT were significantly higher in long-distance athletes ($p < 0.01$) (Table 3).

2. Muscle strength and muscle endurance

Knee extensor strength at isometric maximum voluntary contraction (MVC) averaged 688.7 N in long-distance athletes, showing a significant difference from 828.5 N in short-distance and field athletes ($p < 0.05$). Isokinetic knee extensor strength in long-distance athletes averaged 145.0 Nm at 60 deg/sec and 73.9 Nm at 240 deg/sec, while in short-distance and field athletes it averaged 193.8 Nm at 60 deg/sec and 93.3 Nm at 240 deg/sec. Knee extensor strength at 60 deg/sec in short-distance and field athletes was significantly higher ($p < 0.01$), but knee extensor muscle strength at 240 deg/sec showed no significant difference.

MVC 50% time, which expresses muscle endurance, averaged 71.4 sec in long-distance athletes, and demonstrated a significant difference from the short-distance and field athletes' average time of 35.4 sec ($p < 0.01$) (Table 3).

Table 3 Comparison between two groups

	Long-distance athletes	Short-distance and field athletes
peakV O2(ml/kg/min)	58.7±5.7	49.2±6.4 **
AT(%peakV O2)	67.5±6.7	53.3±9.5 **
MVC(N)	688.7±66.3	828.5±194.4 *
Isokinetic Knee Extension(Nm)60deg/sec	145.0±14.9	193.8±50.9 **
Isokinetic Knee Extension(Nm)240deg/sec	73.9±20.8	93.3±36.2 ns
MVC50%time(sec)	71.4±17.6	35.4±9.3 **

(mean±SD) *: $p<0.05$, **: $p<0.01$

3. Changes in serum components during exercise

Measurement over time of serum components was made on 13 long-distance athletes and 7 dash - field athletes. Difference in change in pattern between long-distance athletes and short-distance and field athletes was observed only in UN ($p < 0.05$) (Figure 2).

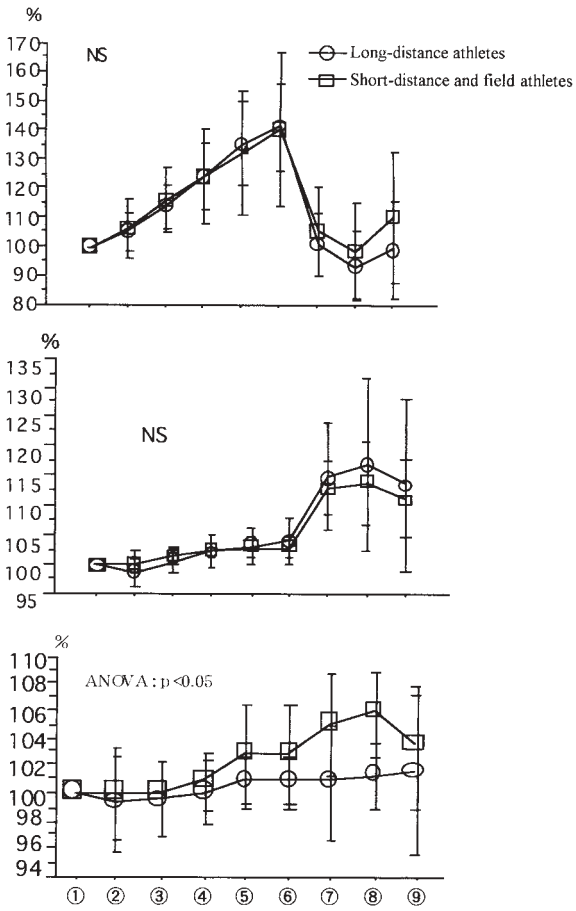

Figure 2 Change in serum components during exercise and after completion of exercise

①: rest, ②: 50%$\dot{V}O_2$max, ③: 60%$\dot{V}O_2$max, ④: 70%$\dot{V}O_2$max, ⑤: 80%$\dot{V}O_2$max, ⑥: 100%$\dot{V}O_2$max, ⑦: recovery30min, ⑧: recovery60min, ⑨: recovery120min,

Above : serum component values elevate with increase in exercise and approach the value at rest following completion of exercise, ex.:P

Middle : no great change in values during exercise and serum component value elevate after completion of exercise, ex.:UA

Below : Change in UN during exercise and after completion of exercise

4. Discriminant equation of athletic characteristics

Discriminant analysis was conducted only on those determined items in which significant difference was demonstrated. As a result of discriminant analysis, the discriminant coefficients of the respective items are shown in Table 4. The discriminant function can be expressed as follows:

$$Z = 0.8220 \times \text{peak } \dot{V}O_2 + 0.0037 \times AT + 0.0010 \times MVC + (-0.0276) \times 60 \text{ deg/sec} + 0.2629 \times MVC\ 50\%\ \text{time} + (-0.8715) \times UN + 36.1659.$$

By this discriminant function, $Z > 0$ can be discriminated

Table 4 Discriminant coefficients of the respective items

parameter	discriminant coefficients
peak $\dot{V}O_2$	0.8220
AT	0.0037
MVC	0.0010
Isokinetic Knee Extension 60deg/sec	−0.0276
MVC 50%time	0.2629
UN	−0.8715
fixed number	36.1659

Table 5 Prediction of the subjects using the discriminant function

No.	actual group	Z	prediction
1	Long	9.313	Long
2	Long	9.343	Long
3	Long	16.007	Long
4	Long	8.426	Long
5	Long	5.786	Long
6	Long	13.535	Long
7	Long	7.726	Long
8	Long	17.898	Long
9	Long	14.145	Long
10	Long	20.921	Long
11	Long	7.950	Long
12	Long	15.297	Long
13	Long	8.482	Long
14	Short	−8.284	Short
15	Short	−4.229	Short
16	Short	−10.134	Short
17	Short	−12.733	Short
18	Short	−17.334	Short
19	Short	missing	
20	Short	−10.904	Short
21	Short	−19.751	Short

Long : long-distance athletes
Short : short-distance and field athletes

as long-distance athletes and Z < 0 can be discriminated as short-distance and field athletes. Using this discriminant function, the predictions of the subjects are shown in Table 5 and Figure3. Subjects were classified into the actual group correctly, while the erroneous discriminant rate was 0.73%.

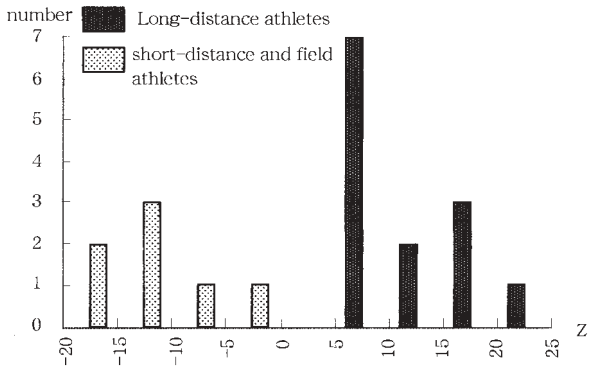

Figure 3 The distribution map of the prediction of the subjects using the discriminant function

DISCUSSION

1. Systemic endurance capacity, muscle strength, and muscle endurance

A large number of studies have been made on systemic endurance capacity in sports and it is well known that $\dot{V}O_2max$ of athletes engaged in endurance events is larger than that of athletes engaged in sport events (19). Particularly in long-distance athletes there is a close relationship between $\dot{V}O_2max$ and athletic record. In addition, a high correlation is known to exist between AT and endurance performance (16).

The results of the present study, also showed a significant difference in peak$\dot{V}O_2$ and AT between long-distance athletes and short-distance and field athletes. Long-distance athletes displayed the characteristics of endurance sports athletes. In addition, with regard to muscle strength and muscle endurance time, isometric muscle strength as absolute muscle strength was large in short-distance and field athletes, whereas muscle endurance time showed a significantly higher value in long-distance athletes. It is considered from the results of the present study that the subjects reflected their respective athletic characteristics.

2. Changes in serum components during exercise

In our previous study, we reported that changes in serum components during exercise can be classified into three major change patterns (9). In the first pattern, serum component values elevate with increase in exercise and approach the value at rest following completion of exercise. In the second pattern, there is no great change in values during exercise and serum component values elevate after completion of exercise. In the third pattern, no significant changes in values are observed during exercise or after completion of exercise. As for the speculated causes for these changes in serum components, it has been considered that energy metabolism, promoted by muscle exercise, is due to exercise and metabolites which are produced and increase in the blood, that membrane permeability is promoted at the cellular level accompanying exercise and enzymes are released in the blood, and that blood becomes concentrated due to changes in water volume in the blood accompanying exercise. A consistent view on the attributable causes has not yet been reached.

Based on these results, we selected serum components which change during exercise and studied the effects of athletic characteristics on serum components changes during exercise. During energy supply accompanying increase in work intensity, there was also elevation of isolated P (Figure 2), but difference due to athletic characteristics could not be observed. Despite the difference in energy supply system during exercise, as phosphorus is isolated during the process of change of adenosine triphosphoric acid (ATP) to adenosine diphosphoric acid (ADP) and adenosine monophosphoric acid (AMP), difference due to athletic characteristics could not be observed.

Of the items determined in the present study, a significant difference in change pattern between long-distance athletes and short-distance and field athletes was only observed in urea nitrogen. Urea nitrogen is produced in the liver via the urea cycle from ammonia and carbon dioxide (12). Ammonia, a precursor of urea nitrogen, is produced in the purine nucleoside cycle involved in energy supply during exercise. In previous studies on the dynamics of blood ammonia, it has been reported that ammonia elevates with increase in exercise and that this elevation differs according to the sport (1,17). Gray et al. (5) have reported that the proportion of slow twitch fibers has a great effect on elevation of blood ammonia level following intense exercise, while Meyer et al. (10) observed that adenine metabolism differs between slow twitch fibers and fast twitch fibers. In view of the findings that muscle fiber type reflects

athletic characteristics (2-4, 7) and that athletic characteristics and muscle fiber type affect ammonia production during exercise (1, 5, 10, 17), it can be speculated that difference in athletic characteristics considered to reflect the difference in muscle fiber type between long-distance athletes and short-distance and field athletes affects in some way the activation of purine nucleoside cycle and thus expresses itself as change in pattern of the final metabolite of urea nitrogen.

3. Discriminant function of athletic characteristics

It is known from the past that muscle fiber type is an effective index of athletic characteristics (2-4, 7). It is necessary to conduct muscle biopsy for the discrimination of muscle fiber type. Muscle biopsy being an invasive examination constitutes a considerable burden on athletes, and conduct of muscle biopsy at the sports location is difficult. In consideration of this point, non-invasive procedures of discriminating muscle fiber type employing electromyography have been developed. It is possible with these procedures to predict muscle fiber type ratio, but it is considered that this muscle fiber type ratio is only one of the factors which expresses athletic characteristics.

An attempt was therefore made to prepare a discriminant function of athletic characteristics based on systemic endurance strength, muscle strength, and muscle endurance time, commonly employed as indices of physical strength in sports, and on changes in serum components during exercise. In preparing a discriminant function using only those items in which significant difference was demonstrated among the measured items, it was found that

$$Z = 0.8220 \times \text{peak } \dot{V}O_2 + 0.0037 \times AT + 0.0010 \times MVC + (-0.0276) \times 60 \text{ deg/sec} + 0.2629 \times MVC\ 50\%\ \text{time} + (-0.8715) \times UN + 36.1659.$$

Subjects were classified into the actual group correctly, while the erroneous discriminant rate was 0.73%. The value of urea nitrogen used in this discriminant analysis was the rate of increase from rest to maximum. As can be observed in Figure 2, change pattern of urea nitrogen peaked at 60 minutes after recovery and to obtain increase rate of urea nitrogen it is only necessary to draw blood at rest and at 60 minutes after completion of exercise without any need to draw blood during exercise. If it is not necessary to draw blood during exercise, it is considered that blood can be drawn comparatively easily at the sports location. In examining the discriminant coefficient of our discriminant function, it can be observed that the items which express endurance factors are positive discriminant coefficients and the items which express spurt factors are generally negative discriminant coefficients (Table 4). Furthermore, in items in which the effort of the examinee is greatly involved such as muscle strength and muscle endurance, weighting of discriminant coefficient becomes small, whereas in items in which the effort of the examinee is not appreciably involved such as peak $\dot{V}O_2$ and change rate in UN, weighting becomes large.

The discriminant function which we prepared contains not only items which the effort of the examinee at time of measurement is not involved but also items in which the effect of training can be evaluated, such as muscle strength and muscle endurance time, which would feasibly enable discrimination of long-distance type and short-distance and field type at the place of sport. When the prediction obtained by our discriminant function is closer to zero, it is considered that the individual has both long-distance and short-distance and field factors and thus there is a possibility to evaluate aptitude as athletes for middle distance events among field and track events, and as ball game athletes such as a basketball player, among other athletic events. It is considered that with the use of such a function more specific feedback of exercise test and muscle strength measurement conducted as part of a physical strength test can be made in sports. We look forward to its application in sports in the future.

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