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Original Article

A Study for Prevention of Chronic Fatigue Part 1. Effects of Endurance Running during One Month on Blood Properties and Subjective Fatigue

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Abstract

The principal objective of this paper is basic research on the development of methods for the prevention of chronic fatigue. Overtraining was paid special attention to as one of the types of chronic fatigue condition. Six healthy male participants in a distance-running competition were recruited and used as subjects for this study with informed consent for all examinations. Subjects, that is, participants in the competition, tried to achieve their objective maximum running distance designated before the competition during one month, while in the same period performing their routine work duties. It was reported that the competition caused participants to exhibit an overtrained condition. In this paper, effects of endurance running during one month on blood properties and the fatigue level felt by the subject (subjective fatigue) were studied.

Examinations carried out in this research were as follows; 1) physical examination was conducted 3 times during the study; 1 week before the competition, immediately before and 3 weeks after the end of the competition, 2) blood sampling was conducted 4 times; prior to the competition, 1 week after the beginning of and immediately before the end of the competition, and about 3 weeks after the competition, 3) subjective fatigue levels were monitored 8 times; 1 week before and one time in every week during the competition, and 1 week and again 3 weeks after the competition.

Immediately before the end of the competition, when subjects might be expected to exhibit the overtrained condition, minor influences on fatigue levels were found. However, effects of the endurance run seemed to remain more than 3 weeks after the competition as indicated by changes of the population of white blood cells and blood hormone levels.

The above mentioned results suggest that it is important to determine signs of overtraining at an early stage. To determine overtraining at an early stage, norepinephrine, testosterone and the ratio of testosterone to cortisol may be the most useful indices. These, as well as the element of "drowsiness and dullness" in the questionnaire on subjective symptoms of fatigue authorized by the Japan Association of Industrial Health and the elements of "anger", "fatigue", and "confusion" in the Profile of Mood State (POMS) questionnaire are thought to be the most important subjective indices.

Key words: Male Adults, Running, Blood property, Subjective fatigue, Overtraining

Introduction

It is socially important to prevent diseases and sudden death, particularly death from overwork, related to chronic fatigue. Chronic fatigue has been defined as a decreased capacity to perform physical and mental work; overwhelming sustained exhaustion, lack of energy, and tiredness; and a combination of these [1]. Overtraining is caused by excessive training [2] and it is thought that one of the types of chronic fatigue is mainly caused by physical exercise stress [3]. There are obvious ethical limitations associated with intentionally overtraining athletes [4] and there is no diagnostic or warning test for the overtraining syndrome [5, 6].

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Many studies have been designed specifically to consider the chronic effects of long-term athletic training on blood properties using athletes as subjects[7-10]. Such long-term athletic training has been carried out following well established training menus learned by experience to prevent overtraining.

On the other hand, fatigue levels felt by subjects are monitored using questionnaire methods[11, 12], which are easier to conduct than measurements of blood properties and can be applied through many types of field surveys[13, 14]. From the point of survey expense, it is desirable to develop the questionnaire method that can determine changing stages of overtraining at an early point. It is thought to be very difficult to estimate the level of physical fatigue using the questionnaire method because results obtained by this method are obviously affected by mental stress but it is reported[15] that the stress from mental work is revealed by the questionnaire method.

The principal objective of this paper is basic research on the development of methods for the prevention of chronic fatigue. Special attention was given to overtraining as one of the types of chronic fatigue. It was reported that a distance endurance run during one month while performing routine work duties was one of model situations causing participants to exhibit an overtrained condition[3]. Subjects, that is, participants of the competition, kept trying to achieve thier objective maximum running distance designated before the competition. In this paper, effects of endurance running during one month on blood properties and the subjective fatigue level felt by each subject, were studied.

Materials and Methods

1. Subjects and protocol

Subjects were six healthy males (age 26-44 years, mean 36.3 ± 6.5); office workers in downtown Tokyo. They were joggers and participants of an endurance run, in October of 1993 a distance run competition was held under the auspices of monthly magazine "Runners." The purpose of the research was explained to subjects before the start of the survey and the survey was carried out from September to November, 1993 with informed consent for all examinations obtained from the volunteers before beginning. Measurement items and intervals of measurements are shown in Fig. 1.

The subjects kept daily training logs[3] during the competioitn; recording daily physical feeling, type of exercise, and running distances.

2. Physical characteristics

Physical examinations were conducted 3 times following the protocol shown in Fig. 1. Age and height were determined 1 week before the competition. Body weight was measured by the standard method. Skinfold thickness was measured at two sites, triceps and subscapular, on all subjects using an Eiyoken-type caliper (Meikosha Co.). The percentage of body fat and the lean body mass were calculated using the skinfold regression formula[16].

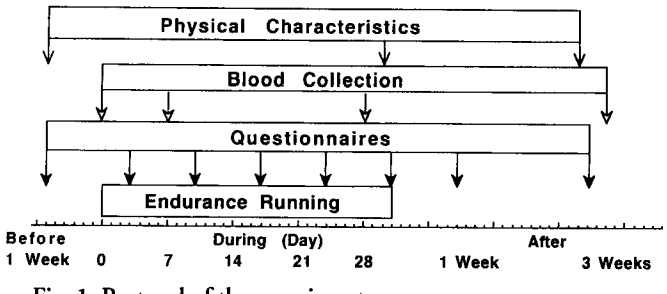

Fig. 1 Protocol of the experiment.

3. Blood sampling and measurements of blood properties

Blood sampling was conducted 4 times at almost the same time (from 8:00 to 8:30 am) in the subjects' offices (shown in Fig. 1). Peripheral venous blood samples were drawn by antecubital venepuncture with subjects in a resting position. One portion of each blood sample was anticoagulated by EDTA-2K for a hematological test. Plasma was immediately obtained from one another portion of each blood sample anticoagulated by EDTA-2Na[17] and serum was separated from each remaining blood sample. The resulting plasma and serum were stored at under -80 °C until the assays. According to the manual of clinical tests[18], epinephrine, norepinephrine, dopamine, cortisol, testosterone, and adrenocorticotropic hormone (ACTH) were measured using the plasma, whereas luteinizing hormone (LH) and follicle-stimulating hormone (FSH) were measured using the serum. Serological tests for total protein (TP), albumin (Alb), triglyceride (TG), total cholesterol (Tcho), blood urea nitrogen (BUN), glutamate oxaloacetate transaminase (GOT), and glutamate pyruvate transaminase (GPT) were carried out using the serum. The ratio of testosterone to cortisol, which is reported to be an index of overtraining[19], was calculated.

4. Examinations for subjective fatigue levels

Using the subjective symptoms of fatigue (SSF) questionnaire authorized by the Japan Association of Industrial Health[11] and the Profile of Mood State (POMS) questionnaire[12, 13], subjective fatigue levels were monitored 8 times following the protocol shown in Fig. 1. The description method of these questionnaires was well explained at the first monitoring time and the subjects filled them in for confirmation. Following the second monitoring time these questionnaires were mailed to each subject to complete at home and each one was requested to send back.

Each score of the three elements in SSF was counted, with 10 as the maximum score for each element[11]. Each score of the six elements in POMS was counted and converted into a T-score[12, 13].

5. Statistical methods

Statistical analysis was performed on a Macintosh IIsi with the use of Stat View software. Statistical evaluation of the data was carried out by applying the repeated measurements of ANOVA test with the Dunnett t values used to identify significant differences. The level of significance in this paper was $P<0.05$. Regression analysis was carried out to examine the correlation between the element of "drowsiness and dullness" in SSF and the element of "fatigue" in POMS.

Results

1. Characteristics of subjects and running distance

Results of physical examinations are summarized in Table 1. As shown in Table 1, no significant change was exhibited in the body weight, the lean body mass (LBM), and the percentage of fat (% Fat) of the subjects during the experiment.

Running distance for each subject participating in the competition during one month is shown in Table 2 indicated as

Table 1 Characteristics of subjects.

	Before 1 Week		During Day 30		After 3 Weeks	
Items	Mean	SD	Mean	SD	Mean	SD
Age (year)	36.3	6.5	-	-	-	-
Height (cm)	170.3	2.8	-	-	-	-
Body Weight (kg)	60.7	3.5	60.3	4.2	60.5	3.9
LBM (kg)	54.2	3.1	53.9	3.6	53.6	3.3
% Fat	10.7	1.0	10.6	1.3	11.3	1.5

Age and height were measured only one time on the day Before 1 Week.
There is no statistically significant difference among the measurement days.

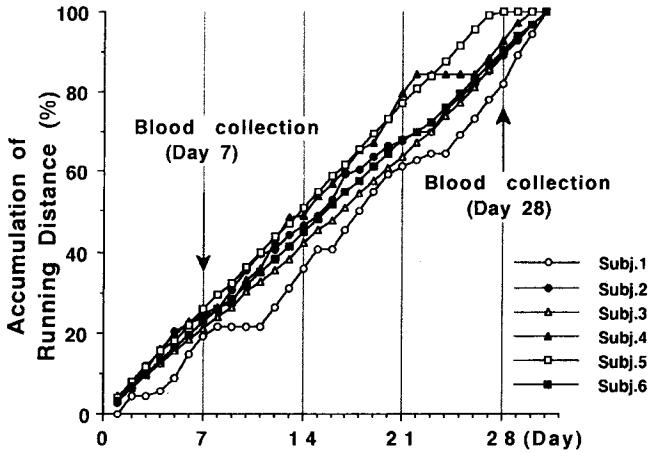

Fig. 2 Accumulative curve of daily running distance during the month.

"October". Each runner's objective maximum running distance designated before the competition and the distance actually run are presented as "Objective" and "Actual", respectively. Running distances of the subjects for one month before and after the competition are also shown in Table 2 as "September" and "November", respectively. Five of the six subjects attained their running distance objectives. To compare the actual running distance to the distance run during the month before the competition, the ratio represented as "Oct./Sept." in Table 2 revealed that the distance in the competition was increased to 2.5 times that of the month before the competition on the average. The mean value of the ratio of running distance in the one month before the competition to that after the competition, indicated as "Nov./Sept." in Table 2, was 0.8, suggesting the decrescent tendency of the running distance after the competition.

Fluctuations of daily running distance are shown as accu-

Table 2 Running distances of subjects by month.

Subject	September (km)	October Objective (km)	October Actual (km)	November (km)	Oct./Sept. (ratio)	Nov./Sept. (ratio)
1	150	300	405	200	2.7	1.3
2	272	400	509	150	1.9	0.6
3	364	500	801	300	2.2	0.8
4	300	500	456	30	1.5	0.1
5	504	1200	1261	513	2.5	1.0
6	266	1100	1111	240	4.2	0.9
Mean	309	667	757	239	2.5	0.8

Table 3 Hemanalytical changes during the experiment.

	Day 0		During Day 7		Day 28		After 3 Weeks	
Items	Mean	SD	Mean	SD	Mean	SD	Mean	SD
RBC (x 10^4/ul)	447.7	24.5	455.3	45.1	436.8	33.1	460.8	25.3
Hb (g/dl)	14.4	0.5	14.2	1.2	13.8	1.1	14.7	0.6
Ht (%)	43.1	1.5	43.6	3.7	42.5	3.2	44.0	1.5
MCV (Fl)	96.4	3.7	95.8	3.5	97.4	3.7	95.6	3.5
MCH (pg)	32.3	1.3	31.3	1.1 !	31.6	1.0 !	32.0	0.9
MCHC (%)	33.5	0.3	32.6	0.3#	32.5	0.3#	33.5	0.7
WBC (/ul)	5283	1594	4783	1297	4283	1038*	4950	1172
Lymph (%)	46.8	5.9	46.9	11.9	47.2	8.1	19.3	2.9 !
Eosin (%)	3.3	2.2	2.5	1.6	3.3	1.0	1.2	0.8
Baso (%)	0.5	0.3	1.2	1.4	1.2	0.8	1.0	1.1
Mono (%)	3.5	1.0	5.6	3.1	3.2	0.8	2.7	1.9
Neutro (%)	45.8	6.4	43.7	13.2	45.2	8.7	75.8	4.3 !
Stab (%)	2.3	1.5	1.7	1.8	2.2	1.0	3.3	1.9
Seg (%)	43.5	6.1	42.1	12.6	43.0	8.1	72.5	6.0 !
Stab/Seg (%)	5.4	3.8	4.1	3.4	5.0	1.9	4.8	3.1

Statistically significant differences between Day 0 and the other days are represented as follows ;
*; P<0.05, #; P<0.01, !; P<0.001.
Definitions of abbrviations are described in the text.

mulation curves in Fig. 2 and 100% of each curve represents the distance actually run by each subject. The daily running distance of subject 1 (shown in Fig. 2) who ran the least total distance fluctuated the most. Subject 4 was suffered from pharyngolaryngitis and could not run from the 22nd through the 26th day in the competition period.

2. Hemanalytical changes

Results of hematological examinations are summarized in Table 3. No significant difference was found in red blood cells (RBC), hemoglobin (Hb), hematocrit (Ht), and mean corpuscular hemoglobin (MCH). There were minor changes, less than 5% of mean values, in mean corpuscular volume (MCV) and mean corpuscular hemoglobin concentration (MCHC); however, statistically significant decreases were observed on the seventh day of the competition (Day 7) and immediately before the end of the competition (Day 28).

The number of white blood cells (WBC) significantly decreased immediately before the end of the competition (Day 28). In contrast to changes of WBC, differential counts of WBC, that is, lymphocyte (Lymph) and neutrophil (Neutro) percentages dramatically changed approximately 3 weeks after the end of the competition (shown in Table 3).

3. Changes of hormone levels and serum clinical chemistry

Blood hormone levels and results of serological tests are summarized in Table 4. No significant difference was found in gonadotropic hormones, LH and FSH, and ACTH secreted from prephypophysis, just as LH and FSH did not change significantly. A significant increase in the level of cortisol (shown in Table 4 as Cortis) was observed approximately 3 weeks after the end of the competition. On the other hand, catecholamine, epinephrine (Epine), norepinephrine (Norepi), and dopamine (Dopam) levels, showed an incremental tendency during the competition. On the seventh day of the competition (Day 7), norepinephrine increased by 156% above the level prior to starting (Day 0). Significant differences were found in norepinephrine on Day 7 and immediately before the end of the competition. In contrast to catecholamine levels, the testosterone (Testos) level and the ratio of testosterone to cortisol (Test/Cort) significantly decreased from the seventh day of the competition to approximately 3 weeks after the end of the competition. Testos and Test/Cort decreased finally to 62% and 50% of the pre-start level, respectively.

In the case of the seven serological tests, TP, Alb, and BUN levels significantly increased on the seventh day of the competition. It is well known that GOT and GPT are increased by physical exercise. Mean levels of GOT and GPT showed an incremental tendency during the competition. A significant increase of GPT was observed on the 28th day of the competition and GOT levels higher than the reference level (>40 IU/L) were found in three subjects on the seventh day and in five subjects on the 28th day of the competition.

4. Changes of subjective fatigue levels

To determine changes in subjective fatigue, the fatigue level felt by the subject, the subjective symptom of fatigue (SSF) and POMS questionnaires were employed. Results of these questionnaires are summarized in Table 5.

The element of "drowsiness and dullness" (shown in Table 5 as SSF-I) and the element of "difficulty in concentration" in SSF (SSF-II) significantly increased from the 10th day to the 24th day and from the 10th day to the 17th day of the competition, respectively. A significant increase was also observed in the element of "projection of physical disintegration" in SSF (SSF-III) on the 17th day of the competition.

The changes of "drowsiness and dullness" (SSF-I) are shown by subject in Fig. 3. The maximum scores appeared on the 10th day for three subjects, on the 17th day for two subjects, and on the 24th day for three subjects. In the case of subject 1, the score

Table 4 Changes of hormonal and serum chemical levels in the experiment.

	Day 0		During Day 7		Day 28		After 3 Weeks	
Items	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LH (mIU/ml)	2.9	1.4	3.3	1.0	3.9	2.1	3.2	1.6
FSH (mIU/ml)	5.6	2.1	6.1	2.5	6.2	1.8	6.1	2.2
ACTH (pg/ml)	32.3	23.9	29.8	11.4	35.8	24.8	38.7	24.7
Epine (pg/ml)	60.2	36.0	56.0	25.4	75.2	45.3	46.5	33.7
Norepi (pg/ml)	386.3	123.9	567.3	113.2#	518.3	44.2*	405.8	102.0
Dopam (pg/ml)	12.0	2.8	13.6	3.0	13.7	2.4	9.3	3.6*
Cortis (μg/ml)	12.1	2.4	11.9	2.3	13.4	4.9	16.2	5.7*
Testo (ng/ml)	664.5	204.0	519.4	113.5*	509.3	112.2*	410.0	63.3#
Test/Cort (x 1,000)	55.7	15.3	44.4	9.5*	42.3	16.4*	27.9	9.7 !
TP (g/dl)	7.5	0.4	8.9	2.0*	7.2	0.5	7.3	0.4
Alb (g/dl)	4.6	0.1	5.5	1.1*	4.5	0.3	4.5	0.3
TG (mg/dl)	68.7	31.9	71.8	28.3	52.0	21.0	74.8	37.1
Tcho (mg/dl)	196.5	30.1	233.3	72.4*	189.5	27.1	195.5	19.4
BUN (mg/dl)	17.2	2.0	24.3	10.2*	19.8	4.5	17.7	4.6
GOT (IU/l)	34.3	7.6	50.4	32.3	53.0	34.4	29.2	11.4
GPT (IU/l)	23.7	7.1	34.5	20.5	38.2	22.7*	18.2	7.7

Statistically significant differences between Day 0 and the other days are represented as follows ;
*; P<0.05, #; P<0.01, !; P<0.001.
Definitions of abbrviations are described in the text.

Table 5 Changes of subjective fatigue scores in the experiment.

	Before				During								After			
	1 Week		Day 3		Day 10		Day 17		day 24		day 31		1 Week		3 Weeks	
Items	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Subjectives Symptoms of Fatigue																
SSF-I	1.7	1.5	3.3	2.2	5.3	2.9#	5.0	1.8#	4.2	3.3*	2.2	2.1	1.5	1.6	1.3	2.3
SSF-II	0.0	0.0	1.0	0.9	1.7	1.9*	2.2	2.6#	1.2	1.6	0.3	0.8	0.0	0.0	0.3	0.5
SSF-III	0.2	0.4	0.7	0.8	0.7	0.8	1.2	1.2*	0.7	0.2	1.2	0.8	0.2	0.4	0.3	0.5
POMS																
Ten	37.8	5.8	36.7	2.3	39.6	5.6	40.9	6.6	38.5	3.7	36.6	5.0	36.7	4.0	38.1	4.2
Dep	36.3	1.5	36.8	1.9	36.9	3.0	39.4	5.6	38.1	4.5	37.4	3.7	36.8	1.8	37.6	3.0
Ang	39.5	5.5	40.5	4.6	43.2	5.7	49.2	8.0 !	45.7	8.7*	43.0	8.1	41.3	6.3	43.2	5.6
Vig	60.9	4.7	59.6	9.5	55.1	10.2	53.0	9.1	53.5	7.5	57.6	10.6	59.2	11.4	58.9	12.1
Fat	41.2	3.7	48.8	5.3*	47.9	5.2	53.9	7.9#	51.7	7.7*	43.4	4.0	39.4	3.4	42.1	8.8
Con	38.4	3.0	38.9	3.5	40.6	4.6	44.4	6.2*	41.8	5.0	37.7	3.3	37.0	2.7	38.9	4.2
F/V (%)	68.2	9.8	88.8	20.5	90.9	27.3	106.0	32.9#	99.4	26.2*	78.0	17.4	68.6	13.5	75.1	27.6

Statistically significant differences between Day 0 and the other days are represented as follows ;
*; P<0.05, #; P<0.01, !; P<0.001.
Definitions of abbrviations are described in the text.

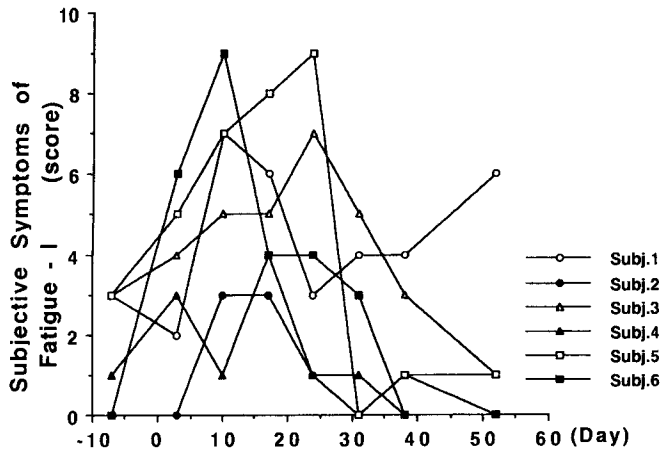

Fig. 3 Individual changes of SSF-I score.

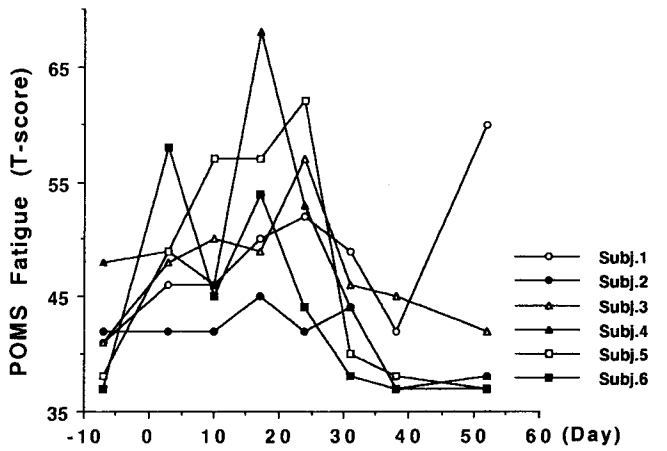

Fig. 4 Individual changes of POMS Fatigue.

of SSF-I was again increased approximately 3 weeks after the end of the competition.

The element of "fatigue" (shown in Table 5 as Fat) in POMS statistically significantly increased once on the third day and again increased from the 17th day to the 24th day with statistical significance. Significant increases were also observed in the elements of "anger" (Ang), "confusion" (Con), and the ratio of "fatigue" to "vigor" (F/V) from the 17th day to the 24th day. In contrast to those significant changes, there was essentially no change observed in the elements of "tension" (Ten), "depression" (Dep), and "vigor" (Vig).

The changes of "fatigue" (Fat) in POMS are shown by subject in Fig. 4. The maximum scores appeared on the third day for one subject, on the 17th day for two subjects, and on the 24th day for two subjects. In the case of subject 1, the score of Fat was increased on the 24th day but the maximum score appeared approximately 3 weeks after the end of the competition.

Discussion

One critical problem of this study is that we could not answer to the question whether overtraining had taken place during the competition [6] because diagnostic or warning tests for the overtraining syndrome are not established at the present time [5,6].

The running distance objective depended on the ability of each subject and covered a wide range. However, each subject kept trying to achieve the distance designated before the competition as the utmost limit. Only one subject, was not able to achieve the running distance objective because he suffered from pharyngolaryngitis and could not run from the 22nd through the 26th day in the competition period. Hanson [20] reported that non-specific symptoms of a minor infection, typically an upper respiratory tract infection, were clinical manifestations of the overtraining syndrome. It is possible that the pharyngolaryngitis of subject 4 is caused by overtraining. Furthermore, subject 4 resumed running from the 27th day and two of the six subjects run over 1,000 km in the competition. This meant that these two subjects ran almost full-marathon distance while continuing their routine work duties every day during the competition. These results suggest that the subjects are devoted to achieving the utmost limit of running distance for their ability and probably exhibited the overtraining condition at the end of the competition. As the physical characteristics of the subjects were not significantly affected by the competition, nutrition conditions

seemed appropriate in terms of increments of energy consumption.

Effects on hematological properties were examined and significant decreases in MCH and MCHC levels were observed on the seventh and 28th days. However, these decreases in MCH and MCHC were caused by differences of minor changes among Hb, RBC, and Ht levels. The Hb level to same extent decreased more than levels of RBC and Ht, which were practically unchanged during the competition. These decreases in MCH and MCHC were minor and did not indicate the existence of sports anemia[21].

On the other hand, a dramatic change in the ratio of neutrophils to lymphocytes was observed approximately 3 weeks after the end of the competition (shown in Table 3). Contradictory results were reported using professional basketball players[8] and national-level swimmers[9] as subjects, since neutrophil and lymphocyte percentages did not practically change in the recovery period. This discrepancy may have been caused by jogging continued after the competition and there was no complete recovery period in this study. The findings of this study seemed to correlate well with results reported by Hooper et al. indicating that stale swimmers compared with the non-stale swimmers showed higher neutrophil levels during tapering[22].

The increase in the number of circulating neutrophils with physical exercise is a result of demargination of neutrophils from endothelial tissues and bone marrow due to hemodynamic redistribution and augmentation by hormone secretion[23, 24]. In this study, there was practically no change in the stab/seg ratio. This result suggests that the contribution of the cells released from the bone marrow is small[25]. It was reported that the WBC fraction is affected by the levels of catecholamine and cortisol[26]. Therefore, changes of catecholamine and cortisol levels were also examined (shown in Table 4). Catecholamine and cortisol are known as immunomodulating hormones[27] and the reduction of lymphocytes is associated with a work-dependent cortisol increase[28]. The dramatic change of the WBC fraction might have been caused by the combined effect of the increased level of cortisol and the declining tendency of catecholamine observed approximately 3 weeks after the end of the competition. Considering reports that phagocytic activity is poorer in athletes[29] and intense training increases susceptibility to infections[30], it is thought that the significant increase of neutrophils observed in this study is one of the adaptations for the prevention of infections[31], although there is a possibility that the change is caused by the jogging continued after the competition.

It is well known that catecholamine levels are increased by physical exercise[28, 32]. In this paper, significant increases were found in the norepinephrine level on Day 7 and immediately before the end of the competition (shown in Table 4). To determine changing stages of acute overtraining[33], the norepinephrine level in blood may be a useful index. It is known that catecholamine levels are severely influenced by the shock of venepuncture and the delay after blood collection[17]. To use the norepinephrine level as an index, blood sampling and measurement conditions have to be carefully controlled even though norepinephrine is less sensitive than epinephrine[17].

The cortisol level is significantly increased by strenuous endurance exercise[34] and the secretion of cortisol is also increased under conditions of physical and psychological stress[28]. However, the cortisol level in this study was not affected during the competition, which correlated well with the report that chronic intense training during 28 days had no effect on resting cortisol levels in trained athletes[10]. On the other hand, testosterone levels were significantly decreased by the competition with statistical significance from the seventh day. This suggests that the testosterone level is a useful index to determine overtraining conditions. The ratio of testosterone to cortisol, which is reported to be a useaul index to determine overtraining conditions[19], was also significantly decreased from the seventh day of the competition. It is possible that some of the subjects are in the acute overtraining[33] condition from the seventh day of the competition.

The results of serum clinical tests are summarized in Table 4. It is well known that serum enzymes are affected and increased by physical stress. However, fluctuations of the enzymes were small and statistical significance was only found in GPT levels on the 28th day. One of the causes for a such small fluctuation observed is thought to be the repeated bout effect[35], that is, changes caused by physical exercise are diminished by the repetition of the same physical exercise. In the case of GOT, no statistical significance was observed; however, five of the six subjects had elevated GOT levels higher than the reference value on the 28th day. These results suggest that GOT and GPT levels may be useful for estimation of overtraining conditions.

The examinations of effects on blood properties are time-consuming and expensive. Therefor, monitoring subjective fatigue levels using a questionnaire is a more convenient and inexpensive method to estimate fatigue. According to the results shown in Table 5, the subjective fatigue was identified by the element of "fatigue" in POMS first, then SSF and again by POMS with a slight lag time. The individual changes of the elements of "drowsiness and dullness" in SSF (shown in Fig. 3 as SSF-I) and "fatigue" in POMS (Fig. 4) seemed to be coincident and there was a statistically significant correlation between these two elements ($n=48$, $r=0.686$, $p<0.001$) as shown by regression analysis. This result agreed with the report of Hooper and colleagues[23] that there were statistically significant correlations between elements in the questionnaire for subjective fatigue. However, immediately before the end of the competition (Day 31), when subjects were expected to exhibit the overtrained condition, no significant influence on the subjective fatigue levels was found (Table 5). This contradictory phenomenon was thought to be caused by psychological effects, excitement and/or the impression of achivement in the competition or liberation from it.

To determine overtraining at an early stage of change, the element of "drowsiness and dullness" in SSF and the elements of "anger", "fatigue", and "confusion" in POMS are thought to be the most important subjective indices. The application of these results to overtraining or chronic fatigue conditions in general seems to be limited because the subjects in this study are highly motivated and voluntarily keep testing their own capabilities.

In this study, immediately before the end of the competition, when fatigue was expected to accumulate, no significant influence on the subjective fatigue levels was found. But effects of the endurance running seemed to remain for more than 3 weeks after the competition as indicated by changes of the population of white blood cells and blood hormone levels. It is possible that this result is affected by the jogging continued after the competition, however, these results support previous studies that complete recovery from overtraining requires weeks or months[36].

Direct comparisons between blood properties and subjective fatigue were not conducted in this study because blood collection was carried out on different days from survey days using the questionnaire method. We could not restrict running during the competition. Thus, results of blood tests during the competition might have been affected by running done on the day before the blood collection day.

According to the results in this study, norepinephrine, testosterone and the ratio of testosterone to cortisol are thought to be the most useful indices of blood properties to determine overtraining in the early stage. In conclusion, these results indicate significant decrease in the testosterone level and the ratio of testosterone to cortisol approximately 3 weeks after the end of the competition, suggest that testosterone and the ratio of testosterone to cortisol may be important indices to estimate the recovery from overtraining conditions.

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