Abstract

Body mass index (BMI) is widely used as an index of obesity in people from the school age children to adults. However, the relationship between the change in BMI with age and the coming of menarche has not been discussed as there are few reports on the changes in BMI with age. In this study, the change in BMI with age was examined by applying the wavelet interpolation method (WIM), and a critical period for body fat in terms of the coming of menarche was estimated from the growth velocity. We investigated delayed menarche according to the influence of stress in athletes by comparing delayed menarche between athletes and non-athletes in relation to the critical period. Data were obtained from 144 female athletes in their first year at university in the Tokai area, all of whom had competed in a national sports competition in high school (athlete group). Health examination records showing these subjects’ heights and weights from the first grade of elementary school to the final year of high school (1984–1995) were collected and BMI was calculated for each grade. Ages at menarche were ascertained from questionnaires. A control group of 73 non-athletes was similarly examined. The age at maximum peak velocity (MPV) derived from the growth (aging) distance curve of BMI was determined in the control group to be 11.96±0.97 years old. This age at MPV of BMI was almost the same as the age at menarche (12.11±0.93 years old). Therefore, this age at MPV of BMI is estimated to be the critical period of body fat for the coming of menarche. The interval between the age at MPV of BMI and age at menarche was 0.74±1.30 years in the athlete group and 0.15±0.81 years in the control group, so there was a significant difference (P<0.01) between the two groups. It is suggested that the delayed menarche in athletes is influenced by the stress of regular sports training.

Introduction

Body mass index (BMI) is widely used in general medicine around the world as an indicator expressing the level of obesity. Since BMI is obtained from numerical values of body height and weight, it obviously does not take into account body fat. However, BMI is thought to have a correlation with amount of body fat (Garrows and Webster, 1985), and is a simple and stable indicator with which to judge obesity. Other indices to express the level of obesity are the Rohrer index \( \text{BMI} = \frac{\text{body weight (g)}}{\text{height (cm)}^2} \times 10^7 \), Livi index (Benn index, Ponderal index: \( \frac{\text{body weight (g)}^{1/3}}{\text{height (cm)}} \)), and Kaup index \( \text{BMI} = \frac{\text{body weight (g)}}{\text{height (cm)}^2} \times 10^7 \). Of these indices, the Kaup index is commonly used to judge obesity in preschool-age children, and the Rohrer index to judge obesity in school-age children.

Takaishi et al. (1987) investigated the changes in the Rohrer index by year, based on the National Nutritional Survey (1983 version). They reported large values in preschool children, after which there is a sharp drop followed by a gradual decline until puberty. An increase is again seen in the early stages of puberty, a tendency which is particularly strong in girls. This is probably because girls are developing the characteristic physique of adult women, based on the increase in subcutaneous body fat. However, there have been no reports dealing with the annual changes in BMI.

BMI also seems to be related to other phenomena and factors in addition to obesity. For example, Glyma et al. (1995) and Hiller et al. (1998) reported that cataracts are more likely to develop in people with high BMI. In addition, a decrease in BMI following hospitalization of senile dementia patients has also been reported by Watanuki et al. (1999). Thus, BMI is not simply an indicator of obesity, but can also be used to help solve other problems in the clinical setting.

BMI has also been considered a criterion for the occurrence of menarche. According to Johnston et al. (1975), Trussell (1980), a certain amount of body fat is necessary for menarche, and Garrows and Webster (1985) reported that body
fat was a correlative indicator of menarche. Considering this, it would seem possible to predict, to a certain degree, the timing of menarche, since BMI is a gauge of body fat. However, to determine this standard for menarche, it would be necessary to know the BMI, that is, the height and weight, of girls at the time of menarche. To obtain information on height and weight at menarche, studies to date have relied on the memory of the girls in question, or adopted a method of using the yearly increase in weight×(the number of months from April until the age at menarche/12 months). Frisch and Revelle (1970) also adopted a method using interpolation to estimate height and weight.

This method is nothing more than a simple linear interpolation of the given growth distance, and cannot be said to have a solid theoretical basis for approximating the true height and weight growth curves. It is therefore not appropriate for use in approximating the height and weight at the time of menarche. This kind of problem could perhaps be solved by applying the wavelet interpolation method (WIM), as proposed by Fujii and Yamamoto (1995) and Fujii and Matsura (1999), to the longitudinal growth data for height and weight; that is, since the growth distance for height and weight can be approximately described by using WIM, the height and weight at menarche could be specified. However, even if one determines the BMI at the time of menarche in ordinary girls, BMI is not necessarily a criterion of the coming of menarche in cases when menarche is delayed, such as in athletes. This is not limited to athletes, because it may be supposed that BMI changes during the period in which menarche is delayed. Therefore, to clearly understand the changes in BMI from delayed menarche, it is necessary to investigate the relationship between delayed menarche and BMI based on the changes in BMI with age.

By using WIM to investigate the changes in BMI with age, the BMI at the age of menarche can be specified, and the relationship between the speed of the BMI increase with age and the age at menarche can be determined. Thus, the rate of BMI increase with age becomes an estimate of the rate of increase in body fat, and this rate of increase is hypothesized to be a standard with which to estimate the critical period for amount of body fat in terms of the occurrence of menarche. Even if this critical period is passed without menarche being achieved, however, menarche will still come and develops as delayed menarche. When menarche does not occur even when this critical period is passed, it can be assumed that it is delayed due to stress. When delayed menarche is a result of an increase in lean body mass as in athletes, the body fat does not reach the critical period, and finally the critical period itself is delayed. This is nothing more than the delay of menarche judged from the interval between age at menarche and age at MPV for height proposed by Fujii (2001). However, menarche that does not come even though the critical period has passed is considered to be evidence indicating the participation of some type of stress. Therefore, to clearly show stress-related delayed menarche it would be necessary to determine the interval between the critical period and the age at menarche. Comparing this interval with that of ordinary girls would seem to provide evidence of delayed menarche related to stress. The necessity of considering stress-related delayed menarche as a criterion for the coming of menarche is also presented here.

In the present study, we first arrived at the changes in BMI with age in ordinary girls, and assumed the age range of the maximum peak velocity (MPV) on the age velocity curve of BMI to be the critical period of body fat for the coming of menarche. We then investigated the relationship between the age at MPV of BMI and the age at menarche. Malina and Bouchard (1991) considered delayed menarche in athletes to be due to both the influences of increased lean body mass from training and the stresses of training. There are very few reports, however, distinguishing between these two factors. To provide information that would clarify the situation, therefore, we investigated stress-related delayed menarche by comparing the interval between menarcheal age and MPV obtained from age changes in BMI in athletes with that in ordinary girls. Based on the hypothesis that the MPV age for BMI is the critical period for menarche, we demonstrated that delayed menarche in female athletes is caused primarily by stress, and thus clarified the contribution of delayed menarche in terms of the occurrence of menarche.

**Methods**

**Subjects**

The health examination records of 144 first-year female university students who participated in national sport competitions at high school level (athlete group) in the Tokai region of Japan were researched. Longitudinal height and weight records of these subjects were obtained extending from the first grade of elementary to the third grade of senior high school (1984 to 1995). Height and weight had been measured in April each year, so the exact age was found from the measurement date and the birthday. Age at menarche was established through questionnaires and interviews. As the response concerning the age at menarche was generally given as a calendar month, the exact age at menarche was obtained by calculating from the birthday again. Details of the questionnaires are shown below.

<table>
<thead>
<tr>
<th>No</th>
<th>Name</th>
<th>Birthday</th>
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<tbody>
<tr>
<td>1.</td>
<td>1) In which sport did you participate?</td>
<td>( )</td>
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<tr>
<td></td>
<td>2) What was your best record?</td>
<td>( )</td>
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<tr>
<td></td>
<td>3) How many days each week did you train?</td>
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</tr>
<tr>
<td>2.</td>
<td>1) In which sport did you participate?</td>
<td>( )</td>
</tr>
<tr>
<td></td>
<td>2) How many days each week did you train?</td>
<td>( )</td>
</tr>
</tbody>
</table>
3. Regarding elementary school sport
   1) In which sport did you participate?
   2) How many days each week did you train?

4. Regarding the onset of menses
   1) When did menses initially appear?
   2) When was the second instance?
   3) When was the third?
   4) How many months were there between the first and second appearance of menses?

Sports item (numbers of individuals in parenthesis) of the 144 female athletes were as follow: track and field (21), basketball (15), volleyball (21), softball (7), tennis (16), softball tennis (25), hockey (8), judo (19), table tennis (6), swimming (3) and gymnastics (3). All were prizewinners in prefectural level competitions, and had been selected for national competitions. All had trained about three to four hours a day, six days a week from the beginning of junior to the end of senior high school (ages 12 to 17). Their previous history of training had generally started from fifth grade of elementary school (ages 10) according to the questionnaires and interview responses, or from junior high school (ages 12) in the case of hockey. However, the hockey athletes, too, had trained about two hours a day, at least six days a week in various sports other than hockey (basketball, track and field, softball) before and after the age of menarche. Therefore, it can be said of the whole athlete group in the present study that their age of menarche was affected by regular sports training.

For the control group of non-athletes, longitudinal height and weight were obtained for a group of students in a similar manner, for the years from the first grade of elementary to the third grade of senior high school (1986–1997), and the exact ages at the time of measurement accordingly calculated. The ages at menarche were also obtained as before from questionnaires and interviews, and accurately determined in the same manner as for the athletes. “Non-athletes” who regularly trained in sport (five days or more a week) before and after the age of menarche were excluded from the control group. As a result, the control group consisting of 73 female non-athletes remained.

Analytical techniques

To approximate the true growth curve from the supplied growth data with the wavelet interpolation method (WIM), the data are interpolated from the wavelet function of the data and a growth distance curve is drawn. This distance curve is differentiated to arrive at the growth velocity curve, and the growth distance value of the age at menarche and the puberty peak is examined. The WIM can sensitively read local phenomena, and has an extremely high level of approximation accuracy. The theoretical background and grounds for its efficacy have been described in previous reports (Fujii and Ynamoto, 1995; Fujii and Matsuura, 1999). In the present paper we shall describe the method of analyzing data using the WIM.

1) Data are measured \((t_i, y_i): i=1, 2, ..., 12\).
   (Here, \(t_i\) is the distance value for age, and \(y_i\) is the distance value for BMI.)
2) Data are arranged to satisfy the following conditions.
   When \(t<0\) or \(t>1\), \(|\psi(2^j t - k)| \leq \varepsilon\). (\(\varepsilon=0.01\) is adopted)
3) A group of 12 integers that satisfies the following conditions is determined.
   \(j \equiv P\) (\(P\) is taken to be 2 or 3) and \(-10 \leq k \leq 10\) are adopted.

4) Using \((j, k) = (j_1, k_1), ..., (j_{12}, k_{12})\), a simultaneous system of equations is determined by arbitrarily combining \(j\) and \(k\).

\[
y_i = \sum_{j, k} a_{j, k} \psi(2^j t_i - k)
\]

5) The wavelet coefficient obtained in 4) \((a_{j, k}; j, k)\) is substituted into the equations below, and a graph of the approximate functions of \(F\) and \(f\), \(y = F_n(t)\) and \(y = f_n(t)\), respectively, is drawn by computer.

\[
F_n(t) = \sum_{j, k} a_{j, k} \psi(2^j t - k)
\]

\[
f_n(t) = \sum_{j, k} 2^j a_{j, k} \psi'(2^j t - k)
\]

The above procedures were applied to BMI values calculated from the growth distance values for height and weight from 6 to 17 years of age in the athlete and control groups. First, WIM was applied to the age distance value for mean BMI. Then, the age distance curves for BMI in both groups were differentiated, and the age at MPV of BMI (MPV of BMI during puberty) from the velocity curve was specified through this process. In addition, this process was conducted for each individual, and the interval between age at MPV of BMI and menarcheal age was calculated for each person.
Results

Mean changes in BMI with age

Fig. 1 is a graph showing the results of applying WIM to the mean age distance of BMI for the control group from the first grade of elementary school (6 years old) to the final year of high school (17 years old). First, the changes with age in the age distance curve of BMI describe a sigmoid shape from a BMI of approximately 15.5 in the first grade of elementary school to a BMI of approximately 21 in the third year of high school. Then, the speed of increase in BMI with age shows a peak in puberty, just as with height and weight. This peak in puberty is the maximum growth velocity of BMI; in other words, it can be specified as the MPV of BMI. This graph thus shows the MPV of BMI to be 11.9 years, and in fact this age is nearly the same as the mean age at menarche of 12.11 ± 0.93 years in ordinary girls. Accordingly, this result can be taken to show that the MPV age of BMI indicates the critical period of body fat for the coming of menarche.

Similarly, WIM was applied to the age distance of BMI in the athlete group, and the results are plotted in Fig. 2. In this graph, similar to the mean graph for the control group, the age distance curve is a sigmoid, showing a peak in puberty in the BMI age velocity curve. The one difference, however, is that whereas a comparison of age at MPV of BMI and age at menarche indicates almost no difference in age at MPV of BMI in either group, an interval is seen between the age at MPV of BMI and age at menarche in the athlete group. In Fig. 2, the age at MPV of BMI in the athletes is 11.9 years, and the mean age at menarche is 12.75 ± 1.23 years.

Relationship between individual changes in BMI with age and age at menarche

Fig. 3 and 4 show sample graphs from the application of WIM to the age distance of BMI for individuals in the control and athlete groups. Unlike the graphs using mean values, there are marked waves of the age distance curve and velocity curve, but the puberty peak, or MPV of BMI, that is seen in the mean graph appears. The WIM was then applied to the age distance of BMI for all individuals in the control and athlete groups, and the MPV age of BMI was obtained. Statistical values of this MPV age of BMI and the menarcheal age were calculated to investigate the normality of the two groups.

In Table 1 and Figs. 5 and 6, in the control group the age at MPV of BMI is 11.96 ± 0.97 years, and the menarcheal age is 12.11 ± 0.93. Very little difference is seen between the two groups. To make this even clearer, the normality of the menarcheal age and age at MPV of BMI according to the distribution of menarcheal age and MPV age of BMI were

![Fig. 1](image1.png) Mean changing in BMI with age from 6.5 to 17.5 years in non-athletes.

![Fig. 2](image2.png) Mean changing in BMI with age from 6 to 17 years in athletes.

![Fig. 3](image3.png) A sample of individual changing in BMI with age from 6 to 17 years in non-athletes.

![Fig. 4](image4.png) A sample of individual changing in BMI with age from 6 to 17 years in athletes.
obtained from the normality distribution function. The normality distribution function of both is shown below.

Age at menarche in the control group

\[
f(x) = \frac{0.5 \times 73}{\sqrt{2\pi \times 0.94}} e^{-\frac{(x - 11.11)^2}{2(0.94)^2}}
\]

Age at MPV of BMI in the control group

\[
f(x) = \frac{0.3 \times 73}{\sqrt{2\pi \times 0.94}} e^{-\frac{(x - 11.96)^2}{2(0.94)^2}}
\]

Calculating \(X^2\) from the normality distribution functions above, we get 21.3 for the MPV age of BMI, and 7.8 for age at menarche, indicating the validity of both. Therefore, the fact that we can judge from both distribution graphs showing this normality would seem to indicate that both have nearly the same distribution.

Next, in the athlete group the age at MPV of BMI was 12.01 \(\pm\) 1.31 years, and the age at menarche was 12.75 \(\pm\) 1.23,

so a clear and significant difference (P<0.01) is seen between the two ages. Therefore, to clarify the results in the athlete group as well, the normality of menarcheal age and MPV of BMI from the distribution of menarcheal age and MPV age of BMI (Fig. 6) was obtained using the normality function, just as in the control group. The normality function of both groups is shown below.

Age at menarche in the athlete group

\[
f(x) = \frac{0.3 \times 144}{\sqrt{2\pi \times 1.31}} e^{-\frac{(x - 12.75)^2}{2(1.31)^2}}
\]

Age at MPV of BMI in the athlete group

\[
f(x) = \frac{0.3 \times 144}{\sqrt{2\pi \times 1.23}} e^{-\frac{(x - 12.01)^2}{2(1.23)^2}}
\]

Calculating \(X^2\) from the normality distribution above, we get 14.0 for MPV age of BMI and 13.5 for menarcheal age, indicating the validity of both. Thus, in the athlete group, unlike the control group, a clear difference is seen between the distributions for menarcheal age and MPV of BMI, with the distribution of age at menarche tending to be delayed in comparison with the distribution of age at MPV of BMI.

Interval between age at MPV of BMI and age at menarche

Table 1 and Figs. 7 and 8 show the statistical values for the interval between menarcheal age and age at MPV of BMI in the control and athlete groups, and graphs of the distribution. In the control group, the interval between age at MPV of BMI and menarcheal age is 0.15 \(\pm\) 0.81 years, which is not a significant difference. The normality of the distribution (Fig. 7) in this interval is obtained from the following normality distribution function.

Interval between age at MPV of BMI and age at menarche

\[
f(x) = \frac{0.3 \times 73}{\sqrt{2\pi \times 0.81}} e^{-\frac{(x - 0.15)^2}{2(0.81)^2}}
\]
The $X_0^2$ value from the normality distribution function is 20.7, demonstrating the validity of the normality. Based on this, a significant interval between the age at MPV of BMI and age at menarche in the control group is not seen to be significant. Therefore, if this interval is within a range of about 0.1-0.6 years, the standard for menarche is established to be at the time of MPV of BMI; that is, at the MPV age. Menarche that occurs outside this range is judged to be delayed or precocious.

Next, the interval between age at MPV of BMI and age at menarche in the athlete group was 0.74 to 1.30 years, which shows a significant difference ($P < 0.01$) between the two. Then, as in the control group, the normality of this interval was shown as below, and the normality distribution function was obtained (Fig. 8).

Interval between age at MPV of BMI and age at menarche in the athlete group

$$f(x) = \frac{0.3 \times 144}{\sqrt{2\pi} \times 1.30} e^{-\frac{(x-0.74)^2}{2(1.30)^2}}$$

From the above normality distribution function, the $X_0^2$ value was 14.5, demonstrating the validity of the normality. Therefore, a lag is clearly seen in the age of menarche behind the age at MPV of BMI in athletes. Moreover, a significant difference ($P < 0.01$) is also seen in a comparison of the interval between the age at MPV of BMI and the age at menarche in the control group, suggesting the delayed menarche is mainly caused by stress in athletes.

**Level of BMI at the age at MPV of BMI**

From Table 2, we see that the MPV of BMI, which is the BMI at the MPV age, is 18.86 $\pm$ 2.13 in the control group and 19.08 $\pm$ 2.57 in the athlete group. Moreover, the BMI at the age of menarche (Table 2) is 18.44 $\pm$ 2.41 in the control group and 19.45 $\pm$ 2.45 in the athlete group, so there is little difference in the BMI at the MPV age of BMI in the two groups. However, BMI at the time of menarche is significantly greater ($P < 0.01$) in the athlete group than in the control group. This is because the critical period of body fat for the occurrence of menarche is reached at the MPV age of BMI in both groups. The greater BMI at the time of menarche in the athlete group than in the control group is a suggestion of the delayed menarche in the athletes.

**Discussion**

**Relationship between changes with age in BMI and delayed menarche in female athletes**

BMI is fundamentally used as an indicator of the level of obesity in most cases, but there are also reports (Glyma et al., 1995; Hiller et al., 1998) of a relationship between BMI and cataracts. BMI therefore also has significance in indicating ways to solve problems, based on its relationship with other phenomena.

Teramoto et al. (1999), Otogi et al. (1999), and Komiya et al. (2000) have investigated the gender difference in distributions of body fat and body composition in young children. The report by Garrows and Webster (1985) of a correlative index with body fat also suggests a relationship between BMI and body fat, as well as the significance of BMI as an indicator of body fat. However, there are no reports on the relationship between BMI and other phenomena, or changes in BMI with age, as is investigated in the present study. Therefore, in the case of dealing with the change in BMI with age, as in height since there is little change in BMI during puberty, these changes cannot be clearly analyzed using a
graphic method dealing with raw data. Accordingly, Fujii and Yamamoto (1995) and Fuji and Matsuura (1999) proposed using the WIM as a means of overcoming these problems. The WIM has already been adopted in a study by Fujii (2001), in which the delayed menarche of female athletes was objectively demonstrated from the interval between the age at MPV of height and the age at menarche. One may consider that these results can be obtained because of the utility of the local detection capacity of the WIM. Thus, based on these findings, we determined the age at MPV of BMI from the changes in this with age using the WIM, and investigated the relationship between the age at MPV of BMI and age at menarche. The results showed a clear puberty peak in the velocity of BMI with age in both the control and athlete groups (Figs. 1, 2). It is noteworthy that whereas in the control group the age at MPV of BMI is nearly the same as the age at menarche, in the athlete group menarche lags behind. This is the first time such findings have been obtained, and they are thought to provide evidence for the proposed critical period of body fat in terms of the occurrence of menarche. However, since this finding was obtained using a graph of means, it will be necessary to conduct individual analyses.

Fig. 3 and 4 show the results of plotting graphs based on the WIM for changes in BMI with age for individuals in the control and athlete groups. Several peaks are seen according to the individual, but it is possible to specify the puberty peak in the aging changes in BMI as the MPV. Therefore, when judging from the statistical values of the age at MPV of BMI calculated individually and the interval between that age and the age at menarche, the age at MPV of BMI and the age at menarche in the control group are nearly the same, similar to the results shown in the graph of mean values, and in the athlete group the age at menarche is seen to lag behind the MPV age of BMI. Moreover, to verify this hypothesis, we investigated whether normality was seen in the frequency distribution of the MPV age of BMI and the interval between that age and the age at menarche in both groups, and compared these frequency distributions.

Normality was seen in the frequency distributions of the age at MPV of BMI and the interval between that age and the age at menarche in both groups. It was clearly demonstrated that the frequency distribution of the age at MPV of BMI and the age at menarche were on almost the same line in the control group, whereas in the athlete group there was a clear lag in the distribution of the menarcheal age behind that of the age at MPV of BMI. From this demonstration, the overlaying of the age at MPV of BMI and age at menarche in ordinary girls confirms that menarche is induced in the period of peak increase in body fat. This fact is thought to be evidence indicating the further development and simplification of the critical body weight hypothesis and critical body fat hypothesis to the critical BMI hypothesis, or the critical period of body fat for the occurrence of menarche.

The critical body weight hypothesis, in which a certain body weight acts as a trigger to induce menarche, was originally proposed by Frisch and Revelle (1970). Soon afterward, this hypothesis was reinvestigated by Johnstone et al. (1971) and Frisch and Revelle (1971). This hypothesis was discussed but refuted by Johnston et al. (1975) and Trussel (1980), and the critical fat hypothesis was proposed, in which body fat was adopted in place of weight. If the delayed menarche of female athletes is discussed in terms of the critical fat hypothesis, the assumption would be that the delayed menarche is caused by regular sports training. However, in the reports of Malina (1983a; 1983b) and Malina et al. (1973, 1978) the critical fat hypothesis is cited for athletes showing extreme increases in lean body mass such as ballerinas, long distance runners, and gymnasts. In addition, Frisch et al. (1980, 1981) also discussed the relationship with amenorrhea, but in athletes of other sports there are cases when body fat reaches the limit but nevertheless menarche does not occur. In such cases, it is hypothesized that in the end the stress of training is the principal factor in delayed menarche.

Delayed menarche due to training stress

If the delayed menarche in athletes is interpreted with the critical fat hypothesis, the influence on the level of gonadotropin circulating in blood due to the increased lean body proportion would be concluded to cause the delay in menarche, with which the factor of stress due to training would be complexly intertwined. As pointed out by Malina (1983a), however, while Warren (1980) speak of stress it is not the type of stress felt by classical musicians, but rather the stress conferred physically that causes the delayed menarche. In judging stress it is necessary at minimum to determine whether or not the critical body fat has been reached; given the large differences among individuals, however, such a determination is difficult.

In the present study, then, the findings obtained from the changes in BMI with age show that menarche occurs in ordinary girls at the age at MPV of BMI. The BMI at that time is not on average significantly different from that of athletes. There is also no difference in the MPV age of BMI between the two groups, which suggests that reaching a critical fat level, or critical period of body fat, induces the occurrence of menarche at the MPV age of BMI. In this sense, even if the delayed menarche in athletes is affected by an increased proportion of lean body mass, the age at MPV of BMI the critical period of body fat is not reached, so in the end menarche is delayed by just the amount of the delay in the critical period. In spite of that, from the fact that there was no change in BMI in the critical period in both groups in the present study, we may exclude the influence due to an increase in lean body mass. Therefore, conjectures as to the reason menarche is delayed so that it does not occur in this period in athletes may be narrowed to the change in circulating blood levels due to the stress of training. However, if this finding is interpreted from mean values, the BMI level at the age at MPV of BMI also differs with the type of sport, so that the relationship with stress from training would also differ. Thus, it
would be rash to conclude that in cases when menarche occurs beyond the critical fat level, the cause is stress from training. There are also athletes in whom menarche is not delayed, and in the future it will be necessary to conduct detailed investigations for individuals including such athletes. However, when menarche occurs past the critical period for amount fat (MPV age of BMI) for the occurrence of menarche, one may suggest stress from training, and a new understanding in terms of the criterion for the coming of menarche may be gained from the relationship between delayed menarche and the changes in BMI with age.

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