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Case Report

Confirmation regarding regression polynomial evaluation of age at menarche against age at MPV of weight

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Abstract

Based on the regression evaluation of menarcheal age relative to the age at MPV of height, a delayed menarche evaluation chart was established. In fact, it is thought that the close relationship between menarche and body weight may lie behind the critical weight hypothesis and body fat hypothesis proposed in relation to the onset of menarche. In other words, the age at maximum peak velocity (MPV) in weight and age at menarche are thought to be highly correlated, so a regression evaluation chart for age at menarche against age at MPV of height can be constructed. Then, in the present study, a delayed menarche evaluation chart based on age at MPV of weight is constructed, and compared it with evaluations of delayed menarche determined by age at MPV of height. The results showed that the age at MPV of weight is later than the age of MPV in height. The level of agreement between girls judged using delayed menarche evaluation charts based on ages at MPV of height and weight was analyzed, and the results showed agreement in 131 of 204 girls (64.2%). The fact that there was disagreement in 74 girls (35.8%) indicates that the validity of delayed menarche evaluation based on age at MPV of weight is probably low.

Keywords: Delayed menarche, Age at menarche, Age at MPV, Wavelet Interpolation Model

Introduction

It is thought that the close relationship between menarche and body weight may lie behind the critical weight hypothesis and body fat hypothesis proposed in relation to the onset of menarche. Malina and Bouchard [1] stated that a body fat percentage of about 17% is needed for the onset of menarche. However, Fujii and Demura [2] suggested that in cases when menarche does not occur even though body has fat reached the critical period, the delay may be due to stress such as that in female athletes. To demonstrate that menarche occurs with a delay in female athletes, Fujii [3] identified menarche by applying the wavelet interpolation method to the maximum peak velocity (MPV) of height, which is not affected by training. Delayed menarche was then demonstrated from the interval between age at MPV of height and age at menarche. Fujii [4] also constructed a regression evaluation of age at menarche against age at MPV of height and established a delayed menarche evaluation system by determining delayed menarche in individuals. However, evaluation of delayed menarche based on age at MPV of weight has not been investigated at all. Obviously, there are more unstable factors involved in growth in body weight than in height, and so it is possible that age at MPV of weight (age at pubertal peak) is more greatly affected by environmental factors than height. Considering these unstable factors in body weight growth, Malina and Bouchard [1] took the age at MPV of height to be a better biological parameter.

Moreover, on the other hand, the assumed close relationship between menarche and body weight is also the basis for the proposed critical weight hypothesis and body fat hypothesis. Fujii and Kawanami [5], judging from the relationship between ages of MPV in height and weight, found a high correlation between the two and that the age at MPV of height came earlier than that of MPV of body weight. However, they did not investigate the relationship with age at menarche. In this study, based on the idea of a high correlation between age at MPV of weight and age at menarche, a regression polynomial evaluation chart of age at menarche against age at MPV of weight is constructed. Then, after evaluating age at menarche with this chart author compared the results with evaluations of delayed menarche determined from age at MPV of height. From this comparative study, the validity of regression polynomial evaluation of menarcheal age with respect to age at MPV of weight is examined.

Methods

Subjects

The subjects in this study were 119 students of a women's university (born April 1980-March 1984) and 119 girls from a high school (born April 1985-March 1986) in the Tokai region of Japan. These female students responded to a questionnaire, from which their date of birth and age at menarche were extracted. Longitudinal growth data for height and weight from the first grade of elementary school (age 6) to the final year of high school (age 17) were obtained from a retrospective survey of the subjects' health checkup records. Age at menarche was confirmed in accordance with internationally used methods of Malina et al. [6] and Mesaki et al.[7]. Only data from measurements in April were used, and the analysis was done for 220 subjects for whom a full set of data was available.

Analytical Method (Wavelet Interpolation Model)

The wavelet interpolation method (WIM) is a method to approximate true growth curves from given growth data. Interpolation of data sets is done with a wavelet function to depict growth distance value curves, derive the growth velocity curve by differentiating the drawn distance curves, and examine the growth distance values at the pubertal peak or the age of menarche. The wavelet interpolation model is effective in sensitively reading local phenomena with an extremely high approximation accuracy. The detailed theoretical background and evidence for its effectiveness have been described in previous reports by Fujii [8-11] and so will be omitted here.

Construction of Delayed Menarche Evaluation System

This system is an established evaluation methodology to judge delayed menarche in individuals. This system is constructed as a regression evaluation that estimates age at menarche from age at MPV of height identified by the wavelet interpolation model. First, a least squares approximation polynomial from first to third order is obtained for the age at menarche against MPV of height. To judge the validity of the order, the residual sum of squares of the least squares approximation polynomial and the Akaike Information Criterion (AIC) are calculated. The validity of the order is judged from the values of the residual sum of squares and AIC. Using the standard error (SE) in the regression polynomial that is considered to be valid, a regression evaluation chart of the most suitable order is then constructed. This standard regression line +1.5 SE or more is taken to indicate "delayed," the standard regression line +0.5 SE to +1.5 SE is "somewhat delayed" the standard regression line ±0.5 SE is "standard" the standard regression line -0.5 SE to -1.5 SE is "somewhat early" and the standard regression line of −1.5 SE or more is "early." Delayed menarche is judged with this regression evaluation chart and the evaluated frequency distribution is shown by this regression evaluation chart.

This method was also applied to age at menarche against age at MPV of weight, and compared.

Results

Regression Analysis of Age at Menarche against Ages at MPV at Height and Weight

Tables 1 show statistics for ages at MPV of height and weight derived from height and weight velocity curves described by wavelet interpolation, and age at menarche obtained from the questionnaire survey. They also show statistics calculated individually for the interval between ages and MPV of height and weight and age at menarche. From this was understood that the age at MPV of weight is delayed compared with that of height.

Figure 1 shows first order least squares approximation polynomials from a regression polynomial analysis of age at menarche against age at MPV of height. The coefficient of determination in the first order regressions is R^2=0.31, and regression significance ($P<0.01$) is seen. As shown in Table 2, the residual sum of squares and AIC of first to third order regression polynomials were calculated, and the results showed validity of the first order regressions.

Next, a regression polynomial analysis like that for height was performed for age at menarche against age at MPV of weight, and first to third order regression polynomial analysis was done (Figure 2). The coefficient of determination in the first order regressions was R^2=0.27, and as with height regression significance ($P<0.01$) was seen. With regard to the validity of the regression formula orders, as shown in Table 4, the second order regression polynomial was judged to be valid.

Table 1: Statistics of age at MPV of height and age at MPV of weight and interval between age at MPV and age at menarche in Japan female.

	N=204	Age at menarche	Age at MPV	Interval between age at MPV and age at menarche
Height	mean	12.23	11.01	1.22
	SD	1.12	1.01	1.02
Weight	mean	12.23	11.67	0.55
	SD	1.12	1.18	1.15

Table 2: Validity of least square approximation polynomial in height and weight.

	Expression	R^2	Residual sum of square	AIC
Height	Linear y=0.5966x+5.6593	0.2931	179.1502	558.4283
	Quadratic y=0.0483x2+1.6521x-0.0575	0.2967	178.2262	559.3734
	Cubic y=0.0365x3-1.2441x2+14.6074x-46.4452	0.3020	176.9016	559.8515
Weight	Linear y=0.4734x+6.6990	0.2506	189.9076	570.3241
	Quadratic y=-0.0689x2+2.0941x-2.7489	0.2657	186.1053	568.1982
	Cubic y=0.0231x30.8873x2+11.6573x-39.6135	0.2697	185.0684	569.0585

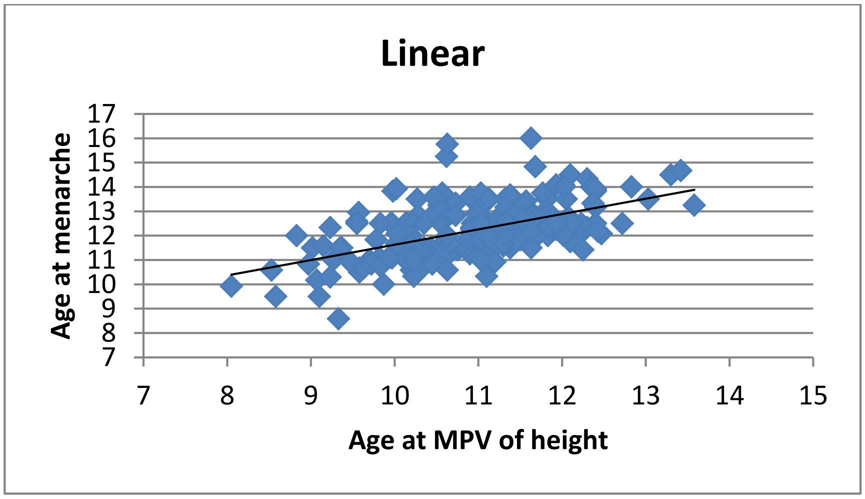

Figure 1: Regression analysis of age at menarche for age at MPV of height.

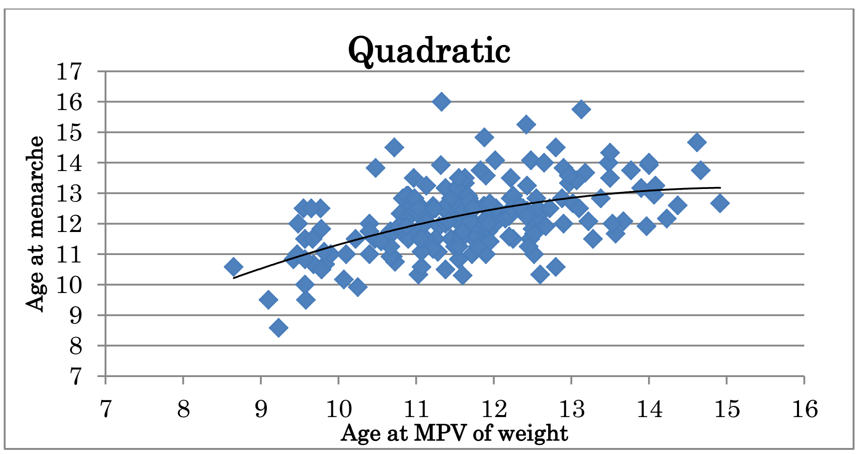

Figure 2: Regression analysis of age at menarche for age at MPV of weight.

Construction of Regression Evaluation Chart for Age at Menarche with Respect to Ages at MPV of Height and Weight

Figures 3 and 4 show a regression evaluation chart derived with the valid order determination from regression analysis of age at menarche against ages at MPV of height and weight. Regression polynomial evaluation charts of the first order were constructed for height and the second order for weight. These evaluation charts adopted a 5-step regression evaluation of early, somewhat early, average, somewhat delayed, and delayed menarche. Frequency distributions were prepared for height and weight, respectively, against these evaluation charts (Figures 5 and 6). Normality was shown based on the frequency distributions of these delayed menarche evaluations, and the validity of the evaluations was seen.

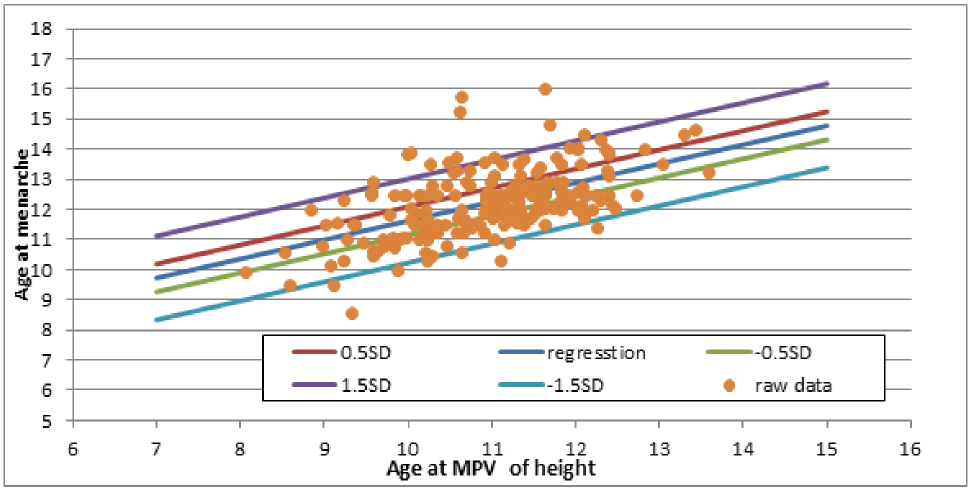

Figure 3: Regression evaluation chart of age at menarche for age at MPV of height.

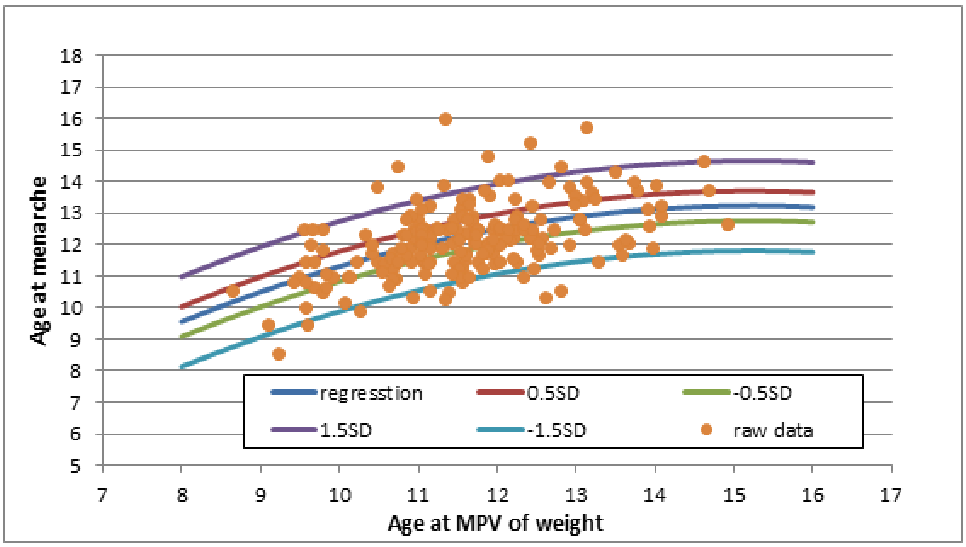

Figure 4: Regression evaluation chart of age at menarche for age at MPV of weight.

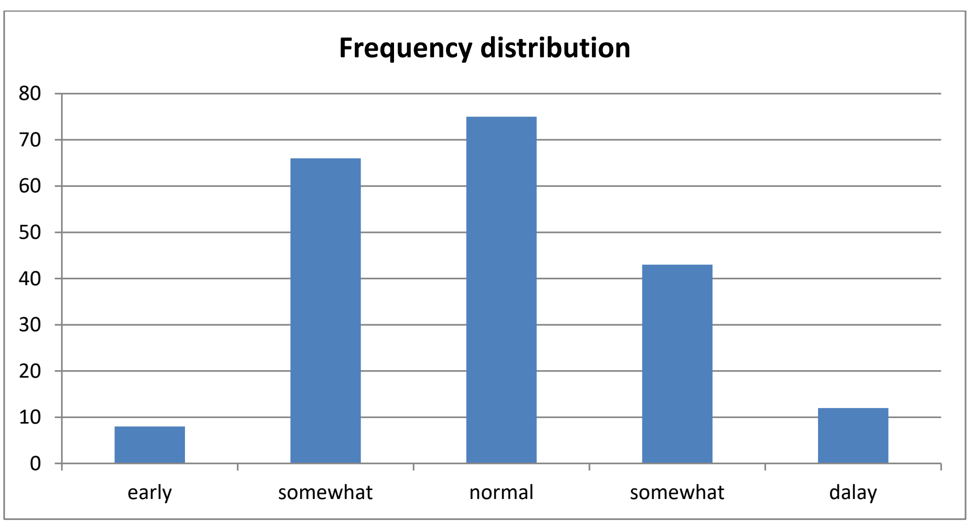

Figure 5: Frequency distribution of delayed menarche judgment by regression evaluation in height.

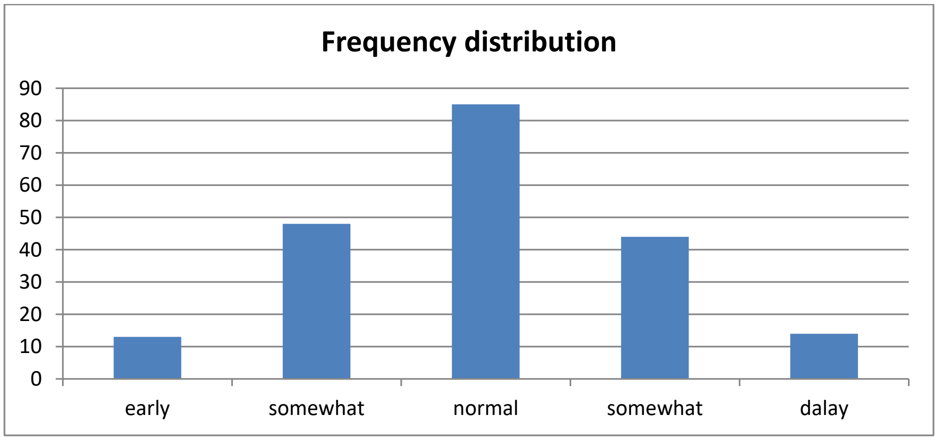

Figure 6: Frequency distribution of delayed menarche judgment by regression evaluation in weight.

Correspondence between Delayed Menarche Evaluations Based on Ages at MPV of Height and Weight

Table 3 shows the level of agreement among subjects judged from the delayed menarche based on the ages at MPV of height and weight. For example, agreement was seen in 3 of the 7 subjects judged to have early menarche, 39 of the 65 subjects judged to have somewhat early menarche, 54 of the 79 subjects judged to have average menarche, 27 of the 40 subjects judged to have somewhat delayed menarche, and 8 of the 13 subjects judged to have delayed menarche. In total, agreement was seen in 131 of 204 (64.2%) subjects.

Table 3: The level of agreement among subjects judged from the delayed menarche based on the ages at MPV of height and weight.

		Weight					Sum
		early	**somewhat**	**normal**	**somewhat**	**delay**	
Height	early	3	4	-	-	-	7
	somewhat	6	39	18	2		65
	normal	-	12	54	13	-	79
	somewhat	-	-	8	27	5	40
	delay	-	-	1	4	8	13

Discussion

In this study, author attempted to evaluate delayed menarche based on the MPV age derived from growth velocity curves for weight. Basically, since there is thought to be a high correlation between age at MPV of weight and age at menarche, we focused on the validity of delayed menarche evaluations. The validity was judged by comparing the delayed menarche evaluations based on age at MPV of height. In the polynomial regression evaluation from age at MPV of weight, the second order least squares approximation polynomial was valid. A delayed menarche evaluation chart was also constructed from the age at MPV of height, and the first order least squares approximation was judged to be valid. By constructing delayed menarche evaluation charts with ages at MPV of height and weight, the delayed menarche evaluations with both evaluation charts could be compared. The results, taking the delayed menarche evaluation chart from age at MPMV of height to be the reference, showed agreement in 3 of the 7 subjects judged to have early menarche, 39 of the 65 subjects judged to have somewhat early menarche, 54 of the 79 subjects judged to have average menarche, 27 of the 40 subjects judged to have somewhat delayed menarche, and 8 of the 13 subjects judged to have delayed menarche, or in 131 of 204 (64.2%) subjects. Naturally, given that there is a history of evaluating the efficacy of delayed menarche evaluations based on the age at MPV of height, agreement of the delayed menarche evaluations based on the age at MPV of weight with those based on height is a precondition for validity. However, when taking the age at MPV of height as the reference, the lack of agreement in 74 (35.8%) subjects indicates lack of agreement in delayed menarche evaluations based on age at MPV of weight. Thus, the validity of delayed menarche evaluations based on the age at MPV of weight may be taken to have low validity.

Tanner [12] and Malina and Bouchard [1] indicated that the age at MPV of height is a meaningful biological parameter, but the age at MPV of weight has not become an indicator of maturity. In other words, weight growth is thought to be easily affected by environment and nutritional intake. Ultimately, because the age at MPV of weight is affected by external environmental factors, Lindgren [13] indicated that there is a slide in the interval between pubertal peak ages for height and weight depending on differences in level of maturity. This means that the age at MPV of weight slides depending on the level of maturity. This finding was also pointed out by Fujii and Kawanami [5], and shows the instability in the age at MPV of weight. Therefore, if the MPV is taken as the basic reference, it means that the variations in MPV of weight are large. Given the above, one may hesitate in adopting the method of evaluating delayed menarche based on the age at MPV of weight.

In this study, a system of evaluating delayed menarche from the age at MPV of weight was constructed and its validity was examined, but the results suggest that the validity of such evaluations is low. Consequently, the study has considerable significance as a reinvestigation of the level of the validity of the delayed menarche evaluation system based on the age at MPV of height proposed by Fujii [4]. In this study, delayed menarche was examined from the age at MPV of weight, which has been previously proposed, and the low level of that validity found in this investigation may also be considered a significant finding.

Conclusion

In this study, author attempted to evaluate delayed menarche based on the age at MPV derived from the weight growth velocity curve. In the results of comparisons of the two delayed menarche evaluations based on age at MPV of height and weight, agreement in the evaluations of delayed menarche based on the ages at MPV of height and weight was found in 131 of 204 subjects (64.2%). The results also showed lack of agreement in 73 of 204 subjects (35.8%). From this, evaluations of delayed menarche against age at MPV of weight can be said to have a low level of validity when the evaluation of delayed menarche against the age at MPV of height is taken as the reference. Weight growth is probably more likely to be affected by external environmental factors than height growth, and a reversal phenomenon of the age at MPV of weight against height may be considered an unstable factor in weight growth.

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