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Research Article

Examination of Physical Fitness and Bone Mineral Density Based on Differences in Morphological Quality in Adolescent Girls

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Abstract

BMI is convenient because it is easily used to determine the level of obesity and slimness, but because the degree of fat mass accumulation differs in relation to body type, the physical strength and athletic ability of obese and slim individuals may be misjudged. Therefore, in this study, in order to establish a method to objectively judge the degree of accumulation of fat mass relative to the body type of junior high school girls, we construct a standardized evaluation chart from a polynomial regression analysis of body fat percentage relative to BMI. Based on the constructed evaluation chart, the degree of fat accumulation is determined in the obese, normal, and slim body types judged by BMI, and classified into categories of more fat, normal and less fat. The aim was to examine physical fitness, athletic performance, and bone density in the classified categories. The subjects were 341 Japan female junior high school students, and physique, body composition, physical fitness tests and bone density were measured. First, among the groups classified into the obese, standard, and slim types based on fatness judged by BMI, physical strength, athletic ability, and bone density were particularly high in the order of obese, standard, and slim. However, in other physical fitness and athletic ability categories, it was shown that sit-ups, long-seated forward bends, side steps, 20-meter shuttle run, 50-meter run, and standing long jump were high in the order of standard, slim, and obese. Next, in order to verify physical strength, athletic ability, and bone density due to differences in morphological quality, we compared nine categories based on a polynomial regression evaluation chart of body fat percentage to BMI based on differences in the degree of fat accumulation (more fat, normal, and less fat). As a result, it was clarified that individuals of the obese type with less fat were superior in terms of grip strength and bone density. In other physical strength and athletic ability measures (sit-ups, long-seated forward bend, side steps, 20 m shuttle run, 50 m run, standing long jump, handball throw), the standard type was superior, and among them those with less fat did the best. For the first time, the relationship between physical strength, athletic ability, and bone density in the morphological qualities of Japan female junior high school students was derived, and it may become useful knowledge for future health education guidance.

Keywords

BMI, Body Fat Percentage, Polynomial Regression Analysis, Physical Fitness, Morphological Quality

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1. Introduction

Studies on physique or body type and physical fitness or athletic ability over the past 50 years are too numerous to count. In the field of sports science these studies are already considered classic research. The regression evaluation of athletic ability versus height in the junior high school years shown by Mizuno [1] was done in the period when the pubertal growth spurt phenomenon is shown, and in periods with marked changes development, the correlation between physique and athletic ability is remarkable. In this phenomenon, Fujii [2] indicated that the developmental trends in athletic ability differ depending on level of maturation. The influence of physique on athletic ability in puberty has been shown to almost entirely due to the influence of level of maturation. It can then be easily conjectured that this pronounced influence of maturation induced the remarkable correlation between height and athletic ability. For boys in particular, anabolism is spurred in this time period with the onset of the pubertal surge, and an increase in body fat is inhibited. Conversely, in girls, as indicated by Fujii and Kim [3], taking a curve of age-related changes in BMI with age as a reference, the change with age in body fat percentage and the curve of age-related changes in BMI show similar trends. The similarity in the two curves was indicated to be very high according to a cross-correlation function. A considerable difference is also shown in muscle percentage, and a diametrically opposed composition of changes with age was shown.

This kind of mechanism functions normally in puberty during the junior high school years. If an abnormality occurs in this mechanism, an increase in body fat may be facilitated or body fat may be excessively burned, causing qualitative changes in morphology. Of course, abnormalities in this mechanism are derived from the living conditions of the junior high school students, and an imbalance between the calorie intake versus the calories burned may contribute to obesity. There are also cases when intake abnormality occurs from stress due school entrance exams or games [4]. These body type differences may be split into either obesity or slimness, but there are also thought to be cases when the amount of fat is high or low for a given body type. A focus in recent years is the phenomenon of normal weight obesity. Naito et al. [5, 6] applied a polynomial regression analysis of body fat percentage to BMI, and established a method to determine normal weight obesity by identifying high and low body fat percentages relative to BMI. With this method it was demonstrated that the physical strength of people determined to have normal weight obesity was lower than those with the standard body type.

Normal weight obesity may be considered evidence that the degree of body fat accumulation due to differences in morphological quality clearly affects physical strength. However, there have been very few reported analyses of physical strength and athletic ability due to differences in morphological quality, including normal weight obesity. That is because the significance and methodology for judging high and low body fat mass with respect to body type have not been straightforward. When discussing physique and body type from the perspective of health science, the general trend in research has been to focus on fatness and slimness. It is well known that the mortality rate is higher with both obesity and leanness compared with standard weight. Thus, making judgments from BMI has become common practice today. This is exactly the type of research significance sought in health science. Ever since the correlation between BMI and body fat percentage was shown by Keys [7] and Garrow and Webster [8], BMI derived from the simple measures of height and weight has been taken to be essential in determining fatness and slimness. Today, it has become possible to measure body fat with impedance, and in the relationship between BMI and body fat percentage, the relationship between fatness derived from the a simple number, BMI, and a number precisely showing the body's internal fat tissue have been re-verified. In this re-verification process, Fujii et al. [9] and Tanaka et al. [10] derived a method to judge the degree of accumulation of body fat with respect to the physique index of BMI from polynomial regression analyses of body fat percentage versus BMI. Thus, a method that can verify physical strength and athletic ability from differences in morphological quality can be said to have been established.

In this study, with a focus on junior high school girls, we judged the differences in morphological quality as established above from polynomial regression evaluations of body fat percentage versus BMI, and tested the physical strength and athletic ability of people who tended to be obese and lean as judged from BMI. Additionally, by analyzing bone mineral density, we also investigated how differences in morphological quality affect bone mineral density and how bone mineral density is related to physical strength and athletic ability.

2. Methods

2.1. Subjects

The subjects were 750 junior high school girls in the city of Osaka (13.03±0.79 age), among which 330 who had no missing measurement data were enrolled. The content of the study and measurements were explained to the subjects in advance, and informed consent was obtained. None of the subjects had any acute or chronic diseases. The measurements were taken from April to June, 2022.

2.2. Physique and Body Composition

For body composition, body weight, total body water (TBW), soft lean mass (SLM), body fat percentage, and fat mass were measured using a body composition analyzer (InBody 3.2, Biospace) that employs segmental bioelectrical impedance analysis and multi-frequency bioelectrical impedance analysis. SLM was calculated with the addition of protein amount, and fat mass was calculated by subtracting SLM and mineral amount from body weight. Height was measured using a digital stadiometer. BMI was calculated by dividing weight (kg) by the square of height (m).

2.3. Measurement of Bone Density (SOS Value)

The speed of sound (SOS) was measured for bone mineral density. SOS values have been specified by the Japan Osteoporosis Society. The standard is 1538±33 m/sec, while less than 1501 m/sec is considered to be bone loss, and less than 1479 m/sec to be osteoporosis.

2.4. Measurement of Physical Strength and Athletic Ability

The measures used for physical strength were grip strength, sit-ups, long-seated forward bend, side steps, and 20 m shuttle run. The items for athletic ability were the 50 m run, standing long jump, and handball throw.

2.5. Analytical Procedures

1) Body type was judged from BMI, and bone mineral density, physical strength, and athletic ability were analyzed according to the effect of level of fatness.
2) A polynomial regression analysis of body fat percentage with respect to BMI was performed, first to third order regression polynomials were calculated, and regression polynomials of an appropriate order were determined.
3) An evaluation chart was constructed from the determined regression polynomials, and physical strength, athletic ability, and bone mineral density of people judged to have different morphological qualities were tested.

3. Results

3.1. Investigation of Physical Strength, Athletic Ability, and Bone Mineral Density by Level of Fatness Derived from Determination of BMI

There are currently no standards for judging obesity based BMI in Japanese children. For the level of fatness derived from BMI judgments, we classified mean value +1.5 SD or higher (BMI of ≥ 21.3) as obese type, mean value -1.5 SD or less (BMI of < 7.3) as slim type, and mean value ±1.5 SD (BMI of 17.4 to < 21.4) as standard type, to ensure a sufficient number of people in each group. An analysis of variance was performed to investigate physical strength between these three groups. Table 1 shows the mean values and standard deviations for physique, body composition, physical strength, athletic ability, and bone mineral density in the slim, standard, and obese types.

Table 1. *Statistics of physique, body compositions and physical fitness classified by fatty-slim degree judgment of BMI in girls.*

	Fatty type (n=66)		Normal type (n=206)		Slim type (n=69)		Tukey-kramer (p<0.01)
	mean	SD	mean	SD	mean	SD	
Height	156.60	5.69	154.79	5.80	155.46	6.10	ns
Weight	57.07	6.12	45.78	4.50	40.00	3.93	Slim<Normal<Fatty
BMI	23.24	1.90	19.07	1.01	16.52	0.76	Slim<Normal<Fatty
Body fat percentage	31.55	5.37	22.39	4.10	17.96	3.92	Slim<Normal<Fatty
Soft lean mass	36.59	3.76	33.36	3.38	30.82	3.12	Slim<Normal<Fatty
Bone density (SOS)	1552.21	35.60	1546.51	35.49	1536.99	32.78	Slim<Normal<Fatty
Grip strength	24.22	4.61	22.47	4.51	21.16	4.12	Slim<Normal<Fatty
Sit-up	21.21	5.48	23.00	4.94	21.96	5.02	Fatty<Slim<Normal
Sit & reach	42.59	9.77	44.27	9.30	42.84	9.37	Fatty<Slim<Normal
Side step	45.24	7.34	48.00	6.55	46.48	6.95	Fatty<Slim<Normal
Shuttle run	44.89	15.88	55.01	17.70	53.06	17.13	Fatty<Slim<Normal
50 m running	9.38	0.88	8.96	0.75	9.15	0.78	Fatty<Slim<Normal
Standing long jump	161.33	20.38	169.57	19.91	165.43	20.00	Fatty<Slim<Normal

	Fatty type (n=66)		Normal type (n=206)		Slim type (n=69)		Tukey-kramer (p<0.01)
	mean	SD	mean	SD	mean	SD	
Handball throw	11.98	3.68	12.42	4.07	10.39	3.47	Slim<Fatty<Normal

The results of the analysis of variance are shown in Table 1. When viewed generally from the notable items, the analysis of variance shows significant differences in grip strength and bone mineral density, which are higher in the order of obese, standard, and slim. A significant difference was also seen in the analysis of variance for the handball throw, which was higher in the order of standard, obese, and slim. However, in the other physical strength and athletic ability items, significant differences were seen in analyses of variance of sit-ups, long-seated forward bend, side-steps, 20 m shuttle run, 50 m run, and standing long jump. Moreover, they were high in the order of standard, slim, and obese. Thus, the findings that grip strength and bone mineral density were the highest with obesity, and the handball throw was second after the standard type could be said to be features of obesity. In other items, the features could be said to be that standard type was the highest and the slim type was next.

3.2. Estimating Body Fat Percentage Versus BMI with Application of a Least Squares Approximation Polynomial

In estimates of body fat percentage versus BMI in junior high school girls with a least squares approximation polynomial, regression polynomials could be derived as follows.

First order regression polynomial: $y = 2.028x - 15.995$ (SE=3.67) {Where y is body fat mass and x is BMI} The coefficient of determination was $R^2 = 0.6493$, $r = 0.8058$ ($P<0.01$), and the residual sum of squares was 4560.64.

Second order regression polynomial: $y = 0.0179x^2 + 1.259x - 7.9181$ {Where y is body fat mass, x is BMI} The coefficient of determination was $R^2 = 0.6626$, and the residual sum of squares was 4557.95.

Third order regression polynomial: $y = -0.0036x^3 + 0.2496x^2 - 3.6565x + 26.13$ {Where y is body fat mass, x is BMI} The coefficient of determination was $R^2=0.6636$, and the residual sum of squares was 4541.18.

In the first to third order least squares approximation polynomials of body fat percentage versus BMI, the coefficient of determination showed a slightly increasing trend in the first to second order least squares approximation polynomial, but in the third order least squares regression polynomial the coefficient of determination was about the same as with the second order. However, the residual sum of squares was the smallest with the third order least squares approximation polynomial. Therefore, in constructing a standard regression evaluation of body fat percentage versus BMI, the application of a third order polynomial was judged to be valid (Figure 1).

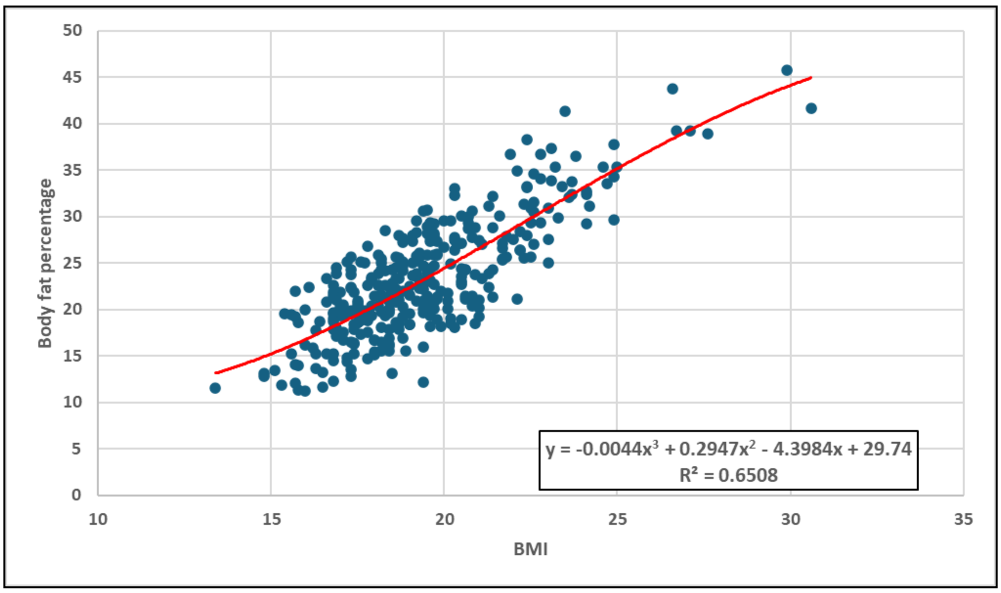

Figure 1. *Cubic polynomial regression analysis of body fat percentage for BMI in girls.*

3.3. Construction of Standard Regression Evaluation of Body Fat Percentage Versus BMI

Figure 2 is a regression evaluation chart from a third order polynomial of body fat percentage versus BMI. It is a regression evaluation diagram drawn taking the standard error from the regression plane to be 3.67. In this way, standard regression evaluation charts that determine the degree of body fat versus BMI were constructed, and the degree of body fat percentage was classified in the obese type, standard type, and slim type derived from judgments of BMI based on these evaluation charts. As a result, the determined distribution of degree was derived for each fatness level with the respective elements, as in Figure 3. A χ^2 test was then performed for the determined distribution of body fat percentage versus BMI for each fatness level in Figure 2, and the results showed no significant difference in the distribution of fat percentage degree in the obese, standard, and slim types. Therefore, it was shown to be possible to investigate physical strength, athletic ability, and bone mineral density between the three groups in which the degree of fat was determined from differences in morphological quality from a standard regression evaluation chart of body fat percentage versus BMI.

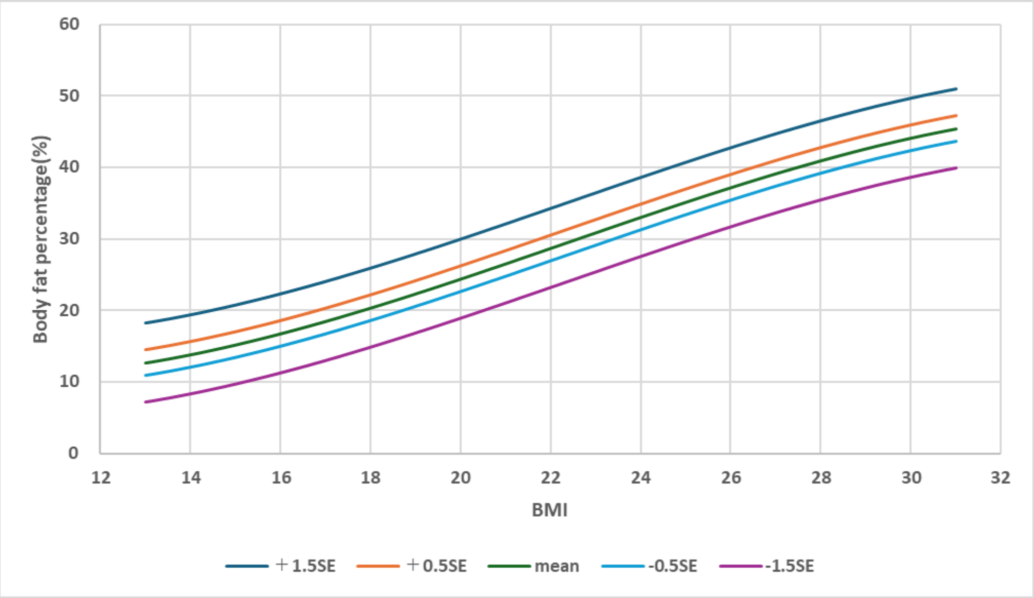

Figure 2. *Cubic polynomial regression evaluation of body fat percentage for BMI in girls.*

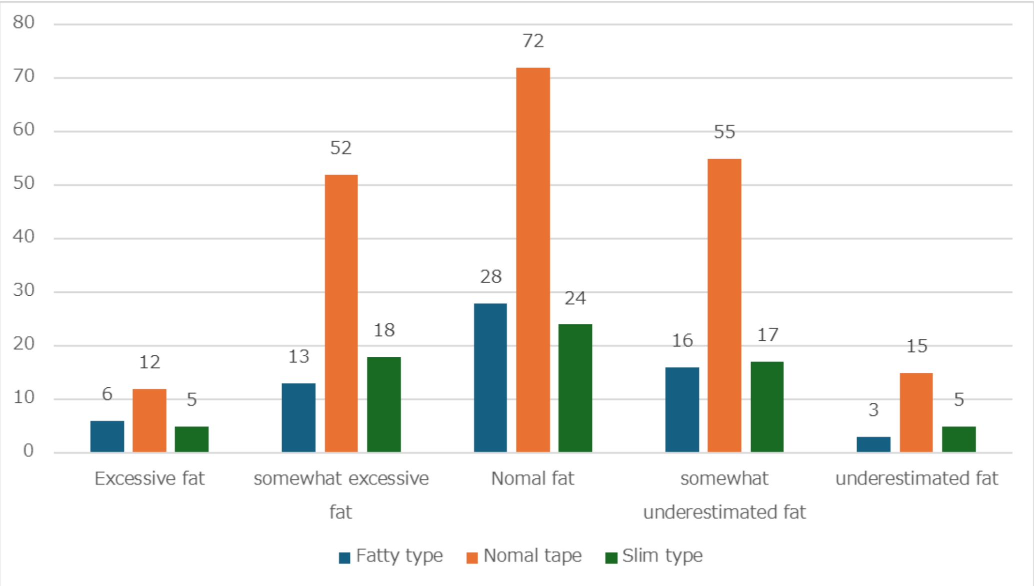

Figure 3. *Determined distribution of body fat percentage versus BMI for each fatness level in Figure 2.*

3.4. Verification of Differences in Morphological Quality Derived from Standard Regression Evaluation Charts

In determining the degree of body fat versus BMI, the evaluation band of ±0.5 SD from the 5-step regression evaluation was taken to be normal amount of fat, that exceeding +0.5 SD to be more fat, and that under −0.5 SD to be less fat. Thus, it should be noted that a three-step evaluation was applied in which somewhat more fat was taken to be more fat, and somewhat less fat was taken to be less fat.

Table 2 gives the statistical values for physical strength, athletic ability, and bone mineral density in nine categories derived from the three-step evaluation of more fat, normal amount of fat, and less fat, which was determined by the degree of body fat versus BMI in each of the three groups of obese, standard, and slim. A single-factor ANOVA was performed for these statistics between physical strength, athletic ability, and bone mineral density in the three groups of more fat, normal amount of fat, and less fat from the degree of fat accumulation in the nine categories. The results showed a significant difference (P<0.05) in all of the categories. Furthermore, using Tukey's multiple comparison test, the differences in physical strength, athletic ability, and bone mineral density were investigated from the degree of fat accumulation (more fat, normal amount of fat, less fat) between the three groups. The results showed that bone mineral density and grip strength were higher in the obese type than in the standard and slim types, from which the less fat group performed the best of the three groups divided by the degree of fat accumulation. In the other items (sit-ups, long-seated forward bends, side steps, 20 m shuttle run, 50 m run, standing long jump, and handball throw), the standard type performed better than the obese and slim types, from which it was shown that even in the standard type, the less fat group performed the best among the three groups divided by the degree of fat accumulation.

Table 2. *Statistics of physique, body compositions and physical fitness classified by fatty-slim degree judgment of body fat percentage versus BMI in girls.*

		Fatty Excessive fat n= 19	Fatty Normal fat n= 28	Fatty underestimated fat n= 19	Normal Excessive fat n= 64	Normal Normal fat n= 72	Normal underestimated fat n= 70	Slim Excessive fat n= 23	Slim Normal fat n= 24	Slim ·underestimated fat n= 22	Tukey-kramer (p<0.01)
Bone density (SOS)	mean	1539.8	1550.7	1566.8	1534.5	1545.7	1558.4	1525.2	1538.1	1548.1	G < A, D, H < B, E, I < F < C D < A E < B
	SD	24.19	36.51	40.00	30.71	26.59	43.32	30.37	28.82	36.37	
Grip strength (kg)	mean	21.74	23.71	27.45	21.20	22.10	24.01	18.91	23.19	21.30	G < A, D, E, I < B, F, H < C D, I < E H < F
	SD	3.62	4.07	4.55	4.01	4.62	4.45	3.59	3.62	4.09	
Sit-up (times)	mean	17.21	21.57	24.68	21.77	21.93	25.23	18.83	22.17	25.00	A < G <B, D, E, H < C, F, I
	SD	4.87	4.89	4.36	4.84	4.35	4.90	3.58	4.75	4.79	
Sit & reach (cm)	mean	37.53	42.93	47.16	45.28	42.65	45.00	41.30	44.83	42.27	A < B, E, G, I < D, F, H < C G < B, E
	SD	7.83	10.41	8.47	10.02	8.73	9.10	10.21	8.01	9.87	
Side step (times)	mean	44.95	44.29	46.95	45.77	47.06	51.01	41.83	48.38	49.27	G < A, B, D < C, E < H, I < F B < D
	SD	3.81	6.43	10.64	7.43	6.62	4.15	7.67	5.09	5.50	
Shuttle run (times)	mean	37.95	42.14	55.89	46.00	54.00	64.30	42.04	54.17	63.36	A < G, B < D < E, H, C < I, F
	SD	10.85	12.28	19.40	13.89	17.18	16.95	12.94	15.30	16.51	
50 m running (second)	mean	9.76	9.50	8.81	9.38	9.02	8.52	9.69	9.14	8.60	A, G < D < H < E < H < C < F, I
	SD	0.79	0.72	0.91	0.83	0.61	0.54	0.70	0.72	0.52	

		Fatty Excessive fat	Fatty Normal fat	Fatty underestimated fat	Normal Excessive fat	Normal Normal fat	Normal underestimated fat	Slim Excessive fat	Slim Normal fat	Slim ·underestimated fat	Tukey-kramer (p<0.01)
		n= 19	n= 28	n= 19	n= 64	n= 72	n= 70	n= 23	n= 24	n= 22	
Standing long jump (cm)	mean	150.16	156.79	179.21	159.23	166.68	182.00	151.35	166.79	178.68	A, G < B <D < E, H < C, I < F
	SD	17.30	14.44	19.66	19.50	16.20	17.21	15.26	21.84	11.21	
Handball throw (m)	mean	9.68	12.00	14.26	10.23	12.04	14.81	8.61	10.46	12.18	G < A < D, H < B, E, I < C < F
	SD	2.52	3.22	3.98	2.99	3.58	4.18	2.71	2.96	3.86	

4. Discussion

In the comparison of physical strength, athletic ability, and bone mineral density for each level of fatness derived from determination of BMI in this study, grip strength and bone mineral density were seen to be higher in the obese type than in the standard and slim types. However, in other items (sit-ups, long-seated forward bends, side steps, 20 m shuttle run, 50 m run, standing long jump, handball throw) the standard type showed better results than the obese and slim types. Kim et al. [11] investigated the characteristics of physical strength and athletic ability in obese students, and reported a tendency for obese students to be poorer in general endurance and muscle endurance. Taking an overall view of physique and body composition (Table 1) for each level of fatness determined by BMI in this study, the obese type with higher BMI also has greater muscle mass, but body fat percentage is significantly higher. From these things it would seem clear that the obese type would have greater grip strength than the standard and slim types. However, bone mineral density is also higher in the obese type, and it may be that the higher bone mineral density in the obese type is due to the load from the physical mass with the conspicuous growth in the junior high school years. Ogino et al. (1996) stated that the load of the absolute value of body weight increases bone density and also affects muscle strength, such as grip strength, which is thought to support the findings of this study.

Watanabe et al. [12] reported a significant difference in $\dot{V}O_2$ max (ml/kg/min) in obese and non-obese groups, and Kitagawa et al. [13] reported that $\dot{V}O_2$ max per body weight was significantly lower in obese people than in non-obese people. From reports such as this it seems clear that the excessive accumulation of fat in obese people is a negative factor on general endurance. In obese people's displays of physical strength, one factor in their poorer physical fitness despite a larger amount of muscle is conjectured to be the heavier load on the body from the accumulation of excessive fat [14]. In this study, subjects performed better in the long-seated forward bend, which is an element of flexibility, in the order standard, slim, and obese. This was similar to other measures of physical strength and athletic ability, which was a little different from the reports of Fujii et al. [9] and Tanaka et al. [10]. That is, in the seated forward bend in girls, the slim type showed significantly lower values than the standard type and obese type, and they stated that it is unlikely that higher BMI and body fat is a negative factor on elements of flexibility. However, in this study, the amount of fat in the obese type was judged to be a negative factor even in flexibility elements, similar to other measures of physical strength and athletic ability.

In the fatness classifications from BMI in this study, grip strength, an element of muscle strength among the physical strength and athletic ability items, was high in the obese type versus the ambiguous findings of the past. Bone mineral density was also higher in the obese type. In all other measures of physical strength and athletic ability (sit-ups, long-seated forward bend, side steps, 20 m shuttle run, 50 m run, standing long jump, handball throw), the standard type was found to perform the best and the obese type the worst. The findings on obesity from this study may be seen as clear findings in terms of synthesizing past research.

Table 2 gives the statistical values for physical strength, athletic ability, and bone mineral density when physique traits are judged in the three morphological categories of more fat, normal amount of fat, and less fat from the degree of fat versus BMI from the standard regression evaluation chart for each group by level of fatness classified by BMI, and for the body fat percentage of BMI. This is the first analysis in Japanese girls that verifies how the qualitative elements of fat accumulation in nine basic categories affect physical strength, athletic ability, and bone mineral density. Then, as in past studies [13, 17-20], it is easily understood from simple comparisons of the obese group and standard group that muscle endurance and general endurance are inferior. Moreover, even among obese people, if the qualitative fat accumulation differs, that factor is thought to affect physical strength and athletic ability. In this study, that is judged from a polynomial regression evaluation of fat qualitative accumulation degree versus BMI, and the physical strength, athletic ability, and bone mineral density associated with the three categories (more fat, normal amount of, less fat) determined among the obese, standard, and slim types were compared.

As a result, the physical strength element of grip strength and bone mineral density were superior in the obese type, but even among the obese type those with less fat were superior. Similarly, the less fat category in the standard and slim types was also superior in the other measures of physical strength and athletic ability (sit-ups, long-seated forward bends, side steps, 20 m shuttle run, 50 m run, standing long jump, handball throw). Thus, it was shown that those abilities differ depending on the degree of fat accumulation. Therefore, when considering muscle strength elements, types with higher absolute value of muscle mass are simply better, and it was apparent that in junior high school girls grip strength was superior in the obese type. In measures of physical strength and athletic ability other than grip strength, the standard type was superior and it became apparent that among them individuals with lower fat percentage were superior. Chiba et al. [15] stated that in university students, high BMI and body fat percentage act negatively in the physical strength elements of muscle endurance, agility, general endurance, and explosive power, high BMI and body fat percentage act positively in displays of muscle strength, and heavier body weights function effectively in displaying physical strength. However, even if it is explained that body fat mass has positive and negative actions on physical strength, it ultimately comes down to the relational composition between larger fat mass and lower physical strength and athletic ability.

Ishihara and Komiya [16] reported on the relationship between physical strength and body composition in adolescent girls. They derived a body composition index meant to correct for differences in height, and stated that that index has a synergistic effect on side-step and standing long jump records, and that the body composition index is effective in evaluating physical strength and athletic ability. Ishihara and Muraki [17] then applied this body composition index and suggested that in displays of physical fitness and athletic ability in high school girls, those classified in categories with a high fat-free mass index among this index performed better. These findings clearly support that there are differences in those abilities due to the degree of fat accumulation, and that was true even in the junior high school girls in this study. Furthermore, Yumigeta et al. [18] said that despite the effect of improvements in low body weight or obesity on higher physical strength in young Japanese women, the maintenance or progression of low body weight and obesity does not affect the changes in physical strength. Considering all of these findings together, it seems that the accumulation of body fat is obviously related to the daily living behaviors of junior high school girls, and the amount of daily activity influences body composition [19, 20]. Therefore, the negative action of fat on physical strength and athletic ability is thought to be that fat accumulates and physical strength and athletic ability deteriorate as a result of a lack of physical activity; fat is not directly involved in physical strength and athletic ability and the two elements have a parallel relationship and closely affect each other as they transition up or down. To comprehensively clarify the relationship between physical strength/athletic ability and fat, it will be necessary to investigate the daily living behavior patterns of junior high school girls in the future, but the significance of deriving a relational composition with physical strength and athletic ability in the differences in morphological quality from the level of fatness and the degree of fat accumulation in junior high school girls is thought to be considerable.

5. Conclusion

BMI is convenient for its easy use in determining the level of fatness, but the degree of fat accumulation differs with respect to body type. As a result, the physical strength and athletic ability in obesity and slimness are sometimes misjudged. In this study, we constructed a standardized evaluation chart from a polynomial regression analysis of body fat percentage versus BMI to establish a method to objectively determine the degree of fat accumulation with respect to body type in junior high school girls. The degree of fat accumulation in the obese, standard, and slim types determined from BMI was judged and applied to the constructed evaluation chart, and categorized as more fat, normal amount of fat, and less fat. The physical strength, athletic ability, and bone mineral density in these nine categories were then examined. The results showed that, first, in physical strength classified in the three types of obese, standard, and slim by fatness judgments based on conventional BMI, grip strength as well as bone mineral density were higher in the order of obese, standard, and slim. In other measures of physical strength and athletic ability, however, sit-ups, long-seated forward bends, side steps, 20 m shuttle run, 50 m run, and standing long jump were shown to higher in the order of standard, slim, and obese. Thus, it was demonstrated that while grip strength was the highest in the obese type, the other measures were highest in the standard type, followed by the slim type. From these things it can be ensured that, first, the judgments of fatness based on BMI in junior high school girls in this study are based on valid data. Then, as a result of verifying the physical strength, athletic ability, and bone mineral density in the nine categories, it was clarified that grip strength and bone density were the highest in those with less fat among the obese type. In other measures of physical strength and athletic ability (sit-ups, long-seated forward bends, side steps, 20 m shuttle run, 50 m run, standing long jump, and handball throw), the standard type was superior, among which it was demonstrated that those with less fat performed the best. A relational composition between physical strength, athletic ability, and bone mineral density was derived from morphological quality differences for the first time in Japanese junior high school girls from this, which it thought to be the major significance of this study.

Abbreviations

BMI Body Mass Index
SD Standard Deviation

Author Contributions

Yuki Takeyama: Conceptualization, Formal Analysis, Funding acquisition, Project administration, Resources, Software, Validation, Visualization, Writing – original draft

Katsunori Fujii: Data curation, Investigation, Methodology, Supervision, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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