

Examination of Physical Fitness Evaluations of Severe Obesity During Junior High School

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ABSTRACT

Hypotheses on physical fitness and motor ability of obesity have not been clearly proven. To be sure, several papers have been reported, but none of them have gone beyond speculation. In other words, statistically warranted amounts of data on obese people have not been obtained. This study examined physique, physical fitness and motor ability measurements obtained in a large-scale investigation over 7 years (from the 2013 to 2019 academic years) based on the physical fitness improvement action plan of City O. The measurement results of children in the second year of junior high school were used. In this study, the wavelet interpolation model was applied specifically to the average value and standard deviation of height, physical strength and motor ability (grip strength, sidesteps, sit-and-reach, sit up, endurance running, 50 m dash, standing long jump, 20 m shuttle run, handball throw) for second year junior high school students. An annual span evaluation chart was then constructed. The height, physical strength, and motor ability of second year junior high school boys and girls judged by the annual span evaluation chart of BMI devised by Fujii [16] were applied to this evaluation chart. As a result, the evaluation of physical fitness and motor ability of the second-year junior high school students derived in this study was not a conjecture. Rather, a clear judgment of "Somewhat poor" or "Poor" in the items except for grip strength, sit-and-reach, and handball throwing was derived, and we suggest that a physical fitness and motor ability evaluation for second year junior high school boys and girls could be established here.

Keywords: Junior High School, Obesity, Physical Fitness, Motor Ability, Wavelet Interpolation Model

INTRODUCTION

Obesity is defined by the World Health Organization as excessive accumulation of fat on the body. The indicator that is most widely used for a simple determination of obesity is probably body mass index (BMI). Fujii et al. [1] and Fujii [2] have already stated that BMI is a somewhat mysterious index. However, it has an exceptional meaning in judging obesity, and evaluations using it have been confirmed in all fields globally. In particular, the figure of BMI = 22 has been

established as a standard weight. The grounds for BMI = 22 derive from a finding in a study by Tokunaga et al. [3] that surveyed the results of a health checkup of 5,000 Japanese men and women aged 30–59 years old, and BMI = 22 was found to have the fewest abnormalities. Similarly, in an investigation of the relationship between BMI and all-cause mortality in an epidemiological study, BMI of 23–24.9 was reported to be associated with the lowest mortality rate [4]. Thus, maintaining a BMI of 22–25 is important for health.

Meanwhile, it is highly likely that obesity has effects on physical fitness and physical ability associated with health. Kitagawa et al. [5], Hayashi [6], Kim et al. [7], Kim et al. [8], and Kitagawa [9] compared the physical fitness of obese and non-obese people, and reported that obese people had poorer performance in moving their own bodies, such as in the 50 m dash, endurance running, and pull-ups. The reason was thought to be that since obese people carry extra weight in fat on the body, they are under a greater burden when moving their bodies than non-obese people. Thus, most obese people have a lower level of physical fitness per their body weight than non-obese people.

In Japan, the percentage of obese people, according to the Ministry of Health, Labor and Welfare [10], was 30.7% among males and 21.9% among females age ≥ 20 in 2018. These figures are thought to be low considering the percentage of obese people in Western countries, which was said by the National Center for Health Statistics (NCHS) [11] in the US to be 39.6% in 2016. Since obesity in Japan is judged to be BMI of ≥ 25 , the percentage would decrease dramatically if the BMI of ≥ 30 in Western countries was applied. In school-age children, according to the School Health Statistics Research in Japan [12], the number of obese 17-year-olds showed a decreasing trend from 12.90% in 2006 to 10.48% in 2018. Thus, a decrease in obesity could be said to be seen in recent years.

However, although the relative frequency of obesity has decreased, the relationship with disease has not improved. Rather, together with advances in medicine, the risk of lifestyle-related diseases from obesity has been demonstrated. In “Economics of Obesity” by Furugori [13] indicated that obese people have a high prevalence of disease as well as higher medical expenses and absentee rates and decreased abilities to act and think, and may cause decreases in company productivity. This finding indicates that significant problems occur in workplaces with obese employees. In other words, these problems permeate all activities up to the daily living activities of obese people. If the physical fitness of obese people could be determined, it would become possible to estimate the living activities of obese people.

It has been reported by Sawada [14], Hayashi [6], Kim et al. [8], and Chiba [15] that muscle strength in obese people tends to be higher than in non-obese people. Chiba [15] in particular reported that grip strength was positively correlated with body fat and weight, and that people with much body fat and those who are heavy tend to have higher muscle strength. The reason is said to be that in obese people, body fat acts as a burden on muscle in daily life. Reports are also seen that flexibility is not susceptible to body type or physique [15], [16]. In this way, the physical fitness of obese people has been shown to differ from that of non-obese people, and there are reports that obese people have poorer physical fitness factors in terms physical quickness and the muscle strength, muscle endurance and general endurance needed when moving the body for long times.

However, these things have not been proven. The amount of data from which these findings were derived was insufficient. Large amounts of data are not needed for clinical research on obesity, but epidemiological surveys need to be done with around 300 obese people to derive statistical significance. No studies on the physical abilities of obese people have been done with more than 300 obese people as subjects. For example, Nakao et al. [17] analyzed the characteristic physical abilities of obese children, but the subjects were 141 boys and girls from the first to sixth grades of elementary school, among whom only 14 were obese children. Thus, the amount of data on obese children was far too little. Consequently, details to date on physical ability in obesity during youth, including the elementary school years, are thought to be simple speculation. That is, the statistical significance from the amount of data on obese children has not been ensured.

In this study, we used the measurement results for fifth grade elementary school students and second year junior high school students from a detailed longitudinal survey of physique, physical fitness, and motor ability obtained in a large-scale survey over seven years based on the City O physical fitness improvement action plan. Next, we constructed an annual span evaluation chart of physical fitness and motor ability from the measurement results of the fifth-grade elementary school students and second year junior high school students. In particular, in this study we identified second year junior high school boys and girls with severe obesity judged from BMI. We applied the physical fitness and motor ability results of the severely obese children to the annual span evaluation chart and evaluated their physical fitness and motor ability over time. We then derived a confirmation of the findings of each ability of the severely obese children derived from the physical fitness and motor ability evaluation. The data obtained in this study were data measured in elementary and junior high schools in all of City O, ensuring huge amounts of data. Therefore, the findings provided here from the physical fitness and motor ability evaluation of obese children, unlike previous speculative findings, are confirmed findings.

METHODS

Subjects

The subject data were measurements of physique, physical strength, and motor ability from the 2013 to 2019 school years for boys and girls in the second year of junior high school in City O in the Kansai region. In addition, data for boys and girls in the second year of junior high school from the results of physical strength and motor ability surveys published by the Ministry of Education, Culture, Sports, Science and Technology for that same period were used. The measured items included physique items (height, weight, BMI), and physical strength items (grip strength, sidesteps, sit-and-reach, sit-ups, endurance running, 50 m dash, standing long jump, 20 m shuttle run, and handball throw).

Construction of annual span evaluation chart

The mean value and standard deviation of physical fitness and motor ability test results for second year junior high school boys and girls were calculated for the 2013 to 2019 school years, and the wavelet interpolation model was applied to the mean value for each measured item. The wavelet interpolation model was also applied to the mean values ± 0.5 SD and mean values ± 1.5 SD. Figure 1 shows the longitudinal trends in height in boys to which the wavelet interpolation model was applied, and is also an evaluation chart of the annual span. As is clear from looking at the annual trends, mean height tended to be around 164 cm. Tall boys tended

to be around 172 cm, and short boys to be under 156 cm. These annual span evaluation charts were constructed for the physical fitness and motor ability items.

Identification of children with severe obesity

In adults, severe obesity may be set as a BMI of 30 or more, but the criterion for adults cannot be applied to severe obesity in second year junior high school students. Fujii [16] constructed an aging span evaluation chart for BMI with findings that verified tracking to obesity in adults, and severe obesity in second year junior high school students was identified by applying that evaluation chart. Figure 2 is an evaluation chart that judge's obesity, but the mean BMI of second year junior high school students is about 20.5. When attempting to judge obesity, a judgment can be made for people in the range of more than +1.5 SD, but if a judgment of severe obesity is to be made, establishing a BMI of 25 or higher is thought to be appropriate. In this study, we set BMI of ≥ 25 as the criterion for severe obesity in second year junior high school students.

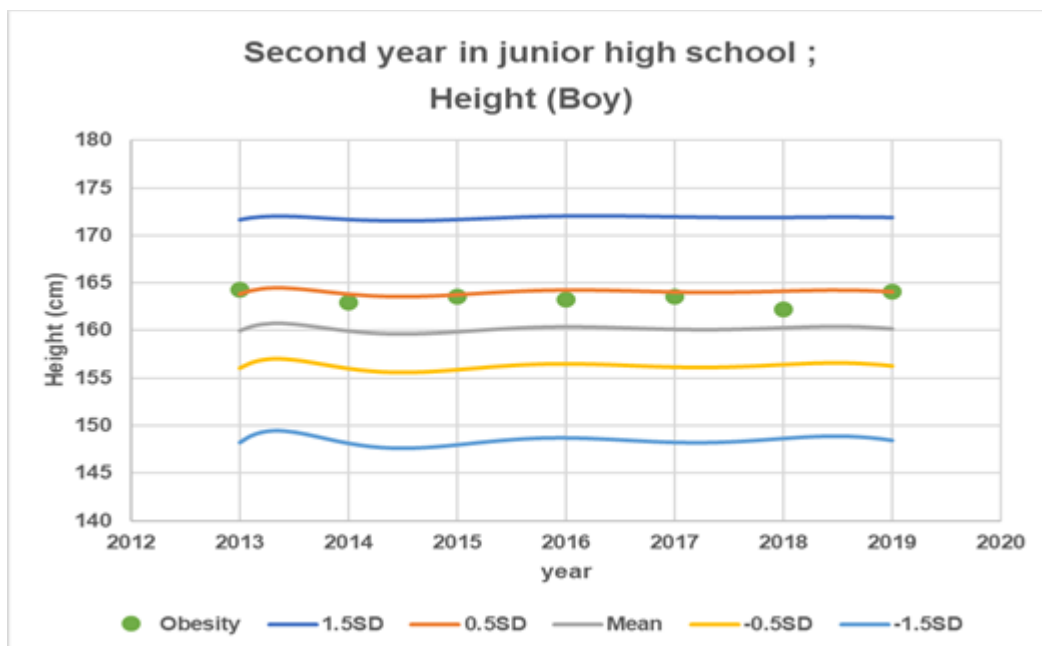


Figure 1. Annual span evaluation chart of height in second year junior high school boys

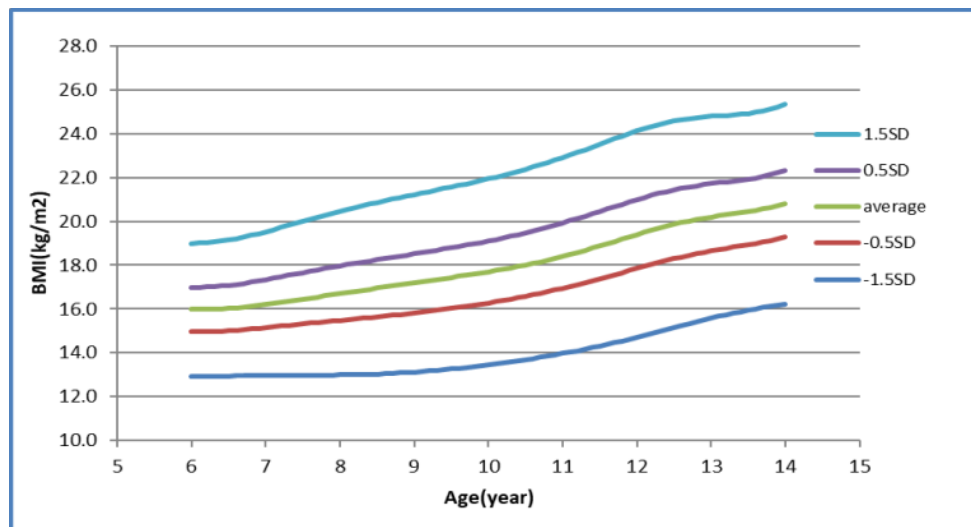


Figure 2. Obesity judgment chart based on changes in BMI with age

Wavelet interpolation model

The wavelet interpolation model is a method in which interpolation between data points is done with a wavelet function (the basis function is the mother wavelet of Meyer) to approximately describe the true growth curve from given growth data, and a growth distance curve is drawn. That growth distance curve is differentiated and a growth velocity curve is derived to examine the growth distance values of things such as pubertal peaks or the age at menarche. The characteristics of the wavelet interpolation model are that it sensitively reads local events and has a very high approximation accuracy. A detailed theoretical background and the evidence for its validity have been described previously by Fujii [18, 19, 20], and so the data analysis algorithm with the wavelet interpolation method will be omitted here.

RESULTS

Longitudinal statistics for height and weight in severe obesity

The results of a one-way analysis of variance conducted for the items of height and physical fitness/motor ability in severely obese people from 2013 to 2019 revealed no significant difference in any of the items. In other words, in these recent seven years no changes were seen in the physical fitness of severely obese people. Therefore, since there were no changes in the physical fitness of second year junior high school students over these seven years, we thought we would construct an annual span evaluation chart for physical fitness and motor ability not in single years but in a seven-year span. By devising an annual span evaluation, we attempted to grasp the physical fitness and motor ability of severely obese second year junior high school students in recent years. A span evaluation chart was constructed for the physical fitness and motor ability items of grip strength, sidesteps, sit-and-reach, sit-ups, endurance running, 50 m dash, standing long jump, 20 m shuttle run, and handball throw, and each physical fitness item for severely obese people was applied to that evaluation chart.

Application of physical fitness items in severely obese children to the annual span evaluation chart

The physique item of height hovered around 164 cm in boys and 156 cm in girls, showing a tendency to be in the “average” evaluation range of -0.5 SD to $+0.5$ SD. Boys in particular tended to be at the upper limit of the average range.

In the physical fitness and motor ability items, grip strength was around 33 kg in boys and 26.5 kg in girls. Grip strength tended to be in a “Somewhat high” evaluation range of $+0.5$ SD to $+1.5$ SD in both boys and girls. For sit-ups, boys performed about 22 sit-ups and girls about 20, which was judged to be “Somewhat low” in both boys and girls. In the sit-and-reach, boys tended to reach around 40 cm and girls around 42 cm, trending in the standard range. In sidesteps, boys stepped about 45 times and girls about 42 times, judged to be “Somewhat low.” In the 20 m shuttle run, boys ran nearly 50 times and girls about 34 times, trending near -1.5 SD in both boys and girls, which was judged to be “Low.” In the 50 m dash, boys ran the distance in about 9 sec and girls about 10 sec, which was the lower limit of “Somewhat low” for both boys and girls. In the standing long jump, boys jumped about 170 cm and girls about 140 cm, trending in the “Somewhat low” evaluation range. In the handball throw, both boys and girls tended to be in the “Average” evaluation range of -0.5 SD to $+0.5$ SD. Finally, in endurance running both boys and girls tended to be in the “Low” evaluation range of -1.5 SD or less.

Here, we would like to draw attention to the fact that the items of the 20 m shuttle run and endurance running are both items that measure endurance ability, and so the number of selected people was smaller.

Table 1. Basic Statistics for height and physical fitness motor ability in severely obese people from 2013 to 2019 (Boys)

Obesity (Boys)		Height	Grip strength	Sit-up	Sit and reach test	Repeated side jump	20m shuttle run	50m run	Standing long jump	Hand-ball throw ing	Endurance running
2013 (N=141)	m ean	164.25	34.43	23.30	40.83	43.76	53.43 ※N=112	8.95	167.33	19.93	520.19 ※N=31
	SD	6.69	8.29	6.80	9.11	8.68	21.18 ※N=112	1.22	24.15	6.45	100.63 ※N=31
2014 (N=152)	m ean	162.95	32.88	22.11	40.89	44.28	46.19 ※N=135	9.08	162.88	19.14	520.56 ※N=25
	SD	7.57	7.91	5.90	9.74	8.73	18.51 ※N=135	1.06	28.66	5.95	81.23 ※N=25
2015 (N=191)	m ean	163.56	34.15	23.23	40.82	44.58	47.84 ※N=179	9.03	166.11	19.41	475.7 ※N=20
	SD	7.44	7.72	5.98	10.51	8.97	18.69 ※N=179	1.24	26.88	5.93	72.95 ※N=20
2016 (N=194)	m ean	163.27	32.95	23.12	40.90	45.23	47.42 ※N=181	9.14	165.76	19.68	549.48 ※N=23
	SD	7.71	7.51	6.08	9.15	8.82	19.70 ※N=181	1.15	28.27	5.51	79.87 ※N=23
2017 (N=178)	m ean	163.56	33.71	22.67	40.98	46.06	48.65 ※N=163	8.97	167.51	19.79	503.27 ※N=30
	SD	7.93	7.37	6.89	10.40	8.26	18.00 ※N=163	1.16	26.94	5.78	79.12 ※N=30
2018 (N=181)	m ean	162.20	32.72	23.41	42.33	46.30	48.58 ※N=177	9.17	166.48	18.30	523 ※N=10
	SD	8.33	8.25	6.20	10.90	7.59	21.73 ※N=177	1.27	31.63	6.01	140.3 ※N=10
2019 (N=195)	m ean	164.10	35.00	24.15	41.84	46.94	51.40 ※N=191	8.86	172.73	19.86	532.25 ※N=4
	SD	7.55	7.96	6.33	10.03	7.54	20.06 ※N=191	1.09	29.62	5.99	98.24 ※N=4

Table 2. Basic Statistics for height and physical fitness motor ability in severely obese people from 2013 to 2019 (Girls)

Obesity (Girls)		Height	Grip strength	Sit-up	Sit and reach test	Repeated side jump	20m shuttle run	50m run	Standing long jump	Hand-ball throwing	Endurance running
2013 (N=115)	mean	155.21	27.62	19.20	41.19	41.13	34.15 ※N=88	9.95	142.50	12.70	367.69 ※N=32
	SD	4.64	4.63	4.73	9.68	5.60	14.05 ※N=88	0.87	21.29	3.98	40 ※N=32
2014 (N=112)	mean	155.85	27.45	19.09	42.82	41.39	34.25 ※N=100	10.02	141.44	12.93	377.13 ※N=16
	SD	5.23	5.12	5.52	9.24	6.89	13.62 ※N=100	1.13	26.55	4.31	48.8 ※N=16
2015 (N=101)	mean	155.25	26.22	19.57	43.81	41.46	31.42 ※N=92	10.01	144.96	12.30	374.92 ※N=12
	SD	5.02	4.30	5.29	8.82	5.99	10.58 ※N=92	0.97	22.15	4.24	48.94 ※N=12
2016 (N=98)	mean	155.80	27.53	20.63	42.87	42.40	34.31 ※N=89	9.85	145.83	12.32	362.08 ※N=12
	SD	5.49	5.51	6.02	9.11	8.39	13.81 ※N=89	1.13	22.80	3.83	46.42 ※N=12
2017 (N=120)	mean	156.95	27.43	20.20	43.68	41.75	31.49 ※N=112	9.88	146.35	12.47	375.63 ※N=19
	SD	4.70	5.19	5.55	9.33	6.95	10.91 ※N=112	1.01	19.33	3.84	72.45 ※N=19
2018 (N=114)	mean	155.35	26.14	19.93	43.30	42.46	33.55 ※N=113	9.78	148.70	12.49	385.33 ※N=9
	SD	5.03	5.04	5.29	9.48	6.54	11.63 ※N=113	0.93	21.77	4.04	55.39 ※N=9
2019 (N=122)	mean	155.82	26.44	20.48	43.39	42.74	33.94 ※N=120	9.88	145.61	12.48	342 ※N=3
	SD	5.28	5.18	5.02	9.53	6.87	11.14 ※N=120	0.96	22.45	4.35	43.85 ※N=3

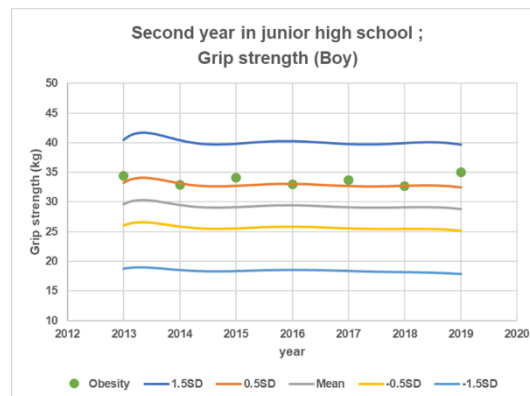


Figure 3. Applied to an annual span evaluation chart for severely obese boys (Grip strength)

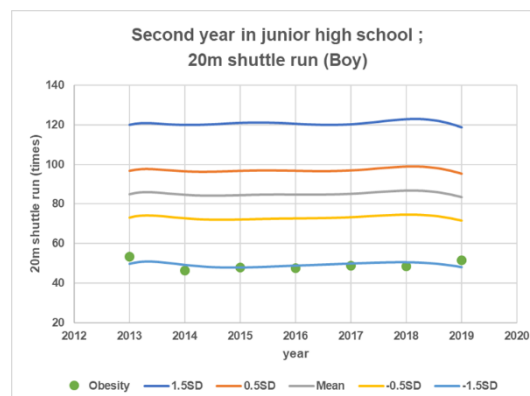


Figure 5. Applied to an annual span evaluation chart for severely obese boys (20m shuttle run)

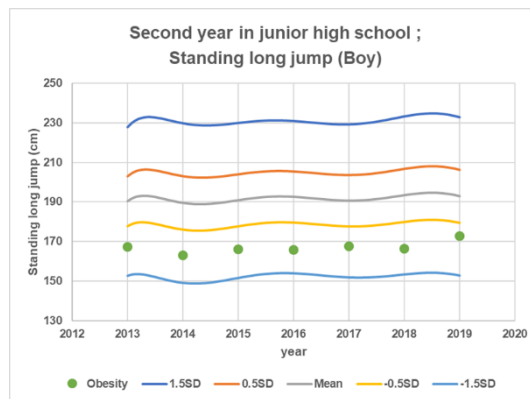


Figure 7. Applied to an annual span evaluation chart for severely obese boys (Standing long jump)

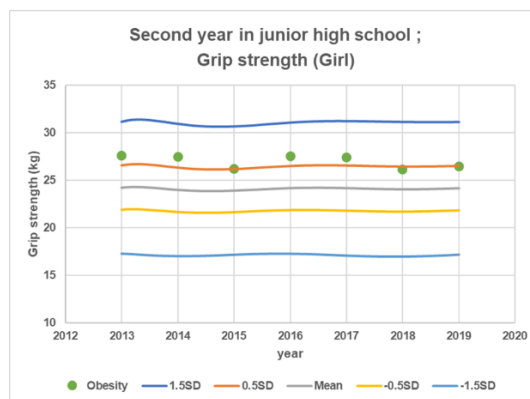


Figure 4. Applied to an annual span evaluation chart for severely obese girls (Grip strength)

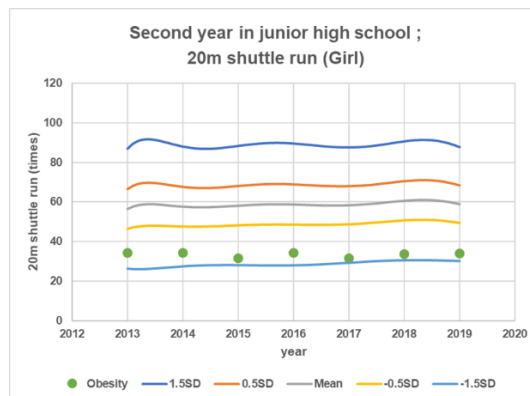


Figure 6. Applied to an annual span evaluation chart for severely obese girls (20m shuttle run)

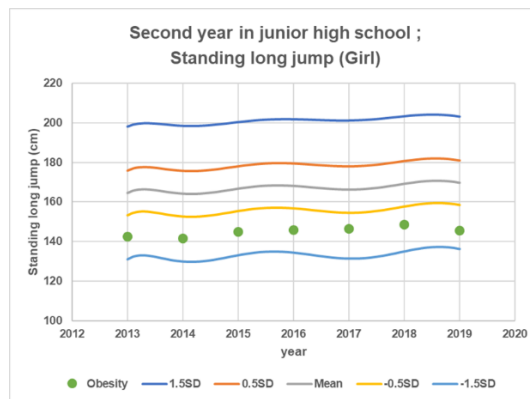


Figure 8. Applied to an annual span evaluation chart for severely obese girls (Standing long jump)

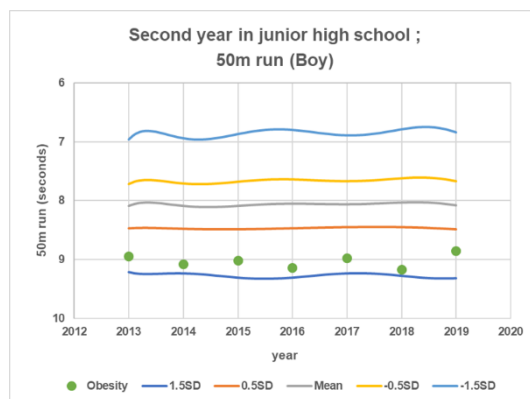


Figure 9. Applied to an annual span evaluation chart for severely obese boys (50m run)

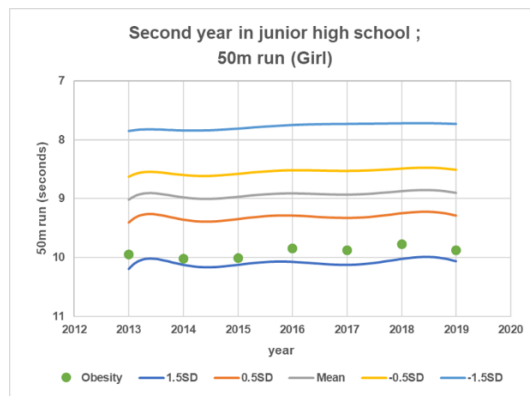


Figure 10. Applied to an annual span evaluation chart for severely obese girls (50m run)

DISCUSSION

It has been thought that, regardless of school age, for the physical fitness of general obese people there is a risk of a burden on the body from fat compared with non-obese people, and their ability to move the body is poorer [5, 6, 7, 8, 9]. In more recent reports, Naito et al. [21, 22] found a tendency for obese people to have poorer performance in the standing long jump, sit-ups, and the ability to move the body quickly in the 50 m dash and over long times in endurance running compared with average weight people. Kim et al. [8] and Shimojo et al. [23] showed that among physical fitness items in obese people, general endurance was the most

affected by fat and was markedly poorer than in non-obese people, indicating a tendency for endurance to be the poorest of all items in previous findings. From the fact that endurance is greatly associated with the amount of physical activity in daily life and exercise habits, Nakatani [24] conjectured that obese people may have a chronic lack of exercise in their daily lives.

Moreover, Reports by Naito et al. [21, 22] showed that items that require muscle strength or power, such as the standing long jump, sit-ups, and 50 m dash, obese students have poorer performance than average weight students even in the time during high school when the development of muscle strength is expected. In other words, increased weight from fat is a burden on the body, and muscle strength and power per body weight cannot be fully displayed, and this is conjectured to have affected the decreased performance of obese people. For grip strength and the handball throw, however, obese people showed ability of about the same level as average weight people. In grip strength in particular, obese people are reported to have superior performance to average weight people. All in all, this shows nothing more than that obese people retain about the same ability as average weight people in muscle strength and throwing ability. The sit-and-reach, which assesses flexibility, was also about the same in obese people and average weight people. Flexibility is due to the qualities of individual joints, and is considered to be less affected by body type and physique [15, 16], from which it is conjectured that there is no negative effect in obese people.

Although previous findings related to physical abilities in obesity are shown above, none go beyond speculation. In other words, clear physical ability assessments cannot be established because of the lack of data on obesity. To verify hypotheses on physical abilities in obesity, it is necessary to ensure the amount of data on obesity that is statistically warranted. In this study, we used physical strength and motor ability measurement data from all areas based on the physical fitness improvement action plan in City O for the seven recent years of the 2013 to 2019 academic years, and succeeded in extracting obesity data from among an enormous amount of data. Severe obesity was used to reliably identify obesity. Because there was such a large amount of data, the evaluation was devised in a longitudinal span rather than constructing evaluations for single years. This evaluation is an evaluation chart that considers longitudinal trends, which are thought to be the best for evaluating physical ability (physical fitness, motor ability) in severely obese people.

When constructing an evaluation chart, it is important to make evaluation lines that demarcate evaluation ranges. A previous method to analyze longitudinal trends was a method devised by Fujii [25] that applied least squares approximation polynomials, but there was a problem in that this did not pass-through observation points. It was effective enough if looking at simple trends, but since this study was a relatively short span of seven years, we decided to apply the wavelet interpolation model, which can pass through observation points, rather than least squares approximation. The reason for applying the wavelet interpolation model is that with primary functions only compositions that increase in a simple linear fashion can be verified, whereas with secondary and higher order functions it is thought that compositions with changing increases can be grasped. Moreover, the wavelet interpolation model does not have fixed characteristics as a mathematical function, and so it is effective in that longitudinally changing trends in physical abilities do not depend on the function. Thus, the longitudinal change trends in physical abilities can be understood as a true change model. The effectiveness of this wavelet interpolation model was previously explained by Fujii [19].

In this study, the wavelet interpolation model was applied to longitudinal trends in height, physical fitness, and motor ability in second year junior high school girls and boys. The wavelet interpolation model was applied to standard values of a 5-step evaluation from the mean and standard deviation for height and physical fitness/motor ability in each academic year, and an annual span evaluation chart was constructed. The height and physical fitness/motor ability (grip strength, sidesteps, sit-and-reach, sit up, endurance running, 50 m dash, standing long jump, 20 m shuttle run, handball throw) of the severely obese second year junior high school girls and boys determined with the BMI aging span evaluation chart devised by Fujii [16] were applied to this evaluation chart. These results were definitive judgments. The height of severely obese students was judged to be in the average range for both boys and girls. Among the physical fitness and motor ability items, grip strength was judged to be “Somewhat high” for both boys and girls. Next, the sit-and-reach and handball throw were judged to be “Average” for both boys and girls. The other physical fitness and motor ability items of sidesteps, sit ups, 20 m shuttle run, 50 m dash, and standing long jump were judged to be “Somewhat low” for both boys and girls. It is noteworthy that the 50 m dash for boys and girls and the 20 m shuttle run for boys were judged to be “Low.”

The evaluation of physical fitness and motor ability in severely obese second year junior high school students derived in this study was not conjecture but a clear determination of “Somewhat poor” or “Poor” for items other than grip strength, sit-and-reach, and handball throw. This determination would seem to be a very important finding in understanding the physical fitness and motor ability of obese second year junior high school students. We suggest that a physical fitness and motor ability evaluation in severely obese second year junior high school students have been established here.

CONCLUSION

In this study we carefully examined physique, physical fitness and motor ability over time obtained in a large-scale survey over seven years (2013 to 2019 academic years) from the City O physical fitness improvement action plan, and used the measurement results for fifth grade elementary school students and second year junior high school students. In particular, the wavelet interpolation model was applied to annual trends in height and physical fitness/motor ability in second year junior high school boys and girls. The wavelet interpolation model was applied to standard values of a 5-step evaluation from the mean and standard deviation for height, physical fitness and motor ability in each academic year, and an annual span evaluation chart was constructed. The height and physical fitness/motor ability (grip strength, sidesteps, sit-and-reach, sit up, endurance running, 50 m dash, standing long jump, 20 m shuttle run, handball throw) of the severely obese second year junior high school girls and boys, determined with the BMI aging span evaluation chart devised by Fujii [16], were applied to this evaluation chart. From these results, it was determined that the height of severely obese students was in the average range for both boys and girls. Among the physical fitness and motor ability items, grip strength was judged to be “Somewhat high” for both boys and girls. Next, the sit-and-reach and handball throw were judged to be “Average.” The other physical fitness and motor ability items of sidesteps, sit ups, 20 m shuttle run, 50 m dash, and standing long jump were judged to be “Somewhat low” for both boys and girls. The evaluation of physical fitness and motor ability in severely obese second year junior high school students derived in this study was not conjecture but a clear determination that items other than grip strength, sit-and-reach, and handball throw were “Somewhat poor” or “Poor.” We suggest that a physical fitness and motor

ability evaluation in severely obese second year junior high school students were established here.

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