Original Article

Relation between the Height–Weight ratio and physical fitness among Japanese elementary school students

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Abstract:

Problem Statement and Purpose: In Japan, children who exercise and those who do not are increasingly polarized. A child's weight–height ratio varies greatly depending on their exercise habits. This study's main aim is to identify links between body mass index and exercise levels. Thus, we examine the relation between children's Rohrer index and their motor ability demonstrated in physical fitness tests.

Approach: The correlation between weight–height ratio (Rohrer index) and motor abilities were investigated using the height, weight, and physical fitness test data of second- and fifth-grade students in Osaka Prefecture in 2017. The physical fitness test measured grip strength, sit-ups, sitting trunk flexion, side step, 20 m shuttle run, 50 m run, standing long jump, and softball throw. A multiple regression analysis between the Rohrer index and each motor skill was conducted, with items showing correlation and significance being analyzed via a quadratic regression curve. **Results and Conclusions:** Among fifth-grade students, the Rohrer index was correlated with the 50 m run, 20 m shuttle run, and standing long jump (boys: 50 m run $R=0.6986$, $P < 0.001$; 20 m shuttle run $R=0.5271$, $P < 0.001$; standing long jump $R=0.5022$, $P < 0.001$; girls: 50 m run $R=0.2200$, $P < 0.05$; 20 m shuttle run $R=0.3489$, $P < 0.01$; standing long jump $R=0.4583$, $P < 0.001$). Furthermore, the coefficient for boys was higher than that for girls. No correlation was observed among second-grade students except for boys' 20 m shuttle run. In terms of weight–height ratio, a correlation was found between acute aerobic exercises (50 m run and standing long jump) and endurance exercises (20 m shuttle run). Children require exercise and physical activity that correspond to their development.

Key Words: Children, Rohrer index, physical fitness test, motor ability, body mass index, growth

Introduction

Japan is becoming increasingly interested in exercise as the country prepares to host the 2020 Tokyo Olympics. School-based physical education in Japan is structured according to age (Ministry of Education, Culture, Sports, Science and Technology, 2017). Typically, in elementary school students (younger than 12 years), the functions of the brain and the nervous system develop at different rates. Meanwhile, junior high school students (12–14 years old) experience cardiopulmonary (respiration/cardiovascular system) development at different degrees (Scammon, 1930; Robinson *et al.*, 2015). Thus, appropriate exercise habits will better support their growth and development, prevent illness and injury, and ensure a healthy life in the future. However, in the past two decades, children's exercise habits have greatly changed that many studies have reported a general decline in their physical activity and an increase in obesity prevalence (Itoi, Yamada, Nakae & Kimura, 2015). Studies have also shown that physical activity decreases among older children and that the prevalence of overweight and underweight tends to change as boys and girls grow older (Robinson *et al.*, 2015; Nakano *et al.*, 2010). Factors include fewer playgrounds as a result of urbanization, reduced free time because of attending cram schools, and a shift from outdoor play to largely sedentary indoor activities such as watching television and playing video games. Dietary shifts are an additional factor, as children in Japan are increasingly consuming high-calorie foods and drinks (Ekelund *et al.*, 2004). According to a 2016 survey by the Japan Sports Agency, about 5% of younger children and about 15% of junior high school girls do not exercise at all outside their physical education classes (Japan Sports Agency, 2016). The lack of physical activity among children leads to increasing obesity and declining physical strength (Ekelund *et al.*, 2004; Japan Sports Agency, 2016; Ministry of Education, Culture, Sports, Science and Technology, 2019; Ono, Sugiyama, Morishita, Yamamoto & Ishii, 1968; Ono, Omori, Sakaki & Kaise, 1971). Overall, the physical strength of Japanese children has been on a downward trend since around 1985 (Ministry of Education, Culture, Sports, Science and Technology, 2019). Many studies have also shown that overweight children tend to have low motor skills (Hidetoshi, 2013).

On the other hand, among children who actively participate in sports, some engage too enthusiastically and suffer injuries as a result. Overuse syndrome has been associated with participation in various sports, including soccer, baseball, basketball, and tennis (Morifuji *et al.*, 2017; Kaufman, Brodine, Shaffer, Johnson & Cullison, 1999; Cassas & Cassettari-Wayhs, 2006). For example, according to a 1995 survey in Japan, over 13% of high school baseball players who have participated in local competitions complained of shoulder pain when throwing (Yoshikawa *et al.*, 1995). Among 7,894 players (average age: 8.9) who had no shoulder and/or elbow pain in September 2014, 12.3% experienced elbow pain, 8.0% suffered from shoulder pain, and 17.4% endured shoulder and/or elbow pain during the previous one year (Takagishi *et al.*, 2017). Other children, particularly older girls (but also including boys), have shown a tendency toward underweight (Shirasawa *et al.*, 2015), which studies have attributed to body image ideals promoting thinness (Ueda, Kondo & Fujiwara, 2015; Nakai *et al.*, 2017; Kaneko, Kiriike, Ikenaga, Miyawaki & Yamagami 1999). Excessive thinness and overexercise among girls have been linked to several additional health problems including secondary amenorrhea and low bone density (Rebar, 2018).

This study's main objective is to identify links between body mass index and exercise levels. Therefore, we investigated the relation between weight–height ratio and physical fitness test results among Japanese second and fifth graders. In this study, the children's motor skills data are based on the results of physical fitness tests conducted at school (in Japan, schools report physical fitness test results for all fifth and eighth graders to the Japan Sports Agency). Physical fitness tests are measured from the first grade in elementary school to the third grade in junior high school. In any grade, the activities include grip strength, sit-ups, sitting trunk flexion, side step, 20 m shuttle run, 50 m run, standing long jump, and softball throw (**Supplementary File 1**). Specifically, the Rohrer index, which represents the weight–height ratio (**Supplementary File 2**) and the physical fitness test data will be examined to see which physical fitness test item is related to the index as well as what kind of records are established based on the Rohrer index results. We can also compare exercise development among second and fifth graders. As shown in **Supplementary File 2**, the Rohrer index is the official tool for categorizing elementary school children and junior high school students by weight classifications in Japan, where the index has been used in many studies (Takagishi *et al.*, 2017; Komiya, Masubuchi, Mori & Tajima, 2008; Ichimura, 1969; Kitagawa, 1974; Matsumoto, Taniguchi, Ifuku, Oishi & Oshige, 1997). The Rohrer index is based on a child-specific body shape (Ichimura, 1969; Kitagawa, 1974).

This study does not in any way promote discrimination by body shape.

Materials and Methods

Research subjects

The relation between the Rohrer index and motor ability was examined among second- and fifth-grade boys and girls from Elementary School A in Osaka Prefecture in 2017. The participating children for each grade were composed of the following:

Fifth grade: 45 boys, 41 girls

Second grade: 37 boys, 38 girls

This study was retrospective and included children who have already graduated. Therefore, they were not able to provide consent, but their data remained completely anonymous. Furthermore, consent from the school director at the time had been obtained for the usage of content and data for the research. This study was conducted with approval from the ethics review committee (H28-06) of the author's affiliated research organization (Kio University).

Research procedure

First, the relation between weight–height ratio (Rohrer index) and each motor ability was examined using height and weight as well as the physical fitness test data of boys and girls from lower elementary school (second-grade students: 7–8 years old) and upper elementary school (fifth-grade students: 10–11 years old) at Elementary School A, Osaka Prefecture, in 2017.

The physical fitness test and physical measurement data in this study were collected as regular school events, so it should be noted that the Rohrer index does not measure obesity in relation to skin layer thickness and body fat percentage. Furthermore, the subjects' birth months were not corrected.

The physical fitness tests and physical measurements were performed separately for boys and girls and analyses were separate as well. Especially in both measures, the data between boys and girls are significantly different. In addition, elementary school children grow fast and attend health and physical events every school year, and the data in those activities are recorded. There was also a characteristic difference in growth between elementary boys and girls; their motor ability is different as well, so it was not treated as a covariate in statistical analysis. Therefore, in this study, statistical analysis was conducted according to grade and gender.

To determine the type of children's weight–height ratio that can perform an exercise to a certain degree, a multiple regression analysis was conducted between the Rohrer index and each motor ability. A quadratic regression curve was drawn and analyzed for physical fitness test items (20 m shuttle run, 50 m run, standing

long jump), which showed correlation and significance. At Elementary School A, physical measurements are taken in May and physical fitness tests conducted from the end of May to mid-June. Therefore, it is believed that there are virtually no differences in physical states between the two research points.

Multiple regression analysis of each physical fitness test item and the Rohrer index

To investigate the relation between each physical fitness test item and other items/Rohrer index, the physical fitness test results and the Rohrer index data were calculated from the physical measurements of the research subjects and used for analysis.

In the physical fitness test, it was considered that “acute aerobic exercises” might be a confounding factor (e.g., standing long jump and 50 mrun, softball throw, and repeated side jump). In fact, previous studies on the relation between the Rohrer index and the physical fitness test showed a similar behavior of the instantaneous system (Hidetoshi, 2013). In addition, the 50 mrun, 20 m shuttle run, and standing long jump were considered to be affected by grip strength, forward bending, and the Rohrer index, respectively.

Thus, the study has three independent variables. The stepwise method was used for analysis. In the multiple regression analysis, to determine the extent to which the Rohrer index explains each exercise, the following were set:

1.50 mrun as the target variable; grip strength, sitting trunk flexion (physical fitness test item), and the Rohrer index as independent variables

2.20 m shuttle run as the objective variable; grip strength, sitting trunk flexion (physical fitness test item), and the Rohrer index as independent variables

3. standing long jump as the objective variable; grip strength, sitting trunk flexion (physical fitness test item), and the Rohrer index as independent variables.

Correlation analysis for each physical fitness test item and Rohrer index using quadratic regression curve

Next, we hypothesized that both overweight and underweight children would have unsatisfactory physical fitness test results. If their mass–height proportion is too low or too high, a linear regression curve is considered suitable instead of a linear function. A Rohrer index of around 130 is viewed as the standard weight–height ratio, with values within ± 15 of this reference point considered normal. Values within +30 and above indicated overweight while values within –30 and lower indicated being too skinny.

For this reason, similar to the multiple regression analysis, a quadratic regression curve was drawn for fifth-grade boys and girls using the Rohrer index and the 50 m run, 20 m shuttle run, and standing long jump, calculating for the correlation coefficient and the P-value. The least-squares method was used to create the quadratic curve, and statistics were performed independently of the multiple regression analysis, using the same data. For all statistical analyses (2–1 • 2–2), the study used BellCurve for Excel for Windows® ver. 3.20 provided by Social Survey Research Information Co., Ltd.

Results

First, Table 1 shows the average values and standard deviations of the Rohrer index and physical fitness tests for fifth graders. The results for second graders are shown in **Supplementary File 3**.

Table 1: Fifth-grade boys and girls: average values and standard deviations of the Rohrer index and physical fitness tests (2017)

	Rohrer index	Grip strength	Sitting trunk flexion	50 mrun	20 mshuttle run	Standing long jump	Sit-ups	Side step	Softball throw
Boys (N=45)									
Average	127.04	14.89	30.11	9.55	49.18	146.71	20.27	40	20.38
Standard deviation	18.9	3.5	7.01	1	17.69	18.38	4.11	4.82	8.29
Girls (N=41)									
Average	121.34	15.46	43.54	9.62	42.46	145.17	20.51	41.93	13.22
Standard deviation	16.64	3.3	7.78	0.62	12.24	18.45	4.35	5.53	4.05

The results for the fifth-grade boys and girls (Table 1) show that boys have better average values except grip strength. The Rohrer index was higher for boys as well.

Multiple regression analysis between each physical fitness test item and the Rohrer index

To examine the association between each physical fitness test item and other items/Rohrer index, analysis was conducted using the physical fitness test results and Rohrer index data calculated from the physical measurements of the second- and fifth-grade students (both boys and girls) of Osaka Prefecture Elementary School A in 2017. The results are shown in Tables 2 and 3.

In the physical fitness test, higher values indicate better records except for the 50 m run, where lower values indicate better numbers. For this reason, positive and negative are reversed.

Table 2: Fifth-grade boys: regression analysis results (N = 45)

Variable	B (partial regression coefficient)	Standard error of B	t-value	P-value	Single correlation
Result of 50 mrun and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion					
Grip strength	-0.1134	0.027	-4.2025	P < 0.001	-0.2429
Rohrer index	0.0411	0.005	8.226	P < 0.001	0.6986
Constant term	6.0199	0.6865			
Result of 20 m run and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion					
Grip strength	1.1284	0.6525	1.7294	0.0913	0.1395
Rohrer index	-0.5259	0.1192	-4.4105	P < 0.001	-0.5271
Sitting trunk flexion	-0.4189	0.3195	-1.3111	0.1971	-0.2359
Constant term	111.7997	19.1245			
Result of standing long jump and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion					
Grip strength	2.3308	0.6182	3.7705	P < 0.001	0.3265
Rohrer index	-0.5739	0.1144	-5.0166	P < 0.001	-0.5022
Constant term	184.9169	15.7233			

Table 2 shows the multiple regression analysis results using the stepwise method for the physical fitness test items of the 45 fifth-grade boys and each of their Rohrer indexes (the independent variables were grip strength, Rohrer index, and sitting trunk flexion).

When the stepwise method was selected in multiple regression analysis, explanatory variables with significantly large F-value significance were removed. In the 50 m run and standing long jump, sitting trunk flexion was removed from the regression equation because the partial regression coefficient was not significantly different from 0 and did not help explain the objective variable (Variable selection method for linear regression, IBM Knowledge Center, 2019).

A significant and positive relation was found between the 50 mrun and the Rohrer index (single correlation: 0.6986). There was a significant negative association between grip strength and 50 mrun speed. As the Rohrer index values increased, the 50 mrun speed decreased, and as grip strength increased, the 50 mrun speed also increased.

Also, the Rohrer index was a significant predictor of 20 m shuttle run scores (single correlation: 0.5271); as the Rohrer index value increases, the 20 m shuttle run score decreases.

In addition, there was a significant positive relation between standing long jump and the Rohrer index results (single correlation: 0.5022). A significant positive association was also observed between grip strength and the number of standing long jumps. As the value of Rohrer index increased, the number of standing long jumps decreased, and as grip strength increased, the number of standing long jumps increased as well.

Table 3: Fifth-grade girls: regression analysis results (N = 41)

Variable	B (partial regression coefficient)	Standard error of B	t-value	P-value	Single correlation
Result of 50 mrun and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion					
Grip strength	-0.1101	0.0244	-4.5137	P < 0.001	-0.5421
Rohrer index	0.0113	0.0049	2.3057	P < 0.05	0.22
Constant term	9.9551	0.6651			

Result of 20 m run and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion

Grip strength	1.9726	0.4707	4.1909	P < 0.001	0.476
Rohrer index	-0.3122	0.0945	-3.3059	P < 0.05	-0.3489
Constant term	49.8478	12.8293			

Result of standing long jump and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion

Grip strength	3.3494	0.6055	5.5313	P < 0.001	0.5276
Rohrer index	-0.6034	0.1215	-4.9659	P < 0.001	-0.4583
Constant term	166.596	16.5049			

Table 3 shows the multiple regression analysis results using the stepwise method of the physical fitness test items of 41 fifth-grade girls and the Rohrer index (the independent variables were grip strength, Rohrer index, and sitting trunk flexion).

When the stepwise method was selected in the multiple regression analysis, explanatory variables with significantly large F-value significance were removed. In the 50 m run, 20 m shuttle run, and standing long jump, sitting trunk flexion was removed from the regression equation because the partial regression coefficient was not significantly different from 0 and did not contribute to the explanation of the objective variable (Variable selection method for linear regression, IBM Knowledge Center, 2019).

A significant and positive relation was found between the 50 m run and the Rohrer index (single correlation: 0.2200). There was a significant negative relation between grip strength and 50 m run speed. As the Rohrer index values increased, the 50 m run speed decreased, and as grip strength increased, then the 50 m run speed also increased.

The Rohrer index was also found to be a significant predictor of 20 m shuttle run scores (single correlation: 0.3489). A significant positive association was seen between grip strength and the number of 20 m shuttle runs. As the Rohrer index value increased, the number of 20 m shuttle runs decreased. As grip strength increased, the number of 20 m shuttle runs increased.

Next, there was a significant positive relation between standing long jump and the Rohrer index results (single correlation: 0.4583). There was also a significant positive relation between grip strength and the number of standing long jumps. As the Rohrer index value increased, the number of standing long jumps decreased, and as grip strength increased, the number of standing long jumps also increased.

Among the fifth-grade students, a significant correlation between the Rohrer index and the 50 m run, 20 m shuttle run and standing long jump was observed for both boys and girls. Furthermore, a significant correlation was also seen with grip strength, which is related to total muscle strength (Wind, Takken, Helder & Engelbert, 2010) (excluding boys' 20 m shuttle run). In addition, the multiple regression analysis showed that boys had a higher correlation coefficient than the girls. However, among the second-grade students, no correlation was found in the multiple regression analysis results, and no significance was seen in any sports items (except for the 20 m shuttle run of second-grade boys) (**Supplementary File 3**). The Rohrer index categorizes physique; in line with this, an analysis of variance was performed (**Supplementary File 2, 4**).

The following will therefore focus on three items—50 m run, 20 m shuttle run, and standing long jump of fifth-grade boys and girls—examining them using correlation analysis.

Correlation analysis between each physical fitness test item and the Rohrer index using quadratic regression curve (fifth-grade children)

The multiple regression analysis results showed a significant correlation between the Rohrer index and the 50 m run, 20 m shuttle run, and standing long jump among fifth-grade students; such correlation was not significant among second graders except for boys' 20 m shuttle run.

To investigate the Rohrer index and to produce the best results, quadratic regression curves of the Rohrer index and the 50 m run, 20 m shuttle run, and standing long jump were drawn for the data of fifth-grade boys and girls in 2017; this was done to calculate for the correlation coefficient and P-value. The rationale behind this is that we thought that children could not have good exercise records if they had too much or too little body weight. The least-squares method was used to create the quadratic curve. Statistics were performed independently of the multiple regression analysis; we used the same data.

A graph was composed with the Rohrer index on the x-axis and the 50 m run, 20 m shuttle run, and standing long jump on the y-axis (Figures 1–3 for boys and Figures 4–6 for girls).

Figure 1: Quadratic regression curve of fifth-grade boys' Rohrer index and 50 m run, 2017

Figure 2: Quadratic regression curve of fifth-grade boys' Rohrer index and 20 m shuttle run, 2017

Figure 3: Quadratic regression curve of fifth-grade boys' Rohrer index and standing long jump, 2017

From Figure 1 ($N=45$), it was found that the fifth-grade boys' 50 m run was $Y=0.1632X^2+0.0007X+18.3374$. The correlation coefficient was 0.699, with the coefficient of determination being 0.4881 for the linear and 0.6020 for the quadratic function. The regression sum of squares was $P<0.001$ for both linear and quadratic functions. The regression coefficient was 0.6020.

From Figure 2 ($N=45$), it was found that fifth-grade boys' 20 m shuttle run was $Y=1.2347X^2 - 0.0063X - 4.5139$. The correlation coefficient was 0.527, with the coefficient of determination being 0.2779 for the linear and 0.3050 for the quadratic function. The regression sum of squares was $P<0.001$ for both linear and quadratic functions. The regression coefficient was 0.3050.

From Figure 3 ($N=45$), it was found that fifth-grade boys' standing long jump was $Y=0.2082X^2 - 0.0025X + 161.8427$. The correlation coefficient was 0.502, with the coefficient of determination being 0.2522 for the linear and 0.2563 for the quadratic function. The regression sum of squares was $P<0.001$ for both linear and quadratic functions. The regression coefficient was 0.2563.

The Rohrer index was a significant predictor of 50 m run, 20 m shuttle run, and standing long jump scores. As the Rohrer index values increased, the 50 m run speed, the number of 20 m shuttle runs, and the number of standing long jumps decreased. (In the physical fitness test, higher numbers indicate better records, but for the 50 m run, lower numbers indicate better values.)

Figure 4: Quadratic regression curve of fifth-grade girls' Rohrer index and 50 m run, 2017

Figure 5: Quadratic regression curve of fifth-grade girls' Rohrer index and 20 m shuttle run, 2017

Figure 6: Quadratic regression curve of fifth-grade girls' Rohrer index and standing long jump, 2017

Figure 6 (N=41) shows that fifth-grade girls' 50 m run was $Y=0.0155X^2+0.0000X+8.1351$. The correlation coefficient was 0.220, with the coefficient of determination being 0.0484 for the linear and 0.0488 for the quadratic function. The regression sum of squares of distributed analysis for the analysis of variance was 0.1669 for the linear and 0.3864 for the quadratic function, showing no significant difference. The regression coefficient was 0.0488.

Figure 5 (N=41) shows that fifth-grade girls' 20 m shuttle run was $Y=0.4569X^2 - 0.0026X+26.6444$. The correlation coefficient was 0.349, with the coefficient of determination being 0.1217 for the linear and 0.1325 for the quadratic function. The regression sum of squares of distributed analysis for the analysis of variance was 0.0254 for the linear and 0.0671 for the quadratic function, and the regression sum of squares was $P<0.05$ for both the linear and quadratic functions. The regression coefficient was 0.1325.

Figure 6 (N=41) shows that fifth-grade girls' standing long jump was $Y=1.5734X^2 - 0.0077X+69.6630$. The correlation coefficient was 0.458, with the coefficient of determination being 0.2101 for the linear and 0.2503 for the quadratic function. The regression sum of squares of distributed analysis for the analysis of variance was 0.0026 for the linear and 0.0042 for the quadratic function, and the regression sum of squares was $P<0.001$ for both the linear and quadratic functions. The regression coefficient was 0.2503. The Rohrer index was a significant predictor of the 20 m shuttle run and standing long jump scores. Also, a significant correlation was observed between the Rohrer index and 50 m run records for boys but not for girls. In addition, there was a significant and positive relation between the 20 m shuttle run, standing long jump, and the Rohrer index results. The higher the Rohrer index value, the lower the number of 20 m shuttle runs and of standing long jumps.

In fact, the multiple regression analysis performed in (1) did not suggest a quadratic curve, and the quadratic curve drawn in (2) did not have a sufficiently large constant term to represent a quadratic function. In other words, even if the Rohrer index was too low, exercise ability was not inferior. However, if one is overweight, that is, if one's Rohrer index is high, their exercise record will also decrease. The application of a

quadratic regression curve also indicated a trend in which the correlation coefficient was larger among the boys than the girls.

The graph in which the Rohrer index and each sports item record were applied to the quadratic curve indicated the correlation coefficient and the P-value. However, it was difficult to identify the kind of records produced in each item based on the Rohrer index value, as there was no clear inflection point in the quadratic regression curve.

Discussion

In this study, we hoped to clarify the relation between children's weight–height ratio and athletic ability so that they can get involved in sports safely and healthily. Therefore, we investigated the connection between the weight–height ratio and physical fitness test results of children from Elementary School A. Specifically, we studied the relation between weight–height ratio evaluation using the Rohrer index, an index that represents children's weight–height ratio, and the results of each physical fitness test item for second-grade students (7–8 years old) and fifth-grade students (10–11 years old).

Among fifth-grade students, in upper elementary school, an overall correlation was seen for both genders in their physical fitness test records related to acute aerobic exercises (e.g., 50 m run and standing long jump) and endurance exercises (e.g., 20 m shuttle run). These results were particularly prominent among boys. However, among second-grade students, no correlation was observed (except for their 20 m shuttle run).

One study stated that second-grade motor ability is associated with the Rohrer index (Hidetoshi, 2013), but it did not show such a correlation. Exercise requires an “integrated” body movement. However, in lower grades, movements that are not yet integrated with the body are more likely to appear in the exercise results than in the effects of weight–height ratio. (For younger children, body movements are awkward regardless of body shape; this includes their coordination of arm swing and foot placement, etc.) (Ito, 1985). In the second grade, a significant correlation was hardly observed between the Rohrer index and weight–height ratio, along with growth; this refers to the ability to coordinate body movement as well as individual differences in weight–height ratio, which are thought to affect one's exercise records. During these three years, children experience a growth spurt, and appropriate exercise and engagement in daily activities may affect their future exercise habits.

We expected that a Rohrer index that was too high or too low would not result in good exercise performance. However, this study could not determine whether children with low weight have low motor skills. This begs the question: In what weight (weight–height ratio) can one produce the best performance in the 50 m run, 20 m shuttle run, and standing long jump? Does a lighter weight correspond to a better performance of acute aerobic exercises?

In this study, the relation between the Rohrer index and physical fitness test records was very linear, with lighter weight providing better results, and this is not good for children. The reason is that light weight may be a result of too much exercise or some hidden factors. Thus, future research needs to investigate the appropriate Rohrer index value that allows for a healthy and safe physical activity. Considered nutritionally and medically “appropriate,” the Rohrer index may not be the best indicator of exercise performance. This can also be inferred from the results of the fifth-grade girls in **Supplementary File 4**. (To show the relation between the Rohrer index and the physical fitness test, we created a receiver operating characteristic curve; see

Supplementary File 5).

Currently, the Japanese education system, particularly primary education, requires students to develop a mind-set of “enjoying sports throughout one's life” (Ministry of Education, Culture, Sports, Science and Technology, 2017). A population that does not engage in exercise has an increased risk of suffering from locomotive syndrome at a young age. In Japan, it has also been found that students can be broadly classified into those who engage in exercise and those who barely do so (Japan Sports Agency, 2016; Ministry of Education, Culture, Sports, Science and Technology, 2012); in 2016, locomotor examinations began at Japanese schools (Ministry of Education, Culture, Sports, Science and Technology, 2014). For children to safely enjoy exercise, it is not enough for schools to only provide physical education.

Conclusion

The relation between the Rohrer index and the physical fitness test was not clear among second graders except for boys' 20 m shuttle run, but among fifth graders, the correlation between the Rohrer index and the physical fitness test (acute aerobic exercises and endurance exercises) was significant. This may be because cooperative movement, which second graders are not good at, has developed in fifth graders. In addition, the correlation was more remarkable for boys. On the other hand, one future issue involves determining the Rohrer index value in which one can exercise healthily and safely. However, a moderate Rohrer index may not necessarily be the most suitable measure for exercise performance.

Appropriate exercise habits and successful experiences from an early age are thought to influence children's future physical health. Schools should help students enhance their thinking about balanced diets and, along with medical facilities, should enhance their physical examinations by employing doctors and physical

therapists. Future research should investigate the association between overweight and underweight in childhood and these conditions, as well as psychosocial factors and interventions to limit their incidence.

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We extracted data from the health and physical educational classes attended by all children at the school. We did not procure any special funds for the study.

Conflicts of Interest

The authors declare no conflicts of interest.

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Supplementary File1: Physical fitness test

In 1964, the Ministry of Education, Culture, Sports, Science, and Technology in Japan created a physical fitness and exercise test to obtain information regarding children's exercise capacity. The test was revised in 1999 to emphasize the safety and relevance of the exercises performed and to change its measurement methods. In 2008, the ministry began using surveys to examine the relations between exercise and lifestyle, attitudes, and consciousness of children in elementary schools (fifth grade: 10–11 years old) and junior high schools (eighth grade: 13–14 years old) in Japan. The “Physical Fitness Test,” which has been conducted since 1999, is a comprehensive review of previous tests based on changes in people's status, advances in sports medicine and science, and progress in the field of aging (Implementation guidelines for new physical fitness test, n.d.). The records are returned to the children and scored using numerical values determined by the Sports Agency. During the physical fitness test for children, the following items are measured (Implementation guidelines for new physical fitness test, n.d.; Ministry of Education, Culture, Sports, Science and Technology, 2012; Implementation guideline for new children's physical fitness test, 2016):

- grip strength (for measuring muscle strength),
- sit-ups (for measuring muscle endurance),
- sitting trunk flexion (for measuring flexibility),
- side step (for measuring agility),
- 20 m shuttle run (for measuring cardiopulmonary endurance; junior high school students can choose to

- perform this endurance run),
- 50 m run (for measuring instantaneous power),
- standing long jump (for measuring instantaneous power),
- softball throw (for measuring instantaneous movement).

References for Supplementary File1:

Implementation guidelines for new physical fitness test. (n.d.). Retrieved November 17, 2019, from http://www.mext.go.jp/a_menu/sports/stamina/03040901.htm.

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Supplementary File 2: Rohrer index

Rohrer index = weight (kg) ÷ height(cm)³ × 10000000 (kg/cm³)

The Rohrer index is widely used to represent the body types of elementary and middle school students in Japan. Currently, body mass index is used in various health studies regardless of child or adult subjects (Burton, 2019), but some studies have used the Rohrer index for children (Banik, 2019; Doak et al., 2013).

In Japan, the Rohrer index is used as an indicator of the physique of children, such as elementary and junior high school students (Takagishi, 2017).

A Rohrer index of around 130 is viewed as the standard body type and remains normal within ±15 of this reference point. A value of +30 and above indicates overweight while -30 and lower indicates underweight. The criteria for higher obesity is 160 and above, with 120–130 generally viewed as normal. The concept of the Rohrer index is based on the idea that weight is proportional to the cube of height. Since volume is the cube of length, it is proportional to the cube of height; hence, standard weight is proportional to the cube of height. This reflects the characteristics of the child's body shape (Burton, 2007; [Komiya](#), [Masubuchi](#), [Mori](#), & [Tajima](#), 2008). In the Rohrer index, the child's body is regarded as a cube, so it is in the third power (Ichimura, 1969; Kitagawa, 1974). However, it should be noted that this index is greatly influenced by height and, as such, it gradually decreases for both boys and girls from infancy onward. The value is lowest at around age 10–13 and then starts to increase (Ichimura, 1969).

Supplementary Table 1: Classification of physique by Rohrer index

Index	Judgment
Less than 100	skinny
100 to less than 115	little skinny
115 to less than 145	normal
145 to less than 160	slightly obese
160 or more	obesity

References for Supplementary File2:

Banik, S. D. (2011). Evaluation of health status of pre-menarcheal and post-menarcheal girls by Rohrer index in Purulia, West Bengal. *Journal of Public Health and Epidemiology*, **3**(1), pp. 13–16.

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[Komiya](#), H., [Masubuchi](#), Y., [Mori](#), Y., [Tajima](#), N. (2008). The validity of body mass index criteria in obese school-age children. *The Tohoku Journal of Experimental Medicine*, **214**, pp. 27–37.

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Supplementary File 3: Multiple regression analysis results for second-grade boys and girls

The average value and standard deviation of the Rohrer index and physical fitness tests are shown for the second grade (Supplementary Table 2).

Supplementary Table 2: Second-grade boys and girls: average values and standard deviations of the Rohrer index and physical fitness tests (2017)

	Rohrer index	Grip strength	Sitting trunk flexion	50 m run	20 m shuttle run	Standing long jump	Sit-ups	Side step	Softball throw
Boys (N = 37)									
Average	127.23	8.45	31.43	11.09	27.7	127.73	12.78	33.14	12
Standard deviation	15.18	1.5	35.98	1.09	12.08	24.57	5.45	4.35	5.09
Girls (N = 38)									
Average	127.98	8.39	30.42	11.18	21.53	123.32	13.66	32.29	7.05
Standard deviation	13.81	1.54	5.7	0.88	8.42	13.12	6.38	3.19	1.96

The results for second-grade boys and girls (**Supplementary Table 2**) show that boys have better average values excluding those for the Rohrer index and for sit-ups.

Supplementary Table 3 shows the multiple regression analysis results using the stepwise method of the physical fitness test results of 37 second-grade boys, each of their physical fitness test items, and the Rohrer index (independent variables: grip strength, Rohrer index, and sitting trunk flexion).

Supplementary Table 3: Second-grade boys: regression analysis results (N = 37)

Variable	B (partial coefficient)	regression	Standard error of B	t-value	P-value	Single correlation
Result of 50 m run and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion						
Grip strength	-0.2356		0.1164	-2.024	0.0507	-0.3237
Constant term	13.0761		0.9984	13.0976	P < 0.001	
Result of 20 m run and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion						
Grip strength	2.0577		1.2874	1.5984	0.1192	0.1986
Rohrer index	-0.2813		0.1287	-2.1861	P < 0.05	-0.3075
Constant term	46.1084		18.2301	2.5293	P < 0.05	
Result of standing long jump and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion						
Grip strength	5.3324		2.3596	2.2599	P < 0.05	0.3604
Rohrer index	-0.4601		0.2318	-1.985	0.0555	-0.1981
Sitting trunk flexion	-0.2807		0.0971	-2.8894	0.0068 (P < 0.01)	-0.4545
Constant term	150.0597		33.7899	4.441	P < 0.001	

In the second grade, no correlation was found between the 50 m run, standing long jump, and the Rohrer index.

The Rohrer index was a significant predictor of 20 m shuttle run scores (single correlation: 0.3075). A significant and positive relation was observed between the 20 m shuttle run and the Rohrer index results. As the value of Rohrer index increases, the number of 20 m shuttle runs decreases.

Supplementary Table 4 shows the multiple regression analysis results using the stepwise methods of the 50 m run and 20 m shuttle run, standing long jump results of 38 second-grade girls, each of their physical fitness test items, and the Rohrer index (independent variables: grip strength, Rohrer index, and sitting trunk flexion).

Supplementary Table 4: Second-grade girls: regression analysis results (N = 38)

Variable	B (partial coefficient)	regression	Standard error of B	t-value	P-value	Single correlation
Result of 50 m run and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion						
Grip strength	-0.3217		0.0792	-4.0637	P < 0.001	-0.5608
Constant term	13.8753		0.6756	20.5384	P < 0.001	
Result of 20 m run and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion						
Grip strength	2.6655		0.7954	3.3513	P < 0.05	0.4876
Constant term	-0.8498		6.7883	-0.1252	0.9011	

Result of standing long jump and each sports item (measured by physical fitness test)/Rohrer index, independent variables: grip strength, Rohrer index, sitting trunk flexion

Grip strength	5.4148	1.0962	4.9395	$P < 0.001$	0.6356
Constant term	77.8596	9.3561	8.3218	$P < 0.001$	

Neither 50 m run nor 20 m shuttle run nor the standing long jump correlated with the Rohrer index, but a significant correlation with grip strength was found.

Supplementary File 4: ANOVA results of motion records according to Rohrer index categorization

The Rohrer index categorizes physique as follows: lower than 100 is “skinny,” 100 to lower than 115 is “little skinny,” 115 to lower than 145 is “normal,” 145 to lower than 160 is “slightly obese,” and 160 or higher is “obese.” Therefore, 100 is “skinny,” 100 to lower than 115 (little skinny) is “too thin,” 115 to lower than 145 (normal) is “standard,” 145 to lower than 160 is “slightly obese,” and 160 or higher (obese) is “overweight,” and analysis of variance was performed.

Supplementary Figure 1: ANOVA results of the 50 m run records of fifth-grade boys and Rohrer index categorization, N = 45, 2017

Supplementary Figure 2: ANOVA results of the 20 m shuttle run records of fifth-grade boys and Rohrer index categorization, N = 45, 2017

Supplementary Figure 3: ANOVA results of the standing long jump records of fifth-grade boys and Rohrer index categorization, N = 45, 2017

Supplementary Table 5: ANOVA results of physical fitness test data of fifth-grade boys and Rohrer index categorization, N = 45, 2017 (ANOVA table)

Factor	Type III sum of squares	Degree of freedom	Mean square	F-value	P-value	*: P < 0.05
						** : P < 0.01
ANOVA results of the 50 m run record of fifth-grade boys and physique categorization of Rohrer index, N = 45, 2017 (ANOVA table)						
Physique	16.23	2.00	8.12	12.32	P < 0.001	**
Error	27.68	42.00	0.66			
Entire	43.91	44.00				
ANOVA results of the 20 m shuttle run record of fifth-grade boys and physique categorization of Rohrer index, N = 45, 2017 (ANOVA table)						
Physique	2235.12	2.00	1117.56	4.07	P < 0.05	*
Error	11537.46	42.00	274.70			
Entire	13772.58	44.00				
ANOVA results of the standing long jump record of fifth-grade boys and physique categorization of Rohrer index, N = 45, 2017(ANOVA table)						
Physique	3383.85	2.00	1691.93	6.19	0.00	**
Error	11475.39	42.00	273.22			
Entire	14859.24	44.00				

Rohrer index less than 115 (N = 8), Rohrer index is 115 or more and less than 145 (N = 21), Obesity/obesity (N = 16) with Rohrer index 145 or higher

According to **SupplementaryFigures 1–3** and **SupplementaryTable 5**, as a result of the analysis of variance for fifth-grade boys, a significant difference was found between the 50 m run, 20 m shuttle run, standing long jump, and physique. From this, the Rohrer index was found to be related to the 50 m run, 20 m shuttle run, standing long jump, and physique. (In the physical fitness test, larger numbers indicate better records, but for the 50 m run, smaller numbers indicate better performance.)

Supplementary Figure 4: ANOVA results of the 50 m run records of fifth-grade girls and Rohrer index categorization, N = 41, 2017

Supplementary Figure 5: ANOVA results of the 20 m shuttle run records of fifth-grade girls and Rohrer index categorization, N = 41, 2017

Supplementary Figure 6: ANOVA results of the standing long jump records of fifth-grade girls and Rohrer index categorization, N = 41, 2017

Supplementary Table 6: ANOVA results of the physical fitness test data of fifth-grade girls and Rohrer index categorization, N = 41, 2017 (ANOVA table)

Factor	Type III sum of squares	Degree of freedom	Mean square	F-value	P-value	*:P < 0.05	
						** : p < 0.01	<
ANOVA results of 50 m run record of fifth-grade girls and physique categorization of Rohrer index, N = 41, 2017 (ANOVA table)							
Physique	0.6913	2	0.3457	0.8575	0.4323		
Error	15.3189	38	0.4031				
Entire	16.0102	40					
ANOVA results of 20 m shuttle run record of fifth-grade girls and physique categorization of Rohrer index, N = 41, 2017(ANOVA table)							
Physique	511.4363	2	255.7181	1.7251	0.1918		
Error	5632.7588	38	148.2305				
Entire	6144.1951	40					
ANOVA results of standing long jump record of fifth-grade girls and physique categorization of Rohrer index, N = 41, 2017 (ANOVA table)							
Physique	2208.8402	2	1104.4201	3.5721	0.0379	*	
Error	11748.9647	38	309.1833				
Entire	13957.8049	40					

Rohrer index less than 115 (N = 4), Rohrer index is 115 or more and less than 145 (N = 20), Obesity/obesity (N = 17) with Rohrer index 145 or higher

According to **Supplementary Figures 4 and 5** and **Supplementary Table 6**, the analysis-of-variance results for fifth-grade girls showed no significant differences between the 50 m run, the 20 m shuttle run, and physique. From these results, the Rohrer index (physique category) could not be said to be related to the 50 m run, the 20 m shuttle run, and physique. This may be because while the average value of the Rohrer index changes with age (Shiga Prefecture Official Website, n.d.; Ichimura, 1969), the numbers that serve as physique classifications (labels: overweight, normal, too skinny) do not change throughout childhood.

According to **Supplementary Figure 6** and **Supplementary Table 6**, as a result of analysis of variance, a significant difference was observed between the standing long jump and physique. Hence, the value determined by the Laurel index is related to the standing long jump and physique.

References for Supplementary File4:

Shiga Prefecture Official Website. (n.d.). Retrieved December 26, 2018, from www.pref.shiga.lg.jp/e/kodomokatei/files/5h28section4.pdf; retrieved August 29, 2019,

from <https://www.pref.shiga.lg.jp/file/attachment/34160.pdf>; retrieved August 29, 2019, from <https://www.pref.shiga.lg.jp/file/attachment/34315.pdf> [in Japanese].
 Souichi, I. (1969). The developmental transition of Rohrer Index. *Japanese Society of Physical Education*, 14(2), pp. 66–72.

Supplementary File 5: Analysis of each physical fitness test item and the Rohrer index using the receiver operating characteristic (ROC) curve

The physical fitness test records set by the Japanese Sports Agency score each sports item from 1 to 10 points (Japan Sports Agency, 2016; Implementation guideline for new children's physical fitness test, 2016). For example, a boy's 50 m run of 8.5 seconds is 8 points. In creating a ROC curve, 8.5 seconds or more (records taken from 8.5 seconds) is set to "0," and 8.5 seconds or less (records superior to 8.5 seconds) is set to "1." I tried to draw a ROC curve using 8 points = 8.5 seconds as a constant and the Rohrer index as a variable. The average of fifth-grade boys in Japan in 2017 is 9.38 seconds, so 8.5 seconds is excellent. The results are shown below (Supplementary Figure 7).

Similarly, a girl's 50 m run of 9.2 seconds is 8 points. When creating a ROC curve, 9.2 seconds or more (records acquired from 9.2 seconds) is set to "0," and 9.2 seconds or less (records exceeding 9.2 seconds) is set to "1." I tried to draw a ROC curve using 8 points = 9.2 seconds as constant and the Rohrer index as a variable. The average of fifth-grade girls in Japan in 2017 is 9.61 seconds, so 9.2 seconds is above average. The results are shown below (Supplementary Figure 8).

As for the 20 m shuttle run and standing jump, the ROC curve is plotted with the Rohrer index as a constant, with the score determined by the Sports Agency (7–8 points) as constant. The cut-off point of the Rohrer index is 110–120. Thus, this figure is slightly "skinny."

※ If there are 8 points in all physical fitness test sports items, and there are 8 items, then the total will be 64 points and will be ranked B in a scale of A–E by Sports Agency standards. This is a good grade. The method for conducting the new physical fitness test is listed in Daiichi Gakushusha Corporation (1999).

Figures

Supplementary Figure 7: ROC curve of the 50 m run and Rohrer index scores for fifth-grade boys, standard: 8.5 seconds (= 8 points), 2017

The analysis showed a cut-off value of 113.8, a sensitivity of 0.800, a 1-specificity of 0.775, and an area under the curve of 0.8350 ($n: \Gamma 0 = 40, \Gamma 1 = 5$).

Supplementary Figure 8: ROC curve of the 50 m run and Rohrer index scores for fifth-grade girls, standard: 9.2 seconds, 2017

The analysis showed a cut-off value of 111.2, a sensitivity of 0.7143, a 1-specificity of 0.7353, and an area under the curve of 0.7269 ($n: \text{「} 0 \text{」} = 27, \text{「} 1 \text{」} = 14$).

References for Supplementary File5:

- Daiichi Gakushusha Corporation. (1999). Elementary School New Physical Fitness Test “Score Standard Table.” Retrieved November 22, 2019, from <http://www.daiichi-g.co.jp/stest/feature/tokuten/xls/sd-1.xls>.
- Implementation guideline for new children’s physical fitness test. (2016). Retrieved November 22, 2019, from http://www.mext.go.jp/sports/b_menu/sports/mcatetop03/list/1371914.htm.
- Japan Sports Agency. (2016). National Health/Exercise Abilities, Exercise Habits Survey Report, p. 102. Retrieved September 12, 2019 [in Japanese].