ORIGINAL PAPER

Nagoya J. Med. Sci. **86**. 24–35, 2024
doi:10.18999/nagjms.86.1.24

Relationship between exercise habits and physical function in children aged 9–12 years

Daiki Takahashi[1], Tadashi Ito[1,2], Yuji Ito[3], Kentaro Natsume[1], Koji Noritake[4], Nobuhiko Ochi[5] and Hideshi Sugiura[1]

[1]Department of Integrated Health Sciences, Nagoya University Graduate School of Medicine, Nagoya, Japan
[2]Three-dimensional Motion Analysis Room, Aichi Prefectural Mikawa Aoitori Medical and Rehabilitation Center for Developmental Disabilities, Okazaki, Japan
[3]Department of Pediatrics, Nagoya University Graduate School of Medicine, Nagoya, Japan
[4]Department of Orthopedic Surgery, Aichi Prefectural Mikawa Aoitori Medical and Rehabilitation Center for Developmental Disabilities, Okazaki, Japan
[5]Department of Pediatrics, Aichi Prefectural Mikawa Aoitori Medical and Rehabilitation Center for Developmental Disabilities, Okazaki, Japan

ABSTRACT

Exercise improves physical health and positively impacts physical functions in children. Additionally, the habitual exercise established during childhood often continues into adulthood. Therefore, childhood is an important period for establishing healthy habits. Investigating the relationship between the presence or absence of daily exercise and physical functions may provide important information to confirm poor physical function in children with poor exercise habits. Therefore, this study examined the relationship between exercise habits as defined by the Japanese Ministry of Health, Labor, and Welfare and physical function in children aged 9–12 years. Approximately 239 children were included in this study. Participants answered a questionnaire about their exercise habits. We evaluated the skeletal muscle mass index, grip strength, standing broad jump, one-leg standing time, and gait deviation index. Logistic regression analyses were performed to assess exercise habit association with skeletal muscle mass index, physical function, and gait deviation index after adjusting for sex. Of the 239 children, 75.5% (n = 178) had exercise habits. A significant association was noted between exercise habits and skeletal muscle mass index and standing broad jump (skeletal muscle mass index: OR, 1.84; 95% CI, 1.01–3.36 and $p<0.05$; standing long jump: OR, 1.02; 95% CI, 1.00–1.04 and $p<0.05$). In conclusion, exercise regardless of exercise level for at least 30 min per day, 2 days per week, for at least 1 year is important for skeletal muscle mass and instantaneous lower limb muscular strength development in school-aged children.

Keywords: children, exercise habits, physical function, skeletal muscle mass index

Abbreviations:
MVPA: moderate to vigorous physical activity
SMI: skeletal muscle mass index
SBJ: standing broad jump
OLST: one-leg standing time
GDI: gait deviation index

Received: July 6, 2022; accepted: February 28, 2023
Corresponding Author: Hideshi Sugiura, MD, PhD
Department of Integrated Health Sciences, Nagoya University Graduate School of Medicine,
1-1-20 Daiko-Minami, Higashi-ku, Nagoya 461-8673, Japan
E-mail: hsugiura@met.nagoya-u.ac.jp

INTRODUCTION

Habitual exercise is important for children to maintain physical health.[1,2] Exercise improves physical health and positively impacts physical functions in children.[3] Therefore, it is important to make exercise a habit. The habitual exercise established during childhood often continues into adulthood.[4] Therefore, childhood is an important period for establishing healthy habits. Children are less likely to participate in sports and spend more time indoors. Children without established exercise habits are more likely to have lower physical function than those with established exercise habits; Furthermore, they are at risk of physical health problems.[5]

According to a previous study, "exercise for 30 min or more per session for at least 2 days a week" was reported to be the minimum necessary to improve motor function.[6] In Japan, the Ministry of Health, Labor and Welfare defined an exercise habit as "exercising for 30 min or more, at least 2 days a week, and continuing for at least 1 year". In 2021, a survey was conducted to determine the percentage of Japanese children habitually exercising at the after-school sports club. They found that 34.7% of boys and 52.1% of girls did not exercise habitually.[7] However, this survey did not assess the relationship between daily exercise habits and muscle function, balance function, and gait quality. Also, physical activity guidelines in the US and UK recommend that children and adolescents engage in moderate to vigorous physical activity (MVPA) for at least 60 min per day, 5 days per week.[3,8] Japanese children who perform the recommended MVPA levels were reported to have significantly higher skeletal muscle mass index (SMI), balance function, and gait quality than those who perform substandard MVPA levels.[5] Thus, it is easy to expect that exercise habits with MVPA affect physical function.

Muscle function, balance function, and gait quality are physical functions. These abilities can be assessed using methods such as grip strength, an indicator of total muscle strength; gait quality, an indicator of gait ability; the standing broad jump (SBJ), an indicator of instantaneous lower limb muscular strength; SMI, an indicator of muscle mass; and one-leg standing time (OLST), an indicator of postural and balance control. Therefore, investigating the relationship between the presence or absence of daily exercise habits with MVPA and these physical functions may provide important information to confirm poor physical functions in children who do not have good exercise habits. Furthermore, no research has focused on children's exercise habits in Asia.

The nervous system development is complete at ages 9–12 years, referred to as the "golden age" of physical activity. This is an important period in physical function development. Moreover, many children in the higher elementary school grades participate in after-school sports club activities in Japan. Although some children had previously acquired exercise habits, we can assume that many acquire exercise habits through after-school sports club activities. It is important to evaluate physical activity, including walking and playing, between 9 and 12 years.

Furthermore, exercise habits focus on exercise, not walking or playing, with the criterion that they must have continued to exercise for at least 1 year. If it can be clarified whether physical function is affected by with or without exercise habits and the level of exercise/physical activity, it may be said that increasing exercise habits at a certain level of exercise/physical activity would help children's physical function development. We hypothesize that exercise habits with MVPA affect physical function. The primary study question examined the differences in physical function between children with and without exercise habits. The second study question examined differences in motor function between children with and without MVPA among children with exercise habits.

MATERIALS AND METHODS

Study population

A population-based study (Okazaki Child Medical Check-up for Physical Function) was performed between January 2018 and April 2021. Elementary school children aged 9–12 years from Okazaki City were selected to participate in the medical check-up study. The exclusion criteria were as follows: orthopedic, neurological, cardiovascular, auditory, respiratory, or ophthalmologic abnormalities that might affect the clinical measurement results; previously diagnosed developmental disabilities such as autism spectrum disorder and attention deficit hyperactivity disorder; Raven's Colored Progressive Matrices substandard score; and the Picture Vocabulary Test-Revised (Nihon Bunka Kagakusha Co, Ltd, Tokyo, Japan), which indicates intellectual disabilities. An orthopedic surgeon evaluated the malalignment by physical examination, although the malalignment was not diagnosed as an orthopedic disease. Participants who met one of the exclusion criteria were excluded. Twenty children were excluded, and 239 were enrolled.

This study was approved by the Ethics Committee of the Aichi Prefectural Mikawa Aoitori Medical and Rehabilitation Center for Developmental Disabilities (IRB approval number 29002). Written informed assent and consent were obtained from all participants and their parents before inclusion. This study complied with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Measurement of variables

Exercise habits. The participants answered a questionnaire about their exercise habits. The Ministry of Health, Labor, and Welfare defined exercise habits as "exercise for 30 minutes or more for at least 2 days a week, which has continued for 1 year or more"[7]. In addition, exercise duration excluded physical education duration at school. We divided the participants into two groups: children with and without exercise habits.

Skeletal muscle mass index. A multi-frequency bioelectrical impedance analyzer (MC-780; Tanita, Tokyo, Japan) was used to measure appendicular SMI. Following the instruction manual, measurements were performed in the appropriate posture. The participants stood with the front and back of the sole placed on the electrodes, grabbing the electrodes. The grasped electrodes brought the palms of both hands in contact with the thumbs. They then stood with their upper limbs extended and spread out to avoid skin contact. Measurements were performed by a well-trained physical therapist or research assistant and were completed within 15 s. SMI score was calculated as appendicular skeletal muscle mass divided by height squared. Multifrequency bioelectrical impedance analysis was used to determine the relationship between electrical resistance volume and the conductor. This analysis uses multiple frequencies to distinguish between extracellular and intracellular fluids to estimate whole-body water contact.[9] This device has been demonstrated to be non-invasive and valid. It is used to evaluate muscle development and muscle cross-sectional areas of children.[10] The SMI is necessary for assessing children's and adolescents' development.[11] As described in the instruction manuals, bioelectrical impedance analysis was performed 2 h after meals.

Moderate to vigorous physical activity. The Japanese version of the World Health Organization Health Behavior in School-Aged Children was used to assess MVPA levels.[12] Participants answered questions about their physical activity levels. The questionnaire is "Over the past 7 days, on how many days were you physically active for a total of at least 60 minutes per day?" Furthermore, this physical activity is any activity that increases your heart rate and makes you get out of breath some of the time[12]. In the questionnaire, those who performed 60 min of MVPA per day five times a week were considered to have the recommended MVPA level.[3,8]

Grip strength. An adjustable Smedley-type handheld dynamometer (GRIP-D; Takei Ltd, Niigata, Japan) was used to measure grip strength. The measured value represented the average grip strength of both hands.[5,13,14] The measurement was performed in the sitting position. The participants were instructed to set the shoulder joint abduction and elbow joint extension position and forearm and articulation manus in the neutral position.[15,16] Each measurement was conducted once. First, the dominant hand's grip strength was measured, followed by that of the non-dominant hand. The participants were instructed to hold the measuring part as hard as possible for 5 s. In addition, during the measurements, participants were provided verbal encouragement. Before the evaluation, a mock measurement was performed to encourage learning.[17]

Standing broad jump. The SBJ was measured while the subject was barefoot. Participants stood with their feet slightly apart, keeping them out of the starting line. We then instructed the subjects to jump with both feet simultaneously as far as possible.[18] The distance from the starting line to the landing point was measured. The landing point refers to the position of the heel closer to the starting line. The participants were informed that resting at the landing point was not necessary. The measurement was taken twice, and the longer distance was used as the measurement value. Participants waved their hands when taking off, allowing them to use recoil.[14] In addition, during the measurements, the participants were provided oral support.[17] SBJ represents instantaneous lower limb muscular strength.[19]

One-leg standing time. The OLST was used to assess the participants' static balance.[18] With their eyes open, the participants were instructed to put their hands on the hip and lift one leg off the floor. In addition, they were instructed to ensure the raised leg did not touch the other leg. The end condition was set as when the raised leg touched the floor, when it touched the stance side leg, or when the balance was maintained for 120 s. The measurement was performed twice. The longer time was used as the measured value, and the average value on the left and right was used.[5,20] This test is reliable in children.[21] Furthermore, OLST is suitable for assessing balance ability.[18] Balance function assessment is one of the most necessary in physical function tests.[5,18,22]

Gait deviation index. Gait deviation index (GDI) is an important indicator of overall gait pattern using numerical values. It was calculated using a three-dimensional gait analysis device.[23] For motion analysis, a three-dimensional motion analysis system manufactured by VICON (MX-T 20S; Vicon, Oxford, UK), a force plate (AMTI, Advanced Mechanical Technology, Inc, Watertown, MA, USA), eight optical, infrared cameras, two video cameras, and reflective markers were used. The plug-in-gait (December 2018 to March 2020) and conventional gait models 2.3 (June 2020 to April 2021) were used to measure gait by placing markers on the lower body.[24,25] The lower limb movement during gait was captured in three dimensions by taking pictures with an optical, infrared camera. In this method, the subjects were instructed to walk barefoot comfortably on a 6-meter auxiliary walkway and a 2-meter force plate. Each trial consisted of right and left walking cycles, and the average of the three cycles was used to calculate the value.[5,13] The GDI is that Schwartz et al developed a comprehensive index of gait pathology in 2008. This provides numerical values indicating overall gait pathology. The reference value is 100 points. Every 10-point decrease in the GDI corresponds to one standard deviation from the mean of healthy controls.[23] Recent studies have also established reference values in children aged 6–12 years in Japan.[26]

Sample size

We used G*Power (Heinrich Heine University Düsseldorf, Düsseldorf, Germany)[27,28] to determine the sample size required to perform a two-tailed Mann–Whitney U test. The statistical power of 0.8, alpha error of 0.05, allocation ratio of 0.43, and effect size of 0.5 were assumed. The required sample size was 160.[7]

Statistical analyses

The distribution normality for each variable was confirmed using the Shapiro–Wilk test. Demographic characteristics, grip strength, SBJ, OLST, and GDI scores were compared between the two groups. Sex was analyzed using the chi-squared test. Where appropriate, participant data were expressed as medians (range) or means (standard deviations) and were compared using the Mann–Whitney U test or independent t-test. In addition, logistic regression analysis was conducted with exercise habits as the dependent variable; SMI, grip strength, SBJ, OLST, and GDI as the independent variables; and sex as the adjusted variable. As a sub-analysis, the relationship between exercise habits and physical activity assessed by MVPA level was analyzed using the chi-squared test.

Further analysis was conducted to investigate how MVPA, in addition to exercise habits, affects physical function. The analysis was divided into three groups: a group that did not have exercise habits and did not perform the recommended MVPA levels, a group that had exercise habits but did not perform the recommended MVPA levels, and a group that had exercise habits and performed the recommended MVPA levels. Two subjects who did not fit into these groupings were excluded. Sex was analyzed using the chi-squared test. Where appropriate, participant data were expressed as medians (range) or means (standard deviations) and were compared using the Kruskal–Wallis test or one-way analysis of variance. In addition, items that showed significant differences were analyzed using Bonferroni's multiple comparison test. Significance was set at p-values <0.05. All statistical analyses were performed using IBM SPSS Statistics software (version 24.0; IBM Corp, Armonk, NY, USA).

RESULTS

Of the 239 children, 75.5% (n = 178) had exercise habits. Regarding the demographic characteristics, no significant differences were observed between the children with and without exercise habits (Table 1).

Table 1 Demographic characteristics

	Children with exercise habits (n=178)	Children without exercise habits (n=61)	p-value
Age (years)	11 (9 – 12)	11 (9 – 12)	0.73[a]
Height (m)	1.43 ± 0.09	1.43 ± 0.09	0.65[b]
Weight (kg)	32.8 (22.4 – 74.4)	34.3 (23.6 – 59.6)	0.86[a]
BMI (kg/m^2)	16.49 (12.91 – 28.95)	16.59 (12.32 – 29.60)	0.63[a]
Sex: boys/girls (n)	88/90	25/36	0.25[c]
Malalignment (yes/no)	29/149	8/53	0.55[c]

BMI: body mass index
Data are presented as means ± standard deviations or medians (ranges).
[a] using the Mann–Whitney U-test
[b] using the independent t-test
[c] using the chi-square test

Children without exercise habits had a lower SMI ($p < 0.01$) than those with exercise habits (Table 2). The item that showed a significant difference in physical function was SBJ ($p<0.01$). There were no significant differences in sex, grip strength, OLST, and GDI scores.

Table 2 SMI and physical function outcomes

	Children with exercise habits (n=178)	Children without exercise habits (n=61)	p-value
SMI (kg/m^2)	6.1 (4.44 – 8.48)	5.74 (4.92 – 8.29)	<0.01[a]
Grip strength (kg)	15.15 (7.20 – 33.00)	14.40 (8.85 – 26.50)	0.12[a]
SBJ (cm)	157 (110 – 207)	143 (118 – 195)	<0.01[a]
OLST (s)	120 (24.82 – 120)	120 (11.85 – 120)	0.07[a]
GDI (points)	95.93 ± 7.85	95.53 ± 7.01	0.73[b]

SMI: skeletal muscle mass index
SBJ: standing broad jump
OLST: one-leg standing time
GDI: gait deviation index
Data are presented as means ± standard deviations or medians (ranges).
[a] using the Mann–Whitney U test
[b] using the independent t-test

Logistic regression analysis showed that exercise habits were significantly associated with SMI and SBJ (SMI: OR, 1.84; 95% CI, 1.01–3.36 and $p<0.05$; SBJ: OR, 1.02; 95% CI, 1.00–1.04 and $p<0.05$). No significant associations were found with the other items (Table 3).

Table 3 Relationship between exercise habits and examination items

Variables	Odds ratio (95%CI)	p-value
Sex	0.90 (0.44 – 1.82)	0.76
SMI	1.84 (1.01 – 3.36)	<0.05
Grip strength	0.99 (0.90 – 1.08)	0.76
SBJ	1.02 (1.00 – 1.04)	<0.05
OLST	1.01 (1.00 – 1.02)	0.06
GDI	0.99 (0.95 – 1.03)	0.62

CI: confidence interval
SMI: skeletal muscle mass index
SBJ: standing broad jump
OLST: one-leg standing time
GDI: gait deviation index
Logistic regression analysis was conducted with exercise habit as the dependent variable; skeletal muscle mass index, grip strength, standing broad jump, one-legged stance time, and gait deviation index as the independent variables; and sex as the adjusted variable.

The sub-analysis showed a significant difference in physical activity levels between the exercise habit groups ($p<0.0001$, Table 4).

Table 4 Relationship between exercise habits and the recommended MVPA levels

Performing the recommended MVPA levels	Exercise habits		p-value
	Yes	No	
Yes (n=123)	121	2	<0.0001
No (n=116)	57	59	

MVPA: moderate to vigorous physical activity
The relationship between exercise habits and physical activity assessed by MVPA level was analyzed by chi-square test.

Of the 237 children, 51.1% (n = 121) had exercise habits and performed the recommended MVPA levels. Regarding the demographic characteristics, there was a significant difference in the malalignment ($p<0.01$, Table 5). The malalignment in the group that met both exercise habits and MVPA was 12 participants (flat foot (2), leg length difference (4), scoliosis (2), limited ankle range of motion (4)). The malalignment in the group that had exercise habits and did not meet MVPA was 17 participants (flat foot (3), leg length difference (6), scoliosis (3), limited ankle range of motion (2), knee hyperextension (2), hallux valgus (1)), and the malalignment in

Table 5 Demographic characteristics among the three groups

	Exercise habits (+), MVPA (+) (n=121)	Exercise habits (+), MVPA (–) (n=57)	Exercise habits (–), MVPA (–) (n=59)	p-value
Age (years)	11.17 (9.17 – 12.75)	11.33 (9.00 – 12.67)	11.75 (9.25 – 12.83)	0.89[a]
Height (m)	1.43 ± 0.09	1.42 ± 0.09	1.44 ± 0.09	0.87[b]
Weight (kg)	32.7 (22.9 – 61.9)	33.4 (22.4 – 74.4)	34.3 (23.6 – 59.6)	0.94[a]
BMI (kg/m^2)	16.48 (12.91 – 28.11)	16.67 (14.14 – 28.95)	16.59 (12.32 – 29.60)	0.75[a]
Sex (male/female)	62/59	26/31	23/36	0.30[c]
Malalignment (yes/no)	12/109[#]	17/40*	6/53	<0.01[c]

BMI: body mass index
MVPA: moderate to vigorous physical activity
Data are presented as means ± standard deviations or medians (ranges).
[a] using Kruskal-Wallis test
[b] using one-way analysis of variance
[c] using the chi-square test
Those who have exercise habits are represented by exercise habits (+), and those who do not have exercise habits are represented by exercise habits (–). Furthermore, those that meet the MVPA are represented by MVPA (+) and those that do not meet the MVPA are represented by MVPA (–).
#: $p<0.05$ vs exercise habits (+) MPVA (–) using Bonferroni's multiple comparison test.
*: $p<0.05$ vs exercise habits (–), MVPA (–) using Bonferroni's multiple comparison test.

the group that did not meet both exercise habits and MVPA was 6 participants (flat foot (2), leg length difference (2), limited ankle range of motion (1), knee hyperextension (1)). The rate of malalignment was significantly higher in the group with exercise habits and did not meet MVPA ($p<0.05$, Table 5).

Table 6 shows the relationship between SMI and physical function among the three groups. Significant differences in SMI and SBJ and OLST were found between the groups that met both exercise habits and MVPA and those that did not meet both (SMI: $p<0.01$, SBJ: $p<0.01$, OLST: $P<0.05$, Table 6). As for GDI, significant differences were shown in the groups that differed in whether the MVPA was met ($p<0.01$, Table 6). No significant differences were identified for SMI and SBJ, and OLST in the groups differed in whether the MVPA was met. Thus, in a sub-analysis between the three groups, the group meeting exercise habits and MVPA had significantly higher SMI, SBJ, and OLST results than the group that did not meet them.

Table 6 SMI and physical function outcomes among the three groups

	Exercise habits (+), MVPA (+) (n=121)	Exercise habits (+), MVPA (–) (n=57)	Exercise habits (–), MVPA (–) (n=59)	p-value
SMI (kg/m^2)	6.11 (4.44 – 8.22)*	6.01 (5.07 – 8.48)	5.74 (4.92 – 8.29)	<0.01[a]
Grip strength (kg)	15.15 (8.60 – 26.40)	15.05 (7.20 – 33.00)	14.40 (8.85 – 26.50)	0.33[a]
SBJ (cm)	159 (110 – 207)*	151 (110 – 205)	143 (118 – 195)	<0.01[a]
OLST (s)	120 (37 – 120)**	120 (24.82 – 120)	120 (11.85 – 120)	0.01[a]
GDI (points)	97.11 ± 7.07[#]	93.42 ± 7.62	95.62 ± 7.07	0.01[b]

MVPA: moderate to vigorous physical activity
SMI: skeletal muscle mass index
SBJ: standing broad jump
OLST: one-leg standing time
GDI: gait deviation index
Data are presented as means ± standard deviations or medians (ranges).
[a] using Kruskal-Wallis test
[b] using one-way analysis of variance
Those who have exercise habits are represented by exercise habits (+), and those who do not have exercise habits are represented by exercise habits (–). Furthermore, those that meet the MVPA are represented by MVPA (+) and those that do not meet the MVPA are represented by MVPA (–).
*: p<0.01 vs exercise habits (–), MVPA (–) using Bonferroni’s multiple comparison test.
**: p<0.05 vs exercise habits (–), MVPA (–) using Bonferroni’s multiple comparison test.
#: p<0.01 vs exercise habits (+) MPVA (–) using Bonferroni’s multiple comparison test.

DISCUSSION

This study showed that exercise habits were significantly related to SMI and SBJ. Children without exercise habits may have shorter SBJ and lower SMI than those with exercise habits. These findings suggest that children without exercise habits are likelier to have lower leg muscle strength and skeletal muscle mass than those with exercise habits.

In this study, 75.5 percent of the children had exercise habits. According to a previous study, the percentage of adults with exercise habits was 36%.[28] According to data from the Ministry of Health, Labor, and Welfare in Japan, 33.4% of adult men and 25.1% of adult women have exercise habits.[29] These results indicate that a higher percentage of children have exercise habits than adults. One of the factors contributing to this is the after-school club activities, which provide children with more opportunities to exercise than adults. The percentage of children without exercise habits was 24.5%. A previous study reported that 7.6% of boys and 13.0% of girls exercised <60 min per week.[30] We can infer that many children do not secure sufficient exercise habits. In addition, Matthijs et al reported that exercise habits acquired during childhood often continue into adulthood.[4] Therefore, poor exercise habits during childhood may lead to serious health problems in adulthood.

This study also showed that children with exercise habits had significantly higher skeletal muscle mass. A previous study reported that children with recommended MVPA levels had significantly higher skeletal muscle mass.[6] Inactive children may develop sarcopenia.[31] These findings indicate that it is important to have exercise habits from school-age onwards. Furthermore, low skeletal muscle mass is associated with the risk of reduced bone mass during childhood.[32] It has also been reported that low skeletal muscle mass is a risk factor for future metabolic syndrome in 8–20-year olds.[33] These findings suggest that habitual exercise significantly contributes to skeletal muscle development, reducing the risk of fractures and obesity.

We found a significant relationship between exercise habits and SBJ results, suggesting that children with higher lower leg muscle strength engage in more exercise habits. SBJ is an index for evaluating the lower limbs' instantaneous muscle strength.[19] Grip strength and SBJ have been reported to be correlated.[34] Nevertheless, in this study, no significant association was found for grip strength, which assesses overall muscle strength in children.[35] There are two possible explanations for this observation. First, previous studies have reported no relationship between physical activity time and grip strength[36] because lower limb muscle strength is more likely to develop than overall muscle strength. Accordingly, exercise habits were related to lower limb muscle strength, and habitual exercise may develop the instantaneous lower leg muscle strength required for SBJ. Second, there was no detailed information on sports types in after-school club activities. Therefore, it is possible that many participants engaged in sports activities that used the lower extremity muscles more often than the upper. No significant relationship was observed between exercise habits and OLST or GDI. Children performing the recommended MVPA level[3,8] have been reported to have significantly better OLST and GDI.[5] A large study by Venckunas et al reported that children and adolescents are likelier to lose lower-limb muscle strength than balance ability as physical fitness declines.[37] These results suggest that motor function decline in children without exercise habits may be more pronounced in school-age children, especially in lower-limb muscle strength, than in balance function and gait quality.

The chi-square test results for exercise habits and MVPA indicated that most children performing substandard MVPA levels did not have good exercise habits. Physical activity guidelines in the US and UK recommend that children and adolescents engage in MVPA for at least 60 min per day, 5 days per week.[3,8] Previous studies have also reported children and adolescents' MVPA levels in Japan.[38,39] Although few studies have compared actual physical function measurements, children who perform the recommended MVPA levels were reported to have significantly higher SMI, balance function, and gait quality than those who perform substandard MVPA levels.[5] Previous studies' results that 24.7% of the children did not perform the recommended MVPA level and did not exercise suggests that securing exercise time is a major issue. To solve this problem, we suggest that children like them first establish good exercise habits.

According to the results of the three-group comparison, significant differences in SMI and SBJ and OLST were found only between the groups that met both exercise habits and MVPA and those that did not meet both. Habitual exercise contributes to increased muscle strength and positively affects physical function.[1,2] Based on the results of previous studies and this study, we conclude that exercise habits with MVPA are preferred, but at least exercise habits may increase SMI and instantaneous lower limb muscular strength. Although, exercise habits with MVPA are necessary to improve balance ability.

As for GDI, the group with exercise habits and MVPA not met had lower GDI than the group meeting both exercise habits and MVPA. The reason may be that more children in the group with exercise habits and MVPA not met were determined to have a flat foot, scoliosis, and leg length difference. These have been reported to affect gait.[40] Therefore, we consider that these factors may have influenced the GDI in this study. However, we could not determine the reason for the high percentage of children in this group who were determined to have a flat foot, scoliosis, and leg length difference. In the future, we will increase the sample size so that the study can be conducted in more detail.

The results of the 2- and 3-group comparisons suggest that having exercise habits is important, as is meeting the MVPA. For children who do not have exercise habits and do not meet the MVPA, we recommend that they develop exercise habits that meet the MVPA.

This study has several limitations. First, this study focused on two elementary schools within Okazaki City; therefore, generalizability is limited. Second, because the questionnaire used in this study was subjective, it may not properly discriminate against exercise habits. Third, bioelectrical impedance analysis is not always the best way to assess body composition because it depends on the subjects' hydration status. This was a cross-sectional study, and the causal relationship is unclear. A longitudinal study is required to clarify these issues.

CONCLUSION

Children without exercise habits had decreased values for SMI and SBJ compared with children with exercise habits. These results indicate that exercise for at least 30 min per day, 2 days per week, for at least 1 year is important for skeletal muscle mass and lower leg muscle strength development in school-aged children.

Furthermore, the group meeting exercise habits and MVPA had significantly higher SMI, SBJ, and OLST results than the group that did not meet them. Therefore, we conclude that exercise habits with MVPA are preferred, but at least exercise habits may increase SMI and instantaneous lower limb muscular strength. Although, exercise habits with MVPA are necessary to improve balance ability.

ACKNOWLEDGMENTS

We want to thank the Okazaki City Board of Education, Okazaki City Medical Association, Aichi Pediatrics Medical Society, Neishi Primary School, Umezono Primary School, Aichi Prefectural Mikawa Aoitori Medical and Rehabilitation Center for Developmental Disabilities staff, and Nagoya University staff for their help in recruiting participants. We would like to thank Editage (www.editage.com) for English language editing.

DECLARATION OF CONFLICTING INTERESTS

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

1 Landry BW, Driscoll SW. Physical activity in children and adolescents. *PM R*. 2012;4(11):826–832. doi:10.1016/j.pmrj.2012.09.585.

2 Janssen I, Leblanc AG. Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7:40. doi:10.1186/1479-5868-7-40.

3 United States, United States Department of Health and Human Services. *Physical Activity Guidelines Advisory Committee scientific report: to the Secretary of Health and Human.* Washington, DC: Department of Health and Human Services; 2018.

4 van der Zee MD, van der Mee D, Bartels M, de Geus EJC. Tracking of voluntary exercise behaviour over the lifespan. *Int J Behav Nutr Phys Act.* 2019;16(1):17. doi:10.1186/s12966-019-0779-4.

5 Ito T, Sugiura H, Ito Y, Noritake K, Ochi N. Relationship between the skeletal muscle mass index and physical activity of Japanese children: A cross-sectional, observational study. *PLoS One.* 2021;16(5):e0251025. doi:10.1371/journal.pone.0251025.

6 Wenger HA, Bell GJ. The interactions of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. *Sports Med.* 1986;3(5):346–356. doi:10.2165/00007256-198603050-00004.

7 Japan Sports Agency. National survey on physical fitness and motor ability and exercise habits. https://www.mext.go.jp/sports/b_menu/toukei/kodomo/zencyo/1411922_00003.html. Published December 2021. Accessed January 10, 2022.

8 Department of Health and Social Care. Physical activity guidelines: UK Chief Medical Officers' Report. https://www.gov.uk/government/publications/physical-activity-guidelines-uk-chief-medical-officers-report#history. Published September 7, 2019. Accessed January 10, 2022.

9 Kyle UG, Bosaeus I, De Lorenzo AD, et al. Bioelectrical impedance analysis--part I: review of principles and methods. *Clin Nutr.* 2004;23(5):1226–1243. doi:10.1016/j.clnu.2004.06.004.

10 McCarthy HD, Samani-Radia D, Jebb SA, Prentice AM. Skeletal muscle mass reference curves for children and adolescents. *Pediatr Obes.* 2014;9(4):249–259. doi:10.1111/j.2047-6310.2013.00168.x.

11 Liu J, Yan Y, Xi B, Huang G, Mi J; China Child and Adolescent Cardiovascular Health (CCACH) Study Group. Skeletal muscle reference for Chinese children and adolescents. *J Cachexia Sarcopenia Muscle.* 2019;10(1):155–164. doi:10.1002/jcsm.12361.

12 Tanaka C, Kyan A, Takakura M, Olds T, Schranz N, Tanaka S. Validation of the Physical Activity Questions in the World Health Organization Health Behavior in School-Aged Children Survey Using Accelerometer Data in Japanese Children and Adolescents. *J Phys Act Health.* 2021;18(2):151–156. doi:10.1123/jpah.2019-0671.

13 Gu Y, Ito T, Ito Y, et al. Factors Related to Locomotive Syndrome in School-Aged Children in Okazaki: A Cross-Sectional Study. *Healthcare (Basel).* 2021;9(11):1595. doi:10.3390/healthcare9111595.

14 Gu Y, Ito T, Ito Y, et al. Physical Activity Related to Body Muscle Mass Index and Stiffness Index in 7-to-10-Year-Old Girls. *Healthcare (Basel).* 2022;10(2):197. doi:10.3390/healthcare10020197.

15 Balogun JA, Akomolafe CT, Amusa LO. Grip strength: effects of testing posture and elbow position. *Arch Phys Med Rehabil.* 1991;72(5):280–283.

16 Bobos P, Nazari G, Lu Z, MacDermid JC. Measurement Properties of the Hand Grip Strength Assessment: A Systematic Review With Meta-analysis. *Arch Phys Med Rehabil.* 2020;101(3):553–565. doi:10.1016/j.apmr.2019.10.183.

17 Ortega FB, Artero EG, Ruiz JR, et al. Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. *Int J Obes (Lond).* 2008;32(Suppl 5):S49-S57. doi:10.1038/ijo.2008.183.

18 Ortega FB, Cadenas-Sánchez C, Sánchez-Delgado G, et al. Systematic review and proposal of a field-based physical fitness-test battery in preschool children: the PREFIT battery. *Sports Med.* 2015;45(4):533–555. doi:10.1007/s40279-014-0281-8.

19 Castro-Piñero J, Ortega FB, Artero EG, et al. Assessing muscular strength in youth: usefulness of standing long jump as a general index of muscular fitness. *J Strength Cond Res.* 2010;24(7):1810–1817. doi:10.1519/JSC.0b013e3181ddb03d.

20 Matsunaga N, Ito T, Ito Y, et al. Decreased Balance Function in School-Aged Children with Behavioral Problems. *Brain Sci.* 2022;12(1):117. doi:10.3390/brainsci12010117.

21 Condon C, Cremin K. Static balance norms in children. *Physiother Res Int.* 2014;19(1):1–7. doi:10.1002/pri.1549.

22 Zumbrunn T, MacWilliams BA, Johnson BA. Evaluation of a single leg stance balance test in children. *Gait Posture.* 2011;34(2):174–177. doi:10.1016/j.gaitpost.2011.04.005.

23 Schwartz MH, Rozumalski A. The Gait Deviation Index: a new comprehensive index of gait pathology.

Gait Posture. 2008;28(3):351–357. doi:10.1016/j.gaitpost.2008.05.001.
24 Ito T, Sugiura H, Ito Y, Noritake K, Ochi N. Effect of the COVID-19 Emergency on Physical Function among School-Aged Children. *Int J Environ Res Public Health.* 2021;18(18):9620. doi:10.3390/ijerph18189620.
25 Ito Y, Ito T, Sugiura H, et al. Physical functions and gait performance in school-aged children born late preterm. *Early Hum Dev.* 2021;163:105478. doi:10.1016/j.earlhumdev.2021.105478.
26 Ito T, Noritake K, Ito Y, et al. Three-dimensional gait analysis of lower extremity gait parameters in Japanese children aged 6 to 12 years. *Sci Rep.* 2022;12(1):7822. doi:10.1038/s41598-022-11906-1.
27 Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods.* 2007;39(2):175–191. doi:10.3758/bf03193146.
28 Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods.* 2009;41(4):1149–1160. doi:10.3758/BRM.41.4.1149.
29 Ministry of Health, Labour and welfare. Summary of National Health and Nutrition Survey. https://www.mhlw.go.jp/content/10900000/000687163.pdf. Published October 2020. Accessed January 10, 2022.
30 Japan Sports Agency. Chapter one Outline of survey. https://www.mext.go.jp/sports/content/20191225-spt_sseisaku02-000003330_4.pdf. Published December 2019. Accessed January 10, 2022.
31 Kim K, Hong S, Kim EY. Reference Values of Skeletal Muscle Mass for Korean Children and Adolescents Using Data from the Korean National Health and Nutrition Examination Survey 2009–2011. *PLoS One.* 2016;11(4):e0153383. doi:10.1371/journal.pone.0153383.
32 Orsso CE, Tibaes JRB, Oliveira CLP, et al. Low muscle mass and strength in pediatrics patients: Why should we care? *Clin Nutr.* 2019;38(5):2002–2015. doi:10.1016/j.clnu.2019.04.012.
33 So R, Matsuo T. The Effect of Domain-Specific Sitting Time and Exercise Habits on Metabolic Syndrome in Japanese Workers: A Cross-Sectional Study. *Int J Environ Res Public Health.* 2020;17(11):3883. doi:10.3390/ijerph17113883.
34 Milliken LA, Faigenbaum AD, Loud RL, Westcott WL. Correlates of upper and lower body muscular strength in children. *J Strength Cond Res.* 2008;22(4):1339–1346. doi:10.1519/JSC.0b013e31817393b1.
35 Wind AE, Takken T, Helders PJ, Engelbert RH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? *Eur J Pediatr.* 2010;169(3):281–287. doi:10.1007/s00431-009-1010-4.
36 Fang H, Quan M, Zhou T, et al. Relationship between Physical Activity and Physical Fitness in Preschool Children: A Cross-Sectional Study. *Biomed Res Int.* 2017;2017:9314026. doi:10.1155/2017/9314026.
37 Venckunas T, Emeljanovas A, Mieziene B, Volbekiene V. Secular trends in physical fitness and body size in Lithuanian children and adolescents between 1992 and 2012. *J Epidemiol Community Health.* 2017;71(2):181–187. doi:10.1136/jech-2016-207307.
38 Yamakita M, Sato M, Suzuki K, Ando D, Yamagata Z. Sex Differences in Birth Weight and Physical Activity in Japanese Schoolchildren. *J Epidemiol.* 2018;28(7):331–335. doi:10.2188/jea.JE20170078.
39 Abe T, Kitayuguchi J, Okada S, et al. Prevalence and Correlates of Physical Activity Among Children and Adolescents: A Cross-Sectional Population-Based Study of a Rural City in Japan. *J Epidemiol.* 2020;30(9):404–411. doi:10.2188/jea.JE20190047.
40 Papageorgiou E, Nieuwenhuys A, Vandekerckhove I, Van Campenhout A, Ortibus E, Desloovere K. Systematic review on gait classifications in children with cerebral palsy: An update. *Gait Posture.* 2019;69:209–223. doi:10.1016/j.gaitpost.2019.01.038.