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Possible determinants of physical fitness in Japanese school children: A cross-sectional study

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Abstract

Background: Physical fitness is one of the most important health indicators in children. Although appropriate body composition or certain lifestyle factors such as frequent physical activity are thought to improve physical fitness, results of previous studies are inconsistent, and most studies were from Western countries.**Objectives:** We investigated associations of body composition and modifiable lifestyle factors such as physical activity, screen time, diet and sleep duration with physical fitness in Japanese primary school children.**Methods:** 2308 children (age 10–12 years old) in 12 primary schools were analysed in this cross-sectional study. Physical fitness was evaluated by sports battery tests conducted routinely and annually at schools. The total score of sports battery tests, 20-m shuttle run (laps) and grip strength (kg) were selected as outcomes. Information about lifestyle factors was collected by two questionnaires. Associations between lifestyle factors and physical fitness were assessed by multivariable linear mixed models by sex.**Results:** Frequent exercise was related to better overall physical fitness. Regarding the 20-m shuttle run, many unfavourable lifestyle factors such as higher BMI in boys (β -7.37, 95% confidence interval [CI] -8.39, -6.35) and girls (β -3.54, 95% CI -4.50, -2.58), longer screen time (β -4.31, 95% CI -7.29, -1.34) in boys and girls (β -5.65, 95% CI -9.01, -2.30); shortest (reference) versus longest, breakfast skipping in boys (β -5.24, 95% CI -8.71, -1.77) and girls (β -3.57, 95% CI -6.84, -0.30); consumers (reference) versus skippers were associated with worse performance. Better quality of diet was associated with better results in the 20-m shuttle run only in girls (β 2.58, 95% CI 0.24, 4.93); lowest (reference) versus highest.**Conclusions:** Frequent exercise was related to better physical fitness. Higher BMI and unfavourable lifestyle factors such as longer screen time and breakfast skipping were associated with worse results of the 20-m shuttle run.

KEYWORDS

body composition, Japan, physical activity, physical fitness, primary school children

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1 | BACKGROUND

Physical fitness is defined as a set of attributes related to a person's ability to perform physical activities.¹ It is known to be a good indicator of various body functions, such as those of the cardiorespiratory, skeletomuscular, haematocirculatory, psychoneurological and endocrine-metabolic systems,² and also an important health marker based on its ability to predict all-cause and cardiovascular morbidity and mortality.²⁻⁶

Physical fitness is regarded as an important health indicator even in children because the onset of cardiovascular disease lies in early childhood, even though the clinical symptoms do not become apparent until much later.⁷ Since physical fitness is often maintained from childhood into adolescence or adulthood,⁸⁻¹⁰ developing better physical fitness in childhood is preferable.

Unfortunately, previous studies have shown declining secular trends in children's physical fitness levels in various countries,¹¹⁻¹³ including Japan.¹⁴ The motor fitness of Japanese elementary school children had improved until around 1985. But after that, it had gradually declined, especially in their ability to run, jump and throw.^{15,16} In addition to the declining trends in physical fitness, a recent report on lifestyle factors of Japanese children showed that they had unfavourable length of recreational screen time and short sleep duration.¹⁷ It is therefore meaningful to understand the current status of children's physical fitness and to explore determinants of favourable physical fitness. Although such studies have been reported in Western countries,¹⁸⁻²⁰ however, only a few reports have appeared from Japan,^{16,21} an Asian country with a different racial background and lifestyle from Western countries.

Here, we investigated associations of body composition and modifiable lifestyle factors such as physical activity, screentime, diet, breakfast skipping and sleep with physical fitness in Japanese primary school children.

2 | METHODS

2.1 | Participants and study outline

The survey was conducted in May 2018 at 12 public primary schools in the prefecture of the northern Kanto region, located in the central part of the main island of Japan. Seven cities and towns were selected from each of the five administrative districts of the prefecture based on survey feasibility. Although the schools were not randomly selected, many characteristics, such as location or number of children in a school, were taken into consideration. Namely, two public primary schools with similar characteristics (e.g. number of enrolled children, location (urban/rural)) were then selected from each city/town by the municipal boards of education. These 12 primary schools enrolled 2308 children as 5th and 6th graders (10-12 years old) in April 2018, all of whom were recruited into the survey. At the same time, all of their guardians, most of whom were the main preparers of meals for the children,

Synopsis

Study question

Which modifiable lifestyle factors, such as physical activity or diet, are associated with physical fitness in Japanese school children?

What is already known

Physical fitness is one of the most important health indicators, even among children. Body composition and exercise habits are known as its determinants, but most previous studies were from Western countries. The influence of other lifestyle factors on physical fitness is inconsistent.

What the study adds

Frequent exercise habits were associated with better physical fitness. Regarding the 20-m shuttle run, higher BMI z-score, longer screen time, breakfast skipping and longer sleep duration were associated with worse results. Better diet quality was associated with better results in girls.

were recruited. In this survey, no exclusion criteria were set for recruitment because all children attending public schools in Japan are required to be educated equally.

2.2 | Outcomes: Physical fitness

Physical fitness was assessed by a sports battery test carried out in each primary school. In Japan, most primary and junior high schools conduct this type of test every year by experienced teachers, in accordance with Ministry of Education, Culture, Sports, Science and Technology guidelines.²² It consists of eight test items (20-m shuttle run, handgrip strength, sit-ups, sit-and-reach flexibility, standing long jump, ball throwing, side-to-side jump and 50-m sprint). Each is assigned a score from 0 to 10 according to sex-specific standards in the guideline. The total score is calculated by summing the results of the eight items, giving a total score range from 0 to 80.²² Besides the total score, we selected the 20-m shuttle run (laps) and hand grip strength (kg) for detailed analysis as indicators of different types of physical fitness, because both of which have been reported to be associated with a number of health outcomes in the past.¹⁻⁷ The 20-m shuttle run reflects cardiorespiratory fitness while handgrip strength reflects muscular strength.^{6,23,24} In the field-based 20-m shuttle run, participants are required to run back and forth between two parallel lines 20m apart at a running pace maintained by an audio signal.^{23,25} The audio signal starts at 8.5 km/h and increases by 0.5 km/h every

consecutive minute. Participants continued until they are no longer able to keep pace with the audio signal for two consecutive laps, at which point their score is recorded.²⁵ Previous studies have shown that children with high cardiorespiratory fitness had lower total and abdominal adiposity, and healthier lipid profiles.^{26,27} Handgrip strength tests upper-limb isometric strength, measured using a Smedley Hand Dynamometer. Grip strength of the right and left hands is measured alternately twice. The better result for each hand is recorded, and the average is recorded as grip strength.²² High muscular fitness has also been related with good skeletal health and healthier lipid profiles.² Better (larger) total scores, more laps in the 20-m shuttle run, and greater hand grip strength in kilograms indicate better results.

2.3 | Exposures

2.3.1 | Questionnaires and variables

Children were surveyed using two questionnaires, a lifestyle questionnaire that asked about basic characteristics and lifestyle factors and a brief-type self-administered diet history questionnaire (BDHQ15y) of dietary intake. The children responded to the lifestyle questionnaire at school by themselves and to the BDHQ15y at home with their guardians.

The lifestyle questionnaire asked about exercise habits, screen time, breakfast skipping and sleep duration on weekdays. Exercise habits were defined by the response to a question about the number of days with exercise of more than 60 min per week and divided into 4 categories, (1) 0 day/week (w), (2) 1–2 days/w, (3) 3–4 days/w and (4) 5–7 days/w. Screentime was the sum of TV time and videogame playing time, determined by 'How many hours a day do you watch TV on school days?' and 'How many hours a day do you play videogames on school days?'. Answer choices were (1) never, (2) <30 min, (3) 30 min–1 h, (4) 1–2 h, (5) 2–3 h and (6) ≥3 h. Answers for each choice were counted as (1) for 0 min, (2) for 15 min, (3) for 45 min, (4) for 1.5 h, (5) for 2.5 h and (6) for 3 h. These were then summed. Screentime was categorised with a boundary at 2 h based on the fact that many national guidelines recommended that school aged children limit recreational screen time to <2 h per day.^{28,29} Breakfast intake was categorised as breakfast consumers or skippers based on whether they habitually skipped breakfast. Sleep duration was defined as hours between bedtime and wake-up time on weekdays.

The nutrient and food intake of children was assessed using the BDHQ15y, a four-page fixed-portion questionnaire that asks about the consumption of selected foods commonly consumed in Japan, general dietary behaviour and usual cooking methods to estimate the dietary intake of foods and beverage items during the preceding month.^{30–33} Estimates of daily intake for foods, energy and selected nutrients were calculated using an ad hoc computer algorithm for the BDHQ15y based on the Standard Tables of Food Composition in Japan.³⁴ Added sugar intake was estimated using a newly developed food composition database.^{33,35} The BDHQ15y

has been appropriately validated and used in several epidemiologic studies.^{32,36}

Overall diet quality was assessed using the Nutrient-Rich Food Index 9.3 (NRF9.3) score,³⁷ a validated composite measure of the nutrient density of the total diet. It is calculated as [the sum of the percentage of intakes of nine qualifying nutrients (protein, dietary fibre, vitamins A, C and D, calcium, iron, potassium and magnesium) relative to the reference daily intakes] minus [the sum of the percentage of intakes of three adverse nutrients (added sugar, saturated fat and sodium) relative to the reference daily intakes].^{37,38} A more precise method for calculating NRF9.3 has been described elsewhere.^{37–40} Age- and sex-specific reference daily values were determined based on the Dietary Reference Intakes for Japanese (2020), except for added sugar.⁴¹ For six nutrients (protein, vitamins A and C, calcium, iron and magnesium), the recommended daily allowances were used as the reference daily values. For vitamin D, adequate intake was used. For dietary fibre, potassium, saturated fat and sodium, the tentative dietary goal for lifestyle-related disease was used. For added sugar, the conditional recommendation of the World Health Organization (WHO) (i.e. upper limit of 5% of energy) was used since there is no recommended maximum or minimum value for added sugar in Japan.^{38,42} A higher NRF9.3 score indicates a better quality of overall diet. Maximum possible score is 900.

2.3.2 | Body measurements

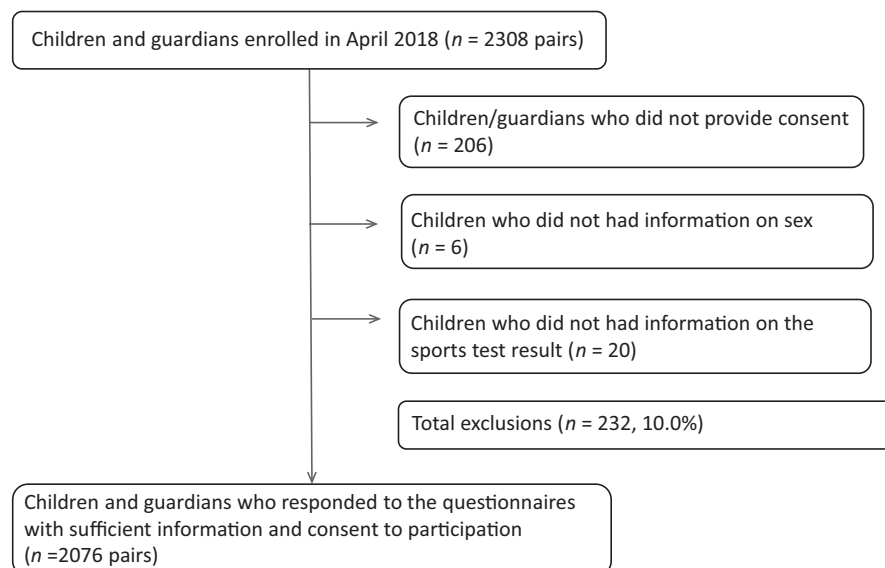
Body height and weight were measured by school nurses as part of a routine health check-up at each school in April to June, 2018. Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively, with the child wearing light clothing without shoes. Body Mass Index (BMI) z-score was calculated based on height, weight, and age in days based on the Japanese reference.^{43,44} BMI z-score was calculated because BMI must be interpreted relative to age and sex in paediatric populations.⁴⁵ We regarded BMI z-score as a lifestyle factor because it is a surrogate indicator of balance between energy intake and expenditure.

2.4 | Statistical analysis

Twelve primary schools provided measured height/weight data and the results of sports battery testing. These 12 schools enrolled 2308 children as 5th and 6th graders in April 2018. Among these, child/guardian pairs who did not provide consent or did not have information on sex or the sports battery test results were excluded (Figure 1). Finally, 2076 child and guardian pairs were included in the analysis (participation rate: 2076/2308 * 100 = 90.0%).

All analyses were performed by sex because the standards for the sports battery tests were sex-specific.

The associations of body composition as well as selected lifestyle factors with physical fitness were investigated using multivariable linear mixed models. In the models, physical fitness (total score,

**FIGURE 1** Flow chart describing participant selection for analysis.

20-m shuttle run and handgrip strength) was treated as outcomes, and age, body composition and lifestyle factors were treated as exposures. All exposures were added to the model simultaneously. A random effect was survey area (six cities/towns). When categories of a variable were in order, trends of association were also examined using the same models which assigned scores to the level of the independent variable.

Further, the association of intakes of nutrients related to the NRF9.3 as well as selected food groups with 20-m shuttle run was analysed by multivariable linear mixed models adjusted by the same set of covariates in the main analysis excluding NRF9.3. This is because the results of the multivariable analysis for the association between NRF9.3 and 20-m shuttle run differed by sex. Selected food groups were frequently and abundantly consumed in the analysed children and accounted for the major source of the nutrients included in the calculation of NRF9.3 (see [Table S1](#)). Nutrient or food group intakes were adjusted by the density method, and divided into tertiles (low, middle and high intakes).

All analyses were performed using STATA version 15.1 (Texas, USA).

2.4.1 | Missing data

Of the 2102 participants who consented to the study, six did not have information on sex and 20 did not have sports test results (9 boys and 11 girls). Multiple imputations were not made for these variables, because sex was necessary for stratification and the sports test results were primary outcomes. Multiple imputation was performed to impute missing data of exposures. The variables with missing data were as below [name of the variable: number in boys (%), in girls (%); [age: 15 (1.5%), 9 (0.9%)], [BMI z-score: 15 (1.5%), 9 (0.9%)], [exercise habits: 35 (3.4%), 38 (3.6%)], [screentime: 35 (3.4%), 32 (3.1%)], [NRF 9.3: 15 (1.5%), 9 (0.9%)], [breakfast skipping: 35 (3.4%), 29 (2.8%)], [sleep duration: 36 (3.5%), 32 (3.1%)] ([Table 1](#)). We

used the Multiple Imputation method in STATA with 50 iterations to impute missing values.

2.5 | Ethics approval

This survey was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures involving survey participants were approved by the Ethics Committee of the Faculty of Medicine, Toho University (approval of revised version: no. A23088_A_22001_ A19003_A17043 on December 7, 2023, first approval: no. A17043 on Sep, 6, 2017). Written informed consent for the children was obtained from their guardians. For the guardians themselves, completion and return of the questionnaires were not mandatory, and those who did so after detailed explanation of the study were deemed to have consented.

3 | RESULTS

Participant characteristics are shown in [Table 1](#). The proportion of children with frequent exercise habits was greater in boys. Screentime was shorter in girls. The sports battery test is summarised in [Table 2](#).

The associations of physical fitness with body composition or lifestyle factors are shown in [Table 3](#). Frequent exercise habits were associated with better score for all three items in both sexes. Higher BMI z-score was associated with worse total score in boys and worse 20-m shuttle run in both sexes. For handgrip strength, higher BMI z-score was associated with better results in both sexes. Longer screentime was associated with worse 20-m shuttle run. Higher NRF9.3 score was associated with better 20-m shuttle run in girls. Breakfast skipping was associated with worse 20-m shuttle run and hand grip strength. Longer sleep duration was associated with worse 20-m shuttle run.

Variable	Unit	Category	n (%) or mean, SD			
			Boys (n = 1030)		Girls (n = 1046)	
Age	(year)		11.1	0.6	11.1	0.6
		Missing ^a	15	(1.5)	9	(0.9)
Grade		5th Grader	511	(49.6)	524	(50.1)
		6th Grader	519	(50.4)	522	(49.9)
Height	(cm)		142.1	7.3	143.4	7.5
Weight	(kg)		36.4	8.3	36.6	8.2
BMI			17.9	3.0	17.6	2.7
BMI z-score ^b		Low [<-1.5]	93	(9.0)	94	(9.0)
		Medium [≥-1.5 to <1.5]	856	(83.1)	891	(85.1)
		High [≥1.5]	66	(6.4)	52	(5.0)
		Missing	15	(1.5)	9	(0.9)
Exercise habits ^c	(days/week)	0	71	(6.9)	120	(11.5)
		1–2	334	(32.4)	417	(39.8)
		3–4	306	(29.7)	276	(26.4)
		5–7	284	(27.5)	195	(18.6)
		Missing	35	(3.4)	38	(3.6)
Screentime ^d	(h/day)	<2	373	(36.7)	546	(52.2)
		2 to <4	395	(38.9)	366	(34.9)
		≥4	227	(22.4)	102	(9.8)
		Missing	35	(3.4)	32	(3.1)
NRF9.3 ^e		Low	575	97	534	101
		Medium	718	25	675	23
		High	807	33	761	34
		Missing	15	(1.5)	9	(0.9)
Breakfast skipping		Consumers	885	(85.9)	921	(88.0)
		Skippers	110	(10.7)	96	(9.2)
		Missing	35	(3.4)	29	(2.8)
Sleep duration on weekdays	(h/day)		8.5	0.8	8.5	0.8
		Missing	36	(3.5)	32	(3.1)

Note: Based on original non-imputed data.

Abbreviations: BMI, body mass index; NRF9.3, Nutrient Rich Food Index 9.3; SD, standard deviation.

^aFor missing values, the percentage of missing values is shown in parentheses.

^bBMI z-score is a BMI standard deviation score calculated based on age, sex, and BMI using Japanese reference data.

^cExercise habits is a number of days doing exercise over 60 min during a week.

^dScreentime is the sum of TV time and videogame playing time.

^eNRF 9.3 is a diet quality score calculated as the sum of the percentage of reference daily values (RDVs) for nine qualifying nutrients (protein, dietary fibre, vitamin A, vitamin C, vitamin D, calcium, iron, potassium, and magnesium) minus the sum of the percentage of RDVs for three disqualifying nutrients (added sugar, saturated fats, and sodium). Highest NRF9.3 score is 900 and the diet with better NRF9.3 scores means better diet quality. The distribution of NRF score in tertiles by sex was as follows: Boy-low 83–672, Boy-Medium 672–760, Boy-High 760–900; Girl-Low 14–634, Girl-Medium 635–715, Girl-High 715–862.

The association between selected nutrient or food intakes and 20-m shuttle is shown in Table S1. Regarding nutrients, higher intake of added sugar was related with worse 20-m shuttle run in girls.

As for food groups, higher intake of confectionaries was associated with worse 20-m shuttle run in girls, whereas higher intake of sweetened beverages was associated with better 20-m shuttle run in boys.

TABLE 1 Characteristics of participating children (n = 2076).

TABLE 2 Results of sports battery tests in the children by sex ($n=2076$).

Event	Unit	Boys ($n=1030$)		Girls ($n=1046$)	
		Mean, SD		Mean, SD	
Total score ^a	Point	59.8	10.0	61.4	9.2
20-m shuttle run	Lap	59.8	21.6	49.5	17.6
Handgrip strength	kg	18.7	4.5	18.1	4.4
Sit-ups	Time	22.9	6.0	21.4	5.6
Sit-and-reach flexibility	cm	37.7	8.9	41.5	9.1
Standing long jump	cm	160.2	22.0	152.2	21.2
Ball throwing	m	23.4	8.6	15.6	5.6
Side-to-side jump	point	45.7	7.4	43.8	6.8
50-m sprint	second	9.0	1.0	9.3	0.9

Note: Based on original non-imputed data.

Abbreviation: SD, standard deviation.

^aTotal score is calculated by summing the results for 8 items in the sports battery test. The results of these 8 items are assigned on score from 0 to 10 according to the sex-specific standards defined by the Japanese government. Possible total scores range from 0 to 80.

4 | COMMENT

4.1 | Principal findings

Frequent exercise was consistently related to better physical fitness in Japanese primary school children. Higher BMI z-score was related to worse results for the 20-m shuttle run, but higher BMI z-score was related to better results for grip strength. Unfavourable lifestyle factors such as longer screen time and breakfast skipping were associated with worse results of the 20-m shuttle run. Lower diet quality was related to better results of the 20-m shuttle run only in girls. To our knowledge, this is the first study to investigate the effects of multiple lifestyle factors on physical fitness in Japanese children.

4.2 | Strengths of the study

Our study has several strengths. First, various components of physical fitness were measured quantitatively in all schools in a uniform manner. Second, comprehensive information on various aspects of lifestyle such as exercise, diet, or sleep was investigated. Third, the children were considered highly representative of the region because they were recruited from multiple public primary schools in all five administrative districts in the surveyed prefecture. Fourth, nutrient intakes were assessed quantitatively by the BDHQ15y, which has been well validated.^{30–33} Overall diet quality was also measured using NRF9.3 score,^{37,39} which has been widely used in epidemiological studies.^{46,47}

4.3 | Limitations of the data

Several limitations should be addressed. First, the study was conducted in a single prefecture in Japan, and the generalizability of the

results should be carefully considered. However, average scores of physical fitness in the analysed population were approximately equal to those in a national survey of the same year.^{15,22} Second, lifestyle factors such as exercise habits were collected by self-administered questionnaire and were not objectively measured. Although children often overestimate their physical activity, correlations between the subjective estimations of physical activity by children and direct measures (e.g. accelerometry or heart rate monitoring) have been moderate.⁴⁸ Thus, the direction of the relationship can be interpreted as observed. Third, since our study was cross-sectional, a causal relationship cannot be discussed; for example, the possibility that children with good cardiopulmonary function are more likely to be physically active cannot be ruled out.

4.4 | Interpretation

Among the lifestyle factors surveyed, frequent exercise habits were related to better physical fitness for all three items in both sexes. The favourable effects of regular physical activities on physical fitness have been noted.^{2,26,49,50} Ortega et al. reported that high-intensity physical activity was associated with better physical fitness in children and adolescents, independent of chronological age, maturation development and sex.² In the 2020 WHO guidelines, it is recommended that children and adolescents undertake more than 60min of moderate- to vigorous-intensity physical activity per day across the week.²⁸ Despite the importance of physical activity, it has been estimated that more than 80% of adolescents (11–17 years old) worldwide were insufficiently active based on the still-current WHO 2020 guideline.^{28,51} In our survey, about 92.2% of children (89.1% of boys, 95.2% of girls) were considered to be insufficiently active based on this guideline.²⁸ Promoting physical activity among children is an urgent public health issue.

BMI was also associated with physical fitness in our study. The trends of association differed by sports item. Higher BMI was associated with worse 20m shuttle run results while it was associated with better results for grip strength. This finding is similar to that of a previous study of physical fitness and its determinants in European adolescents.²⁰ The poorer physical fitness in obese children is probably because their excess body fat is an extra load to be moved during exercises that require dynamic movement, such as the 20-m shuttle run.⁵² For some items of physical fitness like hand grip strength or flexibility, excess fatness is unlikely to interfere with performance.

Longer screentime was associated with worse 20-m shuttle run. Allowing that there were some inconsistencies in previous findings, Carson et al.'s⁵³ review of 21 studies showed that longer screen time was associated with worse physical fitness. One explanation for this association is that longer screentime tends to relate with low levels of physical activities^{54,55} or increased body weight.⁵⁶ In our present study, however, longer screen time was associated with worse physical fitness independently of BMI and exercise habits. Additionally, the proportion of children with insufficient exercise habits did not differ between groups with short (<4h/day) and long (≥4h/day)

TABLE 3 Association of physical fitness with body composition or lifestyle factors (n=2076)^a.

Sex	Variable	Unit	Category	Total Score (points) ^b β (95%CI)	20-m shuttle run (laps) β (95%CI)	Handgrip strength (kg) β (95%CI)
Boys	Age	(day)		0.01 (0.01, 0.02)	0.02 (0.01, 0.02)	0.01 (0.01, 0.01)
	BMI z-score ^c	(SD)		−0.86 (−1.35, −0.38)	−7.37 (−8.39, −6.35)	1.41 (1.19, 1.63)
	Exercise habit ^d	(days/week)	0	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			1–2	2.36 (0.20, 4.51)	6.81 (2.37, 11.26)	0.34 (−0.58, 1.36)
			3–4	6.94 (4.78, 9.10)	15.32 (10.85, 19.79)	0.87 (−0.10, 1.85)
			5–7	10.17 (7.98, 12.36)	23.95 (19.43, 28.46)	1.76 (0.78, 2.75)
	Screentime ^e	(h/day)	<2	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			2 to <4	0.65 (−0.55, 1.85)	−0.53 (−3.04, 1.99)	0.49 (−0.05, 1.03)
			≥4	−0.66 (−2.09, 0.77)	−4.31 (−7.29, −1.34)	0.17 (−0.47, 0.81)
	NRF9.3 ^f		Boy-Low [83–672]	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			Boy-Medium [672–760]	−0.16 (−1.43, 1.10)	−1.31 (−3.95, 1.34)	−0.60 (−1.18, −0.03)
			Boy-High [760–900]	−0.90 (−2.09, 0.77)	−2.34 (−5.10, 0.41)	−0.55 (−1.14, 0.04)
	Breakfast skipping		Consumers	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			Skippers	−1.63 (−3.30, −0.03)	−5.24 (−8.71, −1.77)	−0.78 (−1.54, −0.03)
	Sleep duration ^g	(h/day)		−0.36 (−1.01, 0.29)	−1.67 (−3.02, −0.32)	−0.12 (−0.42, 0.17)
Girls	Age	(day)		0.02 (0.01, 0.02)	0.02 (0.01, 0.02)	0.01 (0.01, 0.01)
	BMI z-score ^c	(SD)		0.24 (−0.25, 0.74)	−3.54 (−4.50, −2.58)	1.75 (1.53, 1.97)
	Exercise habits ^d	(days/week)	0	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			1–2	5.23 (3.60, 6.85)	7.80 (4.69, 10.90)	0.96 (0.24, 1.67)
			3–4	7.40 (5.70, 9.11)	12.14 (8.86, 15.41)	1.24 (0.48, 2.00)
			5–7	8.83 (7.00, 10.65)	17.93 (14.44, 21.43)	1.62 (0.81, 2.43)
	Screentime ^e	(h/day)	<2	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			2–<4	−1.60 (−2.69, −0.50)	−2.65 (−4.77, −0.54)	−0.30 (−0.79, 0.19)
			≥4	−2.03 (−3.77, −0.28)	−5.65 (−9.01, −2.30)	−0.33 (−1.10, 0.46)
	NRF9.3 ^f		Girl-Low [14–634]	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			Girl-Medium [635–715]	0.03 (−1.16, 1.22)	0.66 (−1.65, 2.96)	0.12 (−0.40, 0.66)
			Girl-High [715–862]	0.65 (−0.56, 1.87)	2.58 (0.24, 4.93)	0.05 (−0.49, 0.59)
	Breakfast skipping		Consumers	0.00 (Reference)	0.00 (Reference)	0.00 (Reference)
			Skippers	−1.51 (−3.19, 0.17)	−3.57 (−6.84, −0.30)	−0.85 (−1.61, −0.10)
	Sleep duration ^g	(h/day)		−0.64 (−1.32, 0.03)	−1.52 (−2.83, −0.20)	−0.08 (−0.38, 0.22)

^aMultivariable linear mixed models were used to examine trends of association between physical or lifestyle factors and physical fitness. Dependent variables were total score, 20-m shuttle run and hand grip strength. Independent variables were body composition and lifestyle factors listed in the table. All independent variables were added to the model simultaneously. A random effect was a surveyed area.

^bTotal score is the sum of the results of 8 items of the sports battery test. The results of 8 items are assigned on a score of 0–10 according to the sex-specific standards defined by the Japanese government. Possible total scores range from 0 to 80.

^cBMI z-score is a BMI standard deviation score calculated based on age, sex, and BMI using Japanese reference data.

^dExercise habit is the number of days with more than 60 minutes of exercise during the day.

^eScreentime is the total number of hours of TV time and videogame play.

^fNRF 9.3 is a diet quality score calculated as the sum of the percentage of reference daily values (RDVs) for nine qualifying nutrients (protein, dietary fibre, vitamin A, vitamin C, vitamin D, calcium, iron, potassium, and magnesium) minus the sum of the percentage of RDVs for three disqualifying nutrients (added sugar, saturated fats, and sodium). Highest NRF9.3 score is 900 and a higher score means better diet quality. The distribution of NRF score is shown in tertiles by sex.

^gSleep duration is a sleep duration on weekdays.

screentime, with respective proportions of children with exercise habits of less than 4 days/week of 71.1% and 74.4% in boys and 80.6% and 85.1% in girls. The difference between our results and previous studies may be due to the possibilities that the question

about exercise habits in our questionnaire may have assessed physical activity by exercise, but might not have evaluated physical activity in daily life. The duration of screentime possibly reflects regular physical activity in daily life; correspondingly, a correlation between



screen time and physical fitness was observed even after adjusting for exercise habits.

Longer sleep duration during weekdays was associated with worse 20-m shuttle run. Although the association between sleep duration and physical fitness is inconsistent,^{17,57} Laurson et al. reported that children who spent more time for sleeping spent less time being physically active.⁵⁸ Tanaka et al. found physically active Japanese children performed significantly better in 20-m shuttle run as we showed in this study.²¹ However, they reported there was no difference in 20-m shuttle run between sleep duration and this result differed from ours.²¹ The difference may be explained by lower age and longer sleep duration of their analysed population.

Better diet quality measured by NRF9.3 was associated with a better 20-m shuttle run only in girls. The association between NRF9.3 and 20-m shuttle run is explainable mainly by added sugars derived from confectioneries. Although the biological mechanism of excessive added sugar on the cardiovascular system remains unclear, adverse effects on the cardiovascular system have been shown in epidemiological studies.⁵⁹ In boys, higher intake of sweetened beverages—considered a main source of added sugar intake—was rather associated with a better score of 20-m shuttle run. In Japan, children are often encouraged to take sports drinks during sports activities to prevent heat stroke.⁶⁰ These drinks are categorised as 'sweetened beverages' by the BDHQ15y used in our study. We speculate that physically active boys with better physical fitness consumed more added sugars from sports drinks, and their scores of NRF9.3 were not so high. In contrast, the girls were less physically active than the boys in the present study, and the relationship between higher consumption of sports drinks and higher scores in the 20-m shuttle run might not therefore be observable. Although the definition of better diet quality differs from our study, Hatta et al. also found that the association between more energy intake from healthy foods was associated with better physical fitness in Japanese children.¹⁶

Exercise habits and body composition might have direct effects on physical fitness, but other lifestyle factors may have indirect effects on physical fitness, possibly via exercise habits and body composition. The associations between lifestyle factors and physical fitness may therefore vary among studies.

5 | CONCLUSIONS

Frequent exercise was associated with better physical fitness. Higher BMI and unfavourable lifestyle factors such as longer screen time and others were associated with worse physical fitness. The acquisition of appropriate exercise habits from childhood and obesity prevention based on proper eating habits may achieve better physical fitness in Japanese primary school children. This may in turn lead to the prevention of lifestyle-related diseases in the future.

AUTHOR CONTRIBUTIONS

The authors' contributions were as follows: KA designed the research. SM and KA performed the survey and collected the data. AY

conceptualised the present study, analysed the data and wrote the draft. AF estimated added sugar intake and assisted in interpretation of the results. KA, SS and YN supervised all of the procedures and interpreted the results. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The datasets analysed during the current study are available from the corresponding author on reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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