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Longitudinal changes in musculoskeletal findings of elementary and junior high school students: a 1-year prospective study

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Abstract The purpose of this study was to investigate the characteristics of musculoskeletal findings in elementary and junior high school children using 1-year prospective longitudinal data from a long-term survey. Data from 1209 (97.6%) of 1239 children were analyzed. The main results were as follows: “Limitation of standing forward flexion” was particularly frequent in the 4th grade in all children and in the 5th grade in boys and girls going on to the next grade. “Flat foot” was particularly frequent in boys in the 1st, 6th, and 8th grades going on to the next grade. In girls, the frequency of “flat foot” was particularly high in the 1st, 4th, and 8th grades going on to the next grade. Findings of scoliosis appeared more often in girls than in boys. Minor findings such as “asymmetrical height of the shoulder and scapula”, first appearing in the 4th and 5th grades, may be linked to the increase in “Rib hump” in the stage entering junior high school; it is important to pay attention to such changes in the scoliosis findings. This 1-year prospective longitudinal analysis demonstrated that the frequency of some musculoskeletal findings was high. We suggest that an extended longitudinal study will contribute to a better understanding of the relationship between the appearance of musculoskeletal findings and growth and development in school children. Accordingly, further analysis of the various stages of growth and development are needed.

Keywords : musculoskeletal examination, longitudinal study, school children, growth stages

Introduction

“Musculoskeletal system” is an inclusive term describing muscles, bones, and the associated nervous system¹⁾. The musculoskeletal system is very important for physical activity and daily life, including support of the respiratory, digestive, and circulatory systems.

In Japan, scoliosis screening during school health check-ups began in 1979²⁾. In 1994, the Ministry of Education, Science and Culture (now the Ministry of Education, Culture, Sports, Science and Technology) published the “Enforcement ordinance of School Health and Safety Act” from the Bureau of Physical Education, requiring schools to pay attention to the condition of children’s extremities³⁾. The guidelines were unclear in respect of the specific musculoskeletal system criteria to be examined during health check-ups because the notice was not legally bind-

ing. Therefore, extremity and joint examinations during Japanese school check-ups were insufficient³⁾.

In 2014, the enforcement ordinance was amended making the assessment of the condition of the extremities mandatory. This amendment was put into practice in 2016 and, therefore, musculoskeletal examinations have been included since then. Against this background, the Bone and Joint Decade Japan started to model projects beginning in 2005 in some areas. Reports in some prefectures have published data relevant to 2005⁴⁻⁸⁾. Nevertheless, almost all previous studies used cross-sectional design. For this reason, it remains unclear when the most frequent reports of musculoskeletal findings occurred.

The World Health Organization (WHO) has recommended using the Wilson-Jungner criteria for screening⁹⁾. One of these criteria is as follows: “The natural history of the condition, including development from latent to declared disease, should be adequately understood.” WHO also recommended that case findings should be

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an ongoing process and not a once-and-for-all project; a follow-up scheme for the continual assessment of screening results is necessary. Furthermore, studies have shown longitudinal analysis to be important for research in children to determine individual growth and development^{10,11)}. Therefore, evaluations of the appropriate timing of musculoskeletal examinations are essential.

We started performing musculoskeletal examinations in 2008 in T-City, Ibaraki. The first part of the examination procedure was the distribution of a questionnaire to parents of children in all elementary and junior high schools. Subsequently, in some schools, orthopedic surgeons examined selected children based on the results of the questionnaire. In other schools in T-City, orthopedic surgeons performed direct musculoskeletal examinations on all subjects after the administration of the questionnaire. Finally, selected children were classified as requiring a secondary examination at a medical institution. We created the “Health Notebook” for the follow-up of children¹²⁾. The Health Notebook records the results of examinations and assesses changes in the musculoskeletal system over time. Our previous cross-sectional study investigated the characteristics of musculoskeletal findings in boys and girls in 1st to 6th grades. The main result suggesting the limitation of standing forward flexion showed particularly high rates in 4th grade, and boys were higher than girls in all grades. Although “Flat foot” tended to be high in 1st and 2nd grade children in boys, there was no significant

difference in grade and sex. It has been previously reported that the rates of musculoskeletal findings in grade and sex, which were seen in our study, may be due to the influence on growth and living environment in children¹³⁾.

Based on these previous reports, we hypothesized that there is timing that shows several changes in observation when tracking individual screening results in a 1-year prospective study. However, there are no published longitudinal studies of musculoskeletal changes in school-aged children. Therefore, the purpose of this study was to investigate the characteristics of musculoskeletal findings in elementary and junior high school children using 1-year prospective longitudinal data.

Subjects and Methods

Subjects. The subjects were aged 6-14 years and were in grades 1 to 8 in a single public elementary and junior high school in Ibaraki Prefecture, Japan, in 2017. Initially, 1930 children were enrolled in 2017. Secondly, a total of 1239 children completed follow-up from 2017 to 2018 and were eligible for the study (the decrease in the total number is due to the separation of part of the school district by the establishment of a new school). Finally, we analyzed data without children whose parents did not agree with the research and those missing data. Missing data were defined as a missing record that would prevent us from carrying out the required data analysis.

Fig. 1 Follow-up flow diagram

This study was performed with approval of the research ethics committee of the university (approval number: 678-2). We obtained the consent of parents and school.

Methods. We distributed original questionnaires created by our university, called the Tsukuba Childhood Locomotive-Organ Screening Sheet (T-CLOSS) to parents before screening¹⁴⁾. T-CLOSS was based on a questionnaire developed by a public benefit organization of the Japan School Health Association. A total of 11 orthopedic surgeons performed direct musculoskeletal examinations on all subjects.

Screening items were classified into three types: lower extremity, upper extremity, and spine. The orthopedic surgeons determined the children's findings based on various criteria. A physician performed a musculoskeletal pain and secondary examination. Separate assessments were performed for lower extremity alignment, elbow align-

ment, and tilt of the pelvis. When children had findings, they were double checked by an experienced pediatric orthopedic surgeon in a standardized final evaluation.

In the longitudinal analysis, students who previously had no findings, but eventually developed findings, were defined as the appearance group.

Statistical analysis. For the cross-sectional analysis of 2017 data, we calculated the frequency of musculoskeletal findings of all 1st to 8th grade children. The rates of findings were calculated by dividing the frequency of findings by the total number of children.

With respect to the relatively high rates of findings in the cross-sectional analysis, the rates of appearance were calculated by dividing the frequency of appearance of findings by the number of patients who previously had no findings. This represented the rate at which those who did not have findings in 2017 developed findings in 2018.

Table 1-1. The criteria of abnormal examination findings (lower extremity)

Category	Assessment	The criteria for abnormal evaluation
Lower extremity	Gait abnormality	Difficulty in walking, limping, walking with extreme ankle inversion or eversion, Trendelenburg's symptom.
	Lower extremity alignment	Bowleg: The distance between the inside of both of the knees when standing at attention is 2 fingerbreadth or more Knock-knee: The distance between the inside of both the ankles when standing at attention
	Asymmetrical leg length	Asymmetrical leg length.
	Asymmetrical thickness of legs	Asymmetrical thickness of legs.
	Club foot	Foot inversion of position is seen in one or both feet.
	Flat foot	More than the fourth toe is seen in a vertical line of the tibia when looking at the heel from the back in a standing position. Obviously low arch.
	Deformity of foot	Obvious deformity of the foot, e.g. <i>hallux valgus</i> , toe length discrepancy
	Limited of range of motion of the hip	Inability to fully squat without heel lifting due to limited range of motion of the hip.
	Limited of range of motion of the knee	Inability to fully squat without heel lifting due to limited range of motion of the knee.
	Limited of range of motion of the ankle	Inability to fully squat without heel lifting.

Table 1-2. The criteria for abnormal examination findings (upper extremity)

Category	Assessment	The criteria of abnormal evaluation
Upper extremity	Limited range of motion of the shoulder	Inability to perform a full shoulder flexion due to limited range of motion of the shoulder.
	Elbow alignment	With the arm extended at the side and the palm facing forward <ul style="list-style-type: none"> • <i>Cubitus valgus</i>: carrying angle of 25° or more • <i>Cubitus varus</i>: carrying angle of -10° or less.
	Limited range of motion of the elbow	Inability to perform full flexion or extension due to limited range of motion of the elbow.
	Deformity of the finger	Visually obvious deformity of the fingers.
	Limited range of motion of finger	Inability for full finger flexion or extension because of limited range of motion of the finger.

Table 1-3. The criteria for abnormal examination findings (spine)

Category	Assessment	The criteria of abnormal evaluation
Spine	Torticollis	Limitations in tilting of the head and rotation.
	Asymmetrical height of the shoulder and scapula	Asymmetrical height of the shoulder and scapula in a standing position.
	Curvature of the spine in a standing position	Presence of curvature of the spine in a standing position.
	Rib hump	The posterior ribs on the convex side are bulged to the posterior when bending forward while in a standing position.
	Limitation of standing forward flexion	Inability to touch the floor in the standing position with straight knees.
	Pain in a back bend	The presence of the pain when bending backward in a standing position.
	Tilt of the pelvis	Tilt forward: protrusion of the buttocks when seen from the side in the standing position due to the pelvis position. Tilt back: the abdomen is set back when seen from the side in the standing position due to the pelvis position.

Table 1-4. The criteria for abnormal examination findings (the others)

Category	The criteria of abnormal evaluation
Musculoskeletal pain	Subjects reported of any pain during a consultation with a doctor.
Require secondary examination	Doctor concluded that subjects required a diagnostic examination in a medical institution.

Table 2. Number of subjects

	1st-grade	2nd-grade	3rd-grade	4th-grade	5th-grade	6th-grade	7th-grade	8th-grade	All
All	137 (11.3)	148 (12.2)	152 (12.6)	149 (12.3)	192 (15.9)	132 (10.9)	162 (13.4)	137 (11.3)	1209 (100.0)
Boys	72 (52.6)	78 (52.7)	85 (55.9)	78 (52.3)	92 (47.9)	67 (50.8)	79 (48.8)	58 (42.3)	609 (50.4)
Girls	65 (47.4)	70 (47.3)	67 (44.1)	71 (47.7)	100 (52.1)	65 (49.2)	83 (51.2)	79 (57.7)	600 (49.6)

n (%)

The rate of each grade in children of all was showed.

The proportion of boys and girls indicates in each row.

Statistical analysis was performed using the McNemar test for changes from no findings to findings in each grade level and sex. If significant effects were observed in the McNemar test in either sex, the chi-square test with Yates correction was used for the comparison of the frequency of appearance of findings between the boys and girls.

IBM SPSS Statistics Ver.25 (IBM Japan, Tokyo, Japan) was used to perform the statistical analysis. The significance level was defined as 5%.

Results

All the data from 1209 children (97.6%) were analyzed (Table 2).

Cross-sectional analysis of 2017 data. Table 3 shows the rate of musculoskeletal findings of all subjects in

grades 1 to 8. The following items had particularly high frequencies in all grade levels: “Limitation of standing forward flexion,” “Flat foot,” and “Rib hump.” In addition to these, “Asymmetrical height of the shoulder and scapula” and “Curvature of the spine in a standing position” had high frequencies.

Longitudinal analysis. Figs. 2-6 show the results of the longitudinal analysis. The appearance of “Limitation of standing forward flexion” was particularly frequent in the 4th ($p < 0.05$) and 5th ($p < 0.01$) grade children going on to the next grade. In addition, for both the boys and girls, the frequency of “Limitation of standing forward flexion” was particularly frequent in the 5th grade going on to the next grade.

The appearance of “Flat foot” was particularly frequent in the 1st ($p < 0.01$) and 8th ($p < 0.01$) grades going on to

Table 3. Musculoskeletal findings in the cross-sectional data from 2017

Items	Boys		Girls		All	
Gait abnormality	6	(1.0)	6	(1.0)	12	(1.0)
Bowlegs	36	(5.9)	46	(7.7)	82	(6.8)
Knock-knee	59	(9.7)	53	(8.8)	112	(9.3)
Leg length discrepancy	1	(0.2)	1	(0.2)	2	(0.2)
Thickness of legs	0	(0.0)	1	(0.2)	1	(0.1)
Club foot	2	(0.3)	0	(0.0)	2	(0.2)
Flat foot	128	(21.0)	97	(16.2)	225	(18.6)
Deformity of foot	9	(1.5)	26	(4.3)	35	(2.9)
Limited range of motion of the hip	1	(0.2)	1	(0.2)	2	(0.2)
Limited range of motion of the knee	3	(0.5)	3	(0.5)	6	(0.5)
Limited range of motion of the ankle	46	(7.6)	34	(5.7)	80	(6.6)
Limited range of motion of the shoulder	1	(0.2)	0	(0.0)	1	(0.1)
Cubitus valgus	4	(0.7)	10	(1.7)	14	(1.2)
Cubitus varus	3	(0.5)	0	(0.0)	3	(0.2)
Limited range of motion of the elbow	5	(0.8)	3	(0.5)	8	(0.7)
Deformity of finger	2	(0.3)	2	(0.3)	4	(0.3)
Limited range of motion of the finger	2	(0.3)	3	(0.5)	5	(0.4)
Torticollis	12	(2.0)	6	(1.0)	18	(1.5)
Asymmetrical height of the shoulder and scapula	48	(7.9)	61	(10.2)	109	(9.0)
Curvature of the spine in the standing position	32	(5.3)	66	(11.0)	98	(8.1)
Rib hump	75	(12.3)	121	(20.2)	196	(16.2)
Limitation of standing forward flexion	170	(27.9)	67	(11.2)	237	(19.6)
Pain in back bend	18	(3.0)	7	(1.2)	25	(2.1)
Tilt forward	12	(2.0)	7	(1.2)	19	(1.6)
Tilt back	1	(0.2)	0	(0.0)	1	(0.1)
Require secondary examination	18	(3.0)	40	(6.7)	58	(4.8)

n (%)

The highlight shows particularly high frequencies in all grade levels.

the next grade. In boys, the frequency of “Flat foot” was particularly high in the 1st ($p < 0.05$), 6th ($p < 0.01$), and 8th ($p < 0.01$) grades going on to the next grade. In girls, the frequency of “Flat foot” was particularly high in the 1st ($p < 0.05$), 4th ($p < 0.01$), and 8th ($p < 0.05$) grades going on to the next grade. When comparing the frequency of “Flat foot” between boys and girls in the 6th grade going on to the next grade; the rate was higher in boys than in girls ($p < 0.05$).

The appearance of “Rib hump” was particularly frequent in the 1st ($p < 0.05$), 7th ($p < 0.05$), and 8th ($p < 0.01$) grades going on to the next grade. In terms of sex, the frequency of “Rib hump” was particularly frequent in girls in the 6th ($p < 0.05$) and 8th ($p < 0.01$) grades going on to the next grade. Comparison of the frequency of “Rib hump” between boys and girls in 6th grade going on to the next grade revealed a higher frequency in boys than in

girls ($p < 0.05$).

The appearance of “Asymmetrical height of the shoulder and scapula” was particularly frequent in the 4th ($p < 0.05$), 6th ($p < 0.01$), and 8th ($p < 0.01$) grades going on to the next grade. In terms of sex, the appearance of “Asymmetrical height of the shoulder and scapula” was particularly frequent in girls in the 4th ($p < 0.05$), 6th ($p < 0.01$), and 8th ($p < 0.01$) grades going on to the next grade. For comparison of the frequency in boys and girls in the 8th ($p < 0.01$) grade going on to the next grade, the frequency was higher in girls than in boys.

The appearance of “Curvature of the spine in a standing position” was particularly frequent in the 6th grade going on to the next grade ($p < 0.01$). In terms of sex, the frequency of “Curvature of the spine in a standing position” was high in girls in the 6th grade going on to the next grade ($p < 0.01$).

Fig. 2 The rates of appearance (2017 No, 2018 Yes) of limitation of standing forward flexion

Fig. 3 The rates of appearance (2017 No, 2018 Yes) of Flat foot

Fig. 4 The rates of appearance (2017 No, 2018 Yes) of Rib hump

Fig. 5 The rates of appearance (2017 No, 2018 Yes) of Asymmetrical height of the shoulder and scapula

Fig. 6 The rates of appearance (2017 No, 2018 Yes) of curvature of the spine in a standing position

Discussion

Limitation of standing forward flexion. “Limitation of standing forward flexion” was defined as inability to touch the floor in the standing position with straight knees. This finding was particularly frequent in the 4th grade in both sexes and in 5th grade boys and girls going on to the next grade.

A study showed that the measured value of standing forward flexion was influenced by physical differences in the examinees¹⁵⁾. That is, a greater length of the trunk correlated with higher measured values of standing forward flexion, while a greater leg length correlated with lower values. Therefore, there should be a physique factor when examining “Limitation of standing forward flexion.” The age of peak height velocity in Japanese individuals born in 1990 was 11 years in boys and 9 years in girls¹⁶⁾. The age of peak velocity of leg length growth was earlier than that of height or sitting height¹⁷⁾. Furthermore, leg length showed better growth than sitting height during elementary and junior high school age¹⁸⁾. Considering these reports, it is possible that the timing of the examination in the 4th to 6th grade was responsible for the finding of increased leg length.

In addition to these, there have been reports of individual differences in age at peak velocity¹⁹⁾. Accordingly, assessment of findings from the point of view of differences in individual growth velocity curves should be studied

further. Furthermore, there is room for further investigation of the relationship between the limitation of standing forward flexion and fitness habits or physical fitness tests when evaluating the findings.

Flat foot. “Flat foot” is defined as observing more than the fourth toe in a vertical line of the tibia when looking at the heel of a person in a standing position from behind, or an obviously low arch. “Flat foot” was particularly frequent in the 1st, 6th, and 8th grades going on to the next grade in boys. In girls, it was particularly frequent in the 1st, 4th, and 8th grades going on to the next grade. Moreover, the frequency was higher in boys than in girls in the 6th grade going on to the next grade.

Although there are several cross-sectional studies of feet in Japanese subjects, there have been few longitudinal studies^{20,21)}. Previous studies showed that the foot arch is different between Japanese and people in other countries²²⁾. A few longitudinal studies using footprints described an “arch index,” characterized by the medial foot arch remaining stable from 7 to 9 years of age^{23,24)}. However, a consensus regarding the best measurement method of pediatric foot posture has not yet been reached because there are various indicators of the medial foot arch²⁵⁾. Considering these reports, and the possibility that “Flat foot” is not a natural process in the 1st and 4th grades going on to the next grade, further long-term follow-up examinations are needed. In addition, although there are

problems in establishing a measurement method for the detailed analysis of the foot arch in children, a longitudinal survey is required.

Scoliosis. This study set three indicators for identifying scoliosis. Firstly, the definition of “Rib hump” was the posterior ribs on the convex side are bulged to the posterior when bending forward while in a standing position. Secondly, “Asymmetrical height of the shoulder and scapula” was the asymmetrical height of the shoulder and scapula in a standing position. Thirdly, “Curvature of the spine in a standing position” was defined as the presence of curvature of the spine in a standing position. Therefore, the appearance of “Asymmetrical height of the shoulder and scapula” was particularly frequent in the 4th, 6th, and 8th grades going on to the next grade. Moreover, “Curvature of the spine in a standing position” was particularly frequent in the 6th grade going on to the next grade. Additionally, the appearance of “Rib hump” was particularly frequent in boys and girls in the 7th and 8th grades going on to the next grade and in girls in the 6th and 8th grades.

Radiography examinations of 255,875 children aged 11-14 years in Tokyo after screening for scoliosis using Moiré topography reported that the prevalence rate of idiopathic scoliosis increased more at 13-14 years of age than at 11-12 years, with Cobb angles of 10° or more in both sexes²⁶⁾. Therefore, in musculoskeletal examinations, after the appearance of minor findings such as asymmetrical height of the shoulder and scapula in the 4th to 5th grade, examinations for confirming the findings of “Rib hump” should be increased in the stage entering junior high school.

Notably, all significant effects of timing were only found in girls. Furthermore, the rates of scoliosis were

higher in girls than in boys. It has been previously reported that the overall ratio of girls to boys with scoliosis was 11:1²⁶⁾. The findings of the present study agree with those of other studies in Japan²⁷⁾ and other countries^{28,29)} to the effect that scoliosis mostly occurs in girls. Our results of musculoskeletal examination supports these previous studies; therefore, we believe it is particularly important to pay attention to scoliosis findings in girls.

For this reason, by considering the characteristics of the findings in each grade and sex, early detection and treatment of scoliosis may be possible.

Limitations. This study also had some limitations. Firstly, although we could follow up many children (n = 1209, 97.6%), they were only in a single school. Therefore, the number of schools to be analyzed could be increased and comparisons with other areas made to provide more robust results.

Secondly, the rates of appearance of musculoskeletal findings were calculated from 1-year prospective longitudinal individual data in each grade. Even then, the exclusion of the characteristics of each grade group was unsatisfactory. Moreover, whether or not follow up of musculoskeletal findings continued after the study period was not analyzed in our study and could be a basis for future research.

Another limitation involves our system of examination. More than two doctors had to be stationed at any one time to finish the examinations on time. Even though each doctor performed the examinations with an understanding of the criteria of the examination, there may still have been inter- and intra-rater differences among the examiners. For this reason, when children had findings, a representative doctor double checked them to achieve a standardized

S1 Table. The number and rates of appearance of findings in all

Items	Timing	1st-2nd		2nd-3rd		3rd-4th		4th- 5th		5th-6th		6th-7th		7th-8th		8th-9th	
	2018 2017	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)
Limitation of standing forward flexion	No	101	10 (9.0)	117	4 (3.3)	112	12 (9.8)	110	18 (14.1)†	127	25 (16.4)‡	87	16 (15.5)	114	13 (10.3)	103	3 (2.8)
	Yes	5	21	15	12	9	19	6	15	4	36	8	21	11	24	10	21
Flat foot	No	106	18 (14.5)‡	116	12 (9.4)	108	13 (10.9)	101	19 (15.8)	132	18 (12.0)	94	17 (15.3)	114	15 (11.7)	68	33 (32.7)‡
	Yes	3	10	10	10	13	18	9	20	23	19	7	14	20	13	8	28
Rib hump	No	117	13 (10.0)†	133	6 (4.3)	121	8 (6.3)	117	8 (6.4)	141	18 (11.3)	76	21 (21.6)	102	25 (19.8)†	84	23 (21.5)‡
	Yes	4	3	8	1	17	6	18	6	16	17	14	21	12	23	6	24
Asymmetrical height of the shoulder and scapula	No	122	11 (8.3)	135	4 (2.9)	136	9 (6.3)	128	16 (11.1)†	154	15 (8.9)	90	29 (24.4)‡	105	15 (12.6)	108	23 (17.6)‡
	Yes	3	1	9	0	5	2	4	1	12	11	9	4	26	16	3	3
Curvature of the spine in a standing position	No	130	5 (3.7)	144	3 (2.0)	127	1 (0.8)	140	4 (2.8)	156	14 (8.2)	112	15 (11.8)‡	127	11 (8.0)	116	6 (4.9)
	Yes	1	1	1	0	22	2	3	2	10	12	0	5	13	11	6	9

χ^2 test (boys vs. girls) : *p<0.05

McNemar test : †p<0.05, ‡p<0.01

S2 Table. The number and rates of appearance of findings in boys

Items	Timing	1st-2nd		2nd-3rd		3rd-4th		4th- 5th		5th-6th		6th-7th		7th-8th		8th-9th	
	2018	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)
	2017																
Limitation of standing forward flexion	No	47	6 (11.3)	56	2 (3.4)	53	11 (17.2)	48	14 (22.6)	55	15 (21.4)‡	32	10 (23.8)	46	8 (14.8)	33	3 (8.3)
	Yes	4	15	11	9	6	15	5	11	3	19	6	19	8	17	7	15
Flat foot	No	54	8 (12.9)†	54	10 (15.6)	57	6 (9.5)	51	8 (13.6)	63	8 (11.3)	45	14 (23.7)*‡	50	9 (15.3)	28	16 (36.4)‡
	Yes	1	9	5	9	11	11	7	12	12	9	2	6	14	6	2	12
Rib hump	No	60	7 (10.4)	68	4 (5.6)	69	5 (6.8)	62	5 (7.5)	70	12 (14.6)	45	6 (11.8)	59	13 (18.1)	42	7 (14.3)
	Yes	3	2	6	0	10	1	9	2	4	6	9	7	5	2	3	6
Asymmetrical height of the shoulder and scapula	No	63	6 (8.3)	72	3 (4.0)	79	3 (3.7)	69	6 (8.0)	75	7 (8.5)	47	11 (19.0)	62	3 (4.6)	52	3 (5.5)
	Yes	3	0	3	0	2	1	2	1	6	4	7	2	10	4	1	2
Curvature of the spine in a standing position	No	69	2 (2.8)	75	2 (2.6)	73	0 (0.0)	73	2 (2.7)	77	9 (10.5)	62	4 (6.1)	69	4 (5.5)	52	4 (7.1)
	Yes	0	1	1	0	12	0	2	1	3	3	0	1	4	2	2	0

χ^2 test (boys vs. girls) : *p<0.05

McNemar test : †p<0.05, ‡p<0.01

S3 Table. The number and rates of appearance of findings in girls

Items	Timing	1st-2nd		2nd-3rd		3rd-4th		4th- 5th		5th-6th		6th-7th		7th-8th		8th-9th	
	2018	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)	No	Yes (%)
	2017																
Limitation of standing forward flexion	No	54	4 (6.9)	61	2 (3.2)	59	1 (1.7)	62	4 (6.1)	72	10 (12.2)†	55	6 (9.8)	68	5 (6.8)	70	0 (0.0)
	Yes	1	6	4	3	3	4	1	4	1	17	2	2	3	7	3	6
Flat foot	No	52	10 (16.1)†	62	2 (3.1)	51	7 (12.1)	50	11 (18.0)†	69	10 (12.7)	49	3 (5.8)	64	6 (8.6)	40	17 (29.8)†
	Yes	2	1	5	1	2	7	2	8	11	10	5	8	6	7	6	16
Rib hump	No	57	6 (9.5)	65	2 (3.0)	52	3 (5.5)	55	3 (5.2)	71	6 (7.8)	31	15 (32.6)*†	43	12 (21.8)	42	16 (27.6)‡
	Yes	1	1	2	1	7	5	9	4	12	11	5	14	7	21	3	18
Asymmetrical height of the shoulder and scapula	No	59	5 (7.8)	63	1 (1.6)	57	6 (9.5)	59	10 (14.5)†	79	8 (9.2)	43	18 (29.5)‡	43	12 (21.8)	56	20 (26.3)**‡
	Yes	0	1	6	0	3	1	2	0	6	7	2	2	16	12	2	1
Curvature of the spine in a standing position	No	61	3 (4.7)	69	1 (1.4)	54	1 (1.8)	67	2 (2.9)	79	5 (6.0)	50	11 (18.0)‡	58	7 (10.8)	64	2 (3.0)
	Yes	1	0	0	0	10	2	1	1	7	9	0	4	9	4	4	9

χ^2 test (boys vs. girls) : *p<0.05, **p<0.01

McNemar test : †p<0.05, ‡p<0.01

final evaluation. Nevertheless, intra-rater reliability variance in the final evaluations should be taken into account.

Thus, a follow-up study of the long-term results of the examinations is necessary. Similarly, an analysis to consider the various stages of growth and development should be conducted.

Conclusions

(1) The appearance of “Limitation of standing forward flexion” was particularly frequent in the 4th grade in all sexes and in the 5th grade in boys and girls going on to the next grade.

(2) The appearance of “Flat foot” was particularly frequent in boys in the 1st, 6th, and 8th grades going on to the next grade. In girls, the appearance was particularly frequent in the 1st, 4th, and 8th grades going on to the next grade.

(3) Girls were more likely than boys to show findings of scoliosis. There were minor findings such as “asymmetrical height of the shoulder and scapula” in 4th and 5th grade girls, and findings of “Rib hump” increased in the stage entering junior high school; that is to say, it is important to pay attention to these findings.

(4) The results of this 1-year prospective longitudinal analysis of musculoskeletal findings suggest that there is

a high frequency of certain findings found in the musculoskeletal examination. We suggest that an ongoing longitudinal analysis will contribute to a better understanding of the relationship between musculoskeletal findings and growth and development in school children.

Supplemental data

We provided supplemental data regarding the rates of appearance of musculoskeletal findings.

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Conflict of Interests

The authors declare no conflict of interests associated with this study.

References

- 1) Muto Y. 2009. The knowledge of musculoskeletal system in children. In: *Guidance of Effort at Musculoskeletal Disorders in School* (the Bone and Joint Decade Japan ed.), 1: 4 (in Japanese). Japanese Society of School Health, Tokyo, Japan.
- 2) Minami S and Kawakami N. 2007. Health check-up and musculoskeletal system in school - the change, practice and problems of screening of scoliosis. In: *The Handbook of Musculoskeletal Examination in School* (Muto Y, Kashiwaguchi S, Uchio Y, eds), 2: 63-67 (in Japanese). Nankodo Co, Ltd., Tokyo, Japan.
- 3) Muto Y. 2007. Health check-up and musculoskeletal system in school - the change to musculoskeletal examination including examination of extremities and joint. In: *The Handbook of Musculoskeletal Examination in School* (Muto Y, Kashiwaguchi S, Uchio Y, eds), 2: 70-73 (in Japanese). Nankodo Co, Ltd., Tokyo, Japan.
- 4) Yamagiwa H, Yamamoto N and Endo N. 2009. Results and problems of model cases of musculoskeletal examination in school: in Niigata. In: *The Journal of Clinical Sports Medicine* (Tachiiri K, ed.), 26: 159-163 (in Japanese). Bunkodo Co, Ltd., Tokyo, Japan.
- 5) Yamaguchi N, Chosa E, Yamamoto K, Kawahara K, Hamada H, Taniguchi N, Tajima T, Funamoto T, Kurogi S, Ota T and Nakamura S. 2016. Screening for musculoskeletal problems in Japanese schoolchildren: a cross-sectional study nested in a cohort. *Public Health* 139: 189-197. doi: 10.1016/j.puhe.2016.08.010.
- 6) Matsui Y, Uchio Y, Kuzuo N, Okita E and Kuwahara K. 2009. Results and problems of model cases of musculoskeletal examination in school: in Shimane. In: *The Journal of Clinical Sports Medicine* (Tachiiri K, ed.), 26: 165-170 (in Japanese). Bunkodo Co, Ltd., Tokyo, Japan.
- 7) Tanaka S, Todo M, Nakamura M, Morihara T and Hojo T. 2015. Relationship between the results of musculoskeletal examination and the Rohrer index in elementary school children. *Doshisha Journal of Health and Sports Science* 7: 23-34 (in Japanese). doi: 10.14988/pa.2017.0000014246.
- 8) Morihara T, Tachiiri K, Fukuda K, Ishii S, Matsui T, Seo K, Hiramoto M, Azuma Y, Nishio D, Hojo T and Kubo T. 2014. Locomotive screening in Kyoto -Screening of functional disorder of locomotion using arm elevation, trunk flexion and squatting-. *The Journal of Musculoskeletal Medicine* 25: 225-230 (in Japanese).
- 9) Wilson JMG and Jungner G. 1968. Principles and practice of screening for disease. *Public Health Papers* 34: 26-27. Retrieved from <http://www.who.int/iris/handle/10665/37650>.
- 10) Molinari L and Gasser T. 2004. Part 1: Growth data and growth studies: characteristics and methodological issues. In: *Methods in Human Growth Research* (Hauspie R, Cameron N, Molinari L, eds.), 2: 27-51, The Press Syndicate of the University of Cambridge, Cambridge, UK.
- 11) Malina RM. 2004. Secular trends in growth, maturation and physical performance: a review. *Anthropol Rev* 67: 3-31.
- 12) Kamada H, Abe R, Nishino T, Ochiai N and Miyakawa S. 2010. Medical screening to prevent musculoskeletal dysfunctions and sports injuries in growing children: report of the consistent care project using "health notebooks". *Journal of Japanese Paediatric Orthopaedic Association* 19: 332-336.
- 13) Kasai T, Kamada H, Mashimo S, Warashina Y, Tsukagoshi Y, Tanaka K, Yamazaki M, Miyakawa S and Shiraki H. 2019. Characteristics of the locomotor system based on musculoskeletal examination in elementary school children. *Japanese Journal of Clinical Sports Medicine* 27: 66-75 (in Japanese).
- 14) Tomaru Y, Kamada H, Tsukagoshi Y, Nakagawa S, Tanaka K, Takeuchi R, Mataka Y, Miyakawa S and Yamazaki M. 2019. Screening for musculoskeletal problems in children using a questionnaire. *J Orthop Sci* 24: 159-165. doi: 10.1016/j.jos.2018.07.022.
- 15) Oyama Y. 1965. A hygienic study on the flexibility of the normal. Part 1. The measurement methodology. *Jpn J Hyg (Nippon Eiseigaku Zasshi)* 20: 65-70. doi: 10.1265/jjh.20.65.
- 16) Ministry of Education, Culture, Sports, Science and Technology. 2008. *Annual Report of School Health Statistics Research in 2008*. Retrieved from http://www.mext.go.jp/b_menu/toukei/chousa05/hoken/kekka/k_detail/1279370.htm.
- 17) Csukás A, Takai S and Baran S. 2006. Adolescent growth in main somatometric traits of Japanese boys: Ogi longitudinal growth study. *Homo* 57: 73-86. doi: 10.1016/j.jchb.2005.09.003.
- 18) Hattori K, Hirohara T and Satake T. 2011. Body proportion chart for evaluating changes in stature, sitting height and leg length in children and adolescents. *Ann Hum Biol* 38: 556-560. doi: 10.3109/03014460.2011.577456.
- 19) Malina RM and Bouchard C. 1995. Timing and sequence of changes during adolescence. In: *Growth, Maturation, and Physical Activity* (Translated by Takaishi M and Kobayashi K.), 16: 216-217 (in Japanese). Taishukan Publishing Co, Ltd, Tokyo, Japan.
- 20) Waseda A, Suda Y, Inokuchi S, Nishiwaki Y and Toyama Y. 2014. Standard growth of the foot arch in childhood and adolescence - derived from the measurement results of 10,155 children. *Foot Ankle Surg* 20: 208-214. doi: 10.1016/j.fas.2014.04.007.
- 21) Morita N, Yamauchi J, Kurihara T, Fukuoka R, Otsuka M, Okuda T, Ishizawa N, Nakajima T, Nakamichi R, Matsuno S,

- Kamiie S, Shide N, Kambayashi I and Shinkaiya H. 2015. Toe flexor strength and foot arch height in children. *Med Sci Sports Exerc* 47: 350-356. doi: 10.1249/MSS.0000000000000402.
- 22) Kouchi M, Mochimaru M, Mientje M and Koch DB. 2009. Child foot shape: difference between three countries. *Footwear Sci* 1: 118-120. doi: 10.1080/19424280903063853.
- 23) Tong JWK and Kong PW. 2016. Medial longitudinal arch development of children aged 7 to 9 years: longitudinal investigation. *Phys Ther* 96: 1216-1224. doi: 10.2522/ptj.20150192.
- 24) Bosch K, Gerß J and Rosenbaum D. 2010. Development of healthy children's feet - nine-year results of a longitudinal investigation of plantar loading patterns. *Gait Posture* 32: 564-571. doi: 10.1016/j.gaitpost.2010.08.003.
- 25) Uden H, Scharfbillig R and Causby R. 2017. The typically developing paediatric foot: how flat should it be? A systematic review. *J Foot Ankle Res* 10: 37. doi: 10.1186/s13047-017-0218-1.
- 26) Ueno M, Takaso M, Nakazawa T, Imura T, Saito W, Shintani R, Uchida K, Fukuda M, Takahashi K, Ohtori S, Kotani T and Minami S. 2011. A 5-year epidemiological study on the prevalence rate of idiopathic scoliosis in Tokyo: school screening of more than 250,000 children. *J Orthop Sci* 16: 1-6. doi: 10.1007/s00776-010-0009-z.
- 27) Ohtsuka Y, Yamagata M, Arai S, Kitahara H and Minami S. 1988. School screening for scoliosis by the Chiba University Medical School screening program: results of 1.24 million students over an 8-year period. *Spine* 13: 1251-1257. doi: 10.1097/00007632-198811000-00008.
- 28) Wong HK, Hui JHP, Rajan U and Chia HP. 2005. Idiopathic scoliosis in Singapore schoolchildren: a prevalence study 15 years into the screening program. *Spine* 30: 1188-1196. doi: 10.1097/01.brs.0000162280.95076.bb.
- 29) String AJ, Howel D, Millner PA, Sadiq S, Sharples D and Dickson RA. 1996. Late-onset idiopathic scoliosis in children six to fourteen years old: cross-sectional prevalence study. *J Bone Joint Surg Am* 78: 1330-1336. doi: 10.2106/00004623-199609000-00006.