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Original Article

The influence of COVID-19 pandemic on the incidence of knee pain and physical activity level in children and adolescents in Japan: A prospective observation study

Manato Horii^a, Ryuichiro Akagi^{a,*}, Seiji Kimura^a, Shotaro Watanabe^a, Satoshi Yamaguchi^b, Takahisa Sasho^c, Seiji Ohtori^a

^a Department of Orthopedic Surgery, Graduate School of Medicine, Chiba University, 1-8-1 Inohana, Chuo-ku, Chiba, Chiba, 260-8670, Japan

^b Graduate School of Global and Transdisciplinary Studies College of Liberal Arts and Sciences, Chiba University, 1-33 Yayoi, Inage-ku, Chiba, Chiba, 263-8522, Japan

^c Center for Preventive Medicine, Musculoskeletal Disease and Pain, Chiba University, 1-8-1 Inohana, Chuo-ku, Chiba, Chiba, 260-8670, Japan

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ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) pandemic has had a profound impact on children's lifestyles. Some studies have reported psychological changes in children after the pandemic, but information on musculoskeletal problems is scarce. This study aimed to investigate the incidence of knee pain and changes in physical activity after the spread of COVID-19 among elementary and junior high school students in Japan.

Methods: Knee pain and amount of physical activity were recorded on a monthly basis between August 2019 and February 2021 in children aged 8–14 years using a self-administered questionnaire. The amount of physical activity was scored using the Hospital for Special Surgery Pediatric Functional Activity Brief Scale (HSS Pedi-FABS). The period until February 2020 was defined as "Before pandemic," and the period from March 2020 was defined as "After pandemic." The incidences of knee pain and HSS Pedi-FABS scores before and after the COVID-19 pandemic were compared. Additionally, we compared the prevalence of knee pain and HSS Pedi-FABS scores according to sex and age.

Results: We enrolled 886 and 881 participants before and after the pandemic, respectively. The prevalence of knee pain among the participants before and after the pandemic was 6.7% and 7.9%, respectively ($p = 0.032$). The mean HSS Pedi-FABS scores before and after the pandemic were 14.8 and 14.5, respectively ($p = 0.005$). Participants aged 14 years had a significantly lower incidence of knee pain ($p = 0.013$) and significantly higher HSS Pedi-FABS scores ($p < 0.001$) after the spread of COVID-19.

Conclusions: In elementary and junior high school students, increase in the incidence of knee pain and decrease in the amount of physical activity after the spread of COVID-19 were observed.

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1. Introduction

The global pandemic of a new coronavirus infection (COVID-19) occurred in February 2020 [1]. In March 2020, policies to stop the spread of the infection were implemented in various countries in response to a global outbreak. The Japanese government temporarily closed all schools in the end of February 2020 [2], and declared a state of emergency in April 2020. Restrictions were placed on various activities, completely changing the way of life of

children and adolescents [3]. Simultaneous closure of schools across the country drastically reduced opportunities for students to participate in physical education, walking to and from school, and other school-based physical activities.

Some studies have made reports concerning the health effects of the COVID-19 epidemic [4,5], and some have focused on lifestyle and mental health changes in children [6,7]. An increase in recreational screen time was observed in children aged 4–17 years after the COVID-19 pandemic [8], and increased fruit and junk food intake has been reported [7]. Regarding physical activity, some studies have reported that children's exercise time decreased after the COVID-19 pandemic [8]. Not only are these lifestyle changes

* Corresponding author. Fax: +81 43 226 2116.

E-mail address: rakagi@chiba-u.jp (R. Akagi).

related to health problems, such as insomnia and increased obesity [9], but they may also increase musculoskeletal pain [10]. However, there are few epidemiological studies about the COVID-19 pandemic on musculoskeletal pain in children and adolescents. In particular, the incidence of knee pain in children and adolescents after the spread of COVID-19 has not yet been reported. Furthermore, physical activity after the spread of COVID-19 is unknown.

This study aimed to compare the prevalence of knee pain and physical activity levels before and after the spread of COVID-19 among elementary and junior high school students in Japan.

2. Materials and methods

2.1. Study design

We conducted a prospective cohort study of children aged 8–14 years in a single school in Chiba, Japan, from August 2019 to February 2021. This study was approved by the institutional review board. Before participating in the study, written informed consent was obtained from all the participants and their guardians. Participants with lower limb trauma at the time of baseline examination, musculoskeletal or neurological disorders that made it impossible to perform the physical examination alone or to walk independently, or those with any history of lower limb surgery were excluded.

2.2. Data collection

Participants demographic data, such as sex and age were recorded at the time of initial participation in this study. Self-reported questionnaires were distributed to participants by schoolteachers at the end of each month. Each student completed responses to the questionnaire at home after returning home. The students were required to report the presence of knee pain by palpating the indicated points while looking at the knee schematic diagram of the questionnaire. Additionally, they completed a questionnaire to collect data on their degree of physical activity. The teachers collected the questionnaires and submitted the data every month.

Knee pain was defined as the presence of tenderness by gentle palpation of the suprapatellar and infra-patellar poles and the tibial tubercle in each knee [11]. These three inspection sites were chosen because they are anatomically easy to define and were common sites of anterior knee pain in children [12]. Knee pain was marked as positive if the participant felt pain to any degree on gentle palpation in at least one of these sites. Physical activity was quantified using the Hospital for Special Surgery Pediatric Functional Activity Brief Scale (HSS Pedi-FABS) [13]. The HSS Pedi-FABS is a patient-reported outcome measure, and eight validated items have been designed to quantify movement in children aged 10–18 years. The first six questions ask the frequency of activities that require running, cutting, decelerating, pivoting, duration, and endurance. As the frequency increases per one month, each movement types are scored 0, 1, 2, 3, or 4. The following two questions ask whether the physical activities were competitive or under supervision by coaches, and scored 0, 1, 2, or 3 points with the higher scores indicating more competitive and controlled activities. The scale ranged from 0 to 30 points, depending on how physically active the respondents had been during the past month, with higher scores indicating higher activity levels.

2.3. Statistical analysis

Summary statistics for baseline variables were created using frequencies and proportions for categorical data and means and standard deviations (SDs) for continuous variables.

The study period was divided into two parts: before and after the spread of COVID-19. We calculated the prevalence of knee pain and the mean HSS Pedi-FABS scores for each month and compared them before and after the spread of COVID-19. The period from August 2019 until February 2020 was defined as “Before pandemic” and the period after March 2020, when COVID-19 infection spread significantly, was defined as “After pandemic”. The Japanese government temporarily closed all schools in the end of February 2020 and declared the first state of emergency from April to June 2020. We were unable to collect data from March 2020 to July 2020 due to the closure of schools during the COVID-19 pandemic. As a result, we compared the prevalence of knee pain and the mean HSS Pedi-FABS score between August 2019 and February 2020 and from August 2020 to February 2021. As a secondary analysis, we analyzed monthly trends in the prevalence of knee pain and the mean HSS Pedi-FABS score by sex and age before and after the pandemic. The participants were divided into four age groups: 1) 8 and 9 years, 2) 10 and 11 years, 3) 12 and 13 years, and 4) 14 years. The category was defined because elementary school students were aged 8 to 11, and junior high school students were aged 12 to 14 in Japan. The 14-year-old participants had to spend more time studying than in other grades to prepare for high school entrance exams. Pearson's Chi-square test was used to compare the knee pain prevalence rate, and a comparison of HSS means was made using the t-test. All p values were two-tailed, and statistical significance was set at $p < 0.05$. R statistical software (version 3.5.1) was used for analysis.

3. Results

We included total 1767 students and all students got the self-reported questionnaires. With some missing data in February 2020 and August 2021, the overall collection rate of questionnaires was 95.7%. The characteristics of the participants in this study are shown in Table 1. The number of participants before and after the COVID-19 pandemic was 886 and 881, respectively. The prevalence of knee pain before and after the pandemic was 6.7% and 7.9%, respectively. The prevalence of knee pain after the spread of COVID-19 was significantly higher ($p = 0.032$). Furthermore, the prevalence

Table 1
Characteristics of participants in this study.

Spread of COVID-19	before	after	P value
Total	886	881	n.s.
Sex			
Boys	445 (50.2)	440 (49.9)	n.s.
Girls	441 (49.8)	441 (50.1)	n.s.
Age (y)			
8,9	211 (23.8)	210 (23.8)	n.s.
10,11	221 (24.9)	217 (24.6)	n.s.
12,13	303 (34.2)	304 (34.5)	n.s.
14	151 (17.1)	150 (17.1)	n.s.
Total prevalence of knee pain (%)	6.7	7.9	0.032
Suprapatellar poles	2.1	3.0	
Infrapatellar poles	3.2	3.4	
Tibial tubercle	3.1	3.8	
HSS Pedi-FABS (points)	14.8 ± 8.6	14.5 ± 8.1	0.005
Running	2.8 ± 1.3	2.9 ± 1.2	
Cutting	2.3 ± 1.4	2.3 ± 1.4	
Decelerating	2.2 ± 1.6	2.2 ± 1.4	
Pivoting	2.2 ± 1.5	2.2 ± 1.5	
Duration	1.8 ± 1.5	1.8 ± 1.5	
Endurance	1.4 ± 1.5	1.3 ± 1.6	
Competition	1.0 ± 0.9	1.0 ± 0.9	
Supervision	0.9 ± 1.0	0.9 ± 1.0	

Data are presented as numbers (prevalence), and HSS Pedi-FABS are presented as mean ± standard deviation.
HSS Pedi-FABS: Hospital for Special Surgery, Pediatric Functional Activity Brief Scale.
n.s.: not significant.

of knee pain increased at all palpating points. Additionally, the mean (standard deviation [SD]) HSS Pedi-FABS scores before and after the pandemic was 14.8 (8.6) points and 14.5 (8.1) points, respectively. The mean HSS Pedi-FABS score before the spread of COVID-19 was significantly higher than that after the pandemic ($p = 0.005$). All items consisting of the HSS Pedi-FABS had similar scores. The monthly prevalence of knee pain and mean HSS Pedi-FABS before and after the pandemic showed that the overall prevalence of knee pain was higher after the pandemic, although there were no significant differences in the (Fig. 1). There was a significant difference in the mean HSS Pedi-FABS scores before and after the pandemic in August and January. In August, the mean (SD) HSS Pedi-FABS scores before and after the pandemic were 14.1 (8.8) points and 12.8 (8.8) points, respectively ($p = 0.009$). In January, the mean (SD) HSS Pedi-FABS scores before and after the pandemic was 15.1 (8.5) points and 14.0 (7.9) points, respectively ($p = 0.006$).

The prevalence of knee pain and mean HSS Pedi-FABS scores by sex and the four age groups before and after the pandemic are presented in Table 2. There was no significant difference in the prevalence of knee pain between sexes, but the boys had higher HSS Pedi-FABS scores before the pandemic than after the pandemic (16.8 ± 8.8 points and 16.3 ± 8.3 points, $p = 0.031$). In addition, we calculated the prevalence of knee pain at each palpating point by sex and the four age groups before and after the pandemic and showed the results in Table 3. The prevalence of knee pain at the suprapatellar poles tended to be increased after the pandemic. Especially, the prevalence of knee pain at all palpating points significantly increased in 8–9 years group. In August, comparing the monthly average, there was a significant difference in HSS Pedi-FABS score in the boys (16.2 ± 9.1 points and 14.6 ± 8.7 points, $p = 0.035$) (Figs. 2 and 3). By age category, the 8–9 years group had a significantly higher prevalence of knee pain (8.7% vs. 14%, $p < 0.001$) and a lower HSS Pedi-FABS score (17.1 ± 7.5 points vs. 16.1 ± 6.9 points, $p < 0.001$) after the spread of COVID-19. On the other hand, 14-year-old participants had a significantly lower prevalence of knee pain (5.8% vs. 3.4%, $p = 0.013$) and a higher HSS Pedi-FABS score after the pandemic (6.3 ± 6.4 points vs. 7.6 ± 6.6 points, $p < 0.001$). The monthly trend in each age category showed that the 8–9 years age group had a significantly higher prevalence of knee pain in October, November, and December after the spread of COVID-19 (Fig. 4). On the other hand, the HSS Pedi-FABS scores after the pandemic in participants aged 14 years were significantly higher (Fig. 5).

4. Discussion

To the best of our knowledge, no study has investigated the prevalence of knee pain and the level of sports activity before and

Table 2

Prevalence of knee pain and mean HSS Pedi-FABS scores by sex and four age categories before and after the pandemic.

	Prevalence of knee pain (%)			HSS Pedi-FABS (points)		
	before	after	P value	before	after	P value
Sex						
Boys	7.7	8.9	0.115	16.8 ± 8.8	16.3 ± 8.3	0.031
Girls	6	6.9	0.180	13.0 ± 7.9	12.6 ± 7.5	0.055
Age (y)						
8,9	8.7	14	<0.001	17.1 ± 7.5	16.1 ± 6.9	<0.001
10,11	6.2	5.3	0.330	17.1 ± 7.4	16.2 ± 7.2	0.002
12,13	6.5	7.9	0.104	15.6 ± 8.5	15.4 ± 8.3	0.443
14	5.8	3.4	0.013	6.3 ± 6.4	7.6 ± 6.6	<0.001

The HSS Pedi-FABS data are presented as mean \pm standard deviation.

HSS Pedi-FABS: Hospital for Special Surgery, Pediatric Functional Activity Brief Scale.

after the spread of COVID-19. The most important finding of our study was that the prevalence of knee pain after the spread of COVID-19 was significantly higher than that before the pandemic. Additionally, the HSS Pedi-FABS scores after the pandemic were lower than before the pandemic, indicating less physical activity in children and adolescents. No difference in knee pain prevalence and sports activity scale scores was found by sex before and after the COVID-19 pandemic, but there was a different trend by age category.

Before the spread of COVID-19, the incidence of knee pain in children and adolescents was reported to be 14–30% [14,15]. In a previous report in Japan, the annual incidence of anterior knee pain ranged from 3.0 to 9.6% from 2016 to 2018 [11]. In the present study, the prevalence of knee pain before the spread of COVID-19 was 6.7%, which is comparable to that in previous reports. We observed a significant increase in the prevalence of knee pain to 7.9% after the spread of COVID-19. Furthermore, the increase was even more remarkable in children aged 8–9 years, with a prevalence rate of 14% after the pandemic. We are not able to explain the reason for this increase in knee pain prevalence among children, but this trend is similar to the result of a cross-sectional study that reported more musculoskeletal pain due to lifestyle changes among survivors of natural disasters [10]. Regarding musculoskeletal problems related to the COVID-19 pandemic, a cohort study in the USA showed a significant decrease in pediatric musculoskeletal injuries associated with sports [16]. Another cross-sectional study showed that 40% of participants with no previous back pain developed back pain during the COVID-19 pandemic [17]. To the best of our knowledge, there have been no reports on the incidence of knee pain after the COVID-19 pandemic.

In our study, the mean HSS Pedi-FABS before and after the spread of COVID-19 was 14.8 and 14.5 points, respectively. The normative data for HSS Pedi-FABS in children aged 10–18 years

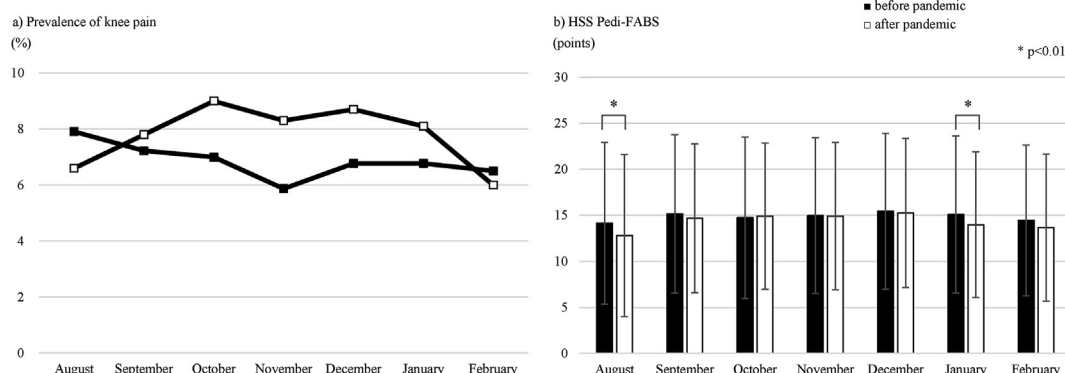
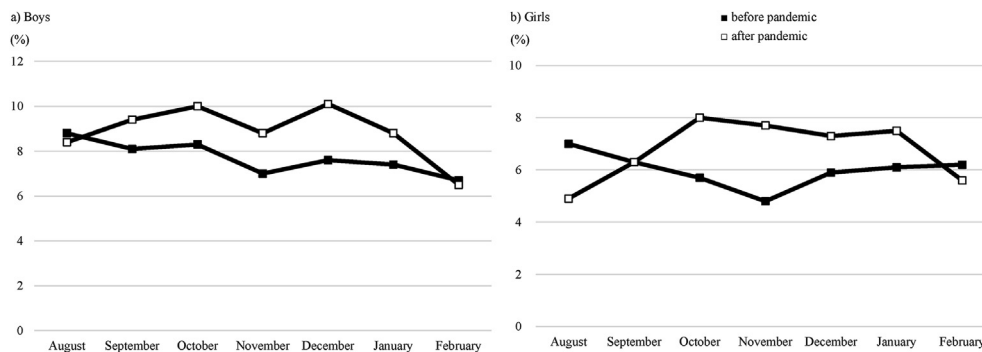
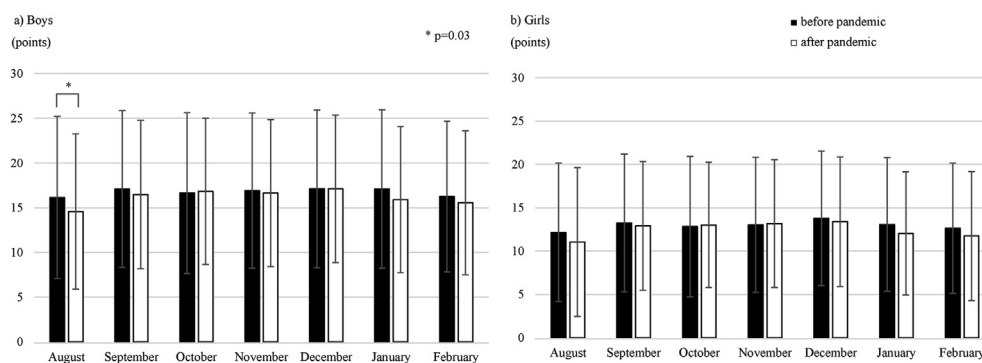


Fig. 1. Prevalence of knee pain and mean HSS Pedi-FABS before and after the spread of COVID-19. a) Prevalence of knee pain. b) HSS Pedi-FABS.

Table 3

The prevalence of knee pain at each tenderness point by sex and four age categories before and after the pandemic.

Spread of COVID-19		before	after	P value
Prevalence of knee pain (%)				
Suprapatellar poles				
Sex	Boys	2.3	3.2	0.021
	Girls	2.0	2.7	0.067
Age (y)	8,9	4.3	7.0	0.002
	10,11	1.5	1.6	0.884
	12,13	1.4	2.6	0.004
	14	1.6	0.5	0.016
Infrapatellar poles				
Sex	Boys	3.7	3.9	0.694
	Girls	2.8	2.9	1.000
Age (y)	8,9	3.0	6.4	<0.001
	10,11	2.9	1.3	0.003
	12,13	3.5	3.8	0.584
	14	3.4	1.5	0.003
Tibial tubercle				
Sex	Boys	3.8	4.8	0.072
	Girls	2.6	2.9	0.485
Age (y)	8,9	3.2	6.8	<0.001
	10,11	3.4	3.2	0.684
	12,13	3.3	3.6	0.522
	14	2.4	1.5	0.167

**Fig. 2.** Prevalence of knee pain for each sex before and after the spread of COVID-19. a) Boys. B) Girls.**Fig. 3.** Mean HSS Pedi-FABS for each sex before and after the spread of COVID-19. a) Boys. b) Girls.

have been reported to be 15.4 points [18], and the HSS Pedi-FABS before and after the spread of COVID-19 from our study were similar to this previous report. Although the HSS Pedi-FABS after the spread of COVID-19 was significantly lower statistically than that before the pandemic, a difference of 0.3 points may not be clinically relevant. In terms of sex and age, the HSS Pedi-FABS after the spread of COVID-19 was significantly lower in boys and in the age of 8–11 years than before the pandemic. However, the mean differences ranged from 0.5 to 1.0 points, and the clinical significance is unclear.

Sports activity level has been reported to be associated with knee pain in children and adolescents [19]. A cross-sectional study showed that elementary and junior high school students who exercise for a long time tend to have more knee pain [20]. It has been reported that many children aged 5–13 years have reduced their physical activity between April and May 2020 in the US [9]. A cohort study in Germany showed that children aged 4–17 years experienced decreased exercise time during the COVID-19 lockdown between March and May 2020 [8]. In Japan, a state of emergency was declared from April to June, forcing restrictions on

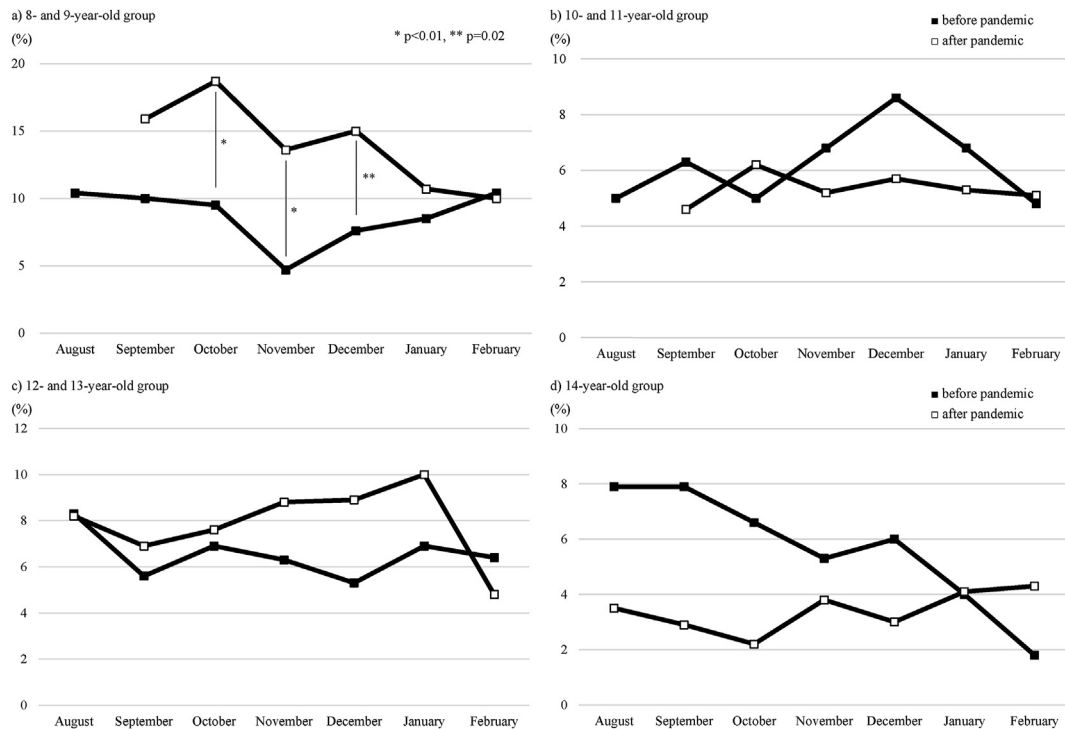


Fig. 4. Prevalence of knee pain in each age group before and after the spread of COVID-19. a) 8 and 9 years group. b) 10- and 11-year-old group c) 12- and 13-year-old group d) 14-year-old group.

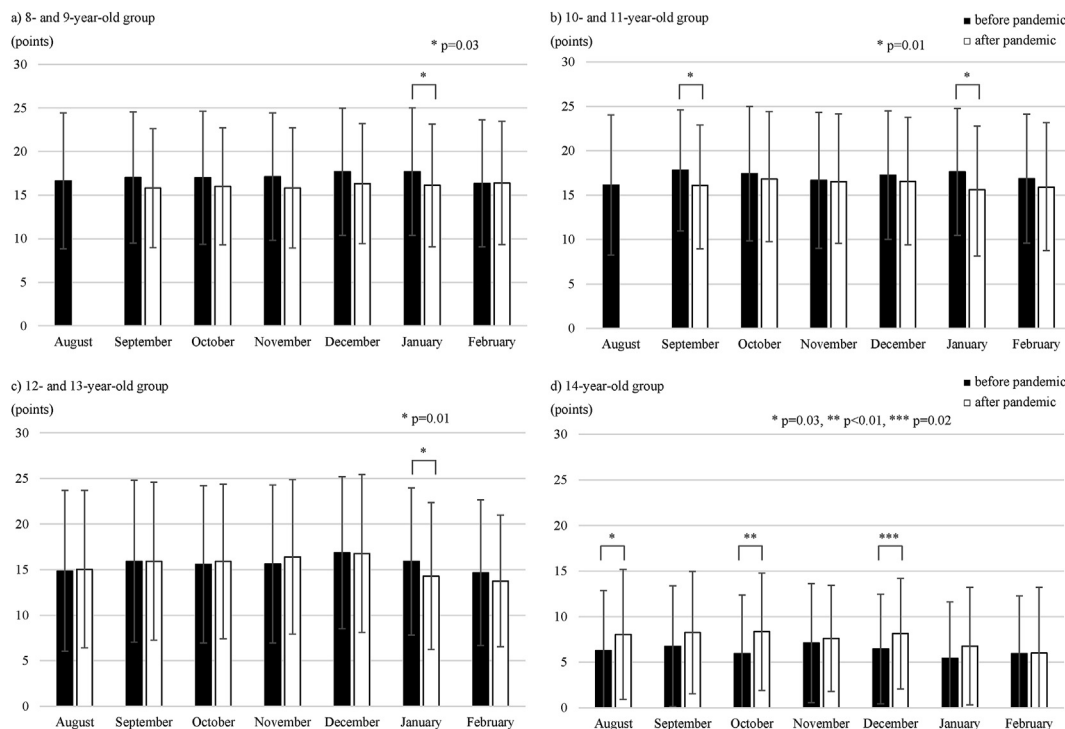


Fig. 5. Mean HSS Pedi-FABS for each age group before and after the spread of COVID-19. a) 8- and 9-year-old group b) 10- and 11-year old group c) 12- and 13-year-old group d) 14-year-old group.

sports activities. Thus, we expected to observe lower physical activity levels and a lower incidence of knee pain immediately after the COVID-19 pandemic. However, our results indicated that the change in HSS Pedi-FABS was small, and the prevalence of knee

pain after the spread of COVID-19 was significantly higher than that before the pandemic. When compared by month, the incidence of knee pain after the spread of COVID-19 tended to be higher than that before the pandemic until December 2020, and it gradually

decreased to the same level as before the pandemic by February (Fig. 1a). This trend was especially significant in children aged 8–9 years (Fig. 4a). In contrast, the HSS-Pedi FABS remained similar before and after the COVID-19 pandemic (Fig. 1b). We assumed that many children resumed their sports activities as soon as the state of emergency was disengaged. Rapid recovery to the same activity level as before the spread of COVID-19 might have led to an increased number of children and adolescents with knee pain in the early period after quarantine. We hypothesized that improvement in body condition after a few months of continuous physical activity and the number of children and adolescents with knee pain gradually decreased.

Interestingly, the incidence of knee pain after the spread of COVID-19 tended to be lower in children aged 14 years old. Before the pandemic, the incidence of knee pain was high in this age category, with a gradual decline from August to December, which remained low after the pandemic (Fig. 4d). This trend was possibly because the age of 14 years in this study corresponded to the third year of junior high school, which requires studying for high school entrance exams. It has been reported in a Japanese observational study that the amount of physical activity of the third-grade junior high school students are high in April through July, and would decrease significantly after August [21]. Before the spread of COVID-19, it was common for many students of this age to prepare for the national sports competition held from July to August; thus, increasing the amount of training, and perhaps, the incidence of physical pain at this time of year. After August, a reduction in physical activity was observed when the students shifted to studying for their high school entrance exam, thereby reducing the incidence of knee pain simultaneously. In 2020, owing to the COVID-19 pandemic and school closure, as well as the cancellation of sports competitions, physical activity was largely restricted in July. We consider this decrease in physical activity as one reason for the low incidence of knee pain observed after the pandemic in this age category.

This study is one of the few studies investigating the incidence of knee pain and sports activity scale scores in children and adolescents after the spread of COVID-19. The strength of this study is that it was a large longitudinal survey with more than 1600 respondents. Additionally, we assessed physical activity using the HSS Pedi-FABS instead of activity time as some previous reports [4,8]. As this study was conducted in children and adolescents, we chose the HSS Pedi-FABS, a physical activity assessment method specifically designed for children and adolescents. Furthermore, compared to other physical activity assessments, the HSS Pedi-FABS is more likely to capture changes in physical activity due to seasonal variations [22]. We believe that the HSS Pedi-FABS is an appropriate assessment method for this study, which investigated monthly changes in physical activity. However, our study has some limitations. First, we evaluated knee pain based on a participants' self-reported tenderness. Because pain is a subjective symptom, if the pain is not troubling to the children, they might not have reported the presence of knee pain. Additionally, it is unclear which conditions were most responsible for the knee pain observed in the study, and we were not able to reach a definitive diagnosis. Second, the participants' lifestyle and HSS Pedi-FABS scores during the COVID-19 pandemic are unknown. Furthermore, any psychosocial change that occurred to the children may have influenced the physical activity and response to pain. Additional questionnaires to assess the psychological status may help evaluating these effects, but due to the concern that too many questions will reduce accuracy of the response, especially in our young subjects, we declined to investigate this point. Third, we do not know how the change in physical activity level influenced the actual physical fitness. Thus, we are not able to determine if the increase in knee pain is related

to change in physical strength. Finally, this study was conducted in a single public school; therefore, the generalizability of the results is questionable.

5. Conclusion

We conducted a prospective cohort study of Japanese children and adolescents and compared the prevalence of knee pain and HSS Pedi-FABS scores before and after the spread of COVID-19. The prevalence of knee pain after the spread of COVID-19 was significantly higher than that before. However, physical activity after the spread of COVID-19 was significantly lower than before. We also showed that physical activity in boys and the prevalence of knee pain in fourteen years old were significantly lower after the spread of COVID-19 than before.

Ethics approval

This study was approved by the Ethics Committee of the Graduate School of Medicine of Chiba University.

Declaration of competing interest

The authors declare that they have no conflict of interest.

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