



The effects of COVID-19 on the Physical Activity and Recreational Screen Time among Chinese children and adolescents

Ming Ming Guo^a, Koon Teck Koh^b, Xiao Zan Wang^{a,*}

^a College of Physical Education and Health, East China Normal University, Shanghai, 200241, China

^b Physical Education & Sports Science, National Institute of Education, Nanyang Technological University, 637616, Singapore

ARTICLE INFO

Keywords:

Physical activity
Recreational screen time
Chinese children and adolescents
Pandemic
National trends

ABSTRACT

Background: The lack of Physical Activity (PA) and prolonged Recreational Screen Time (RST) among children and adolescents has been exacerbated during the COVID-19 pandemic, causing this issue to escalate into a crucial public health concern. This study aims to investigate the trends in PA and RST among Chinese children and adolescents from 2019 to 2022, thereby analyzing the short-term and long-term effects of the pandemic on PA and RST among Chinese children and adolescents.

Methods: A nationally representative sample of Chinese primary, middle, and high school students was surveyed annually between September and December from 2019 to 2022 using a consistent set of questionnaires. Trends in PA and RST across different school levels, genders, areas (urban/rural), and regions (north/south) were analyzed using Segmented Linear Regression.

Results: From 2019 to 2022, the PA and RST of children and adolescents displayed an inverted U-shaped trend, initially increasing and subsequently declining. Specifically, from 2019 to 2021, the PA of children and adolescents significantly increased but dramatically declined from 2021 to 2022. This trend in PA is more pronounced among primary, male, urban, and northern children and adolescent. The RST of children and adolescents increased from 2019 to 2020 but significantly decreased from 2020 to 2022. This trend in RST is more pronounced among primary, urban, and southern children and adolescent.

Conclusions: This research unveils the effects of the pandemic on PA and RST in children and adolescents, suggesting short-term beneficial and long-term adverse effects on PA and short-term adverse and long-term beneficial effects on RST. These findings provide a foundation for formulating policies related to children and adolescents' PA and RST during the pandemic.

1. Introduction

In March 2020, the World Health Organization (WHO) declared the pneumonia disease caused by the novel coronavirus to be named COVID-19 (Coronavirus Disease 2019) and defined it as a "pandemic", indicating that the virus had spread at the community level in multiple countries.¹ In response, governments worldwide implemented a range of pandemic prevention and control measures to mitigate the further spread of the virus. These included, but were not limited to, lockdowns, home quarantines, closures of schools and public facilities, cancellations of large-scale events, restrictions on gatherings, and travel bans.² These measures significantly impacted the lives and education of the majority of children and adolescents globally.³ Due to China's unique social conditions, characterized by a large population and a scarcity of

grassroots medical resources, China adopted more stringent and longer-lasting measures compared to other countries.⁴ As a result, from the beginning of 2020 to early 2023, China's children and adolescents experienced continuous disruptions due to these measures, including numerous stay-at-home mandates during critical periods of the pandemic.

Physical Activity (PA) is defined as any human skeletal muscle movement resulting in energy expenditure.⁵ Recreational Screen Time (RST), on the other hand, encompasses all discretionary and leisure-time screen-based activities undertaken in a sedentary posture, predominantly including watching television, playing video games, and using computers.⁶ Emerging evidence suggests that regular and sufficient PA, coupled with reduced RST, strengthens immunity, thereby diminishing the risk of infectious diseases and amplifying immune responses

* Corresponding author.

E-mail addresses: guo.mingming@stu.ecnu.edu.cn (M.M. Guo), koonteck.koh@nie.edu.sg (K.T. Koh), xzwan@ecnu.edu.cn (X.Z. Wang).

<https://doi.org/10.1016/j.jesf.2024.04.002>

Received 8 January 2024; Received in revised form 17 April 2024; Accepted 17 April 2024

Available online 24 April 2024

1728-869X/© 2024 The Society of Chinese Scholars on Exercise Physiology and Fitness. Published by Elsevier (Singapore) Pte Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

following vaccination.^{7,8} Additionally, it mitigates negative emotional states during the pandemic, thus preserving mental health.⁹

Prior research has underscored a significant decline in PA and a rise in RST among children and adolescents attributed to pandemic prevention and control measures. For instance, Neville et al. reported a 20 % worldwide reduction in PA among children and adolescents during this period with Moderate to Vigorous Physical Activity (MVPA) witnessing the steepest fall of 32 %.¹⁰ Trott et al. also observed a significant increase in RST during the pandemic, with an additional hour of RST per day for children and half an hour of RST for adolescents.¹¹ In China, similar trends were observed. Xiang et al. found a 22 % decrease in Chinese children and adolescents participating in MVPA during the pandemic and a 24 % reduction in those with RST under 2 h daily.¹² In addition, Yang et al. found the percentage of Chinese children and adolescents engaged in at least 60 min of MVPA daily decreased from 14.4 % before the pandemic to 11.7 % during pandemic, while those exceeding 2 h of RST daily increased from 22.2 % to 27.9 %.¹³ Benzing et al. also highlighted that, due to China's relatively stringent pandemic measures, Chinese children and adolescents faced more pronounced declines in PA and increases in RST.¹⁴

Taken together, studies conducted in China have generally utilized relatively small sample sizes, rendering them inadequate to fully capture the pandemic's impact on all Chinese children and adolescents.^{12,13} Furthermore, the aforementioned studies were predominantly carried out within the first year of the pandemic or around lockdown periods, limiting insights into the pandemic's long-term effects on children's and adolescents' PA and RST. More critically, no research has addressed the differential impacts of the pandemic on PA and RST across various demographics to date, including school levels, genders, geographical areas, and regions. This absence of nuanced research hampers our understanding of the impacts of the pandemic on children and adolescents' PA participation and RST habits, as well as the ability to develop tailored programs and make appropriate recommendations for modifying pandemic prevention and control measures. Therefore, the aim of this study is to investigate both the short-term and long-term effects of the pandemic and China's prolonged and stringent preventive measures on the PA and RST of Chinese children and adolescents across various demographic groups through annual cross-sectional surveys conducted from 2019 to 2022, thereby offering insights that could inform the prevention and management of future challenges related to pandemics.

2. Materials and methods

2.1. Participants and study design

The present study received approval from the Human Experimentation Ethics Committee of East China Normal University and was conducted in strict adherence to the ethical principles outlined in the Declaration of Helsinki. It encompasses a series of annual cross-sectional surveys conducted from 2019 to 2022, with each year's survey period spanning from September to December. The participants, students from grades 4 to 12, were selected through stratified sampling from the project "Construction of a Big Data Platform for Children and Adolescents' Sports and Fitness in China (CBDPCASF)." Funded by the National Science Foundation of China, the CBDPCASF project seeks to establish a comprehensive database of sports and fitness-related data for Chinese children and adolescents. The objective is to furnish a valuable data resource for research on the sports and health of children and adolescents, ultimately contributing to the development of policies designed to promote the health of children and adolescents. Annually, the project enlists primary, middle, and high schools across China for participation. Schools participating in the CBDPCASF project are invited to engage in various studies, with this study being one of them.

From 2019 to 2022, a total of 122,177 participants (48 % females) from grades 4 to 12 (with an average age of 11.4 ± 2.1 years) participated in this study.

2.2. Procedures

Before commencing the survey each year, informed consent was obtained from the participants and their guardians through their respective schools. Subsequently, participants received a web link to a questionnaire from their teachers, which was hosted on the Questionnaire Star platform.¹⁵ The questionnaire collected students' basic information such as school name, grade, and gender, in addition to PA and RST over the preceding seven days. Information about the area (urban/rural), region (north/south), and administrative divisions (provinces, cities, counties) was acquired using the Baidu Map Open Platform.¹⁶ The corresponding population data for China, grouped by year, region, province, area, school level, and gender, was sourced from the 2021 Chinese Statistical Yearbook.¹⁷ Finally, participants with incomplete information, incorrect responses (e.g., uniform answers across all items), outliers (values that exceed the normal range based on Tukey's method),¹⁸ and those unable to engage in PA due to exceptional circumstances (e.g., fractures) or pre-existing medical conditions (e.g., disabilities) during the survey period were excluded.

2.3. Instruments

Participants' PA was assessed through the Chinese version of the Physical Activity Questionnaire for Older Children (PAQ-C).¹⁹ This self-reported questionnaire, featuring a seven-day recall, has been validated for both reliability and validity in numerous studies, and was thus deemed appropriate for assessing PA among Chinese children and adolescents.^{20,21} The PAQ-C comprises ten items: the first item queries the frequency of participation in 21 different sports activities e.g., skipping, swimming, tennis, martial arts, and basketball. The second to eight items assess PA during specific times—physical education classes, recess, lunchtime, after school, evenings, weekends, and a self-descriptive item. The ninth item gauges the frequency of engaging in PA for more than 30 min daily over the past week. The tenth item, a screening question, identifies potential barriers to PA engagement in the previous seven days. The first nine items utilize a five-point Likert scale, ranging from 1 (minimal PA participation) to 5 (maximum PA participation). The overall PA score is calculated by averaging the responses to items one through nine, resulting in a score range from 1 to 5, where 1 represents the lowest level of PA and 5 indicates the highest level of PA.¹⁹ In line with previous research, a score above 2.87 indicates compliance with the WHO PA guidelines, that is, 60 min of MVPA per day.²⁰

Participants' RST was assessed using the Chinese version of the Adolescent Sedentary Activity Questionnaire (ASAQ).²² The ASAQ is a self-administered survey consisting of six items with a seven-day recall period. Its reliability and validity have been established in previous studies, making it suitable for assessing RST in Chinese children and adolescents.^{22,23} These items specifically query the duration of television or movie viewing, and the use of smartphones, computers, or tablets for non-academic and non-work-related purposes. The total weekly RST is determined by summing the responses to these six items, and the average daily RST is subsequently calculated by dividing the weekly RST by seven.²² According to the Canadian 24-h Movement Guidelines⁶ and the Chinese Children and Adolescents' Physical Activity Guidelines,²⁴ participants with less than 2 h of daily RST were deemed in compliance with the RST guidelines.

The area (urban-rural) categorization of participants was established according to the geographical location of their schools, using the Application Programming Interface (API) provided by the Baidu Maps' open platform.¹⁶ Considering that local school attendance is mandatory in accordance with Chinese policy, the school's geographical location is considered representative of the student's location.²⁵ Additionally, based on the distinct characteristics of China's natural geography and economic development, participants were segmented into southern and northern geographical regions based on the Qinling Huaihe Line. The

Qinling-Huaihe Line is the geographical boundary that distinguishes the northern and southern regions in China. To the north and south of this line, there are significant differences in natural conditions, geographical landscapes, agricultural production, and people's customs and ways of life.²⁶

To enhance the representativeness of the data analysis and ensure accurate weighting of the data in this study, the national population for each participant group, segmented by region, province, urban or rural area, school level, and gender, were sourced from the 2021 Chinese Statistical Yearbook.¹⁷ The 2021 Chinese Statistical Yearbook provides an extensive overview of China's economic and social progress, including detailed statistics on the student population across various demographics.¹⁷

2.4. Statistical analyses

All samples were grouped based on the year, region, province, area, school level, and gender categories. Subsequently, the PA and RST compliance rates for each group were computed. To achieve a more precise representation and given the multi-layered structure of the data (spanning regions, provinces, and areas), Mixed Linear Regression (MLR) was utilized to estimate the missing rural or urban compliance rates for provinces that encompassed solely urban or rural participants, by leveraging data from provinces with both urban and rural participation.²⁷ Furthermore, to mitigate biases arising from variations in sample sizes across different years, regions, and areas, the total population of each group was integrated into the dataset as a weighting variable for further analysis.²⁸

Following this, the weighted average PA and RST compliance rates and the 95 % Confidence Intervals (95 % CI) were calculated based on participants' region, area, school level, and gender. To analyze the annual phased changes in PA and RST compliance rates, Segmented Linear Regression (SLR) was employed to examine the differences in PA and RST compliance rates for the years 2019–2020, 2020 to 2021, and 2021 to 2022. Additionally, the trends of PA and RST compliance rates for each school level, gender, area, and region were visually depicted using line charts, with years as the horizontal axis and compliance rates as the vertical axis. All data were processed and analyzed using Python (Python 3.10, Python Software Foundation) with statsmodels, scipy, seaborn, and matplotlib extension libraries,²⁹ with a significance level set at $p < 0.05$.

3. Results

3.1. Participant characteristics

After the data cleaning process, a total of 24,654 participants (20.17 %) were excluded from the analysis for several reasons: lack of grade information ($n = 53$), unable to engage in PA due to exceptional circumstances (e.g., fractures) or pre-existing medical conditions (e.g., disabilities) ($n = 6333$), inaccurate responses (e.g., uniform answers across all items) ($n = 8535$), total sitting time exceeding 24 h a day ($n = 4387$), outliers (values that exceed the normal range based on Tukey's method) in PA score or RST ($n = 5206$), and groups with less than 10 individuals after grouped by region, province, area, school level, and gender ($n = 140$). As a result, a total of 97,523 participants were included in the study, of whom 49.15 % (47,930) were female. This sample comprised 58,964 primary school students, 27,538 middle school students, and 11,021 high school students. The annual sample size ranged from 5537 to 23,805 for primary school students; 3051 to 12,706 for middle school students; and 1640 to 5506 for high school students. Overall unweighted sample sizes for each year, grouped by school level, gender, area, and region, are displayed in Table 1. The corresponding weighted sample sizes are presented in Supplementary Table S1.

Table 1

Sample size for physical activity and recreational screen time in Chinese children and adolescents 2019–2022.

	No. of Participants			
	2019	2020	2021	2022
Overall	10491	27466	17549	42017
School Level				
Primary	5537	17744	11878	23805
Middle	3051	8082	3699	12706
High	1903	1640	1972	5506
Gender				
Male	5087	14284	8774	21448
Female	5404	13182	8775	20569
Area^a				
Urban	8379	21402	14743	32519
Rural	2112	6064	2806	9498
Region^b				
North	9705	13765	7108	11764
South	786	13701	10441	30253

^a The area type was provided by the Baidu Maps Open Platform based on the school location.

^b The region type was determined by China's natural geographic boundary, specifically, the Qinling-Huaihe Line.

3.2. Physical activity

In 2022, PA compliance rates among Chinese children and adolescents were notably low. Specifically, 34.4 % of primary school students, 26.5 % of middle school students, and 14.5 % of high school students met the PA guidelines (see Table 2). Supplementary Table S2 provides estimates of PA compliance rates for children and adolescents across different years, school levels, genders, areas, and regions.

Between 2019 and 2020, a notable increase in PA compliance rates was observed among students from southern regions ($p < 0.05$). Although increases were also noted across all school levels, genders, urban areas, and among students from northern regions, these changes were not statistically significant. From 2020 to 2021, there was a significant increase in PA compliance rates among primary school students ($p < 0.05$), male students ($p < 0.01$), rural students ($p < 0.01$), and students from northern regions ($p < 0.01$). Meanwhile, PA compliance rates for middle school students, female students, urban students, and students from southern regions also increased but not statistically significant. In contrast, 2022 witnessed substantial declines in PA compliance rates among primary school students ($p < 0.01$), in both genders ($p < 0.01$), in all areas ($p < 0.01$), and across all regions ($p < 0.01$). A decrease in PA compliance rates among high school students was also observed, though this change was not statistically significant. For trends in PA compliance rates, please refer to Table 3 and Fig. 1. Supplementary Table S3 details the trends across different years, school levels, genders, areas, and regions.

3.3. Recreational screen time

In 2022, high RST compliance rates were observed among children and adolescents. Specifically, 80.2 % of primary school students, 82.6 % of middle school students, and 85.7 % of high school students adhered to the RST guidelines (see Table 2). Supplementary Table S2 offers detailed RST compliance rates across varying years, school levels, genders, areas, and regions.

In comparison to 2019, RST compliance rates did not significantly change in 2020, although a decline was observed among primary and high school students, urban students, and across all genders and regions. Notably, 2021 saw a substantial rise in RST compliance rates among primary school students ($p < 0.05$), urban students ($p < 0.05$), and students from southern regions ($p < 0.05$). While middle and high school students, both genders, rural students, and students from northern regions also saw increases in compliance rates, these were not statistically

Table 2
Weighted physical activity and recreational screen time compliance rates among Chinese children and adolescents 2019–2022^a.

	Physical Activity and Recreational Screen Time Compliance Rates by Year ^a			
	2019	2020	2021	2022
	Physical Activity Score ≥ 2.78 , Weighted % (95 % CI)			
School Level				
Primary	26.3 (21.6, 31.0)	30.3 (27.4, 33.2)	43.0 (40.0, 46.0)	34.4 (31.9, 36.9)
Middle	18.4 (15.0, 21.9)	18.8 (16.1, 21.6)	26.0 (20.9, 31.2)	26.5 (23.2, 29.7)
High	12.7 (4.8, 20.6)	17.3 (9.6, 24.9)	17.1 (9.0, 25.2)	14.5 (8.7, 20.2)
Gender				
Male	25.9 (22.0, 29.8)	29.5 (26.6, 32.4)	44.3 (40.4, 48.1)	34.7 (31.9, 37.5)
Female	19.7 (15.7, 23.7)	24.3 (20.6, 27.9)	35.0 (31.1, 38.9)	26.2 (23.3, 29.0)
Area^b				
Rural	33.4 (30.5, 36.3)	33.1 (30.4, 35.9)	45.1 (41.8, 48.3)	35.2 (32.6, 37.9)
Urban	21.0 (17.4, 24.6)	25.8 (22.5, 29.0)	38.9 (34.9, 42.9)	30.1 (27.2, 33.0)
Region^b				
North	24.1 (20.5, 27.6)	25.9 (23.1, 28.7)	40.0 (35.5, 44.4)	26.2 (23.4, 28.9)
South	20.7 (15.8, 25.6)	28.4 (24.4, 32.4)	39.9 (36.0, 43.7)	32.5 (29.8, 35.3)
	Recreational Screen Time ≤ 2 Hours Per Day, Weighted % (95 % CI)			
School Level				
Primary	78.0 (74.6, 81.3)	74.7 (72.0, 77.4)	80.1 (77.8, 82.5)	80.2 (77.7, 82.7)
Middle	79.4 (75.3, 83.6)	82.0 (79.1, 84.9)	84.7 (80.5, 88.9)	82.6 (79.5, 85.7)
High	89.4 (84.2, 94.7)	84.4 (75.3, 93.6)	85.2 (75.8, 94.7)	85.7 (80.5, 90.9)
Gender				
Male	78.1 (74.5, 81.6)	75.2 (72.2, 78.2)	78.9 (76.0, 81.8)	79.9 (77.4, 82.4)
Female	80.6 (77.5, 83.7)	78.7 (75.9, 81.6)	83.2 (80.7, 85.7)	82.8 (80.3, 85.3)
Area^b				
Rural	70.7 (67.9, 73.6)	71.7 (69.5, 73.9)	71.5 (68.7, 74.2)	72.2 (69.5, 74.8)
Urban	80.9 (78.0, 83.8)	77.9 (75.0, 80.8)	82.8 (80.4, 85.1)	82.6 (80.4, 84.8)
Region^b				
North	78.5 (75.6, 81.4)	76.8 (74.3, 79.2)	79.0 (76.1, 81.8)	82.4 (79.7, 85.2)
South	80.9 (76.6, 85.2)	77.0 (73.4, 80.6)	82.4 (79.7, 85.1)	80.8 (78.5, 83.1)

^a Weighted estimates and 95 % CIs were estimated for each survey year. All estimates were weighted to be nationally representative.

^b For definitions of area and region, refer to the footnotes in Table 1.

significant. A significant rise in RST compliance rates among students from southern regions was observed in 2022 compared to 2021 ($p < 0.05$). While RST compliance rates also increased among primary and high school students, both genders, urban students, and students from northern regions, these changes were not significant. Conversely, a non-significant decrease was noted among middle school students and rural students. Table 3 and Fig. 2 highlight the changes in RST compliance rates, with Supplementary Table S3 detailing the trends across different years, school levels, genders, areas, and regions.

4. Discussion

The purpose of the present study was to investigate the short-term and long-term effects of the pandemic and China's prolonged and stringent preventive measures on the PA and RST of Chinese children and adolescents across different school levels, genders, areas, and

Table 3
Crude weighted trends in physical activity and recreational screen time among Chinese children and adolescents 2019–2022^a.

	Trends in Physical Activity and Recreational Screen Time Years					
	2019 To 2020		2020 To 2021		2021 To 2022	
	β	P	β	P	β	P
	Physical Activity Compliance Trends					
School Level						
Primary	3.97	0.12	12.66	<0.05	-12.54	<0.01
Middle	0.39	0.88	7.17	0.12	0.05	0.14
High	4.54	0.34	-0.18	0.6	-7.18	0.81
Gender						
Male	3.55	0.17	14.81	<0.01	-13.11	<0.01
Female	4.57	0.1	10.69	0.17	-13.39	<0.01
Area^b						
Rural	-0.25	0.9	11.92	<0.01	-9.59	<0.01
Urban	4.77	0.08	13.13	0.06	-13.59	<0.01
Region^b						
North	1.78	0.44	14.09	<0.01	-15.61	<0.01
South	7.7	<0.05	11.48	0.47	-15.04	<0.01
	Recreational Screen Time Compliance Trends					
School Level						
Primary	-3.24	0.13	5.38	<0.05	3.31	0.07
Middle	2.6	0.3	2.64	0.98	-4.69	0.3
High	-5	0.26	0.75	0.49	5.47	0.97
Gender						
Male	-2.87	0.2	3.66	0.07	3.89	0.43
Female	-1.84	0.37	4.39	0.07	1.46	0.12
Area^b						
Rural	0.95	0.64	-0.26	0.71	-0.26	0.76
Urban	-2.96	0.14	4.79	<0.05	2.76	0.09
Region^b						
North	-1.73	0.33	2.16	0.2	5.21	0.7
South	-3.91	0.17	5.35	<0.05	2.36	<0.05

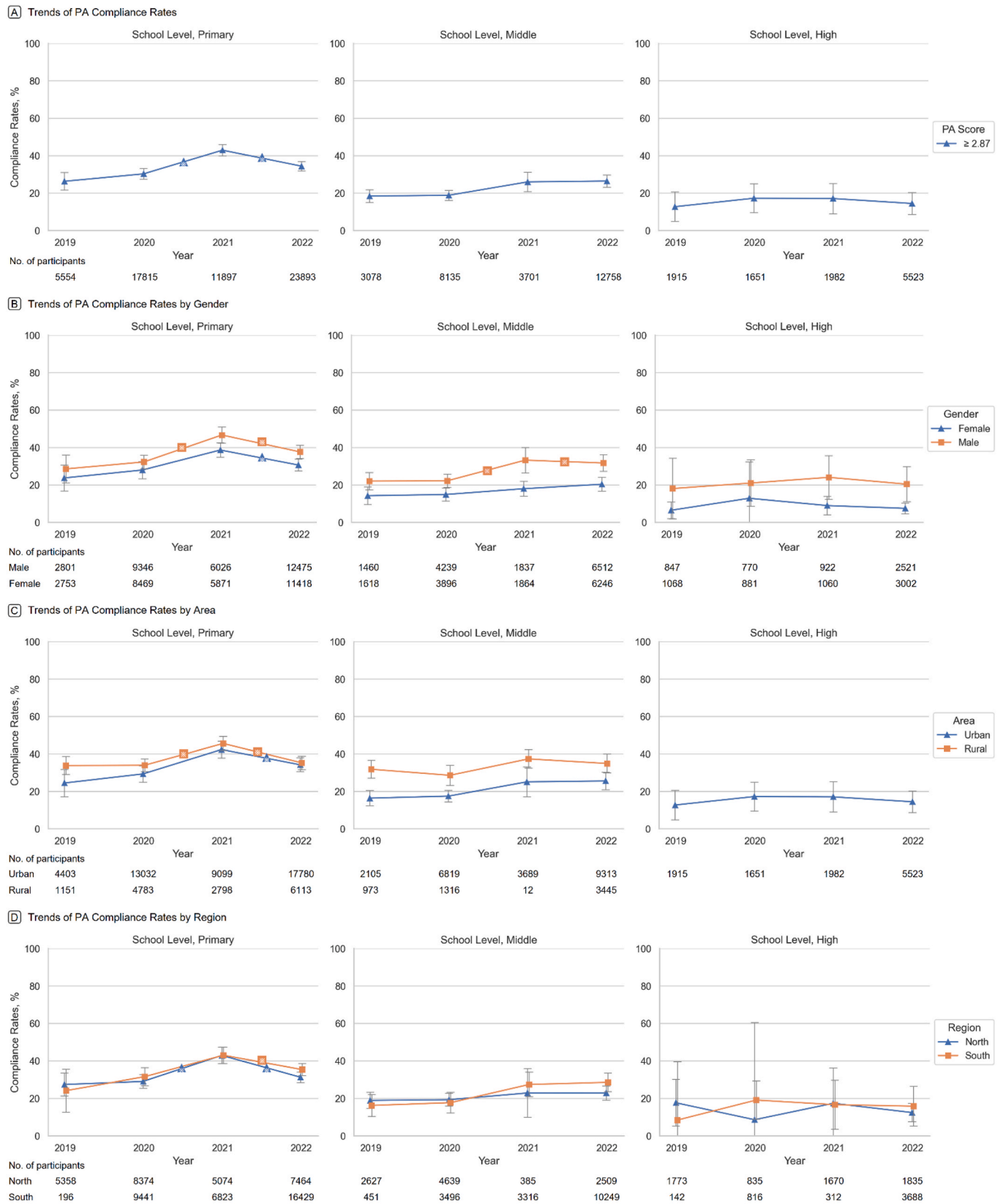
^a The estimate β and P for trend were calculated using segmented linear regression that included the year data as a continuous variable. The estimate β can be interpreted as the average percentage point change in compliance rates during that period.

^b For definitions of area and region, refer to the footnotes in Table 1.

regions to provide insights that could shape the prevention and management of future pandemic-related challenges.

The results of this study suggest an inverted U-shaped trend in children's and adolescents' PA compliance rates following the onset of the pandemic in 2020. This is in contrast with previous research, which propose a U-shaped trend in children's and adolescents' PA during and after the pandemic i.e. initially declining and then increasing. For instance, Neville et al. reported a significant decrease in children's and adolescents' PA during the pandemic,¹⁰ while Chen et al. and So et al. indicated increases in PA only after the pandemic.^{30,31} Several reasons may have contributed to the consistent increase in Chinese children's and adolescents' PA from 2019 to 2021. Firstly, the survey in 2020 was administered in the latter half of the year, after the initial impact of the pandemic when lockdown measures were starting to ease.³² Furthermore, widespread vaccination efforts were initiated from March 2021 in China, which, to a certain extent, curtailed the spread of the COVID-19 pandemic.³³ As a result, easing of pandemic control measures began, and some schools resumed in-person classes, contributing to an increased level of PA among children and adolescents. However, due to the rapid spread of the Omicron variant, China experienced a second outbreak of the COVID-19 pandemic in 2022, leading to a reinforcement of pandemic control measures, including school closures and stay-at-home policies,³⁴ which may have consequently caused a rapid decline in the PA of children and adolescents.

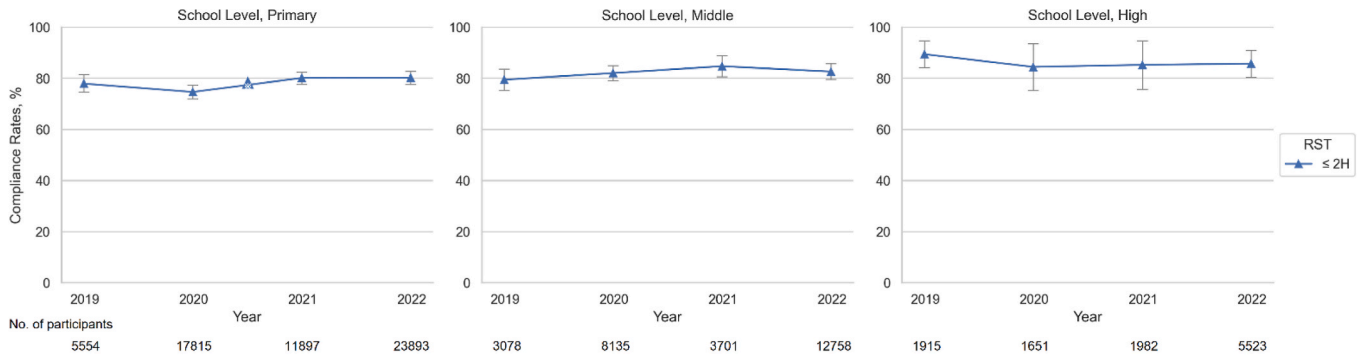
Additionally, consistent with the findings of Guo et al., our study indicates that male children and adolescents are significantly affected by the pandemic in terms of PA compared to their female counterparts.³⁵ This phenomenon might be elucidated by traditional Chinese culture, which promotes quietness and good manners among females, while males are encouraged to exhibit strength and masculinity.³⁶



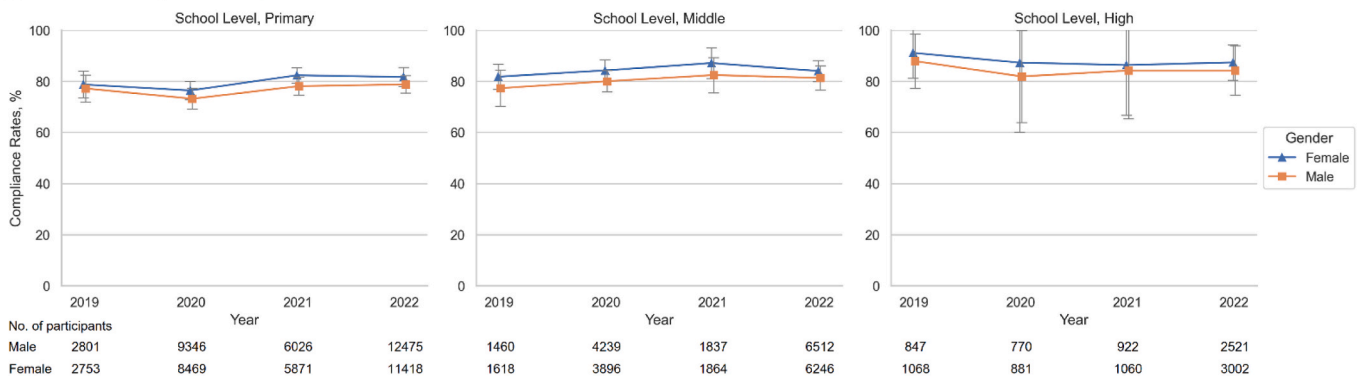
Data were weighted to be nationally representative. Error bars indicate 95% CIs. ▲ or ■ indicating that the category represented by ▲ or ■ changed significantly over the time period.

Fig. 1. Crude weighted trends in physical Activity among the Chinese children and adolescents, from 2019 to 2022.

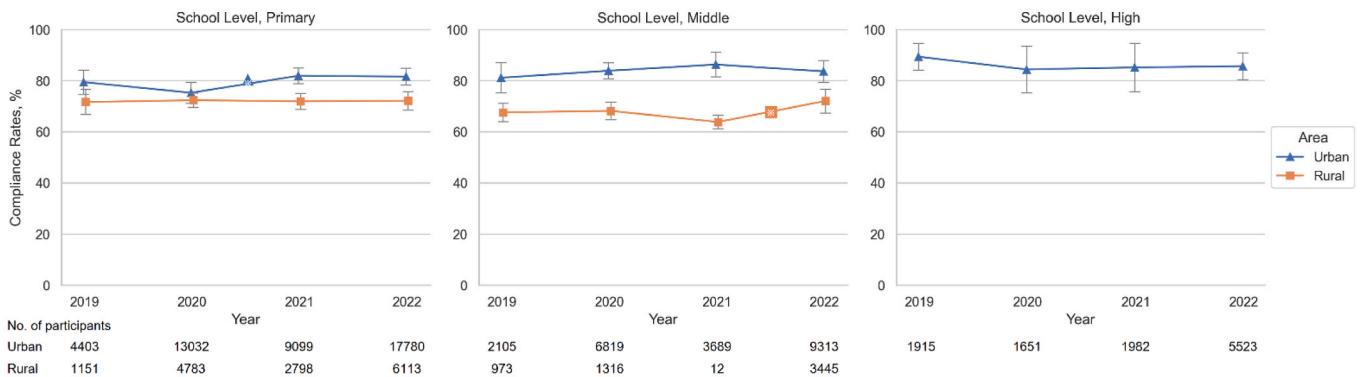
(A) Trends of RST Compliance Rates



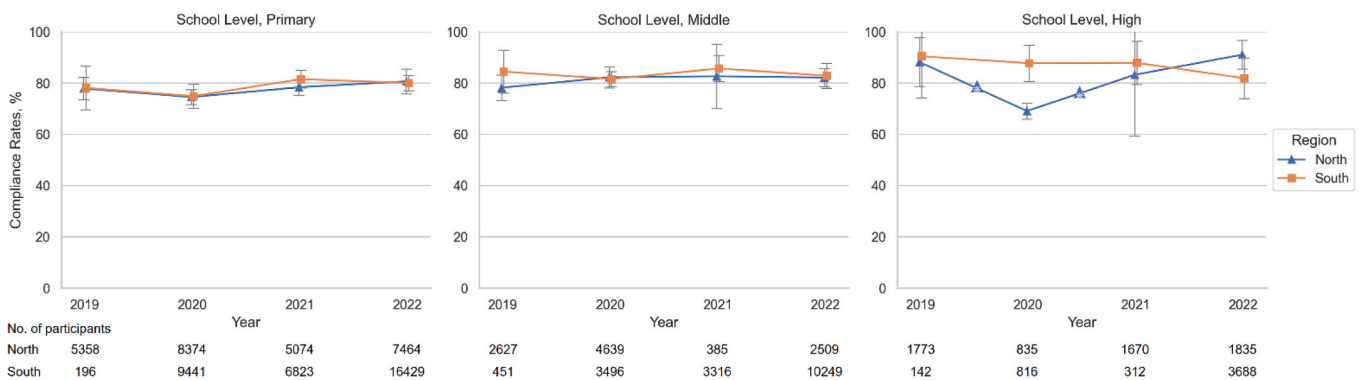
(B) Trends of RST Compliance Rates by Gender



(C) Trends of RST Compliance Rates by Area



(D) Trends of RST Compliance Rates by Region



Data were weighted to be nationally representative. Error bars indicate 95% CIs. ▲ or ■ indicating that the category represented by ▲ or ■ changed significantly over the time period.

Fig. 2. Crude weighted trends in recreational screen time among the Chinese children and adolescents, from 2019 to 2022.

Consequently, males are more likely encouraged to participate in PA. Furthermore, Guo et al.'s research also revealed that high school students' PA was more adversely affected by the pandemic compared to primary and middle school students.³⁵ In contrast, our findings demonstrate that primary school students experienced significant impact on PA due to the pandemic, with no notable changes in PA levels among middle and high school students. We believe this discrepancy may be attributed to differences in the timing of the surveys and pandemic measures imposed by the government. Guo et al. conducted their survey in March 2020, when China's pandemic containment measures were at their strictest period, with most schools closed and students required to study at home without permission to participate in outdoor activities.³⁷ Importantly, this period was less than three months before the national college entrance examination (Gaokao), where under the dual pressures of pandemic containment and examination stress, high school students had to maximize their study time, leading to a significant reduction in their PA. In contrast, our surveys were conducted from September to December annually, during which the containment policies in most regions of China had been relaxed in 2020 and 2021, coupled with the lower academic pressure on primary students,³⁸ resulting in a rapid recovery in their PA levels. Lastly, our findings also indicate that, compared to urban areas, children and adolescents in rural areas were significantly affected by the pandemic in terms of PA. Studies from other countries shown similar trend that during the pandemic, PA levels of children and adolescents in rural areas were significantly higher than those in urban areas. For instance, Zenic et al. in Croatia and Colley et al. in Canada found that during the pandemic, the PA levels of urban students were lower than those of students in suburban or rural areas.^{39,40} This is primarily due to the availability of spaces for PA during the pandemic. Urban students, often residing in apartments, may have limited access to public spaces such as sports fields and parks due to pandemic control measures, whereas rural students might have had access to their own yards for engaging in PA, leading to a significant increase in PA when opportunities arose.

Additionally, our study indicates that since the outbreak of the pandemic, a trend of initially increase followed by a decrease in RST among children and adolescents was observed. This finding is in contrast to studies conducted in other regions of the world, which observed a continuous increase in RST among children and adolescents, both during and after the pandemic.^{11,30} We argue that the initial increase in RST among children and adolescents in China in 2020 can be attributed to the online learning policy issued by the Ministry of Education. In early 2020, in response to school closures, the Ministry of Education in China mandated online learning for all students.³⁷ This made it necessary for parents to equip each student with a device that had internet access, such as a computer, tablet, or mobile phone. While students used these devices for online classes, it is inevitable that they also engaged in some non-educational activities, such as browsing the internet or text messaging, which would have indirectly contributed to an increase in their RST. In 2021, with the widespread administration of vaccines and reopening of schools,³³ students significantly reduced their interaction time with the aforementioned electronic devices upon returning to school. Consequently, this led to a rapid decline in their RST.

In line with the findings of Runacres et al., our study demonstrates that, compared to rural areas, the impact of the pandemic on RST among urban children and adolescents is more pronounced.⁴¹ This is primarily because, relative to their rural counterparts, urban children and adolescents have a higher ownership rate of electronic screens (such as televisions, computers, tablets, and smartphones), leading to easier access to these devices during lockdown periods and, consequently, an increase in their screen time.⁴¹ Following the lifting of pandemic restrictions, urban children and adolescents had more opportunities to participate in various organized PA compared to those in rural areas, resulting in a rapid decline in their screen time. Furthermore, our findings indicate that the impact of the pandemic on RST among children and adolescents in the relatively warmer southern regions was

significant compared to the colder northern regions. This aligns with the conclusions of Chaabane's study, which found that due to climatic influences, children and adolescents in colder regions had longer sedentary periods which tended to remain unchanged before and after the pandemic, while those in warmer regions were more inclined to engage in outdoor activities, thereby reducing their sedentary time.⁴² Finally, our study shows that the impact of the pandemic on RST was more significant among primary school students compared to middle and high school students. However, the research by Guo et al. indicated that high school students were significantly affected by the pandemic in terms of screen time compared to primary and middle school students.³⁵ We believe this inconsistency may be due to differences in the definition of screen time between our study and that of Guo et al., as well as the varying academic pressures faced by students at different school levels. In our study, RST does not include time spent on screen-based learning, whereas Guo et al.'s study considered screen-based learning time as part of overall screen time.³⁵ Moreover, the difference in academic pressures between high school and primary students,³⁸ coupled with home-based learning policies during the pandemic lockdown,³⁷ resulted in a significant increase in screen-based learning time for high school students during the pandemic, while primary students, facing less academic pressure, were more likely to use screens as a form of entertainment.

In conclusion, the various lockdown measures and policies during the pandemic have greatly restricted the PA of children and adolescents and increased their exposure to various screens. This impact is more severe for urban children and adolescents who lack spaces for PA at home, as well as for those with greater opportunities for screen exposure, and for middle and high school students burdened with higher academic pressure. Therefore, we suggest that in future pandemic response policies, the government should appropriately encourage children and adolescents to participate in PA, and increase the proportion of physical education and other types of PA in online education courses. It should also limit the time children and adolescents spend on screens, potentially by enlisting the help of parents to monitor the usage. In addition, future research should focus on clarifying the lockdown measures and policies in different regions and correlating them with changes in PA and RST in children and adolescents in order to further refine the impact of each measure/policy on PA and RST. Moreover, future studies should pay attention to the pandemic's differential impacts on various types of PA, such as exercise, household chores, and commuting, in order to precisely define the impact of the pandemic on PA among children and adolescents.

To our knowledge, this is the first study that examines the trends in PA and RST among Chinese children and adolescents preceding, during, and after the pandemic. The study's findings contribute valuable insight into comprehending the pandemic's short- and long-term effects on children and adolescents' PA and RST. The strengths of this research are embodied in its use of a nationally representative sample, its deployment of consistent tools for surveys conducted before, during, and after the pandemic, and its analysis of the diverse trends in PA and RST among children and adolescents across different school levels, genders, areas, and regions.

Despite its strengths, this study has several limitations. Firstly, the schools invited to participate in the study each year are not fixed, which led to certain differences in region, area, and school level of the sample sources of this study each year. Furthermore, this study did not include children and adolescents who were unable to engage in PA during the survey period. Although this study has used weighting and other statistical methods to compensate for the bias caused by the sample sources, the bias caused by the sample sources should still be noted when generalizing the research results of this study. Secondly, the survey tools used in this study are subjective measures and may not accurately represent the actual PA and RST of participants. Additionally, the PA survey tool, PAQ-C, does not account for the duration, frequency, and types of PA, making it impossible to further analyze the pandemic's specific impacts on participants' PA duration, frequency, and types.

Nevertheless, both surveys have been extensively utilized in research on PA and RST amongst children and adolescents, and the errors from these measurements are believed to have minimal impact on the analysis of temporal trends in PA and RST. Lastly, the surveys were not conducted during the most severe period of the pandemic, specifically, the first half of 2020. Therefore, the findings of this study cannot reflect the changes in PA and RST among children and adolescents during the most severe period of the pandemic. However, the continuous four-year survey conducted in this study effectively reflects the short- and long-term impact of the pandemic on the PA and RST of children and adolescents.

5. Conclusions

In this nationally representative survey analyzing PA and RST among primary, middle, and high school students in China from 2019 to 2022, we observed that the trends of children's and adolescents' PA and RST both increased initially before decreasing. This suggests that the pandemic had a short-term positive effect on PA but a long-term negative impact on it. Interestingly, the influence of the pandemic on RST was the exact opposite. Additionally, we found significant differences in the trends of PA and RST across different school levels, genders, areas, and regions. From a public health perspective, these findings remind us of the necessity to pay attention to the long-term impact of pandemic prevention and control measures on the PA and RST of children and adolescents. Moreover, when formulating pandemic prevention and control policies, it is crucial to thoroughly consider the varied effects of these policies on PA and RST among children and adolescents in different school levels, genders, areas, and regions.

Availability of data and materials

The datasets analyzed in the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Committee on Human Research Protection of East China Normal University (HR 222–2019). Informed consent was obtained from all subjects involved in the study.

Funding

This research was funded by the National Social Science Found of China (22ATY005 and 20CTY011).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRedit authorship contribution statement

Ming Ming Guo: contributed to the conception and design of the study, as well as this paper, carried out the data collection for the main study and authored the original draft of this, performed the data analysis, revised the manuscript critically for important intellectual content. All authors have read and agreed to the published version of the manuscript. **Koon Teck Koh:** contributed to the conception and design of the study, as well as this paper, revised the manuscript critically for important intellectual content. All authors have read and agreed to the published version of the manuscript. **Xiao Zan Wang:** contributed to the conception and design of the study, as well as this paper, carried out the data collection for the main study and authored the original draft of this.

Acknowledgments

The authors would like to express their gratitude to the students and teachers who participated in the data collection process. Special thanks go to Yang Ming Zhu for coordinating with the CBDPCASF School and to Jin Wang Zhang for validating the school data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2024.04.002>.

References

- World Health Organization. *Responding to Community Spread of COVID-19*. Geneva, Switzerland: World Health Organization; 2020.
- Guan H, Okely AD, Aguilar-Farias N, et al. Promoting healthy movement behaviours among children during the COVID-19 pandemic. *Lancet Child Adolesc Health*. 2020;4(6):416–418. [https://doi.org/10.1016/S2352-4642\(20\)30131-0](https://doi.org/10.1016/S2352-4642(20)30131-0).
- The United Nations Educational, Scientific and Cultural Organization. Education: from school closure to recovery. UNESCO Web site. <https://www.unesco.org/en/covid-19/education-response>. Accessed June 20, 2023.
- Schmidt SCE, Anedda B, Burchartz A, et al. Physical activity and screen time of children and adolescents before and during the COVID-19 lockdown in Germany: a natural experiment. *Sci Rep*. 2020;10(1), 21780. <https://doi.org/10.1038/s41598-020-78438-4>.
- Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Publ Health Rep*. 1985;100(2):126–131.
- Tremblay MS, Carson V, Chaput JP, et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metabol*. 2016;41(Suppl. 3):S311–S327. <https://doi.org/10.1139/apnm-2016-0151>, 6.
- Valenzuela PL, Simpson RJ, Castillo-García A, et al. Physical activity: a coadjuvant treatment to COVID-19 vaccination? *Brain Behav Immun*. 2021;94:1–3. <https://doi.org/10.1016/j.bbi.2021.03.003>.
- Laddu DR, Lavie CJ, Phillips SA, et al. Physical activity for immunity protection: inoculating populations with healthy living medicine in preparation for the next pandemic. *Prog Cardiovasc Dis*. 2021;64:102–104. <https://doi.org/10.1016/j.pcad.2020.04.006>.
- Puccinelli PJ, da Costa TS, Seffrin A, et al. Reduced level of physical activity during COVID-19 pandemic is associated with depression and anxiety levels: an internet-based survey. *BMC Publ Health*. 2021;21(1):1–11. <https://doi.org/10.1186/s12889-021-10470-z>.
- Neville RD, Lakes KD, Hopkins WG, et al. Global changes in child and adolescent physical activity during the COVID-19 pandemic. *JAMA Pediatr*. 2022;176(9):886–894. <https://doi.org/10.1001/jamapediatrics.2022.2313>.
- Trott M, Driscoll R, Iraldo E, et al. Changes and correlates of screen time in adults and children during the COVID-19 pandemic: a systematic review and meta-analysis. *eClin Med*. 2022;48, 101452. <https://doi.org/10.1016/j.eclinm.2022.101452>.
- Xiang M, Liu Y, Yamamoto S, et al. Association of changes of lifestyle behaviors before and during the COVID-19 pandemic with mental health: a longitudinal study in children and adolescents. *Int J Behav Nutr Phys Activ*. 2022;19(1):1–11. <https://doi.org/10.1186/s12966-022-01327-8>.
- Yang D, Luo C, Feng X, et al. Changes in obesity and lifestyle behaviours during the COVID-19 pandemic in Chinese adolescents: a longitudinal analysis from 2019 to 2020. *Pediatr Obes*. 2022;17(5):1–11. <https://doi.org/10.1111/jipo.12874>.
- Benzing V, Gaillard P, Scheidegger D, et al. COVID-19: physical activity and quality of life in a sample of Swiss school children during and after the first stay-at-home. *Int J Environ Res Publ Health*. 2022;19(4):13. <https://doi.org/10.3390/ijerph19042231>.
- Question Star. Question Star, more than just surveys and online exams. QS Web site. <https://www.wjx.cn>. Accessed May 2, 2023.
- Baidu. *Baidu Map Open Platform*. Baidu Web site. <https://lbsyun.baidu.com>. Accessed August 11, 2022.
- National Bureau of Statistics. *China Statistical Yearbook 2021*. Beijing: China Statistics Press; 2021.
- Tukey JW. *Exploratory Data Analysis*. Addison-Wesley Pub. Co; 1977.
- Kowalski KC, Crocker PR, Donen RM. *The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual*. College of Kinesiology University of Saskatchewan; 2004.
- Voss C, Dean PH, Gardner RF, et al. Validity and reliability of the physical activity questionnaire for children (PAQ-C) and adolescents (PAQ-A) in individuals with congenital heart disease. *PLoS One*. 2017;12(4), e0175806. <https://doi.org/10.1371/journal.pone.0175806>.
- Wang JJ, Baranowski T, Lau WP, et al. Validation of the physical activity questionnaire for older children (PAQ-C) among Chinese children. *Biomed Environ Sci*. 2016;29(3):177–186. <https://doi.org/10.3967/bes2016.022>.
- Hardy LL, Booth ML, Okely AD. The reliability of the adolescent sedentary activity questionnaire (ASAQ). *Prev Med*. 2007;45(1):71–74. <https://doi.org/10.1016/j.yjped.2007.03.014>.

23. Qiang G. *A Study on Physical Activity Levels Among Chinese Children and Adolescents and Their In-Fluencing Factors [PhD Thesis]*. Shanghai, China: East China Normal University; 2016.
24. Zhang Y, Ma S, Chen C, et al. Physical activity guidelines for children and adolescents in China. *Chin J Evid Based Pediatr*. 2016;(6):5–12. <https://doi.org/10.19633/j.cnki.11-2579/d.2016.06.001>.
25. Ministry of Education. Further improving the enrollment process for primary and secondary schools. MOE Web site. http://www.moe.gov.cn/srcsite/A06/s3321/202204/t20220401_612689.html. Accessed April 4, 2023.
26. Liu G. *Atlas of Natural Geography of China*. Beijing: China Map Publishing Press; 2010.
27. Guthold R, Stevens GA, Riley LM, et al. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1-6 million participants. *Lancet Child Adolesc Health*. 2020;4(1):23–35. [https://doi.org/10.1016/S2352-4642\(19\)30323-2](https://doi.org/10.1016/S2352-4642(19)30323-2).
28. Yang L, Cao C, Kantor ED, et al. Trends in sedentary behavior among the US population, 2001-2016. *JAMA*. 2019;321(16):1587. <https://doi.org/10.1001/jama.2019.3636>.
29. Python Organization. Python. Python Web site. <https://www.python.org>. Accessed January 28, 2023.
30. So HK, Chua GT, Yip KM, et al. Impact of COVID-19 pandemic on school-aged children's physical activity, screen time, and sleep in Hong Kong: a cross-sectional repeated measures study. *Int J Environ Res Publ Health*. 2022;19(17), 10539. <https://doi.org/10.3390/ijerph191710539>.
31. Chen S, Wang B, Imagbe S, et al. Adolescents' behaviors, fitness, and knowledge related to active living before and during the COVID-19 pandemic: a repeated cross-sectional analysis. *Int J Environ Res Publ Health*. 2022;19(5):2560. <https://doi.org/10.3390/ijerph19052560>.
32. Xue E, Li J, Li T, et al. China's education response to COVID-19: a perspective of policy analysis. *Educ Philos Theor*. 2021;53(9):881–893. <https://doi.org/10.1080/00131857.2020.1793653>.
33. Chinese Government. National videoteleconference on vaccination against new coronaviruses. Chinese Government Web site. https://www.gov.cn/guowuyuan/2021-03/22/content_5595005.htm. Accessed December 11, 2023.
34. National Health Commission. Cumulative total of reported infections in the local outbreak since March exceeds 15,000 cases. NHC Web site. <http://health.people.com.cn/n1/2022/0315/c14739-32375333.html>. Accessed December 11, 2023.
35. feng Guo Y, qi Liao M, li Cai W, et al. Physical activity, screen exposure and sleep among students during the pandemic of COVID-19. *Sci Rep*. 2021;11(1):8529. <https://doi.org/10.1038/s41598-021-88071-4>.
36. Guo MM, Wang XZ, Koh KT. Association between physical activity, sedentary time, and physical fitness of female college students in China. *BMC Wom Health*. 2022;22(1):502. <https://doi.org/10.1186/s12905-022-02108-y>.
37. Ministry of Education. Utilizing online platforms to ensure classes suspended but learning continues. MOE Web site. http://www.gov.cn/xinwen/2020-01/30/content_5473048.htm. Accessed December 12, 2023.
38. Dong Y, Lau PWC, Dong B, et al. Trends in physical fitness, growth, and nutritional status of Chinese children and adolescents: a retrospective analysis of 1.5 million students from six successive national surveys between 1985 and 2014. *Lancet Child Adolesc Health*. 2019;3(12):871–880. [https://doi.org/10.1016/S2352-4642\(19\)30302-5](https://doi.org/10.1016/S2352-4642(19)30302-5).
39. Zenic N, Taiar R, Gilic B, et al. Levels and changes of physical activity in adolescents during the COVID-19 pandemic: contextualizing urban vs. rural living environment. *Appl Sci*. 2020;10(11):3997. <https://doi.org/10.3390/app10113997>.
40. Colley RC, Watt JE. The unequal impact of the COVID-19 pandemic on the physical activity habits of Canadians. *Health Rep*. 2022;33(5):22–33. <https://doi.org/10.25318/82-003-x202200500003-eng>.
41. Runacres A, Mackintosh KA, Knight RL, et al. Impact of the COVID-19 pandemic on sedentary time and behaviour in children and adults: a systematic review and meta-analysis. *Int J Environ Res Publ Health*. 2021;18(21), 11286. <https://doi.org/10.3390/ijerph182111286>.
42. Chaabane S, Doraiswamy S, Chaabna K, et al. The impact of COVID-19 school closure on child and adolescent health: a rapid systematic review. *Children*. 2021;8(5):17. <https://doi.org/10.3390/children8050415>.