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Interventions to prevent or reduce unhealthy habits in children and adolescents during restricted conditions

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Interventions to prevent or reduce unhealthy habits in children and adolescents during restricted conditions

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Editorial: Interventions to prevent or reduce unhealthy habits in children and adolescents during restricted conditions

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Editorial on the Research Topic
Interventions to prevent or reduce unhealthy habits in children and adolescents during restricted conditions

The prevalence of childhood overweight and obesity has increased worldwide in recent decades. Childhood obesity is associated with serious health problems and the risk of premature illness and death later in life (1, 2). Obesity is linked to cardiometabolic risk factors such as insulin resistance, type 2 diabetes, hyperlipidemia, and hypertension, all of which can lead to cardiometabolic disease. Several important risk factors such as low physical activity, sedentary behavior, increased screen time activity and high fast-food intake lead to overweight and obesity in children and adolescents (3, 4).

In a situation such as the COVID-19 pandemic, due to physical distancing, school or university closures and other preventive precautions, all the potential mentioned risk factors were more probable. Many studies during the COVID-19 pandemic show that children were more overweight, had lower levels of physical activity, and spent more time on screens (5, 6).

In the foreseeable future, the world may encounter a situation such as the COVID-19 pandemic again, and society should be ready for a clear response. Since many healthy and unhealthy habits are formed during childhood and adolescence, and many of these habits are irreversible, the current Research Topic entitled "*Interventions to prevent or reduce unhealthy habits in children and adolescents during restricted conditions*" was developed to propose new and novel strategies to modify vulnerable conditions. In the first article in this Research Topic, Kuzik et al., sought to update a comprehensive national assessment of physical activity and related behaviors, characteristics, and opportunities for children and youth (ParticipACTION Report Card on Physical Activity for Children and Youth) during the COVID-19 pandemic. The research team captured the best data on physical activity

throughout the COVID-19 period, which was synthesized across 14 different indicators in four categories. The authors conclude that during the COVID-19 pandemic, the overall physical activity score decreased from a D+ (2020) to a D, coinciding with a decline in scores reflecting fewer opportunities for sports and community/facility-based activities and higher levels of sedentary behaviors. Fortunately, improvements in Active Transportation and Active Play during COVID-19 prevented a worse shift in children's health behaviors.

Li et al., assessed the mediating role of self-esteem in the relationship between family functioning and problematic Internet pornography use (PIPU). Their results showed that self-esteem partially mediated the relationship between family functioning and PIPU. The authors concluded that for adolescents with high belongingness needs who are at high risk for PIPU, good family functioning may have a protective effect by boosting self-esteem.

Barsch et al., tried to answer the question of whether sports boarding schools pose a particular risk of infection for students. They found that in a single-center prospective cohort study, no significant group difference between sports boarding schools and day schools was detected with respect to the number of COVID-19 infections. Their results indicate that sports boarding schools do not pose an increased risk of infection, assuming that the facilities prevent viral transmission with appropriate preventive strategies and hygiene measures.

Lee B. et al., examined the relationship between the playfulness experienced by middle school students during their early morning exercise and their physical self-efficacy and education for happiness. The authors reported that middle school playfulness had a significant effect on physical self-efficacy and a significant effect on education for happiness. In another study, Major et al., examined changes in screen time and its components (screen time spent on videos, games, homework, and other activities) of adolescents affected by COVID-19 school closures compared to controls from pre-pandemic years. They reported that COVID-19-related school closures modified and increased age-specific increases in screen time for both boys and girls. In a study exploring the relationship between perceived school climate and exercise behavior among obese adolescents, Yin et al. observed that perceived school climate among obese adolescents positively predicted exercise behavior and that obese adolescents' perception of school climate can effectively enhance their motivation to participate in exercise behavior and indirectly influence exercise behavior through exercise benefits and perseverance qualities.

In another article, Irschik et al., assessed changes in BMI and weight development in children during and (in particular) after the COVID-19 restrictions in Austria. The researchers reported that the rate of obesity increased by 88.5%, from 6.4 to 12.1%, during the pandemic, reaching a maximum of 15.2% during the restrictions. With the exception of obese children, all children in the study population experienced significant weight loss after the restrictions were lifted. Obese children continued to gain weight without any sign of normalization. In another work, Saintila et al. tried to determine the association between social network addiction (SNA) and anxiety symptoms with the risk of metabolic syndrome (MetS) in adolescents. The authors concluded that SNA and the presence of anxiety symptoms are associated with MetS.

In a study conducted by Qi et al., the research team aimed to determine the mediating role of school-based rope-skipping sports participation (SRSP) in the connection between social support and moderate- to vigorous physical activity (MVPA). They surveyed 721 adolescents residing in Changsha City and found a significant influence of the interaction between increased participation in and social support on school children's engagement in MVPA. An open-label randomized control trial by Kaur et al., assessed the effectiveness of the program to lower unwanted media screen time (PLUMS) among children aged 2–5 years in Chandigarh, Union Territory, North India. They found that the PLUMS intervention significantly reduced children's mean ST on a typical day and increased physical activity immediately post-intervention and during the 6-month follow-up period.

In their study to assess the relationship between parental anxiety and adolescent internet addiction, Wang et al. showed that family environment and adolescent emotional behavior issues played an indirect role in the link between parental anxiety and internet addiction. Their findings emphasize the importance of addressing parental anxiety and fostering a positive family environment as effective measures to alleviate adolescent emotional behavior problems and reduce the risk of internet addiction. In a web-based survey by Yuan et al., the authors evaluated parental knowledge of myopia control and explored its change during the outbreak of the COVID-19 pandemic. They showed that the COVID-19 pandemic obviously changed children's daily routines. More efforts should be made to narrow the gap between knowledge and behavior of myopia control, and to stay alert to the potential increased risk of myopia after the COVID-19 pandemic.

In a study conducted by Pope et al. to identify community settings and intervention strategies to prioritize for an intervention promoting healthy weight in rural preschool children, the authors reported that priority intervention strategies included providing nutrition and physical activity education, increasing access to healthy foods and physical activity in the built environment, and enhancing food security and their findings will be useful for the development of a multi-level community-based intervention. Finally, the last article in this Research Topic was authored by Lee Y.-R. et al., to explore how early childhood teachers (ECTs) can improve their personal resilience to adapt to and cope with disasters as part of early childhood education and care. According to their findings general disaster preparedness must be improved, followed by the development of strategies to strengthen children's resilience and work-related disaster preparedness.

In conclusion, the articles included in this Research Topic point out the importance of preventing the risk factors for obesity in children and adolescents and also highlight the burden of obesity in some situations where limitations are in place, such as the COVID-19 pandemic of 2020. To prevent this issue and act in the future, we need planning and programs at the family, community, school or university level.

Author contributions

MK: Conceptualization, Project administration, Supervision, Validation, Writing – original draft, Writing – review &

editing. ME: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. MD-N: Conceptualization, Investigation, Writing – original draft, Writing – review & editing. MH-B: Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The 2022 ParticipACTION Report Card on Physical Activity for Children and Youth: Focus on the COVID-19 pandemic impact and equity-deserving groups

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Introduction: The ParticipACTION Report Card on Physical Activity for Children and Youth is the most comprehensive national assessment of physical activity and related behaviors, characteristics, and opportunities for children and youth. The 2022 Report Card assigned grades based on data gathered during the COVID-19 pandemic to reflect this extraordinary time-period in Canada. Further, while not graded, efforts were made to summarize key findings for early years children and those identifying as: having a disability, Indigenous, 2SLGBTQ+, newcomers to Canada, racialized, or girls. The purpose of this paper is to summarize the 2022 ParticipACTION Report Card on Physical Activity for Children and Youth.

Methods: The best available physical activity data captured during the whole COVID-19 pandemic was synthesized across 14 different indicators in four categories. The 2022 Report Card Research Committee assigned letter grades (i.e., A–F) based on expert consensus of the evidence.

Synthesis: Grades were assigned for: Daily Behaviors (*Overall Physical Activity*: D; *Active Play*: D–; *Active Transportation*: C–; *Organized Sport*: C+; *Physical Education*: Incomplete [INC]; *Sedentary Behaviors*: F; *Sleep*: B; *24-Hour Movement Behaviors*: F), Individual Characteristics (*Physical Literacy*: INC; *Physical Fitness*: INC), Spaces and Places (*Household*: C, *School*: B–, *Community and Environment*: B), and Strategies and Investments (*Government*: B–). Compared to the 2020 Report Card, the COVID-19 specific grades increased for *Active Play* and *Active Transportation*; and decreased for *Overall Physical Activity*, *Sedentary Behaviors*, *Organized Sport*, and *Community and Environment*. There were many data gaps for equity-deserving groups.

Conclusion: During the COVID-19 pandemic, the grade for *Overall Physical Activity* decreased from a D+ (2020) to a D, coinciding with decreases in grades reflecting fewer opportunities for sport and community/facility-based activities

as well as higher levels of sedentary behaviors. Fortunately, improvements in *Active Transportation* and *Active Play* during COVID-19 prevented a worse shift in children's health behaviors. Efforts are needed to improve physical activity for children and youth during and post-pandemic, with a greater emphasis on equity-deserving groups.

KEYWORDS

advocacy, policy, health communication, child health, knowledge translation

1. Introduction

The benefits of physical activity for school-aged children and youth (5–17 years) are well known and span many health and well-being indicators (e.g., adiposity, cardiometabolic biomarkers, physical fitness, bone health, quality of life/well-being, motor skill development, psychological distress, pro-social behavior) (1). However, in Canada a D+ grade was assigned for Overall Physical Activity in the 2020 ParticipACTION Report Card on Physical Activity for Children and Youth (2)—based on 61% not meeting the physical activity recommendation of ≥60 min/day of moderate- to vigorous-intensity physical activity (MVPA) (3, 4). Reflecting the depth and breadth of benefits combined with the low prevalence of sufficient physical activity for children and youth, public health efforts have been employed to improve physical activity and related behaviors, characteristics, and opportunities (e.g., MVPA, sleep, physical fitness, school environment) (5–7).

ParticipACTION[1] i.e., a & b is a Canadian non-profit organization aiming to help people in Canada move more (8). One avenue for pursuing this mission is knowledge mobilization and active dissemination efforts, such as the ParticipACTION Report Card on Physical Activity for Children and Youth. The Report Card aims to synthesize and disseminate research "*to drive social action for policy and behavior change relating to physical activity among children and youth*" (9). While the prevalence of insufficient physical activity is high for children and youth in Canada, *Overall Physical Activity* Report Card letter grades have either improved slightly or remained the same from 2007 to 2020 (2, 10).

On 11 March 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic leading to a drastic shift in the ways children and youth could access physical activity opportunities. Public health officials determined that it was necessary to implement measures to curb transmission of the virus including lockdowns, closures, and reduced capacity limits for schools, sports programs, recreation facilities, and outdoor activity spaces (e.g., playgrounds, parks) (11). While the pandemic and implemented public health measures impacted all Canadians, some groups may have experienced a disproportionate impact based on pre-existing inequalities (12). Thus, the 2022 ParticipACTION Report Card on Physical Activity for Children and Youth represents a unique glimpse into a period defined by COVID-19. The purpose of this paper is to summarize the development of the 2022 Report Card and the subsequent findings in the context of COVID-19 and with a focus on equity-deserving groups (those who face barriers to equal access, resources, and opportunities within society due to systemic discrimination and disadvantage) (13, 14).

2. Methods

The 2022 Report Card was produced by ParticipACTION, with the Healthy Active Living and Obesity Research Group (HALO) at the Children's Hospital of Eastern Ontario (CHEO) Research Institute[2] playing a critical role in the research and development. Representatives from ParticipACTION and HALO had the first guiding meeting in January 2021. At this meeting, 10 Canadian experts for the Report Card Research Committee (RCRC) were proposed and subsequently invited (100% success rate) to steer the Report Card along with the Report Card Chief Scientific Officer, Research Manager and Lead Author, and Project Manager, for a total of 13 members. The invited experts were recruited for their content expertise in different domains of children's physical activity, geographic dispersion, and sector representation (i.e., academic, government, and non-government). The first RCRC meeting was held in June 2021 to discuss the structure and content of the Report Card (e.g., included indicators, benchmarks). Subsequently, data were gathered and synthesized from multiple sources, including national datasets and the best available peer-reviewed research for the RCRC to appraise at a meeting held in December 2021. The challenges of synthesizing COVID-19-specific data were discussed, and an additional meeting was arranged to appraise the evidence relevant to the pandemic. In March 2022, the final RCRC meeting was held. The 2022 Report Card development process was similar to previous years (2, 15, 16) with the exceptions of some pandemic influenced changes (e.g., shorter and virtual meetings).

The evidence appraisal conducted at the RCRC meetings consisted of reviewing and discussing the gathered data, assigning letter grades to the synthesized data across 14 indicators, within 4 categories—Daily Behaviors (*Overall Physical Activity, Active Play, Active Transportation, Organized Sport, Physical Education, Sedentary Behaviors, Sleep, 24-Hour Movement Behaviors*), Individual Characteristics (*Physical Literacy, Physical Fitness*), Spaces and Places (*Household, School, Community and Environment*), and Strategies and Investments (*Government*). Each indicator consisted of 1–7 benchmarks that were established *a priori*, and grades were assigned

1 www.participACTION.com

2 https://www.haloresearch.ca/

based on the average percent score (e.g., percent of children meeting the *Overall Physical Activity benchmark*), or consensus appraisal, across all benchmarks (see Table 1). If the RCRC determined insufficient evidence was available an incomplete grade was assigned (INC).

National surveys and device-measured data are the preferred sources to inform grades. Specific to this Report Card, grades were assigned based on data collected during the COVID-19 pandemic, ranging from April 2020 to Spring 2022. COVID-19 disrupted data collection for many nationally representative surveys, resulting in some smaller and less representative data sources in the 2022 Report Card compared to previous years. Surveys used within this Report Card can be found in Table 2.

Another unique feature of the 2022 Report Card was a focus on equity-deserving groups. While grades were assigned to the general population of children and youth in Canada aged 5–17 years, deliberate efforts were made to also summarize key findings for those identifying as: having a disability, Indigenous, 2SLGBTQ+ (Two-Spirit, Lesbian, Gay, Bisexual, Transgender, Queer or Questioning and additional sexual orientations and gender identities), newcomers to Canada, racialized, or girls. While early years children (<5 years) were not considered an equity-deserving group, they were considered a population of interest, and results were summarized together. Equity-deserving groups, or populations of interest, were selected based on RCRC consensus for key groups of youth to discuss in relation to physical activity and COVID-19. However, it was recognized that the selected groups were not all-encompassing and other unrepresented groups deserving attention should be explored in the future.

3. Synthesis

3.1. Daily behaviors

3.1.1. Overall physical activity: D

According to the Canadian Community Health Survey (CCHS), Cohort Study for Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behavior (COMPASS), and ParticipACTION COVID-19 Surveys (PCS), the average percent of children and youth meeting the physical activity recommendations (i.e., MVPA recommendation: at least 60 min/day, on average, of MVPA; muscle and bone strengthening recommendation: muscle and bone strengthening activities at least 3 days/week) within the Canadian 24-Hour Movement Guidelines for Children and Youth (4) according to self- or parent-report was 28%. Within the CCHS, it was estimated that the percent of youth (12–17 years) meeting the MVPA recommendation decreased from 51% pre-pandemic (fall 2018) to 37% during the COVID-19 pandemic in fall 2020. In the COMPASS study, 58% of youth in grades 9–12 met the MVPA recommendation, while 34% met the MVPA and muscle and bone strengthening recommendations. In the PCS, 24% of children 5–11-years-old and 13% of youth 12–17-years-old met the MVPA recommendation at the start of the pandemic (April 2020), compared to 18% of children and 12% of youth in October 2020. The 28% average resulted in a D grade–a decrease from the D+ grade assigned in 2020 (Figure 1) (2).

3.1.1.1. Equity-deserving groups

For the *Overall Physical Activity* indicator, COVID-19-specific results were available for equity-deserving groups within the National Physical Activity Measurement (NPAM) study (children and youth with disabilities), CCHS (Indigenous youth, newcomer youth, racialized youth, and girls), COMPASS (racialized children and youth, and girls), and PCS (girls). COVID-19-specific results were not found for other equity-deserving groups (Figure 2).

In May 2020, 7% of children and youth with disabilities met the MVPA recommendation, compared to 6% in November 2020 in the NPAM study. Within the CCHS, the percent of youth (12–17 years) meeting the MVPA recommendation pre-pandemic (fall 2018) and during the pandemic (fall 2020) was 67% and 38% for Indigenous youth, 56% and 35% for newcomer youth, 47% and 34% for racialized youth, and 46% and 35% for girls (55% and 40% for boys), respectively.

3.1.2. Active play: D–

According to the Parent Survey on Physical Activity and Sport (PSPAS), 25% of children and youth (5–17 years) had an average of >2 h/day of total time engaged in indoor and outdoor unstructured play. This included physical activity and sport at home, outdoor unstructured play in the community, outdoor time in spaces such as parks and green spaces, and outdoor time at school. Based on 25% meeting this benchmark, a D– grade was assigned. This is an increase from the F grade assigned in 2020 (Figure 1).

3.1.2.1. Equity-deserving groups

For *Active Play*, COVID-19-specific results were available for girls within the PSPAS (Figure 2). Specifically, 24% of girls and 25% of boys had an average of >2 h/day of total time engaged in indoor and outdoor unstructured play.

3.1.3. Active transportation: C–

From the Active Transportation and Independent Mobility Study (ATIM) and PSPAS, the average percent of children and youth typically using active transportation to get to and from places (e.g., school, park, mall, friend's house) was 41%. Results of the PSPAS survey indicated 46% of children and youth (5–17 years) either solely used active transportation, or partially used active transportation (active transportation in combination with non-active modes to or from school, such as walking or bicycling at least part of the way to school). Within the ATIM study, the percent of 7–12-year-old children that used active transportation to get to school was 37% in December

TABLE 1 Conversion of percent scores to report card letter grades.

A+	94%–100%	B+	74%–79%	C+	54%–59%	D+	34%–39%			INC	Insufficient data to assign a grade
A	87%–93%	B	67%–73%	C	47%–53%	D	27%–33%	F	0%–19%		
A–	80%–86%	B–	60%–66%	C–	40%–46%	D–	20%–26%				

TABLE 2 Key data sources.

Data source	Sample description	Indicators
Canadian Community Health Survey (CCHS), Statistics Canada, Custom analysis (17, 18)[a]	*n* = ~5,000, 12–17 years	Overall physical activity
Cohort Study for Obesity, Marijuana Use, Physical Activity, Alcohol Use, Smoking and Sedentary Behavior, Custom analysis uwaterloo.ca/compass-system	*n* = 133 schools, Grades 9–12	Overall physical activity
		Organized Sport
		Sedentary behaviors
		Sleep
		24-h movement behaviors
ParticipACTION COVID-19 Surveys (PCS), ParticipACTION (19, 20)	*n* = ~1,500, 5–17 years	Overall physical activity
		Sedentary behaviors
		Sleep
		24-h movement behaviors
National Physical Activity Measurement (NPAM) study (21)	*n* = 86, 4–17 years with a disability	Overall physical activity
		Sedentary behaviors
		Sleep
		24-h movement behaviors
Parent Survey on Physical Activity and Sport sub-sample, Canadian Fitness and Lifestyle Research Institute (CFLRI), Custom analysis cflri.ca/settings-based-studies	*n* = ~6,000, 5–17-years	Active play
		Active transportation
		Organized
		Sport
		Household
		Community and environment
Active Transportation and Independent Mobility Study, Custom analysis pathresearch.wordpress.com/projects/	*n* = ~2,300, 7–12 years	Active transportation
		Sedentary behaviors
		Sleep
		24-h movement behaviors
Opportunities for Physical Activity at School Study sub-sample, CFLRI, Custom analysis cflri.ca/settings-based-studies	*n* = ~500, school administrators	School
Survey of Physical Activity Opportunities in Canadian Communities, CFLRI, Custom analysis cflri.ca/settings-based-studies	*n* = ~900, communities with at least 1,000 residents	Community and environment

[a]CCHS results were synthesized from Watt and Colley (17) for the Overall Physical Activity grade and Colley and Watt (18) for Overall Physical Activity in equity-deserving groups.

2020 and 40% in June 2021. Based on 41% of children and youth meeting this benchmark, a grade of C– was assigned. This is an increase from the D– grade assigned in 2020 (Figure 1).

3.1.3.1. Equity-deserving groups

For *Active Transportation*, COVID-19-specific results were reported for girls in the PSPAS and the ATIM studies (Figure 2). Within the PSPAS, 43% of girls and 48% of boys either solely or partially used active transportation to or from school. The percentage of girls in the ATIM study using active transportation to get to school was 38% in December 2020 (36% of boys) and 42% in June 2021 (38% of boys).

3.1.4. Organized sport: C+

Based on data from COMPASS and PSPAS, the average percent of children and youth participating in organized sport was 57%. Within COMPASS, 50% of youth in grades 9–12 participated in an organized sport program during the pandemic. The PSPAS survey indicated 63% of children and youth (5–17 years) participated in sport, compared to 74% pre-COVID-19. Based on 57% meeting this benchmark, a grade of C+ was assigned, which is a decrease from B in 2020 (Figure 1).

3.1.4.1. Equity-deserving groups

For *Organized Sport*, COVID-19-specific results were available within COMPASS (racialized youth, and girls), and the PSPAS (girls;

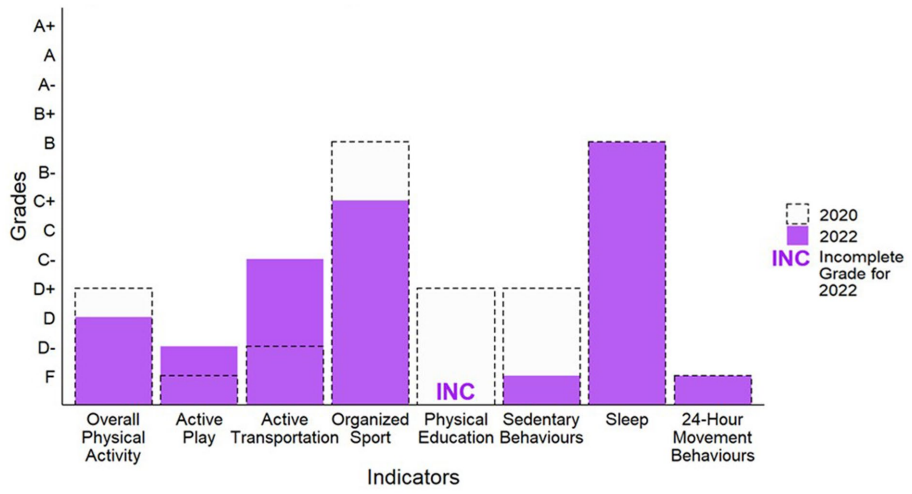

FIGURE 1
Grades for daily behaviors in 2020 and 2022.

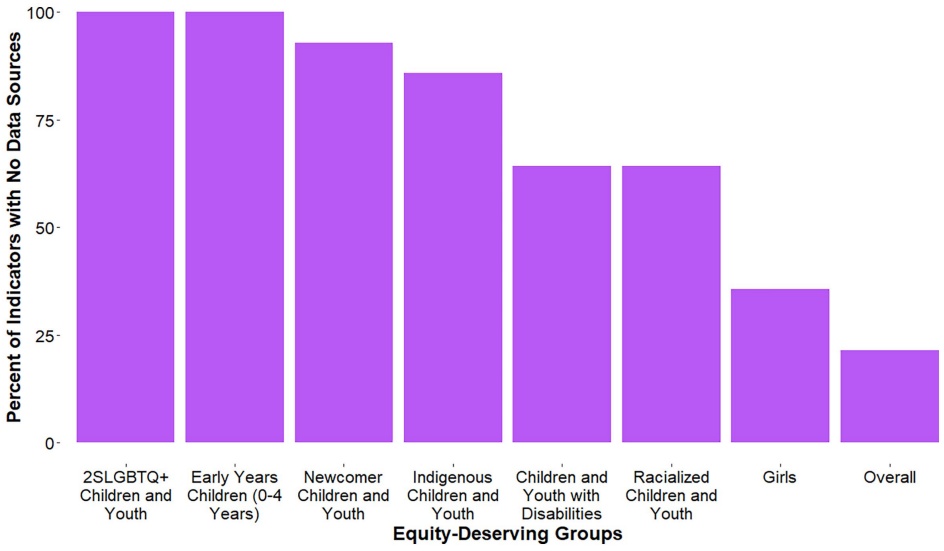

FIGURE 2
Percent of indicators with no results, for each equity-deserving group.

Figure 2). The percent of racialized youth in COMPASS who participated in organized sports during the pandemic was 37% for Asian students, 52% for Black students, 40% for Latin American/Hispanic students, 46% for other/multiple and 52% for White students. Forty-seven percent of girls in COMPASS participated in organized sport during the pandemic, compared to 54% of boys. Sixty percent of girls and 66% of boys participated in organized sport during the COVID-19 pandemic according to the PSPAS.

3.1.5. Physical education: INC

No COVID-19-specific data were available to assign a grade for the *Physical Education* indicator, thus it is deemed Incomplete (INC; Figures 1, 2).

3.1.6. Sedentary behaviors: F

In the COMPASS, ATIM, and PCS, 18% of children and youth met the sedentary behavior recommendation within the Canadian 24-Hour Movement Guidelines for Children and Youth of no more than 2 h of recreational screen time per day (4). For the COMPASS study, 3% of youth in grades 9–12 met the screen time recommendation from November 2020 to June 2021. Within the PCS, 16.5% of children (5–11 years) and 6.6% of youth (12–17 years) met the screen time recommendation at the start of the pandemic (April 2020), compared to 35.4% of children and 16.5% of youth in October 2020. In the ATIM study, 23% of 7–12-year-old children met the screen time recommendation in December 2020 and 25% in June 2021. Based on an average of 18%, an F grade was assigned for the *Sedentary Behavior*

indicator, which is a decrease from the 2020 Report Card grade of D+ (Figure 1).

3.1.6.1. Equity-deserving groups

For the *Sedentary Behaviors* indicator, COVID-19-specific results were available for equity-deserving groups within the NPAM study (children and youth with disabilities), COMPASS (racialized children and youth, and girls), ATIM (girls), and PCS (girls; Figure 2). In May 2020, 7% of children and youth with disabilities in the NPAM study met the screen time recommendation, compared to 17% in November 2020. The percent of racialized youth in COMPASS meeting the screen time recommendation during the pandemic was 4% for Asian students, 4% for Black students, 2% for Latin American/Hispanic students, 4% for other/multiple, and 3% for White students. Four percent of girls in COMPASS met the screen time recommendation during the pandemic, compared to 3% of boys. Further, at the start of the pandemic, 16% of girls 5–11-years-old (17% of boys) and 8% of girls 12–17-years-old (5% of boys) met the screen time recommendation, compared to 38% of girls 5–11-years-old (33% of boys) and 17% of girls 12–17-years-old (16% of boys) later on in the pandemic (October 2020). Finally, within the ATIM study, the percentage of girls meeting the screen time recommendation was 24% in December 2020 (21% of boys) and 26% in June 2021 (23% of boys).

3.1.7. Sleep: B

In the COMPASS, ATIM, and PCS the average percent of children and youth meeting the sleep duration recommendation (5–13-year-olds, 9–11 h/night on average; 14–17-year-olds: 8–10 h/night on average) within the Canadian 24-Hour Movement Guidelines for Children and Youth (4) was 60%. For the COMPASS study, 58% of youth in grades 9–12 met the sleep duration recommendation from November 2020 to June 2021. Within the PCS, 69.9% of children (5–11 years) and 72.1% of youth (12–17 years) met the sleep duration recommendation at the start of the pandemic (April 2020), compared to 54.9% of children and 59.5% of youth in October 2020. In the ATIM study, the percent of 7–12-year-old children meeting the sleep duration recommendation was 55% in December 2020 and 53% in June 2021. While the average of 60% equates to a B− grade, members of the RCRC reached consensus on a B grade based on less gradable data sources available compared to previous years, which may have skewed the percentages lower. Further, there is research indicating that sleep has increased or remained the same throughout the pandemic (22). This aligns with the B grade in 2020 (Figure 1).

3.1.7.1. Equity-deserving groups

For the *Sleep* indicator, COVID-19-specific results were available for equity-deserving groups within the NPAM study (children and youth with disabilities), COMPASS (racialized children and youth, and girls), ATIM (girls), and PCS (girls; Figure 2). In May 2020, 59% of children and youth with disabilities in the NPAM study met the sleep duration recommendations, compared to 62% in November 2020. The percent of racialized youth in COMPASS meeting the sleep duration recommendation during the pandemic was 49% for Asian students, 46% for Black students, 51% for Latin American/Hispanic students, 52% for other/multiple, and 61% for White students. Sixty percent of girls in COMPASS met the sleep duration recommendation during the pandemic, compared to 58% of boys. Further, at the start of the pandemic 73% of girls 5–11-years-old (68% of boys) and 74% of girls 12–17-years-old (71% of boys) met the sleep duration recommendations, compared to 59% of girls 5–11-years-old (52% of boys) and 62% of girls 12–17-years-old (57% of boys) later on in the pandemic (October 2020). Finally, within the ATIM study, the percentage of girls meeting the sleep duration recommendation was 57% in December 2020 (53% of boys) and 56% in June 2021 (51% of boys).

3.1.7.2. 24-hour movement behaviors: F

In the COMPASS, ATIM, and PCS an average of 5% of children and youth met the combined physical activity, screen time, and sleep duration recommendations within the Canadian 24-Hour Movement Guidelines for Children and Youth (4). For the COMPASS study, from November 2020 to June 2021, 1% of youth in grades 9–12 met all recommendations. Within the PCS, 5% of children (5–11 years) and 1% of youth (12–17 years) met all the recommendation at the start of the pandemic (April 2020), compared to 5% of children and 2% of youth later on in the pandemic (October 2020). The percent of 7–12-year-old children meeting the sleep recommendation was 10% in December 2020 and 13% in June 2021 in the ATIM study. Based on the 5% average of children and youth meeting this benchmark, an F grade was assigned, consistent with the F in 2020 (Figure 1).

3.1.7.3. Equity-deserving groups

For the *24-Hour Movement Behaviors* indicator, COVID-19-specific results were available for equity-deserving groups within the NPAM (children and youth with disabilities), COMPASS (racialized children and youth, and girls), ATIM (girls), and PCS (girls; Figure 2). In both May 2020 and November 2020 for the NPAM study, 0% of children and youth with disabilities met all the recommendations within the 24-Hour Movement Guidelines. For all girls, boys, and racialized groups of youth in COMPASS, 1% met all 24-Hour Movement Guideline recommendations (including the muscle- and bone-strengthening recommendation) during the pandemic. For the PCS, at the start of the pandemic, 3% of girls 5–11-years-old (7% of boys) and 1% of girls 12–17-years-old (1% of boys) met all 24-Hour Movement Guideline recommendations, compared to 5% of girls 5–11-years-old (4% of boys) and 1% of girls 12–17-years-old (2% of boys) in October 2020. Within ATIM, the percentage of girls meeting all 24-Hour Movement Guideline recommendations was 11% in December 2020 (9% of boys) and 12% in June 2021 (13% of boys).

3.2. Individual characteristics

3.2.1. Physical literacy: INC

No COVID-19-specific results were available to assign a grade; thus, the grade for the *Physical Literacy* indicator is Incomplete (INC; Figures 2, 3).

3.2.2. Physical fitness: INC

No COVID-19-specific results were available to assign a grade; thus, the grade for the *Physical Fitness* indicator is Incomplete (INC; Figures 2, 3).

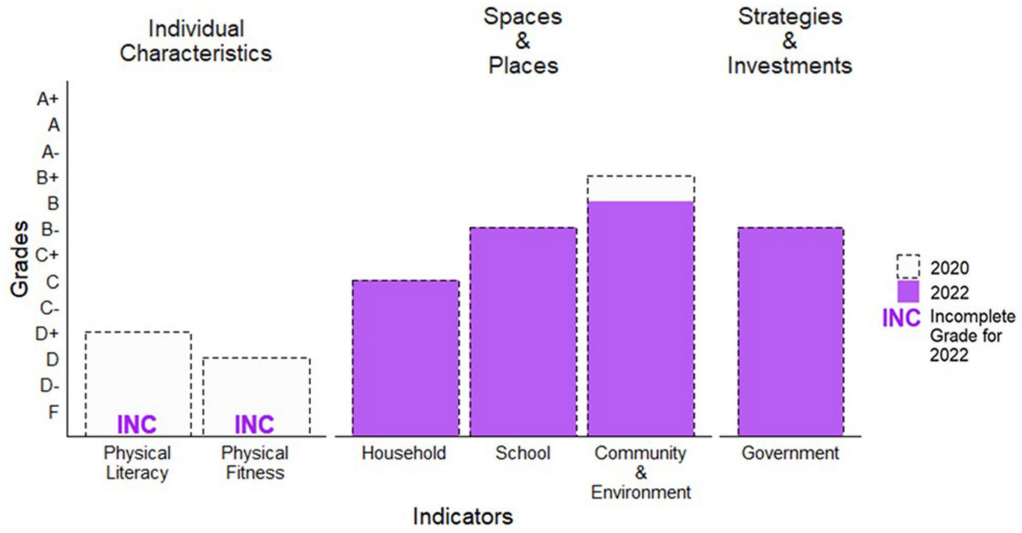

FIGURE 3
Grade comparisons beyond daily behaviors in 2020 and 2022.

3.3. Spaces and places

3.3.1. Household: C

According to the PSPAS, an average of 53% was calculated from the *Household* indicator benchmarks. Specifically, 53% of parents responded they facilitated physical activity and sport opportunities for their children often or very often, with examples of facilitation including: transporting, spectating, encouraging outdoor play regularly, encouraging their children to participate in play instead of screens, placing limits on screen time, and playing active games or sports with their children. Based on the 53% meeting this benchmark, a C grade was assigned—the same grade assigned in 2020 (Figure 3).

3.3.1.1. Equity-deserving groups

For the *Household* indicator, COVID-19-specific results were available for girls within the PSPAS (Figure 2). Within the PSPAS, no significant gender differences were observed for the *Household* indicator benchmarks, though according to parent report 74% of boys and 69% of girls were encouraged to play outdoors regularly.

3.3.2. School: B–

The average percent across the *School* indicator domains of policies, human resources, facilities, partnerships, and other programming was 64% based on the Opportunities for Physical Activity at School Study (OPASS). For policies, 66% of schools had active school policies. For human resources, 67% of schools had a physical education specialist or teacher with at least one elective credit in physical education, and >65% of students were taught physical education by a physical education specialist. For facilities, 61% of schools indicated that their outdoor and indoor facilities for physical education and physical activity met students' needs well or very well. For partnerships, 60% of schools indicated that they had agreements with municipalities or sport organizations to share facilities or resources and programming. Finally, for other programming, 68% of schools indicated that intramural activities, inter-school activities, and other physical activity outings were available to their students. Based on the 64% average score, a B– grade was assigned, which is consistent with the 2020 Report Card (Figure 3).

3.3.2.1. Equity-deserving groups

For the *School* indicator, COVID-19-specific results were not available for any equity-deserving groups (Figure 2).

3.3.3. Community and environment: B

The average across the *Community and Environment* indicator domains of policies; human resources; facilities and infrastructure; partnerships; and programming for children, youth, and families was 70% according to the Survey of Physical Activity Opportunities in Canadian Communities (SPAOCC) and one benchmark from the PSPAS. For policies, 27% of communities had a formal plan for parks, recreation, physical activity and sport, or active transportation. For human resources, 65% of communities indicated they had sufficient human resources supporting physical activity. For facilities and infrastructure, 81% of communities indicated having at least one amenity promoting active transportation (public transport, crossing guards, school safety zones, etc.); 74% of communities reported having designated bike lanes on roads or multi-purpose trails; 75% of communities reported having at least one family-friendly amenity (i.e., family changing facilities, washrooms at parks, drinking fountains, childcare services); 79% of parents in the PSPAS reported that some or many facilities in their community (public, commercial, playgrounds, parks, other community facilities) were available to participate in physical activity or sport. For partnerships, 66% of communities indicated they had agreements in place with schools, school boards, or sport organizations to share facilities or resources and programming. For programming for children, youth, and families, 92% of communities reported having programming targeted to children, youth, and families. Based on the 70% average across the benchmarks, a B grade was assigned for the *Community and Environment* indicator. The B grade for 2022 is a decrease from the B+ grades assigned in 2020 (Figure 3).

3.3.3.1. Equity-deserving groups

For the *Community and Environment* indicator, COVID-19-specific results were not available for any equity-deserving groups (Figure 2).

3.4. Strategies and investments

3.4.1. Government: B–

The RCRC graded the *Government* indicator using the benchmarks: (1) evidence of leadership and commitment in providing physical activity opportunities for all children and youth, (2) allocated funds and resources for the implementation of physical activity promotion strategies and initiatives for all children and youth, and (3) demonstrated progress through the key stages of public policy making (i.e., policy agenda, policy formation, policy implementation, policy evaluation and decisions about the future). Specific data synthesized included federal, provincial, and territorial budgets, as well as initiatives related to children's physical activity [see full summary (13)]. The RCRC reached consensus on a B– grade for the 2022 *Government* indicator, which is consistent with the 2020 Report Card grade (Figure 3).

3.4.1.1. Equity-deserving groups

For the *Government* indicator, synthesized information (13) included COVID-19-specific results for children and youth with disabilities, Indigenous children and youth, and girls (Figure 2).

4. Discussion

During the COVID-19 pandemic, the 2022 ParticipACTION Report Card on Physical Activity for Children and Youth grade for *Overall Physical Activity* was a D, a decrease from a D+ in the 2020 Report Card. This is the first decrease in the *Overall Physical Activity* grade since 2007, where it had either remained unchanged or improved up to 2020 (2, 10). Canadian national results from the CCHS demonstrated that physical activity decreased for children and youth, which was related to decreased access to schools and opportunities for sports and recreation (17). Unsurprisingly, the *Overall Physical Activity* grade drop coincides with grade drops for *Organized Sport*, *Community and Environment*, and *Sedentary Behaviors*.

It is important to highlight that for some children and youth, positive changes to the landscape of physical activity opportunities were apparent. Specifically, increases in the grades for *Active Transportation* and *Active Play* were observed when comparing the 2022 to the 2020 grades. Aligning with the WHO's recommendation of "*whenever feasible, consider riding a bicycle or walking*" (23) for maintaining physical distancing and promoting physical activity during transport, some cities in Canada (e.g., Montreal, Halifax) expanded or allocated car-free spaces for active transportation (24, 25). The beginning of the pandemic included restrictions on outdoor spaces such as playgrounds, coinciding with parental perception of lower levels of children's outdoor play in April 2020 compared to pre-pandemic levels (11). As the public health guidelines evolved, restrictions to outdoor spaces were relaxed and in October 2020 levels of outdoor play improved for Canadian children and youth compared to April 2020, although outdoor play levels were still considered lower than pre-pandemic levels (20). While parents felt children's level of outdoor play was lower than pre-pandemic levels in April and October 2020, according to the PSPAS survey, 25% of children and youth (5–17 years) had an average of >2 h/day of total time engaged in indoor and outdoor unstructured play—thus, warranting the D– minus grade for *Active Play*, an improvement from the F in 2020. These improvements are important considering the positive association between outdoor time and adherence to the 24-Hour Movement Guidelines for children and youth during COVID-19 (26).

The distribution of improvements in physical activity opportunities during COVID-19 (i.e., *Active Transportation* and *Active Play*) could be considered one-sided, as the car-free spaces were generally in areas with fewer visible minority populations and fewer households with children (24). Further, increases in outdoor time were more likely for children in higher income families, living in a house (not apartment), and living in lower population-density neighborhoods (27). As well, the unfavorable trends in behaviors seen generally (e.g., *Overall Physical Activity*, *Organized Sport*, *Sedentary Behaviors*) may have been exacerbated for equity-deserving groups given the pre-existing barriers to physical activity. For instance, for some equity-deserving groups (e.g., children and youth with disabilities, newcomers to Canada) community resources, structured programming, and school-based activities (21, 28) are key facilitators of physical activity, and COVID-19 pandemic restrictions left limited accessible alternatives (21). Thus, COVID-19 recovery plans should address inequalities for health, and health behaviors, as recommended by the Chief Public Health Officer of Canada (12).

Reflecting on the challenges that COVID-19 presented for children and youths' physical activity opportunities, Canada should strive toward a recovery plan that draws on the momentum seen for *Active Transportation* and *Active Play*. Public health officials should advocate for increased access to the car-free and outdoor spaces that likely prevented the *Overall Physical Activity* grade from decreasing even further during COVID-19. However, all health promotion efforts need to be considered from an equity lens, or the risk of widening inequalities for physical activity and related behaviors, characteristics, and opportunities will remain an ongoing issue. Further, support is needed for surveys with large sample sizes, across robust sets of physical activity related variables, that allow for meaningful examinations of sub-groups during the recovery period of COVID-19.

4.1. Strengths and limitations

A strength of this review was the RCRC, a group of international leading experts in children's physical activity from across Canada representing the academic, government, and non-government sectors. While there was a lack of data on equity-deserving groups, the effort to synthesize available evidence could be considered a strength. We hope this Report Card serves as a catalyst for future equity-based children and youth physical activity research and initiatives, such as the 2022 Canadian Para Report Card on Physical Activity for Children and Adolescents with Disabilities (29). However, limitations of this work must be acknowledged. While the selected benchmarks and

indicators undergo expert appraisal and consensus by the RCRC, it is essential to continue exploring alternative and additional approaches to ensure the most essential concepts related to children's physical activity are synthesized. For instance, while recreational screen time is a common benchmark for sedentary behavior (4, 30), a more fulsome understanding of sedentary behavior may be achieved by examining additional benchmarks (e.g., sitting time, types of recreational screen time). The synthesized data represents multiple time-points during COVID-19. The restrictions to physical activity opportunities during COVID-19 were not temporally or geographically homogenous. Temporally, restrictions were generally stricter during the first wave of the pandemic and began gradually relaxing in later waves. Geographically, differences existed in restrictions, infection rates, and movement behaviors across provinces and territories (31). COVID-19 also imposed restrictions on data collection that decreased the quantity and quality of grade-informing evidence compared to previous years. For instance, this Report Card relied on less nationally representative data and no device-measured data were available. Finally, by broadly focusing on multiple equity-deserving groups we may have missed important nuances within groups (e.g., disability impairment types and severity) and between groups (e.g., intersections between gender and race). However, the possibility of examining important nuances within groups and intersections among groups requires sufficiently powered and representative population-level data, and standardized definitions for group categorization (e.g., International Classification of Functioning, Disability and Health) (32, 33).

5. Conclusion

The impact of COVID-19 on children and youth included decreased physical activity and increased sedentary behaviors—both important health-related behaviors. Improvements in *Active Transportation* and *Active Play* during COVID-19 may have prevented an even greater negative shift in children's health-related behaviors and overall well-being. Future efforts should continue enhancing equitable access to car-free and outdoor spaces. Additionally, surveys with large sample sizes capable of conducting meaningful comparisons for all children and youth, including equity-deserving groups, are needed to better understand the COVID-19 impacts and recovery efforts.

Author contributions

NK synthesized the results and drafted the manuscript. All authors contributed to the report card conception, design, grading; and contributed to the article and approved the submitted version.

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Conflict of interest

JD was employed by ParticipACTION.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Family functioning and problematic internet pornography use among adolescents: a moderated mediation model

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Background: In recent years, the issue of problematic Internet pornography use (PIPU) among adolescents has become increasingly prominent, attracting widespread attention from society. Family functioning has been recognized as a protective factor for PIPU, but the underlying mediating and moderating mechanisms remain unclear. The purpose of this study is (a) to investigate the mediating role of self-esteem in the relationship between family functioning and PIPU, and (b) to examine the moderating role of the need to belong in this mediating pathway.

Methods: A total of 771 high school students (M_{age} = 16.19, SD = 0.90) were surveyed using the Problematic Internet Pornography Use Scale, Family Assessment Device, Rosenberg Self-Esteem Scale, and the Need to Belong Scale.

Results: Correlation analysis showed a significant negative correlation between family functioning and PIPU ($r = -0.25$, $p < 0.001$), a significant positive correlation between self-esteem and family functioning ($r = 0.38$, $p < 0.001$), a significant negative correlation between self-esteem and PIPU ($r = -0.24$, $p < 0.001$), and a significant positive correlation between need to belong and PIPU ($r = 0.16$, $p < 0.01$). Mediation analysis showed that self-esteem partially mediated the relationship between family functioning and PIPU, with a mediation effect of −0.06. Further moderated mediation analysis showed that for adolescents with higher need to belong, the mediating effect of self-esteem was stronger.

Conclusions: For adolescents with high belonging needs who are at high risk for PIPU, good family functioning may have a protective effect by boosting self-esteem.

KEYWORDS

family functioning, problematic internet pornography use, self-esteem, need to belong, adolescents

1. Introduction

The development of the Internet has led to an exponential increase in the number of users of online pornography. Pornography is familiar to both men and women, with research showing that watching pornography is the most addictive activity on the internet (1). The latest research estimates that the prevalence of lifetime pornography consumption is around 92–98% in men and 50–91% in women (2). Most people who watch pornography do so for entertainment purposes and do not experience serious problems. However, a small minority of pornography viewers exhibit problematic internet pornography use (PIPU), with rates of 1–7% for women and 3–10% for men (3–5). Due to the similarities between PIPU and substance addiction in terms of occurrence and development mechanisms (6, 7),

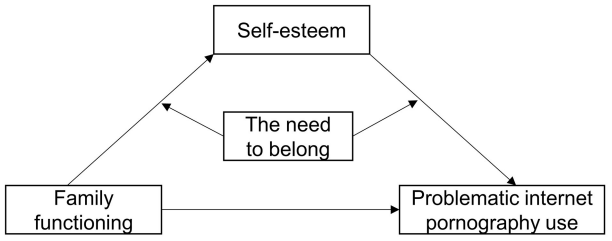

FIGURE 1
The proposed moderated mediation model.

PIPU is also referred to as online pornography addiction by many scholars and is typically defined as the inability to control excessive consumption of pornography despite its serious negative consequences (8). Research has found that internet pornography use is associated with many negative effects, such as physical health problems, emotional problems, and interpersonal relationship problems (9–11). Therefore, it is necessary to better understand the risk factors and related mechanisms of PIPU in adolescents in order to provide insights for prevention and intervention efforts.

The family, as a microsystem for personal development, is the most direct and specific microenvironment that affects psychological development and has a direct and profound impact on individual development (12, 13). A number of studies have found that family functioning has an important impact on adolescent PIPU, with good family functioning (such as parental love and care, effective communication, etc.) effectively reducing adolescent PIPU, while the breakdown of family functioning (such as lack of communication, low commitment to the family, poor parent-child relationships, etc.) significantly increases the proportion of adolescents participating in online pornography (14–16). Although previous studies have examined the relationship between family functioning and adolescent PIPU, the mediating (how family functioning is related to PIPU) and moderating (when this relationship is most closely linked) mechanisms between the two are still not well understood. Exploring the internal impact mechanism between family functioning and PIPU is of great significance for enhancing our understanding of PIPU and developing effective intervention methods. Therefore, this study constructed a conceptual model (Figure 1) with adolescents as the sample, in which self-esteem plays a mediating role between family functioning and PIPU, and the mediating path of self-esteem is moderated by the need for belonging.

As is well known, family functioning is related to self-esteem, and a large body of research shows that family functioning can predict the level of self-esteem in adolescents. For example, high levels of family intimacy and emotional expression are significantly positively correlated with high levels of self-esteem in adolescents, while denial and rejection in family relationships can lead to feelings of inferiority and helplessness, resulting in lower levels of self-esteem in individuals (17). According to Davis's cognitive-behavioral model of pathological internet use, low self-esteem is one of the risk factors for addiction (18). Some studies have reported a correlation between the use of pornography and low self-esteem, finding a positive correlation between PIPU and lower general self-esteem (19), as well as sexual self-esteem (20). Similarly, Borgogna et al. (21) found that men with low self-esteem are particularly prone to being attracted to pornography and exhibit more symptoms of PIPU. In summary, self-esteem may play a mediating role in the relationship between family functioning and PIPU, but there has been no research to date that has examined this.

Although family functioning may affect adolescent PIPU through the mediating role of self-esteem, adolescents' sensitivity to family functioning and self-esteem may differ, so it is necessary to further investigate the moderating factors of family functioning. The need to belong is a basic human motivation that has a significant impact on individuals' emotions, cognition, and behavior (22). Individuals with a high need for belonging have a higher motivation to obtain satisfactory interpersonal relationships (23). Given that an important goal of adolescent internet pornography viewing is to cope with negative emotions and alleviate feelings of loneliness (24–26), it is reasonable to hypothesize that adolescents with a high need for belonging will view internet pornography more frequently, thereby increasing the risk of PIPU. In addition, the need for belonging may moderate the indirect relationship between family functioning and adolescent PIPU. The organism-environment interaction model suggests that individuals with different personality traits react differently to similar environments, and the dynamic changes in personality traits and environment help individuals to adapt psychologically and socially (27). Family functioning, as an interpersonal or environmental factor, can only explain a small part of the differences in individual behavior. Without relevant information about individual personality traits, it is difficult to clearly explain whether family functioning will be a strong predictor of behavior. Therefore, the need for belonging can be regarded as a personality trait to better explain the relationship between family functioning and adolescent PIPU.

In summary, this study tested a moderated mediation model with adolescents as the sample. The study hypothesized that: (a) good family functioning would enhance adolescents' self-esteem, and thereby reducing PIPU. That is, self-esteem plays a mediating role in the relationship between family functioning and adolescent PIPU. (b) the need for belonging positively predicts PIPU. Meanwhile, the indirect relationship between family functioning and PIPU through self-esteem will vary depending on the level of the need for belonging. For individuals with a high need for belonging, the mediating path of self-esteem will be stronger.

2. Methods

2.1. Participants

The target schools were selected using a convenient sampling method. In two ordinary high schools located in Sichuan Province in western China, the cluster random sampling method was used to select three classes from each grade from 10th to 12th grade. Out of the 814 high school students who received the questionnaire, 800 returned the questionnaire, resulting in a response rate of 98.28%. In order to ensure data accuracy, strict screening was conducted on the collected questionnaires, excluding those with missing responses, straight-line responses (where the same answer

is given for every question, such as "1, 1, 1, 1, 1…"), and pattern responses (following a certain artificial rule, such as "1, 2, 3, 4, 5, 1, 2, 3, 4, 5…"). After invalid questionnaires were removed, 771 valid questionnaires were obtained (94.72% effective response rate). There are 253 students in the 10th grade, 279 students in the 11th grade, and 239 students in the 12th grade. Of these, 405 were male (52.53%) and 366 were female (47.47%). The age range of the participants was 14–18 years old, with an average age of 16.19 ± 0.90 years old.

2.2. Measures

2.2.1. Family functioning

The Chinese version of the Family Assessment Device (FAD) was used to assess family functioning (28). The scale contains 60 items and is divided into seven dimensions: problem-solving, communication, roles, affective responsiveness, affective involvement, behavior control, and general functioning. The scale was scored on a 4-point scale ranging from 1 (very like my family) to 4 (not at all like my family). The average of all items in each subscale was calculated as the total score for that subscale. The higher the total score, the worse the family functioning. To be consistent with positive thinking habits, the scoring direction of positive and reverse scoring questions was reversed in this study, so the higher the score, the better the family functioning. The FAD has been demonstrated to have good reliability and validity in Chinese adolescents (29, 30). The index of confirmatory factor analysis (CFA) showed an acceptable fit of the scale model: χ^2/df = 4.28, RMSEA = 0.07, CFI = 0.87, TLI = 0.89, and SRMR = 0.05. The Cronbach's α coefficient of this scale in this study was 0.87.

2.2.2. PIPU

The Chinese version of the Problematic Internet Pornography Use Scale (PIPUS) was used in this study (31). The scale consists of 12 questions, including four dimensions: distress and functional problems, excessive use, difficulty in self-control, and negative emotional avoidance. The scale uses a 6-point Likert scale ranging from 0 (never) to 5 (always). The PIPUS has been shown to have good internal consistency reliability and to be associated with hypothesized psychopathological variables in Chinese samples (32, 33). The index of CFA showed a good fit of the scale model: χ^2/df = 1.35, RMSEA = 0.03, CFI = 0.98, TLI = 0.98, and SRMR = 0.04. The Cronbach's α coefficient of this scale in this study was 0.88.

2.2.3. Self-esteem

The Rosenberg Self-Esteem Scale (RSES) was used to measure the participants' self-esteem levels (34). The scale consists of 10 items and uses a 4-point scoring system, with 1 indicating "strongly agree" and 4 indicating "strongly disagree". The higher the score, the higher the level of self-esteem. The RSES has been well validated in Chinese adolescents (35). The index of CFA showed a good fit of the scale model: χ^2/df = 3.62, RMSEA = 0.06, CFI = 0.97, TLI = 0.98, and SRMR = 0.02. The Cronbach's α coefficient of this scale in this study was 0.89.

2.2.4. The need to belong

The Need to Belong Scale (NBS), developed by Leary et al. (36), measures individuals' needs for non-rejection, inclusion, and a sense of belonging. The scale consists of 10 items and uses a 5-point scoring system, with 1 indicating "strongly disagree" and 5 indicating "strongly agree". The higher the score, the greater the individual's need for belonging. The NBS has been found to have satisfactory psychometric properties (23). The index of CFA showed an acceptable fit of the scale model: χ^2/df = 4.19, RMSEA = 0.06, CFI = 0.90, TLI = 0.89, and SRMR = 0.04. The Cronbach's α coefficient of this scale in this study was 0.81.

2.3. Procedures and data analysis

Testing was conducted by class, with trained graduate students serving as the examiners. Before the test, the participants were given instructions for attention, and the completed questionnaires were collected on site. The data were analyzed using SPSS 22.0. Descriptive information and correlation matrices were calculated first. Then, Hayes' PROCESS macro was used for moderated mediation analysis (37). All continuous variables were standardized, and the interaction term was calculated from standardized scores. In addition, the bootstrapping method was used to test the statistical significance and obtain the standard error of parameter estimates.

2.4. Ethics

This study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethical Committee of the School of Psychology, Chengdu Medical College (No. XL2022006). According to China's "Information Security Technology—Personal Information Security Specification" (Chinese National Standard: GB/T35273-2020), individuals between the ages of 14 and 18 can agree to and provide their own data or have their guardians provide it on their behalf, while individuals under the age of 14 must obtain their guardians' consent. In view of the sensitivity of the survey, not relying on parental consent can ensure anonymity and reduce sample bias that may distort the results. Therefore, adolescents aged 14 and above in this study signed informed consent form by themselves.

3. Results

3.1. Control and testing of common method bias

Common method bias was controlled through methods such as anonymous answering, reverse scoring, and different instructions for different questionnaires. Harman's single-factor test was used for principal component analysis, and the results showed that there were 28 factors with eigenvalues >1. The first factor accounted for 13.84% of the variance, which was <40%, indicating that there was no serious common method bias in this study.

3.2. Correlation analysis

Descriptive statistics and Pearson correlation analysis were conducted, and the results are shown in Table 1. As expected, family functioning was significantly positively correlated with self-esteem and significantly negatively correlated with PIPU. Self-esteem was significantly negatively correlated with both belongingness need and PIPU. The need to belong was significantly positively correlated with PIPU.

3.3. Moderated mediation model testing

First, model 4 in Process was used to test the mediating effect of self-esteem between family functioning and PIPU. The results showed that, controlling for gender and age, family functioning significantly negatively predicted PIPU ($c = -0.22$, $SE = 0.04$, $t = -6.66$, $p < 0.001$). When family functioning and self-esteem were simultaneously entered into the equation, family functioning significantly positively predicted self-esteem ($a = 0.36$, $SE = 0.03$, $t = 11.02$, $p < 0.001$), and self-esteem significantly negatively predicted PIPU ($b = -0.15$, $SE = 0.04$, $t = -3.97$, $p < 0.001$). In addition, family functioning significantly negatively predicted PIPU ($c' = -0.16$, $SE = 0.04$, $t = -4.27$, $p < 0.001$). The bias-corrected percentile Bootstrap test found that self-esteem had a significant mediating effect between family functioning and PIPU, with ab = −0.06, BootSE = 0.02, 95%CI = (−0.10, −0.03). The proportion of the total effect accounted for by the mediating effect was $ab/(ab + c') = 25.23\%$. Therefore, Hypothesis 1 was supported.

Furthermore, Process (model 58) was used to test the moderating effect of the need to belong on the relationship between family functioning and self-esteem (first stage) and between self-esteem and PIPU (second stage). For the first stage, the results showed that the interaction between family functioning and the need to belong significantly positively predicted self-esteem ($\beta = 0.12$, $SE = 0.02$, $t = 5.35$, $p < 0.001$), as shown in Table 2. To further explain this interaction, the need to belong was divided into high and low groups based on one standard deviation above and below the mean, and a simple slope test was conducted (38). As shown in Figure 2, for individuals with low belongingness need, family functioning significantly positively predicted self-esteem ($\beta = 0.19$, $SE = 0.04$, $t = 2.02$, $p < 0.05$); for individuals with high belongingness need, family functioning had a stronger positive effect on self-esteem ($\beta = 0.48$, $SE = 0.04$, $t = 12.18$, $p < 0.001$).

However, for the second stage, the interaction between self-esteem and the need to belong was not significant, $\beta = -0.02$, $SE = 0.02$, $t = -0.69$, $p = 0.49$. Therefore, Hypothesis 2 is partially supported.

4. Discussion

The impact of family functioning on adolescent PIPU has been extensively studied. However, the underlying mediating and moderating mechanisms remain unclear. This study constructed a moderated mediation model to test whether family functioning is related to adolescent PIPU through self-esteem as a mediator, and whether this indirect effect is moderated by the need for belonging. The results showed that the impact of family functioning on adolescent PIPU can be partially mediated by self-esteem, and the first half of this indirect effect is moderated by the need for belonging. In other words, for adolescents with a high need for belonging, the increase in self-esteem brought about by good family functioning is a protective factor against PIPU.

4.1. Mediation effect of self-esteem

The study found that good family functioning enhances adolescents' self-esteem, and self-esteem is significantly negatively correlated with adolescent PIPU. That is to say, self-esteem plays a mediating role in the relationship between family functioning and adolescent PIPU. In the first stage of the mediation model (family functioning → self-esteem), this study found that good family functioning helps to enhance an individual's self-esteem, which is consistent with self-determination theory or attachment theory (39, 40). It indicates that good family and interpersonal relationships play an important role in an individual's psychological growth (such as high self-esteem), which in turn prevents them from engaging in a series of problem behaviors such as PIPU. For the second stage of the mediation model (self-esteem → PIPU), this study showed that self-esteem negatively predicts adolescent PIPU. This finding is consistent with the cognitive-behavioral model of pathological internet use (18), which suggests that individuals with cognitive maladaptation (such as those with low self-esteem) are more likely to be addicted to the internet. In addition, this study further shows that high self-esteem is a protective factor for adolescent PIPU, which is consistent with the positive correlation between low self-esteem and PIPU found in previous studies (19–21).

TABLE 1 Descriptive statistics and correlations of the main variables.

Variables	*M*	*SD*	Min–max	1	2	3	4
1. Family functioning	2.73	0.22	1.85–3.48	1			
2. Self-esteem	27.52	3.44	14–36	0.38***	1		
3. The need to belong	33.42	5.02	14–49	−0.09	−0.14*	1	
4. PIPU	8.18	6.48	0–36	−0.25***	−0.24***	0.16**	1

N = 771.
PIPU, problematic internet pornography use; SD, standard deviation.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

TABLE 2 Testing the moderated mediation effect of family functioning on adolescent PIPU.

Variables	Model 1 Criterion: PIPU				Model 2 Criterion: self-esteem				Model 3 Criterion: PIPU			
	β	*SE*	*t*	Boot 95%CI	*β*	*SE*	*t*	Boot 95%CI	*β*	*SE*	*t*	Boot 95%CI
Gender	−0.02	0.03	−0.39	(−0.07, 0.19)	−0.06	0.06	−0.75	(−0.15, 0.01)	0.03	0.07	0.41	(−0.11, 0.16)
Age	−0.07	0.04	−0.73	(−0.11, 0.05)	−0.01	0.04	−0.12	(−0.08, 0.07)	−0.04	0.04	−0.98	(−0.12, 0.04)
FF	−0.22***	0.04	−6.66	(−0.31, −0.16)	0.36***	0.03	11.02	(0.29, 0.42)	−0.16***	0.04	−4.27	(−0.23, −0.08)
NTB					−0.15*	0.05	−4.39	(−0.23, −0.05)	0.15***	0.03	4.44	(0.07, 0.24)
SE									−0.15**	0.04	−3.97	(−0.24, −0.06)
FF × NTB					0.12***	0.02	5.35	(0.07, 0.17)				
SE × NTB									−0.02	0.02	−0.69	(−0.07, 0.06)
R^2	0.06				0.21				0.11			
F	50.51***				40.03***				15.18***			

N = 771.
Standardized regression coefficients are reported.
FF, family functioning; SE, self-esteem; NTB, the need to belong; PIPU, problematic internet pornography use; Bootstrap sample size = 5,000; CI, confidence interval.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

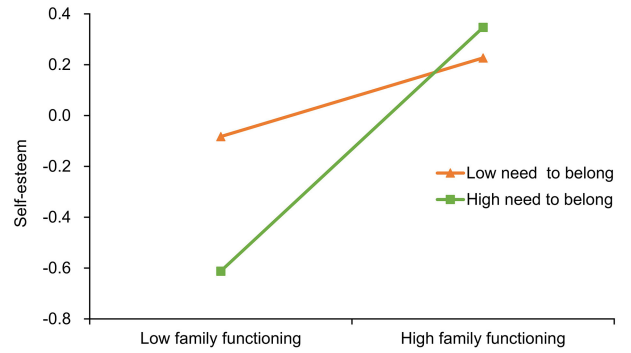

FIGURE 2
Moderating effect of the need to belong on the relationship between family functioning and self-esteem.

4.2. Moderating effect of the need for belonging

This study found that the need for belonging moderates the relationship between family functioning and self-esteem, and for individuals with a high need for belonging, the predictive effect of family functioning on self-esteem is stronger. The need for belonging is a sense of social activity demand, and individuals with a strong need for belonging have a higher demand for strengthening social connections and integrating into society (41). Therefore, for these individuals, because of their higher demands for social needs and social integration, they are more sensitive to the family environment, and the impact of good family functioning on their self-esteem is greater. Previous studies have found that the need for belonging can prompt people to engage in a series of activities that may enhance social connections, and individuals with a high need for belonging may apply the internet more frequently, thereby increasing the risk of internet addiction (42, 43). This study replicated previous results and found a positive correlation between the need for belonging and PIPU. In summary, this study indicates that due to individuals with a high need for belonging have a higher susceptibility to PIPU, the protective effect of good family functioning through the increase in self-esteem is more pronounced for them. This suggests that in the prevention process of PIPU, special attention should be paid to adolescents with a high level of the need for belonging. Actively focusing on and improving their family functioning can effectively reduce the risk of PIPU.

4.3. Significance and limitations of the study

The results of this study are of great significance. Firstly, this study emphasizes the importance of family functioning in preventing adolescent PIPU. Negative family relationships, such as parent-child conflicts, lack of family organization, and low levels of parental support, are all related to PIPU (14–16). Especially for Chinese left-behind adolescents, neglect and lack of parental

companionship may increase their risk of PIPU (44). Secondly, by establishing a mediation model, this study helps to understand how family functioning is related to adolescent PIPU and provides theoretical support for potential intervention measures, such as increasing adolescents' self-esteem level, which can effectively reduce the risk of PIPU. Finally, although belongingness is a basic need, the intensity of the need to belonging varies among individuals (23). Individuals with a high need to belong may be more susceptible to PIPU. Therefore, it is necessary to prioritize interventions for individuals with high belongingness needs in the prevention and intervention of adolescent PIPU.

There are several limitations to this study. Firstly, this study is a cross-sectional study, so causal relationships cannot be inferred. Future research should use longitudinal study designs to further validate the causal hypotheses in this study. Secondly, this study only focuses on family functioning, while other interpersonal relationships such as peer communication may also affect adolescent PIPU. Therefore, further research should consider other interpersonal relationships. Thirdly, due to the sufficient number of items already included in the questionnaire, we did not control for some background variables such as socioeconomic status (e.g., parental education level, parental occupation, and family income). Previous studies have found lower socioeconomic status to be associated with higher levels of pornography consumption (45, 46). Therefore, this potential confounds should be carefully controlled for in future research. Finally, convenience sampling was used in this study. The data was gathered from a single geographic location, which may limit the generalizability of our results to other populations. Future research should aim to improve sample representativeness so that results can be generalizable to a wider range of Chinese adolescents.

5. Conclusion

In conclusion, the present study demonstrates that family functioning is a protective factor for PIPU. Mediation analysis found that self-esteem may be a possible mechanism underlying this relationship. In addition, high level of need for belonging predicted PIPU in adolescents, and the mediated moderation model revealed that the protective effect of family functioning through self-esteem was stronger for adolescents with high need for belonging.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Chengdu Medical College Institutional Review Board. The participants provided their written informed consent to participate in this study. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

LL and JW involved in study concept and design. LL, XW, and ST involved in data preparation, statistical analysis, and wrote the manuscript. JW involved in study supervision and edited the manuscript. All authors had full access to all data in the study, take responsibility for the integrity of the data, and the accuracy of the data analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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A study on the relationships between playfulness, physical self-efficacy, and school happiness among middle school students participating in "0th-period physical education class" in South Korea

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The purpose of this study is to create a scientific basis for the establishment of "0th-period physical education class" activities in schools in the future, with the expectation that the associations of morning exercise can be activated in the Korean educational community. To achieve this goal, the present study aimed to determine the relationship between the playfulness experienced during the early morning exercise of middle school students and their physical self-efficacy and education for happiness. To examine the model, questionnaires were collected from 296 middle school students located in Seoul and Gyeonggi-do, South Korea. Correlation analysis and standard multiple regression analysis were performed to analyze the data using the SPSS 21.0. The findings were as follows: First, the playfulness of the middle school "0th-period physical education class" had a significant effect on physical self-efficacy. Second, playfulness had a significant effect on education for happiness. Thirdly, physical self-efficacy was found to have a significant effect on education for happiness. Based on the results of this study, we suggest that a "0th-period physical education class" with various activities should be held during the legally required time in South Korea.

KEYWORDS

Korean P.E. system, early morning exercise, early morning physical activity, 0th-period physical education class, 0th-period physical activity, education for happiness

1. Introduction

In South Korea in 2010, the broadcasting of "0th-period physical education class (0th-period PE class)" became a social issue based on research results that showed exercise had a positive effect on the academic brain area and had a significant impact on students' academic ability (1). As these research results received media attention, the "0th-period PE class" implementation activities began to expand, centering on local offices of education and elementary, middle, and high schools in Korea.

In South Korea, "0th-period PE class" is academically defined as participating in various sports in the morning hours before the start of the regular curriculum (2). In the Korean academic world, the term is used as "Physical Education Class in Period 0," "Morning Exercise," and "Physical Education in Period 0 (3)," whereas in other countries, it is known by terms such as "early morning physical activity,"' before-school physical activity program," and "early morning exercise" (4–6).

For the past decade or so, "0th-period PE class" has been conducted by teachers and students together during morning self-study or before the start of the first period. The program involves various physical activities, such as walking, soccer, basketball, and circuit training of moderate to high intensity, and is conducted independently by physical education teachers in elementary, middle, and high schools (7). Although "0th-period PE class" has not been implemented as a formal curriculum so far, it is necessary to generate a variety of positive academic evidence on the benefits of early morning physical activity for Korean adolescents in the future to generate positive implications for the growth of the Korean physical education system (5, 8, 9).

Changes and maturity in the middle school period are acquired based on positive activity experiences and can be naturally acquired in emotional activities related to interest and fun. This naturalness can be found in playfulness through sports (10). Generally, playfulness in sports is related to basic human needs, and the need is to perform various functions in human life (11). From this principle, playfulness in the middle school period is related to sociality among human development tasks. This is because there is a strong desire to value relationships with peer groups. Additionally, children and adolescents encounter natural play through group activities, and the peer relationship is closer than that of parents and teachers (12). Playfulness is the subjective experience of an individual in a state of play, or a characteristic mechanism that synchronizes an individual in a state of play. In other words, playfulness is a personal trait (13). Accordingly, it was reported that adolescents who show high playfulness not only have excellent creativity and problem-solving ability, but are also more likely to achieve excellent academic results, and to lead a smooth school life pattern and a high sense of school happiness. One important characteristic of playfulness is deeply related to not accepting various experiences of the environment to which an individual belongs as stress. Therefore, middle school students' experience of playfulness has the function of promoting individual success necessary for promoting sociality and leadership (14). In other words, playfulness in school physical education classes and activities includes emotional aspects related to fun and sensory physical vitality such as excitement and an individual's unique emotional leisure that can be immersed in fun and pleasure for a long time or distinguished from others. These factors are important psychological skills to relieve daily stress or improve a close intimacy (15). Thus, it can be seen as one way to cope with the stress that an individual feels from the environment, especially for middle school students whose peer influence is greater than their relationship with their parents (16).

Physical self-efficacy is defined as an individual's level of confidence and ability to perform a specific task related to the body (17). In other words, feeling anxious and depressed in a crisis is a result of feeling lethargic because there is no way to cope with the situation. If control is possible in a crisis, anxiety and depression are reduced because of high self-efficacy (18). This physical self-efficacy is significant in predicting human behavior as a psychological factor of confidence concerning exercise behavior for the body (19).

Accordingly, various studies have been conducted on physical self-efficacy and exercise task performance. Hamilton et al. (20) found that active physical activity in adolescents is indirectly predicted by self-efficacy through intention, and this intervention was further controlled by the level of support from friends, demonstrating that friend support can partially buffer the lack of self-efficacy (20). Furthermore, among high school students who participated in the school sports association, physical self-efficacy and psychological well-being were reported to be related to ego resilience and psychological well-being, respectively (21). Therefore, participation in different physical activities during adolescence is an important factor in achieving a positive quality of life by improving physical self-efficacy (22).

Happiness through school life has a significantly positive effect on adolescents' creativity and psychological energy (23). Happiness relates to the practical achievement of life goals and is a personal assessment of overall life satisfaction (24, 25). School happiness has a cognitive and emotional characteristic that evaluates students' thoughts about themselves or the overall school environment, such as classes and relationships, based on what they experience in the learning process or human relationships (26). Happiness includes concepts such as subjective well-being, quality of life, and life satisfaction. According to previous studies, physical self-efficacy and relationships with parents, friends, and teachers were suggested as factors that affect happiness among students' individual characteristics. Particularly, physical self-efficacy has a positive relationship with students' school happiness and has been consistently reported in almost all preceding studies (27). Moreover, through the verification of happiness in school life, it is possible to positively control social deviance factors related to youth risk behavior (smoking, drugs, violence, drinking, social cheating, etc.,) and to conclude that sociality in school groups is doing well (28, 29).

The above analysis of the literature suggests that playfulness, as perceived by adolescents, promotes positive functions such as happy emotions, pleasurable experiences, motivation, creativity, relationships, and relaxation. In addition, playfulness has been shown to increase physical self-efficacy, which in turn improves adjustment to relationships with teachers and peers and adjustment to school life. Playfulness and physical self-efficacy were also strongly associated with education for happiness. Notably, these factors are closely related to the type, intensity, and frequency of physical activity participation during adolescence. Therefore, it may be important to investigate whether regular "0th-period PE class" for middle school students can positively predict the relationship between their playfulness, physical self-efficacy, and education for happiness. Specifically, there is a lack of research on the positive association between playfulness, physical self-efficacy, and education for happiness through participation in "0th-period PE class." Recently, Korean society has been experiencing social problems such as bullying, violence and suicide among adolescents. In this situation, the positive association between playfulness, physical self-efficacy, and education for happiness may be valid in providing limited ways to cope with social problems. However, there is a lack of studies that have explored the relationship

between the three variables. Thus, the purpose of this study is to explore the relationship between playfulness, physical self-efficacy and education for happiness as experienced by middle school students participating in "0th-period PE class."

1.1. Hypotheses and research framework

The hypotheses of this study were established based on the relationship between playfulness, physical self-efficacy and education for happiness. A conceptual model of the hypotheses is shown in Figure 1.

Figure 1 contains H1, which is the playfulness in the "0th-period PE class," which positively affects towards physical self-efficacy. Secondly, H2 is the playfulness that positively affects education for happiness. Lastly, H3 is physical self-efficacy, which positively affects education for happiness.

2. Methods

2.1. Participants

In this study, middle school students located in Seoul and Gyeonggi-do, South Korea, were selected as sample groups. For sampling, 350 samples were extracted using a simple random sampling method among probability sampling methods. More specifically, given the characteristics of each region, Seoul was divided into four regions and one school was selected from each of the 28 cities in Gyeonggi-do. These were classified according to the legal administrative divisions in South Korea, and one school per division was randomly selected. Approximately 10–12 questionnaires were collected from each school. With the permission of the PE teachers at each school, the survey was conducted by two researchers using a face-to-face questionnaire with the students. Among the sampled survey data, 296 datasets were used for the final analysis, after eliminating 54 questionnaires that were judged to have been incorrectly indicated, or being incomplete. When removing the questionnaire, it was conducted by experts (statistical analysis experts and two PhD who majored in sociology of sport) other than researchers. The general characteristics of the study subjects are shown in (Table 1).

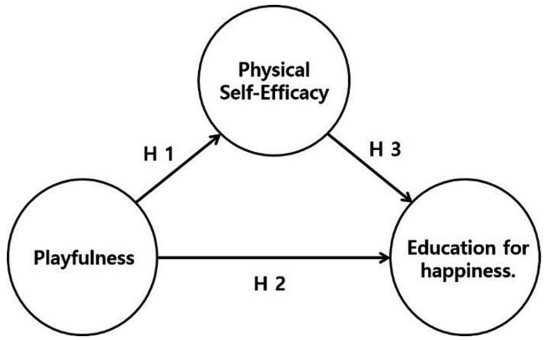

FIGURE 1
A conceptual model.

2.2. Measurements of key variables

To achieve the purpose of this study, we used structured questionnaires based on prior research and theory. The questionnaire comprises a total of 52 questions, including 2 items on demographic characteristics, 20 questions on playfulness, 10 questions on self-efficacy, and 20 questions on education for happiness. Playfulness was developed by Staempfli et al. (30). To confirm the factor structure of the Korean version of the 'Adolescent Playfulness Scale' and to test its reliability and conceptual validity, Kang (31) adapted the items of the 'Adolescent Playfulness Scale' (20 items) developed by Staempfli (30), conducted item analysis, and conducted exploratory and confirmatory factor analysis. Furthermore, the correlations between the sub-factors of the Korean version of the Youth Playfulness Scale and the openness and extraversion factors were examined, and the construct validity was tested. The Playfulness scale comprises 5 items: physical animation (4 questions), social engagement (4 questions), mental spontaneity (4 questions), emotional fluidity (4 questions), and humorous perspective (4 questions), for a total of 20 questions. The physical self-efficacy scale was measured by using the questions adopted and modified from the questionnaire developed by Ryckman et al. (17), and the questionnaire translated and used by Hong and Pyo (32) in Korean. The physical self-efficacy scale comprises two items: perceived physical ability (4 questions), and physical self-presentation confidence (6 questions), for a total of 10 questions. Education for happiness was measured using the questions adopted and modified from a previous study (33). It comprises five items: self-esteem (4 questions), thoughtfulness (4 questions), teacher-student relationship (4 questions), optimism (4 questions), and peer relationship (4 questions), comprising a total of 20 questions. The response of all of the above measurement tools comprised a 5-point Likert scale (from 1–strongly disagree to 5–strongly agree).

In this study, to examine the validity of the structured questionnaire, content validity verification of the questionnaire was conducted through consultation with three professors and two Ph.D. graduates who majored in the sociology of sport and sports pedagogy. To confirm the validity and internal consistency of the measurement tools, we conducted a confirmatory factor analysis by the Maximum likelihood method and a reliability analysis using Cronbach's α. The outcomes are shown in Table 2.

2.3. Procedure and statistical analysis

To achieve the purpose of this study, the researcher visited the school in person and requested for the cooperation of the teacher in

TABLE 1 General features of the study participants.

Section		Frequency	Percentage (%)
Sex	Female	170	57.4
	Male	126	42.6
Grade	First Grade	72	24.3
	Second Grade	192	64.9
	Third Grade	32	10.8

TABLE 2 Confirmatory factor analysis and reliability of latent variables.

Factor	Latent variable		Measuring variables	B	β	S.E.	*t*	α
Playfulness	Physical Animation	→	a01	1	0.576	0.180	5.94***	0.799
		→	a02	1.069	0.654	0.201	7.10***	
		→	a03	1.430	0.825	0.186	6.98***	
		→	a04	1.299	0.799			
	Social Engagement	→	b01	1	0.540	0.202	6.23***	0.766
		→	b02	1.255	0.699	0.226	6.27***	
		→	b03	1.417	0.731	0.233	6.16***	
		→	b04	1.438	0.695			
	Mental Spontaneity	→	c01	1	0.686	0.124	3.62***	0.946
		→	c02	0.449	0.346	0.130	5.47***	
		→	c03	0.710	0.589	0.130	5.11***	
		→	c04	0.666	0.500			
	Emotional Fluidity	→	d01	1	0.669	0.143	7.44***	0.805
		→	d02	1.068	0.777	0.121	6.62***	
		→	d03	0.801	0.634	0.143	7.40***	
		→	d04	1.058	0.730			
	Humorous Perspective	→	e01	1	0.726	0.127	9.31***	0.853
		→	e02	1.178	0.782	0.126	10.19***	
		→	e03	1.288	0.861	0.121	8.66***	
		→	e04	1.045	0.745			
χ^2: 262, df: 154, TLI: 0.903, CFI: 0.921, SRMR: 0.063, RMSEA: 0.068								
***$p < 0.001$								
Physical Self-Efficacy	Perceived Physical Ability Scale	→	a01	1	0.248	1.054	−2.73**	0.736
		→	a02	−2.811	−0.629	1.520	−2.79**	
		→	a03	−4.243	−0.819	1.499	−2.83**	
		→	a04	−4.237	−0.847			
	Physical Self-Presentation Confidence Scale	→	b01	1	0.584	0.211	5.16***	0.749
		→	b02	1.089	0.654	0.174	2.12*	
		→	b03	0.369	0.209	0.174	3.41***	
		→	b04	0.592	0.344	0.208	4.47***	
		→	b05	0.930	0.495	0.209	5.64***	
		→	b06	1.178	0.680			
χ^2: 49.1 df: 34, TLI: 0.937, CFI: 0.952, SRMR: 0.062, RMSEA: 0.054								
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$								
Education for happiness	Self-esteem	→	a01	1	0.718	0.142	5.95***	0.778
		→	a02	0.848	0.508	0.141	7.99***	
		→	a03	1.128	0.695	0.150	9.25***	
		→	a04	1.386	0.798			
	Thoughtfulness	→	b01	1	0.668	0.148	7.31***	0.780
		→	b02	1.084	0.616	0.179	7.28***	
		→	b03	1.301	0.750	0.178	6.90***	
		→	b04	1.255	0.702			
	Teacher relationship	→	c01	1	0.563	0.265	4.18***	0.713
		→	c02	1.110	0.429	0.238	6.92***	
		→	c03	1.648	0.761	0.269	5.85***	
		→	c04	1.577	0.643			
	Optimism	→	d01	1	0.727	0.265	4.18***	0.825
		→	d02	1.046	0.697	0.238	6.92***	
		→	d03	1.060	0.779	0.269	5.85***	
		→	d04	1.135	0.783			
	Peer relationship	→	e01	1	0.616	0.153	7.99***	0.751
		→	e02	1.226	0.664	0.165	6.00***	
		→	e03	0.993	0.616	0.154	6.39***	
		→	e04	0.986	0.655			
χ^2: 256, df: 142, TLI: 0.902, CFI: 0.927, SRMR: 0.067, RMSEA: 0.073								
***$p < 0.001$								

charge. Additionally, after being explained the purpose and method of filling out the questionnaire, the study participants were asked to complete the survey using the self-evaluation technique. If it was difficult for participants to respond to the survey face-to-face, it was conducted through a zoom program. The data collection in this study followed the following procedure: First, frequency analysis was conducted using the SPSS 21.0 program. Second, confirmatory factor analysis and reliability verification (Cronbach α) were conducted to verify the validity of the survey tool using the jamovi 1.2.27 program. Third, correlation analysis and standard multiple regression analysis were performed using the SPSS 21.0 program. The statistical significance probability of this study was set at 0.05.

3. Results

3.1. Correlation analysis among variables

Table 3 shows the correlation between each factor to determine the satisfaction of discriminant validity between each factor for factors identified as single dimensionality. Additionally, the correlation (r) between the relevant variables was −0.458 to 0.774, and it was shown that there was a partially significant correlation between the variables. Since the values of all correlation numbers did not exceed 0.80, discrimination was obtained based on the criteria in Kline (34). Furthermore, all variables appear smaller than 0.80—the criterion for multicollinearity between independent variables—indicating that there is no problem with multicollinearity (35).

3.2. Regression analysis results for playfulness on physical self-efficacy in "0th-period PE class"

Table 4 is the result of the influence of the playfulness of physical activity in the 0th-period of middle school students on their perceived physical ability and physical self-presentation confidence, which are sub-variables of physical self-efficacy.

The regression model of playfulness and perceived physical ability was statistically significant ($p < 0.001$), the explanatory power of the regression model was found to be about 17.2% ($R^2_{adj} = 0.172$), and the Durbin-Watson statistic was 1.850, showing a value close to 2, which was evaluated as no problem in the independence assumption of the residuals. The Variance Inflation Factor (VIF) was also found to be less than 10, indicating that there was no multicollinearity problem. Among the playfulness variables, physical animation ($\beta = 0.295$, $p < 0.01$) has confirmed a positive (+) influence relationship. This means that the higher the physical animation, the higher the perceived physical ability.

As a result of regression analysis between playfulness and physical self-presentation confidence, the regression model was statistically significant ($p < 0.01$), the explanatory power of the regression model was found to be about 7.8% ($R^2_{adj} = 0.078$), and the Durbin-Watson statistic was 2.060, showing a value close to 2, which was evaluated as no problem with the independence of the residuals. Among the playfulness variables, emotional fluidity ($\beta = 0.314$) has (+) predictive effect on physical self-presentation confidence at the 0.1% level. Conversely, mental spontaneity ($\beta = -0.190$) has (−) predictive effect on physical self-presentation confidence at the 0.5% level.

3.3. Regression analysis results for playfulness on education for happiness in "0th-period PE class"

The results of the playfulness of middle school "0th-period PE class" on self-esteem, thoughtfulness, teacher relationship, optimism, and peer relationship, which are sub-variables of education for happiness, are shown in Table 5.

As a result of regression analysis of playfulness and self-esteem, the regression model was statistically significant

TABLE 3 Correlation analysis among variables.

	1	2	3	4	5	6	7	8	9	10	11	12
1	1											
2	0.695**	1										
3	0.378**	0.519**	1									
4	0.387**	0.550**	0.459**	1								
5	0.565**	0.762**	0.575**	0.568**	1							
6	0.409**	0.368**	0.095	0.195*	0.312**	1						
7	0.143	0.187*	0.001	0.279**	0.129	0.460**	1					
8	0.428**	0.564**	0.526**	0.389**	0.502**	0.442**	0.362**	1				
9	0.276**	0.435**	0.496**	0.469**	0.337**	0.217**	0.318**	0.621**	1			
10	0.404**	0.473**	0.403**	0.434**	0.495**	0.393**	0.354**	0.699**	0.502**	1		
11	0.449**	0.560**	0.391**	0.483**	0.533**	0.430**	0.431**	0.760**	0.535**	0.763**	1	
12	0.578**	0.653**	0.454**	0.523**	0.636**	0.436**	0.352**	0.675**	0.514**	0.731**	0.774**	1

1. Physical animation, 2. Social engagement, 3. Mental spontaneity, 4. Emotional fluidity, 5. humorous perspective, 6. Perceived physical ability, 7. Physical self-presentation confidence, 8. Self-esteem, 9. Thoughtfulness, 10. Teacher relationship. 11. Optimism, 12. Peer relationship.
**$p < 0.001$.

($p < 0.001$), the explanatory power of the regression model was found to be about 37.4% ($R^2_{adj} = 0.374$), and the Durbin-Watson statistic was 1.981 which was approximately 2 and evaluated as no problem in the independence assumption of the residuals. The Variance Inflation Factor (VIF) was also found to be less than 10, indicating that there was no multicollinearity issue. Among the playfulness variables, social engagement ($\beta = 0.331$) and mental spontaneity ($\beta = 0.304$) has confirmed a positive (+) influence relationship on the self-esteem at the 0.01 and 0.1% levels, respectively.

The explanatory power between playfulness and the sub-variable of education for happiness, thoughtfulness, in the middle school "0th-period PE class" was found to be 33.1% ($R^2_{adj} = 0.331$). Among the playfulness variables, mental spontaneity ($\beta = 0.361$) and emotional fluidity ($\beta = 0.291$) had predictive (+) effect on the thoughtfulness scale at the 0.001% level and social engagement ($\beta = 0.306$) at the 0.01% level. Conversely, humorous perspective ($\beta = -0.241$) had predictive (−) effect on thoughtfulness at the 0.05% level.

In the findings of regression analysis between playfulness and teacher relationship, the regression model was statistically significant ($p < 0.001$), the explanatory power was found to be about 28.5% ($R^2_{adj} = 0.285$), and the Durbin-Watson statistic was 1.847, which was close to 2, so it was evaluated that there was no problem with the independence of the residuals. Emotional fluidity ($\beta = 0.177$, $p < 0.05$) confirmed a positive (+) influence relationship in the teacher relationship as a result of testing the significance of the regression coefficient.

The explanatory power between playfulness and optimism was 35.5% ($R^2_{adj} = 0.355$), and the DW statistic was 2.029. Among the playfulness variables, social engagement ($\beta = 0.237$) and emotional fluidity ($\beta = 0.206$) had a predictive (+) impact on optimism at the 0.05 and 0.01% level, respectively.

The explanatory power between playfulness and peer relationships was 50.3% ($R^2_{adj} = 0.503$), and the DW statistic was 1.874. Among the playfulness variables, humorous perspective ($\beta = 0.227$, $p < 0.05$), physical animation ($\beta = 0.220$, $p < 0.01$), social engagement ($\beta = 0.205$, $p < 0.05$), and emotional fluidity ($\beta = 0.171$, $p < 0.05$) has confirmed a positive (+) influence relationship on the peer relationship.

TABLE 4 Regression analysis results for playfulness on physical self-efficacy.

Section	Perceived physical ability		Physical self-presentation confidence		VIF
	β	*t*	β	*t*	
Physical animation	0.295	2.817**	.033	.297	1.944
Social engagement	0.153	1.138	0.141	0.978	3.320
Mental spontaneity	−0.169	−1.800	−0.190	−1.917*	1.573
Emotional fluidity	0.005	0.050	0.314	3.314**	1.597
Humorous perspective	0.121	0.964	−0.066	−0.499	2.811
DW R^2_{adj} F	1.850 $R^2 = 0.172$ F = 7.119***		2.060 $R^2 = 0.078$ F = 3.504**		

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 5 Regression analysis results for playfulness on education for happiness.

Section	Self-esteem		Thoughtfulness		Teacher relationship		Optimism		Peer relationships		VIF
	β	*t*	β	*t*	β	*t*	β	*t*	β	*t*	
Physical animation	0.056	0.620	−0.050	−0.527	0.126	1.294	0.102	1.103	0.220	2.713**	1.944
Social engagement	0.331	2.788**	0.306	2.488**	0.078	0.610	0.237	1.963*	0.205	1.931*	3.320
Mental spontaneity	0.304	3.716***	0.361	4.271***	0.122	1.396	0.049	0.587	0.055	0.757	1.573
Emotional fluidity	0.032	0.393	0.291	3.415***	0.177	2.008*	0.206	2.456**	0.171	2.330*	1.597
Humorous perspective	0.024	0.220	−0.241	−2.132*	0.194	1.658	0.150	1.349	0.227	2.328*	2.811
DW R^2_{adj} F	1.981 $R^2 = 0.374$ F = 18.596***		2.087 $R^2 = 0.331$ F = 15.555***		1.847 $R^2 = 0.285$ F = 12.730***		2.029 $R^2 = 0.355$ F = 17.164***		1.874 $R^2 = 0.503$ F = 30.742***		

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 6 Regression analysis results for physical self-efficacy on education for happiness.

Section	Self-esteem		Thoughtfulness		Teacher relationship		Optimism		Peer relationships		VIF
	β	*t*	β	*t*	β	*t*	β	*t*	β	*t*	
Perceived physical ability	0.350	4.251***	0.090	1.018	0.292	3.474***	0.294	3.634***	0.348	4.213***	1.269
Physical self-presentation confidence	0.201	2.442**	0.277	3.132**	0.219	2.610**	0.295	3.654***	0.192	2.319*	1.269
DW	2.172		2.186		1.930		2.072		1.868		
R^2_{adj}	$R^2 = 0.216$		$R^2 = 0.095$		$R^2 = 0.181$		$R^2 = 0.243$		$R^2 = 0.209$		
F	F = 21.304***		F = 8.741***		F = 17.271***		F = 24.598***		F = 20.371***		

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

3.4. Regression analysis results for physical self-efficacy on education for happiness in "0th-period PE class"

The results of the physical self-efficacy of middle school "0th-period PE class" on self-esteem, thoughtfulness, teacher relationship, optimism, and peer relationship, which are sub-variables of education for happiness, are illustrated in Table 6.

The regression model of physical self-efficacy and self-esteem was statistically significant ($p < 0.001$), the explanatory power of the regression model was found to be about 21.6% ($R^2_{adj} = 0.216$), and the DW statistic was 2.172, showing a value close to 2, which was evaluated as no problem in the independence assumption of the residuals. The Variance Inflation Factor (VIF) was also found to be less than 10, indicating that there was no multicollinearity problem. Among the physical self-efficacy variables, perceived physical ability ($\beta = 0.350$, $p < 0.001$) and physical self-presentation confidence ($\beta = 0.201$, $p < 0.01$) have predictive (+) effect on self-esteem. This means that the higher the perceived physical ability and physical self-presentation confidence, the higher the self-esteem.

As a result of regression analysis of physical self-efficacy and thoughtfulness, the regression model was statistically significant ($p < 0.001$), the explanatory power of the regression model was found to be about 33.1% ($R^2_{adj} = 0.331$), and the DW figure was 2.186 which was approximately 2 and evaluated as no problem in the independence assumption of the residuals. The Variance Inflation Factor (VIF) was no multicollinearity issue. Among the physical self-efficacy variables, physical self-presentation confidence ($\beta = 0.277$) had predictive (+) effect on the thoughtfulness scale at the 0.01% level.

The explanatory power between physical self-efficacy and the sub-variable of education for happiness, teacher relationship, in the middle school "0th-period PE class" was found to be 18.1% ($R^2_{adj} = 0.181$). Moreover, the DW figure was 1.930. Among the physical self-efficacy variables, perceived physical ability ($\beta = 0.292$) and physical self-presentation confidence ($\beta = 0.219$) has confirmed a positive (+) influence relationship on the teacher relationship at the 0.001 and 0.01% levels, respectively.

The explanatory power between physical self-efficacy and optimism was 24.3% ($R^2adj = 0.243$), and the DW was 2.072. Among the physical self-efficacy variables, physical self-expression confidence ($\beta = 0.295$, $p < 0.001$) and perceived physical ability ($\beta = 0.294$, $p < 0.001$) has confirmed a positive (+) influence relationship on the optimism.

In the findings of regression analysis between physical self-efficacy and peer relationship, the regression model was statistically significant ($p < 0.001$), the explanatory power was found to be about 20.9% ($R^2_{adj} = 0.209$), and the DW was 1.868. Perceived physical ability ($\beta = 0.348$) and physical self-presentation confidence ($\beta = 0.192$) has confirmed a positive (+) influence relationship on the peer relationship at the 0.001 and 0.05% levels, respectively.

4. Discussion

This study sought to determine the relationships of playfulness experienced in early morning exercises in middle school students on physical self-efficacy and education for happiness. There was some evidence from overseas case studies as well as from the Korean education community of the positive and varied effects of morning exercise before classes (2, 6, 7, 36, 37), and it was intended to create an academic basis for establishing regular classes in schools soon. On the basis of the results of this study, we propose the following:

First, in the "0th-period PE class," which has been operational in several middle schools in South Korea, the playfulness experienced by students had a predictive effect on physical self-efficacy. The implication of this finding is that playfulness in early morning exercise could be an effective means of increasing students' physical self-efficacy. Results from a study of high school students in Korea also showed that morning exercise had a positive effect on the development of physical self-concept (38). Many scholars have tried to find out what internal and external factors affect the playfulness of infants, children, and adolescents, and how they are related to playfulness and development (39, 40). Since playfulness comprises physical, social, and cognitive spontaneity, expression of pleasure, and sense of humor (41), it is highly likely to feel pleasure and freedom through the playfulness factor and further transfer to positive human personality characteristics (42). For this reason, it is judged that the program of "0th-period PE class" needs to be planned focusing on the playfulness of students. Particularly, judging from the results of this study, it is quite significant to organize a program to maximize the positive effect of play on physical self-efficacy. This is because the quality and style of

early morning exercise in which students participate is important (43). Furthermore, it is crucial to understand the psychological, emotional, and behavioral tendencies of students before organizing the program. This is because this process will not only have a productive effect on students' acquisition of physical self-efficacy but can also be a sure means of improving their quality of life and invigorating them throughout their lives (44).

Second, we investigated the associations between playfulness and education for happiness and found some evidence of impact. According to previous studies, youths with excellent playfulness have exceptional creativity and problem-solving skills, are highly likely to perform outstandingly in academics, and are highly likely to have a smooth school life and high school happiness. This is because it is easy for students to acquire an internal disposition toward their environment, which exists in the inner dimension of a person through playfulness, which largely influences their choices and behavior (8). In other words, playfulness, a personal strategy that explains behavior, allows students to feel happy in various situations they face in school life. Ratey and Hagerman (45) introduced in the media the amazing effect of physical activity in the 0th-period by presenting students at Naperville High School in Illinois as an example. Additionally, it was emphasized that early morning exercise should be approached as a lifestyle logic rather than an educational aspect. More specifically, it was announced that it relieves students of their stress or anxiety and has a positive impact on emotional control. As shown in the findings of this study, "0th-period PE class" can be the basis for a major educational strategy that can increase students' school happiness. Pekrun (46) proved that emotions affect adolescents' learning, and stated that the development of emotions related to achievement is formed by individual factors and social environments. Since the emotion of achievement is defined as an emotion related to the results of success and failure of sports activities (46), "0th-period PE class" can affect achievement emotions and academic performance, and can be a basis for connecting to school happiness. According to a study conducted in Korea, high school students mentioned that early morning exercise has become a vital source of school life (8). It is in line with the results of this study. More importantly, the successful participation experience of early morning exercise has a positive effect on attitudes toward physical education classes (47). This can be of great academic significance that can lead to the institutional establishment of the "0th-period PE class" along with the results of this study.

Third, physical self-efficacy was found to have a predictive effect on education for happiness. The physical self-efficacy acquired by students in PE classes in the 0th-period can be inferred as a cause of increasing school happiness in various aspects. The physical self-efficacy scale, developed by Ryckman (17), has been widely used in exercise science. Particularly, Sonstroem (48) stated that physical activities such as exercise and dance increase an individual's objective physical ability, resulting in a positive change in self-perception of physical ability, thereby increasing subjective physical ability—a secondary self-evaluation of physical performance. Ben-Eliyahu et al. (49) found in a study related to youth's deep interests (sparks) that the most powerful spark is related to sports activities, and that it is deeply related to the positive developmental outcomes of adolescents. These changes are important for a healthy life. In addition, an individual's perceived self-efficacy has a very great influence on their proper social life or school life. After all, strong self-efficacy induces a desire to achieve, reduces stress, and reduces vulnerability to negative emotions such as depression, thereby improving individual achievement and well-being (50). As shown in a study by Jeon et al. (7), students who participated in the "0th-period PE class" showed a positive perception of school life adaptation. Additionally, physical activity in the 0th-period has a positive effect on the physical strength and physical self-efficacy of middle school students and is in line with the results of the study that showed that it has a positive effect on learning attitudes (51). In this regard, the physical self-efficacy gained through early morning exercise may be an important factor in school satisfaction.

Notably, in Korea, although sports activities in the 0th-period are conducted through various programs, they are not legally mandated, and are mainly carried out according to the teachers' will. Conversely, overseas, sports activities in the 0th-period are carried out based on legal grounds, schools and community infrastructure are organically linked, and education rights have been guaranteed (52). Therefore, besides the results of this study, we would like to suggest that the "0th-period PE class" comprising various activities, should be legally mandated in Korea.

Nevertheless, the results of this study have a limitation in that it is only indirectly supported, not a direct procedure for institutionalization of "0th-period PE class." First, the current study focused on the relationships between variables analyzed through regression analysis, which limited the analysis of differences in demographic characteristics by gender and grade. If the study had focused on the relationships between variables based on gender or grade differences, the results may have been interpreted differently. Second, this study is limited to the personal psychological variables of playfulness, physical self-efficacy, and school happiness as perceived by middle school students. In other words, there are limitations in drawing connections between variables such as students' academic performance and attitudes toward physical education. Therefore, future research should focus on the impact of various school physical education activities on students' school life and social adjustment by examining the relationship between macro variables. Third, although there were no controls for gender, race, family characteristics, teacher characteristics, and school characteristics in the regression analysis, it is possible that these variables affect students' attitudes toward physical education and academic performance.

5. Conclusion

The purpose of this study is to investigate the effect of middle school students' playfulness in the "0th-period PE class" on their physical self-efficacy and education for happiness. Based on the analysis findings, the following conclusions were obtained: First, playfulness experienced through early morning exercise in middle school had a significant effect on physical self-efficacy. Second, playfulness had a significant effect on education for happiness. Third, physical self-efficacy had a significant effect on education for happiness.

Meanwhile, we would like to make the following suggestions for the parts that were not covered in this study and for active follow-up studies in the future. Physical activity in the 0th-period of middle school can increase satisfaction with school life by increasing physical perception in adolescence. In this respect, since early morning exercise is expected to have a positive effect on peer relationships, it is

necessary to examine in depth the link between peer relationships and physical activity included in the 0th-period of physical activity in the future. Thus, it is expected to be used as basic data to prevent social problems such as school violence and bullying in Korean society.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by Kangnam University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

BL and KJ: original draft preparation. WJ: data analysis. WJ and BL: critical review of the contents. KJ and WJ: data collection and critical review of the manuscript. KJ, WJ, and BL: supervision. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The impact of perceived school climate on exercise behavior engagement among obese adolescents: a dual mediation effect test of exercise benefits and perseverance qualities

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Introduction: This study explores the relationship between perceived school climate and exercise behavior among obese adolescents, as well as the multiple mediating effects of perseverance qualities and exercise benefits.

Methods: A survey was conducted on 586 obese adolescents in Beijing, with an age range of 13–18 years old and an average age of 15.40 ± 1.824, among who 337 were male, 249 were female, 303 were high school students and 238 were middle school students. A standard scale was used to evaluate perceived school climate, exercise benefits, perseverance qualities, and exercise behaviors. The data was analyzed by independent samples *t*-test, bivariate correlation analysis, descriptive statistical analysis, and structural equation model (SEM).

Results: (1) Perceived school climate among obese adolescents positively predicted exercise behavior ($Z = 2.870$, $p < 0.01$), perseverance qualities ($Z = 3.107$, $p < 0.01$) and exercise benefits ($Z = 4.290$, $p < 0.001$); perseverance qualities positively predicted exercise behavior in obese adolescents ($Z = 4.431$, $p < 0.001$); exercise benefits positively predicted the obese adolescents' exercise behavior ($Z = 4.267$, $p < 0.001$). (2) Perseverance qualities ($Z = 2.282$, 95% CI [0.032, 0.191], [0.028, 0.179]) and exercise benefits ($Z = 2.518$, 95% CI [0.060, 0.287], [0.053, 0.271]) play a mediating role in the obese adolescents' perceived school climate and exercise behavior, respectively. These two factors have parallel multiple mediating effects between obese adolescents' perceived school climate and exercise behavior, with mediating effects accounting for 16 and 25%, respectively. The mediating effect of exercise benefits is greater than that of perseverance qualities. (3) There is no difference in the specific indirect effects of perseverance qualities and exercise benefits ($Z = -0.800$, 95% CI [– 0.198, 0.064], [–0.190, 0.068]).

Conclusion: Obese adolescents' perception of school climate can effectively enhance their motivation to participate in exercise behavior and indirectly influence exercise behavior through exercise benefits and perseverance qualities, cultivate good physical exercise behavior among obese adolescents, and effectively prevent and intervene in the occurrence of obesity.

KEYWORDS

obese adolescents, physical activity, sports participation, dual mediation effect, individual perception

Introduction

The increasing prevalence of obesity among adolescents is a serious public health issue. Obesity is a chronic disease, mainly caused by an energy imbalance between excessive calorie intake from food, calories consumption or insufficient physical activity, resulting in the enlargement or increase of fat cells (Bray, 2004; Camacho and Ruppel, 2017; Ibrahim et al., 2021).

The Report on the Nutrition and Chronic Disease Status of Chinese Residents (2020) shows that the overweight and obesity rate of children and adolescents aged 6–17 has risen to 19%. *The China Children's Obesity Report* points out that the overweight and obesity rate of children and adolescents in China is also constantly rising, and if without intervention, the number of overweight and obese children aged 7 and above will rise to nearly 50 million by 2030 (Zhang and Ma, 2017). The focus of *Implementation Plan of Obesity Prevention and Control in Children and Adolescents* is to promote the balance between food intake and physical activity among children and adolescents, strengthen school responsibilities, maintain a healthy weight for children and adolescents, ensure physical activity time at school, strengthen physical education classes and extracurricular exercise (China, M. o. E. o. t. P. s. R. o, 2020), and thus to control obesity weight through physical exercise (Xu et al., 2021). The high prevalence of overweight and obesity is mainly due to a decrease in physical activity levels (Tremblay et al., 2011; Tabacchi et al., 2016; Marsigliante et al., 2022), and regular physical exercise can effectively intervene in obesity and is an important factor in preventing overweight (Strong et al., 2005; Richardson et al., 2013; Wyszyńska et al., 2020; Marsigliante et al., 2022).

The World Health Organization defines physical activity as any physical movement performed by skeletal muscles that requires energy consumption. Physical activity refers to all activities, including leisure time activities, traveling between different locations, or as part of a person's job. Both moderate and high intensity physical activity can improve health (World Health Organization, 2021). And activity behavior refers to the conscious and active participation in physical exercise by individuals under the influence of a variety of internal and external stimuli, excluding passive or forced participation (Pan et al., 2021). The Theory of Planned Behavior points out that the factors that affect behavior are indirectly influenced by behavioral intention (weight control), and physical exercise can effectively reduce BMI, body fat percentage, and other factors in obese individuals (Marteau et al., 2012).

Due to spending most of their adolescence in school, the school sports environment is a setting that provides opportunities for teenagers to participate in behaviors that have a positive impact on them. Research has shown that schools provide an appropriate environment for implementing positive and healthy lifestyle interventions (Ip et al., 2017), and learning correct and healthy lifestyles is an effective way to intervene in obese students (Lirola et al., 2021). Therefore, in order to continue improving the predictive explanatory abilities of obese adolescents' behavior, this study investigated the transition process from perceived school climate to exercise behavior among obese adolescents, and it also investigated whether exercise benefits and perseverance qualities mediate the relationship between perceived school climate and exercise behavior among obese adolescents, in order to determine other key influencing factors of perceived school climate and exercise behavior.

Perceived school climate and exercise behavior

Perceived school climate refers to the humanistic environmental characteristics that are perceived or experienced by school members as having the significant psychological and behavioral impact that are enduring and stable. Human behavior is not only driven by thoughtful considerations (e.g., knowledge, attitudes, and beliefs), but also influenced by environmental stimuli (Ge and Yu, 2006). For teenagers, school is an important place for them to learn and exercise, and the school environment climate is a unique cultural attribute formed by it, which is an internal psychological characteristic shared by school members (Lv, 2021). Previous studies have shown that the school sports environment not only has a direct effect on physical exercise behavior, but also has a specific indirect effect on physical exercise behavior through mediating variables (Ma et al., 2022), and the school sports venue environment can enhance the adolescents' physical activity level, thus effectively reduce the risk of obesity (Duckworth et al., 2007). Accordingly, the research hypothesis is proposed. H1: There is a significant positive correlation between perceived school climate and physical exercise behavior among obese adolescents.

The mediating role of perseverance qualities

Perseverance qualities refer to an individual's tendency to strive to achieve long-term goals and maintain passion and effort, especially in situations of challenges and setbacks, which can help individuals better adapt to the environment (Hu et al., 2022). Current research on perseverance qualities mainly focuses on the cultivation level (Song, 2019a,b) and the relationship between academic perseverance and academic performance (Wang, 2021). Persistence is a form of perseverance qualities, and the perseverance character of exercise behavior can be effectively control body weight (Zhang and Chen, 2010), achieving the effect of reducing fat. The level of teacher support in the school environment climate is significantly positively correlated with perseverance qualities (Li, 2020), and teacher support can effectively enhance students' perseverance qualities. Accordingly, the research hypotheses were proposed: H2: perceived school climate is an important factor influencing the perseverance qualities of obese adolescents, and perceived school climate positively influences

adolescents' perseverance qualities. Hypothesis H3: perseverance quality is an important factor influencing adolescents' adherence to exercise, and it positively predicts exercise behavior. Based on the hypotheses of H2 and H3, this study aims to verify the mediating effect of perseverance qualities on perceived school climate and exercise behavior.

The mediating effect of exercise benefits

Exercise benefits perception refers to the obese adolescents' perception of various benefits of physical activity, and physical exercise benefits refer to an individual's intuitive evaluation and perception of the results of accompanying physical exercise behavior (Guo and Xu, 2011). A reasonable cognitive concept and correct understanding of the benefits of physical exercise will lead to reasonable physical exercise behavior (Wang, 2021). Students' perception of the teaching and learning environment will fluctuate with environmental perception factors, thereby affecting their cognitive engagement (exercise benefits) (Lu et al., 2021). Thus, it can been seen that perception of the school learning environment is an important factor for individuals to perceive the exercise benefits, and exercise benefits are important predictive factors for promoting individuals' physical exercise behaviors. Accordingly, a hypothesis model H4 is proposed: obese adolescents perceive school climate as a positive predictor of individual cognition of exercise benefits; hypothesis H5: the exercise benefits positively predict physical exercise behavior. Based on hypotheses H4 and H5, it is verified that the mediating effect of exercise benefits on obese adolescents' perceived school climate and physical exercise behavior.

In summary, there is currently limited empirical research in the field of physical education on the impact of perceived school climate on students' psychological aspects of exercise behavior among obese adolescents. From the perspective of the psychology of exercise behavior, this study constructs a path model for the influence of exercise behavior intention among obese adolescents with dual mediating effects of exercise benefits and perseverance qualities, and analyses the mechanism of action to enrich the theory of exercise behavior among obese adolescents, and ultimately, it encourages them to consciously form the practical significance of adherence to physical exercise. Based on the above theoretical assumptions, a theoretical model of the relationship between perceived school climate and physical exercise behavior was constructed (see Figure 1).

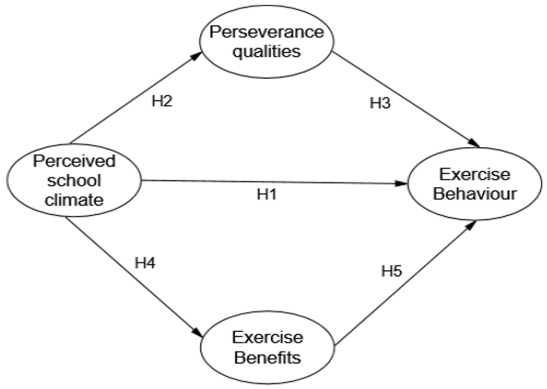

FIGURE 1
A hypothetical model for perceived school climate and physical exercise behavior.

Research objects and methods

Survey objects

The Body Mass Index (BMI) method was adopted as the standard for selecting obese adolescents, and the calculation formula is: BMI = weight[kg] ÷ (height[m])^2, and BMI ≥ 28 can be determined as obesity. Sixty eight teaching classes from 10 ordinary high schools in Beijing were selected, and 600 obese adolescents were screened through the results of the physical fitness test and physical education teacher sampling to conduct a questionnaire survey on the relationship between perceived school climate and exercise behavior. After removing invalid questionnaires, 586 valid questionnaires were obtained, with a valid questionnaire rate of 98%. The age range of the subjects was 13–18 years old, with an average age of 15.40 ± 1.824, including 93 senior 1 students, 119 senior 2 students, 91 senior 3 students, 142 junior 1 students, 85 junior 2 students, and 56 junior 3 students; 337 male students (57.5%) and 249 female students (42.5%), 303 were senior high school students, and 238 were junior high school students.

This study was approved by the Ethics Committee of Xiangya School of Public Health, Central South University (Project No. XYGW-2022-44; 20 July 2022). and conducted in accordance with the guidelines of *Declaration of Helsinki*. Students were informed prior to the survey that the questionnaires were answered anonymously, emphasizing voluntary completion. The content is strictly confidential and the results are only used for scientific research. All questionnaires were collected on the spot. All subjects were informed of the purpose and characteristics of the study and signed an informed consent form.

Survey tools

Physical Activity Rating Scale

The Physical Activity Rating Scale (PARS-3) revised by Liang (1994) was used, which examines the amount of exercise from three items: intensity, time and frequency of participation in physical activity. The 5-point Likert scale was used, with the total score representing the level of physical activity, and the higher the score, the higher the level of physical activity. The study has proved that the Cronbach's a coefficient of the scale in physical activity test for college students was 0.820. The Cronbach's alpha coefficient of the questionnaire in this study was 0.710.

Perceived School Climate Scale

The Perceived School Climate Scale developed by Jia et al. (2009) was used, which consists of 25 items, including three dimensions: teacher support (7 items), peer support (13 items), and autonomy opportunities (5 items), and is scored on a 4-point scale of "1 (never) to 4 (always)." The higher the score, the better the perceived school climate, and the higher the exercise level of the participants' perceived school climate. The study has confirmed that the scale has high reliability among Chinese and American adolescents. Cronbach's

alpha coefficients ranges from 0.69 to 0.86. The Cronbach's alpha coefficient for the total scale in this study is 0.960, with dimensions ranging from 0.89 to 0.98.

Chinese version of perseverance qualities scale (12-Item Grit Scale, 12-IGS)

Xie et al. (2017) translated and revised the Grit Scale, which consists of 12 items, including 2 variables of unremitting effort and enduring enthusiasm. Each variable contains 6 items, and is scored on a 5-point scale. The higher the score, the higher the level of perseverance qualities. This study has proved that the Chinese version of the scale has been preliminarily revised in the adult population in China, with a Cronbach's a coefficient of 0.729. The Cronbach's alpha coefficient of the scale is 0.941 in this study.

Exercise benefits scale

Adopting the top 5 items in the study by Wang et al. (2022) that ranked the highest proportion of agreement and strong agreement on the benefits of exercise, the item "Exercise can prevent heart attacks" was revised to "Exercise can prevent obesity." Each item used the Likert 5-level scoring method, and the higher score, the better the benefits from exercise. The study has proved that the Cronbach's alpha coefficient of this scale is 0.820 in the exercise behavior of elderly patients with chronic obstructive pulmonary disease (COPD), and the Cronbach's alpha coefficient of this scale is 0.702 in this study.

Mathematics statistics

Firstly, SPSS 26.0 (SPSS Inc., Chicago, IL, United States) was used to input and organize the collected data. Independent samples *t*-test was used to analyze the differences in direct quantitative data between two different clusters. The obtained data was tested using the Harman's single-factor method. Then, bivariate correlation analysis was used to analyze the correlation between various dimensions and measure the degree of correlation between the two variable factors. The statistical description is expressed in terms of mean and standard deviation ($M \pm SD$).

Structural Equation Model (SEM) was then used to estimate the correlations between physical exercise, potential influencing factors and pathways. The AMOS 24.0 (SPSS Inc., Chicago, IL, United States) maximum likelihood estimation method was used for SEM, and the applicability of the model was determined through a variety of indices, including the ratio of the minimum difference to degree of freedom (CMIN/DF), the Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Comparative Fit Index (CFI) and Standardized Root Mean Square Residual (SRMR) (Jackson et al., 2009; Whittaker, 2011). Direct effect analysis focuses on non-standardized path coefficients, with significance levels set at $p < 0.05$ and $Z > 1.96$.

Finally, a two factor mediating effect analysis was conducted to determine whether the relationship between perceived school climate and exercise behavior was indirectly influenced by perseverance qualities and exercise benefits. 5,000 Bootstrap multiple mediating effects tests were conducted using the syntax in AMOS 24.0, including direct effects, indirect effects, and specific indirect effects to compare differences. The test results are mainly determined through the bias-corrected 95% and Percentile 95% estimation methods to determine whether the confidence interval obtains contain 0.

Results and analysis

Basic statistical data

The study used independent sample *t*-tests to determine whether there were differences between different genders in 4 dimensions of perceived school climate, perseverance qualities, exercise benefits and exercise behavior. The results showed that there were no significant differences between different genders and these 4 dimensions at the 0.05 level, as detailed in Table 1.

Independent sample *t*-tests were used to determine whether there are differences between different grades in 4 dimensions of perceived school climate, perseverance qualities, exercise benefits, and exercise behavior. The results show that there is no significant difference between different grades and these 4 dimensions at the 0.05 level, as shown in Table 2.

Common method control and test

Common method biases refer to the artificial covariation between predictor and criterion variables due to the same data source or rater, measurement environment, project context, and project characteristics. In order to prevent the possibility of common method bias in the collected data, corresponding control measures have been taken during the testing process. The Harman single factor method was used to test for covariance. The test criteria were: there were more than one factor with a characteristic root greater than 1 and the explanatory degree of the maximum factor's variance was less than 40%. The results of this study show that there are a total of 7 factors with eigenvalues greater than 1 and the variance explained by the first factor was 24.17%, which is less than the critical criterion of 40%. The extraction amount of common variance is higher than 70% (74.02), which indicates that there is no common method bias (Zhou, 2004).

Correlation analysis of various dimensions

In this study, the AVE method was used to test the discriminant validity of each dimension. The AVE method was proposed by Fornell and Larcher, which means that the average variance extraction amount of each dimension must be greater than the square value of the correlation coefficients between each dimension. However, since the AVE is a square value, it must first be converted to the same square unit if it is to be compared with Pearson correlation between dimensions. Therefore, the AVE value was opened and rooted before comparison could be made. Therefore, the AVE value was marked with a root before it could be compared. If it is higher than the Pearson correlation value between dimensions, it can be declared that the dimension has differential validity. In this study, except for the exercise behavior dimension of 0.458, all other dimensions were greater than 0.5, which is in line with the criteria proposed by Hair et al. (2009).

The correlational analysis of obese adolescents' perceived school climate (three subscales of teacher support, peer support, and autonomy opportunity), perseverance qualities (two subscales of unremitting effort and persistent enthusiasm), exercise benefits, and exercise behavior (Table 3) shows that teacher support is significantly and positively correlated with peer support, autonomy opportunity,

TABLE 1 Independent samples *t*-test of different genders and dimensions.

Dimension	Mean equivalence *t*-test				Gender	Number of cases	*M*	*SD*
	T	DF	*P*	Mean difference				
Perceive school climate	−1.330	584	0.184	−0.055	Male	337	3.574	0.523
					Female	249	3.630	0.460
Perseverance qualities	−0.804	584	0.421	−0.063	Male	337	3.951	0.917
					Female	249	4.014	0.964
Exercise behavior	0.326	584	0.745	0.025	Male	337	3.820	0.921
					Female	249	3.795	0.895
Exercise benefits	−0.222	584	0.824	−0.009	Male	337	3.326	0.496
					Female	249	3.335	0.484

TABLE 2 Independent sample *t*-test of different grades and dimensions.

Item	Mean equivalence *t*-test				Grade	Number of cases	*M*	*SD*
	T	DF	*P*	Mean difference				
Perceive school climate	−1.419	584	0.156	−0.058	Senior high school	303	3.570	0.537
					Junior high school	283	3.628	0.451
Perseverance qualities	−0.421	584	0.674	−0.033	Senior high school	303	3.962	0.954
					Junior high school	283	3.995	0.920
Exercise behavior	−1.540	584	0.124	−0.116	Senior high school	303	3.754	0.883
					Junior high school	283	3.869	0.935
Exercise benefits	−0.319	584	0.750	−0.013	Senior high school	303	3.323	0.499
					Junior high school	283	3.336	0.483

unremitting effort, persistent enthusiasm, exercise behavior, and exercise benefits ($r = 0.098–0.438$, $p < 0.01$ or $p < 0.05$). Peer support is significantly and positively correlated with autonomy opportunity, exercise behavior and exercise benefits ($r = 0.168–0.540$, $p < 0.01$). Autonomous opportunity is significantly positively correlated with unremitting effort, persistent enthusiasm, exercise behavior and exercise benefits ($r = 0.141–0.185$, $p < 0.01$). Unremitting effort is significantly positively correlated with persistent enthusiasm ($r = 0.645$, $p < 0.01$) and exercise behavior ($r = 0.210$, $p < 0.01$). Persistent enthusiasm is significantly positively correlated with exercise behavior ($r = 0.211$, $p < 0.01$) and exercise benefits ($r = 0.095$, $p < 0.05$). Exercise behavior is significantly positively correlated with exercise benefits ($r = 0.249$, $p < 0.01$).

Model goodness of fit test

The model fitting test result of the relationship model between perceived school climate and exercise behavior among obese adolescents constructed in this study are good. CMIN/DF = 1.78 < 3; GFI = 0.887 > 0.8 acceptable, AGFI = 0.875 > 0.8 acceptable, IFI = 0.970, CFI = 0.970, TLI = 0.968, RMSEA = 0.036 < 0.08, SRMR = 0.036 < 0.05, and above empirical path analysis goodness-of-fit indicators all meet the empirical rule of thumb criteria suggested by general scholars (Fornell and Larcker, 1981). It can be used for later statistical data analysis to indicate the effectiveness of the equation model of the relationship between perceived school climate and exercise behavior among obese adolescents. The model is shown in Figure 2.

Model hypothesis testing

Direct effect path test

The direct path results of the relationship between perceived school climate and exercise behavior among obese adolescents (see Table 4) show that there are five direct impact paths between the four latent variables of perceived school climate, perseverance qualities, exercise benefits and exercise behavior. The non-standardized

TABLE 3 Statistics for correlation analysis of various variables.

Variables	Teacher support	Peer support	Autonomy opportunity	Unremitting efforts	Persistent enthusiasm	Exercise behavior	Exercise benefits	*M*	*SD*
Teacher support	**0.844**							3.602	0.680
Peer support	0.358**	**0.817**						3.638	0.596
Autonomy opportunity	0.438**	0.540**	**0.708**					3.552	0.607
Unremitting efforts	0.098*	−0.015	0.141**	**0.725**				4.009	1.000
Persistent enthusiasm	0.103*	−0.003	0.152**	0.645**	**0.754**			3.947	1.066
Exercise behavior	0.170**	0.175**	0.185**	0.210**	0.211**	**0.458**		3.809	0.910
Exercise benefits	0.134**	0.168**	0.158**	0.071	0.095*	0.249**	**0.634**	3.330	0.491

**At the 0.01 level (two-tailed). *Correlations significant at 0.05 level (two-tailed), diagonal bold text is open root value of AVE, lower triangle is Pearson correlation of dimensions.

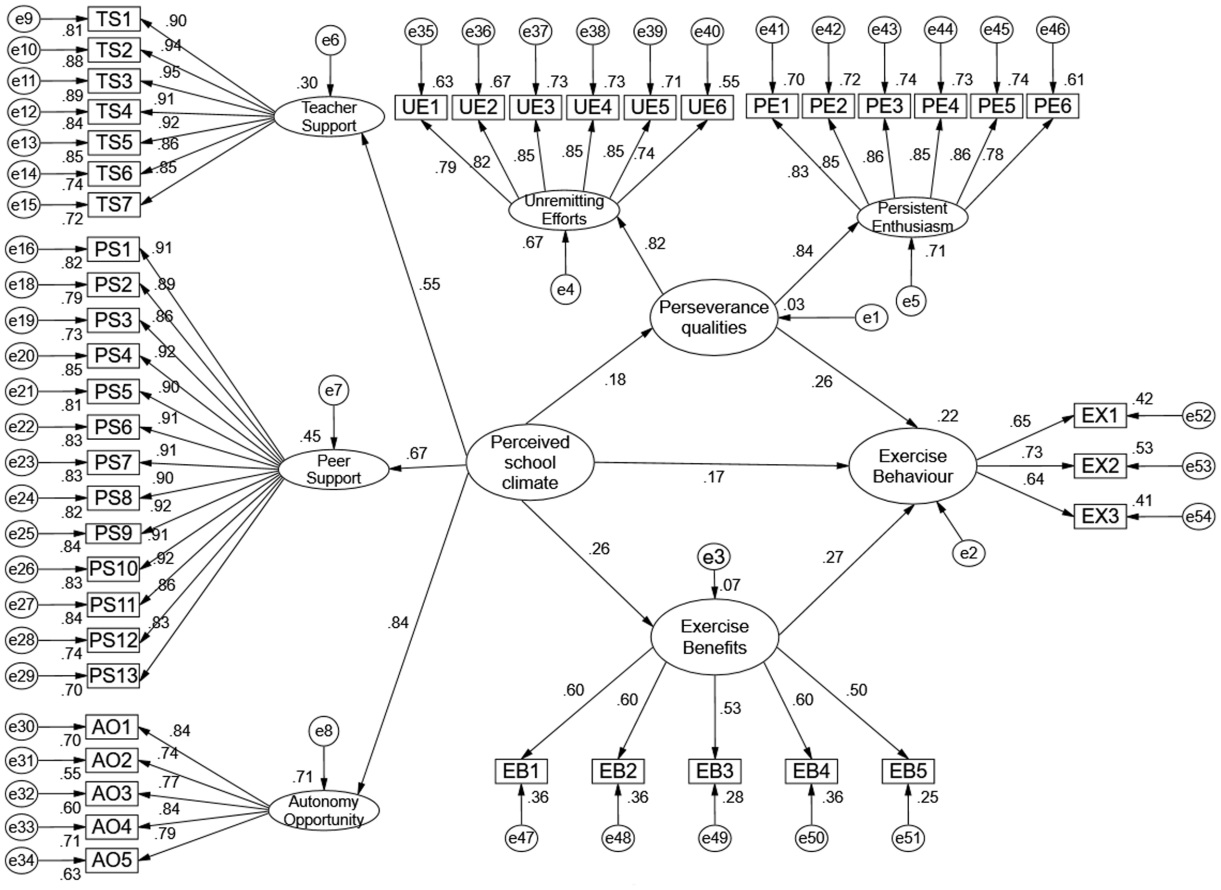

FIGURE 2
Model fitting of the relationship between perceived school climate and exercise behavior among obese adolescents.

coefficient results mainly evaluate whether the results are significant or not. This study shows that each impact path is of significant and valid, with $p < 0.05$ and $Z > 1.96$.

The standardized path coefficient mainly evaluate the significance of each path coefficient. The results showed that among the path coefficients of exercise behavior as the dependent variable, the absolute value path coefficient of exercise benefits was the highest, with a standardized absolute value path coefficient of 0.274, accounting for 23.9% of the total effect. The path coefficient of perseverance qualities was 0.261, accounting for 22.8% of the total

TABLE 4 Path analysis results.

Direct path impact	Non-standardized path coefficient	Standard error	Z	C.R.	*P*	Standardized path coefficient
Perceived school climate -> Perseverance qualities	0.348	0.112	3.107	3.108	0.002	0.176
Perceived school climate -> Exercise benefits	0.276	0.064	4.313	4.290	0.000	0.265
Perceived school climate -> Exercise behavior	0.330	0.115	2.870	2.876	0.004	0.169
Exercise benefits -> Exercise behavior	0.512	0.120	4.267	4.275	0.000	0.274
Perseverance qualities -> Exercise behavior	0.257	0.058	4.431	4.434	0.000	0.261

effect. The minimum path coefficient of perceived school climate was the smallest, 0.169, accounting for 14.8% of the total effect. In the direct influence path coefficient of perceived school climate as an independent variable, the maximum path of exercise benefits in the standardized coefficient is the highest, 0.265, accounting for 23.1% of the total effect. The path coefficient of perseverance qualities is 0.176, accounting for 15.4% of the total effect. The above data shows that the proportion of coefficient effects and total effects of each path is different, with H5 > H4 > H3 > H2 > H1.

Two factor mediation effect test

The causal path test and the Sobel *Z*-test are also statistical methods for testing the existence of mediating effects. In the causal path test (Baron and Kenny, 1986) a and b statistics are significantly representative of the existence of mediation effect. Sobel *Z*-test is a coefficient product test, and Sobel t has a major flaw that requires the indirect effect of the sample to be normal, but a*b is basically asymmetric (not normal), with skewness and kurtosis not zero (Hayes, 2009).

This study used Bootstrap 5,000 to test the mediating effect and whether there were differences in specific indirect effects. 5,000 Bootstrap samples were extracted and put back in the original data to form an approximate sampling distribution, and indirect effects, direct effects and specific indirect effects were tested for differences. The test results are as follows (see Table 5): Perceived school climate has a direct effect on exercise behavior ($Z = 2.481$, 95% CI [0.107, 0.639], [0.101, 0.632]), with a *Z*-value greater than 1.96 and a 95% CI confidence interval that does not include 0, suggesting that perceived school climate is a significant factor in predicting exercise behavior. The mediating effect of perseverance qualities on perceived school climate and exercise behavior ($Z = 2.282$, 95% CI [0.032, 0.191], [0.028, 0.179]), and the indirect effect of exercise benefits on perceived school climate and exercise behavior also exists ($Z = 2.518$, 95% CI [0.060, 0.287], [0.053, 0.271]). Among them, the perceived school climate has the greatest direct effect on exercise behavior, with an effect value of 0.330, accounting for 59%. In the indirect effect, the perceived school climate -> exercise benefits -> exercise behavior path effect value is 0.141, accounting for 25%. The perceived school climate -> perseverance qualities -> exercise behavior path effect value is 0.089, accounting for 16%. There was no significant difference in the mediating effect of exercise benefits compared to perseverance qualities ($Z = -0.800$, 95% CI [−0.198, 0.064], [−0.190, 0.068]). The *Z*-value was less than 1.96 and the 95% CI confidence interval include 0. However, the mediating factor of exercise benefits was still more important than the mediating factor of perseverance qualities (0.141 > 0.089).

Discussion

The relationship between perceived school climate, exercise benefits, perseverance qualities and exercise behavior among obese adolescents

The results of this study found that obese adolescents have a significant positive correlation between their perception of school climate and exercise behavior. This may be due to the fact that school is an important place for adolescents to learn and live. Obese individuals' perceptions of school climate, including teacher-student relationships, peer relationships, and independent opportunity choices, directly affects their emotional experience in school life, and further influences their cognition and engagement in exercise behavior. School based social environment factors (e.g., teacher behavior) are associated with physical exercise among adolescents. In one study, students, teachers, principals and parents recognized that the overall school climate indeed promotes children's participation in physical activity (Macquarrie et al., 2015). The climate created by teachers in the classroom is associated with more activities both inside and outside of physical education, and students believe that they receive rewards for learning and improving the latter by outperforming others. The teacher's "independent support" in physical education classes also shows a consistent association with physical exercise (Morton et al., 2016). The importance of teachers providing encouragement (Zhang and Ma, 2017) and supporting sports activities (Kubik et al., 2005; Robbins et al., 2010) show a positive correlation. Role models (Zhang and Ma, 2017) are also emphasized as important behaviors for teachers to encourage students. In a quantitative study of 93 papers with varying quality, intervention in environmental factors can increase the participation in physical exercise among adolescents (Morton et al., 2016), and the research has demonstrated that the school environment positively influences outdoor physical exercise (Liu et al., 2021) ($\beta = 0.97$, $p < 0.001$), this study perceived that the school climate environment positively predicted exercise behavior ($Z = 2.481$, 95% CI [0.107, 0.639], [0.101, 0.632]). The lack of school climate is not effective in intervening in physical exercise among adolescents (Doak et al., 2006). Perceived exercise benefits among obese

TABLE 5 Results of the two factor mediation test for perseverance qualities and exercise benefits.

Variable path	Point estimation value	Coefficient product		Bootstrapping			
				bias-corrected 95% CI		Percentile 95% CI	
		SE	*Z*	Lower	Upper	Lower	Upper
Indirect effect							
Perceived school climate - > Perseverance qualities- > Exercise behavior	0.089	0.039	2.282	0.032	0.191	0.028	0.179
Perceived school climate - > Exercise benefits - > Exercise behavior	0.141	0.056	2.518	0.060	0.287	0.053	0.271
Direct effect							
Perceived school climate - > Exercise behavior	0.330	0.133	2.481	0.107	0.639	0.101	0.632
Total effect	0.560	0.150	3.733	0.312	0.898	0.311	0.896
Comparison of mediation effect differences							
Perseverance qualities vs. Exercise benefits	−0.052	0.065	−0.800	−0.198	0.064	−0.190	0.068

Bootstrap 5,000 self-sampling was used.

adolescents significantly predict exercise behavior (Xue-liu and Mu, 2021), and physical exercise can promote physical health through different exercise methods. Conversely, perceived exercise benefits among obese adolescents can also influence their exercise behavior (Callaghan et al., 2002). There is a significant positive correlation between individual perseverance qualities and exercise behavior. Obese adolescents' enthusiasm and persistence in perceiving the school sports environment climate during school may enhance their sense of individual cognition. Perseverance qualities emphasize the maintenance of sustained enthusiasm and hard work when pursuing long-term goals (weight loss) (Von Culin et al., 2014), perseverance quality, exercise commitment, and athletic performance were significantly and positively associated with exercise performance (Zhai et al., 2019) ($\beta = 0.284$, $p < 0.01$). Obese adolescents perceive that school climate has a positive contributor to exercise behavior, and intervention in the environment can effectively increase their participation in physical exercise. The research has pointed out that school based physical exercise interventions mainly focus on students' motivation, basic psychological needs, goal orientation, enjoyment and stimulating teaching atmosphere in physical education (Demetriou et al., 2019). Exercise benefits and perseverance qualities are individual psychological activity behaviors in this study. It was found that these two factors are also important psychological indicators for intervening in adolescents' participation in school based physical exercise, and good psychological perceptions can promote better engagement in exercise behavior among obese individuals.

The mediating effect of perseverance qualities between perceived school climate and exercise behavior among obese adolescents

The results of this study show that the perseverance qualities of obese adolescents plays a mediating role in their perceived school climate and exercise behavior. On the one hand, it indicates that obese adolescents' perceived school climate directly influences exercise behavior. The better the perceived school climate among obese adolescents, the more beneficial it is for their participation in exercise behavior, which is basically consistent with the existing research results (Guo, 2019). The explanatory power of school factors on the total amount of physical exercise among college students is 20.2%, and the explanatory power of this study reaches 59%. On the other hand, obese adolescents' perceived school climate influences exercise behavior engagement through the mediating effect of perseverance qualities (unremitting effort and persistent enthusiasm). Perceived school climate positively affects individual perseverance qualities, and perceived teacher behavior in school climate positively predicts students' perseverance qualities (Reed, 2014). Teacher support significantly and positively predicts perseverance qualities (=0.174, 0.182, $t = 5.092$). Teachers are able to help students establish correct beliefs and behaviors by constructing supportive relationships (Li, 2020), so it is hypothesized that perceived school climate can positively predict perseverance qualities among obese adolescents. Perseverance quality is a significant predictor of individual exercise behavior (Reed, 2014). Psychological studies have shown that perseverance qualities are positively correlated with academic performance (Liu and Gao, 2020). Both interest conformity and persistent effort significantly and positively predict academic performance in T1, β interest conformity = 0.26, $p < 0.001$ and β persistent effort = 0.08, $p < 0.001$. Perseverance qualities significantly predicted exercise behavior in this study, with $Z = 4.431$, $p < 0.001$. Persistent effort can also increase the occurrence of exercise behavior among obese adolescents. Therefore, existing relevant studies provide supporting evidence for the results of this study. This study verified the mediating effect of perseverance qualities on the relationship between perceived school climate and exercise behavior among obese adolescents, and clarified the relationship between latent variables such as perceived school climate, perseverance qualities and exercise behavior.

The mediating effect of exercise benefits between perceived school climate and exercise behavior among obese adolescents

The results of this study suggest that the perceived exercise benefits among obese adolescents play a mediating role between perceived school climate and exercise behavior. The results also indicate that obese adolescents' perception of school climate can not only directly predict exercise behavior, but also indirectly influence exercise behavior through the "bridge" of exercise benefits. The cultural environment of schools can influence students' cognition and identification (Yang, 2022), and cognition can affect behavior, and perceived school climate can promote both behavior and cognition (Jiang, 2019), perceived school climate has a significant correlation with adolescent externalization behavior ($\beta = -0.112$, SE = 0.037, 95% CI [−0.185, −0.039]) (Pan et al., 2023), consistent with the results of this study ($\beta = -0.330$, SE = 0.133,95% CI [0.107, 0.639], [0.101, 0.632]), and some studies have shown a certain relationship between family environment and perceived exercise benefits (Guo et al., 2017). This study also verified that perceived school climate significantly predicts exercise benefits. Perceived exercise benefits positively influence exercise behavior (Xue-liu and Mu, 2021), with an effect size of 0.234. The perceived exercise benefits among obese individuals can enhance their cognitive level, thereby enhancing the occurrence of exercise behavior. This study validated the mediating effect of exercise benefits on the relationship between perceived school climate and exercise behavior among obese adolescents, and clarified the relationship between latent variables such as perceived school climate, exercise benefits and exercise behavior.

This is a cross-sectional study that is consistent with the research methods of Ip et al. (2017). They used robust Poisson regression to verify that school students with at least 11 sports friendly environmental factors (7.0%) have a much lower risk of obesity than students without environmental factors. A physical activity friendly school environment is associated with a lower risk of obesity. We collected exercise behavior data on school physical activity environment, teacher support and peer support. The analysis verified that perceived school climate can directly affect exercise behavior (Rodrigues et al., 2018; Dong, 2021), and that three factors in the school environment, namely "peer support," "teacher support" and "autonomy opportunity," influence students' participation in physical exercise (Guo, 2019). The two factors of perseverance qualities and exercise benefits play a mediating role between perceived school climate and exercise behavior, suggesting that perceived school climate can also indirectly influence exercise behavior through perseverance qualities and exercise benefits.

Insufficient physical activity is not only common in high-income countries, but also in low-income and middle-income countries (LMICs). According to reports, the physical activity levels of Asian school-age children and adolescents are also low (Dan et al., 2011; Shokrvash et al., 2013). Diversified intervention measures (combining education with physical activity courses, educational materials, school environments and family education) may be promising strategies for increasing physical activity among Asian children and adolescents (Barbosa Filho et al., 2016; Ahmed et al., 2021). Comprehensive multi-component interventions in sports, such as participating in health education courses, participating in physical exercise after class or after school, and involving family members together, are more effective than a single strategy interventions (Salmon et al., 2007; van Sluijs et al., 2008; Meyer et al., 2011; Barbosa Filho et al., 2016). Previous studies have shown that focusing on changes in multiple health behaviors is more effective than a single strategy (De Meester et al., 2009; Crutzen, 2010).

School policies can also reduce unhealthy dietary behaviors and obesity risk among children in mega cities in China (Ding et al., 2023). Schools with prolonged physical activity may reduce the likelihood of obesity among students, and adequate physical activity may help prevent childhood obesity (Sprengeler et al., 2017). School management policies mainly include: written guidelines for the school, annual work plans for the school's sports and health departments, monitoring of students' physical health status, student obesity prevention meetings, and involvement of class administrators. School health education: health education (such as professional teachers and curriculum arrangements), obesity related lectures, student courses and activities, advice for overweight/obese students, and school obesity prevention reports for parents (Cheng et al., 2020). School environmental factors are the result of multiple levels of interaction, and strategies should not only focus on children and adolescents at the interpersonal level, but also on friends, teachers, parents, and school administrators, and school based interventions may increase the participation rate of adolescents in physical activity (Hu et al., 2021).

Innovation and limitations

This study focuses on the impact of perceived school climate on exercise behavior, advancing relevant research in the fields of perceived school climate and exercise behavior. By constructing a dual mediation model and starting from the perspective of exercise psychology, it explores the relationship between obese adolescents' perceived school climate and exercise behavior, which has practical significance in promoting their participation in physical exercise. Firstly, the impact of school climate on exercise behavior among obese adolescents was confirmed, and the relationship between perceived school climate and exercise behavior among obese adolescents was interpreted from the perspectives of perseverance qualities and exercise benefits. Secondly, the differences in mediating effects and specific indirect effects were examined.

There are also limitations in this study. Firstly, self-reporting may raise the correlation between variables and lead to common method biases. Therefore, the study tests for common method bias to avoid this limitation as much as possible, but there are still some uncontrollable factors that affect the research results, such as: self-expectation and participants' response emotions. In the future, longitudinal tracking or experimental intervention designs can be applied to more effectively explain the impact of perceived school climate on exercise behavior among obese adolescents. Secondly, this study only examined the mediating effect of perseverance qualities and exercise benefits. Future studies will continue to examine variables closely related to exercise behavior, such as self-efficacy, sensory seeking and psychological resilience, in order to comprehensively reveal the relationship model between perceived school climate and physical activity behavior among obese adolescents.

Conclusion

Obese adolescents' perceived school climate positively predicts exercise behavior, perseverance qualities and exercise benefits.

Perseverance qualities and exercise benefits positively predict exercise behavior among obese adolescents. Perseverance qualities and exercise benefits play a mediating role between perceived school climate and exercise behavior among obese adolescents, respectively. These two factors have parallel multiple mediating effects between obese adolescents' perceived school climate and exercise behavior, with mediating effects accounting for 16 and 25%, respectively. The mediating effect of exercise benefits is greater than that of perseverance qualities. There is no difference in the test results of specific indirect effect between perseverance qualities and exercise benefits. Therefore, in the process of improving the exercise behavior among obese adolescents, it is recommended to start by strengthening their perception of the school climate, focusing on enhancing their perception of the exercise benefits as well as their willpower to persist in exercise. By improving their cognitive level of willpower and exercise benefits, it is recommended to promote the improvement of their exercise behavior, cultivate lifelong exercise awareness, and develop a healthy lifestyle.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics Committee of Xiangya School of Public Health, Central South University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

YY contributed to the evaluation and interpretation of data, writing the first drafts, final version of the manuscript, and scrub data and maintain research data for initial use and later re-use. YQ contributed to the statistical analysis of data and development of the review concept, critically reviewed the manuscript, and participated in the interpretation and synthesis of data. CZ contributed to application of statistical to analyze and synthesize study data. CQ and ZC contributed to verification of the overall replication of results and other research outputs. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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COVID-19 pandemic-related weight gain in the pediatric population declined after restrictions ended, except among obese patients

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Introduction: Childhood obesity has become an important topic, not only of increasing relevance during the COVID-19 pandemic but specifically enhanced by it. Restrictions implemented to mitigate further outbreaks led to major constraints on daily physical activity, leading to a severe increase in body weight among children. This study highlights changes in BMI and weight development in children during and (in particular) after the COVID-19 restrictions in Austria, focusing on various socioeconomic factors.

Methods: Weight development throughout the pandemic and socioeconomic factors were evaluated by anonymous cross-sectional surveys filled out by parents at a pediatric practice.

Results: This study included 388 children. The rate of obesity increased by 88.5%, from 6.4 to 12.1%, throughout the pandemic, reaching a maximum of 15.2% during the restrictions. Overall, age-adapted BMI *z*-scores increased significantly by 0.22 during the restrictions and remained increased by 0.19 compared to pre-pandemic levels. With the exception of obese children, all children in the study population experienced significant weight loss after the restrictions were lifted. Obese children continued to gain weight without any sign of the onset of normalization. Socioeconomic factors, such as participation in regular activity in the form of organized sport or the availability of an outdoor area, were associated with relevant differences before the pandemic but had no protective effect against intra-pandemic weight gain. A higher level of parental education was the only factor associated with less weight gain in children during the early phase of the pandemic.

Discussion: Austrian COVID-19 restrictions have had concerning effects on pediatric BMI, with very little effect of socioeconomic background. After restrictions were loosened, measurable weight loss occurred, but the significant increase in children's BMI percentiles persisted. No weight loss was observed among children who were obese prior to the pandemic. There is a need for broad projects tackling childhood obesity, as obese children are the most vulnerable group with the strongest and most severe long-term effects.

KEYWORDS

COVID-19, childhood obesity, pandemic, restrictions, socioeconomic factors, risk factors

1. Introduction

An intriguing trend relating to the incidence of overweight and obesity affecting even the early stages of life, not only in Austria (1, 2) but also across the whole of Western society, has been observed in recent decades (3–5). It has been established that obesity and overweight are strongly correlated with lower socioeconomic status (6). In the specific situation of children, parental socioeconomic status, and education level in particular, play an important role in weight distribution (7, 8). During the early stages of the COVID-19 pandemic, it was observed that the obesity rate among Austrian children increased (8, 9). From 15 March 2020 to 5 March 2022, the lockdowns, prohibition of team sports, and closure of schools and preschool services at different levels greatly affected daily life during the COVID-19 pandemic in Austria. Restrictions and rules were the same for every child and every social group. It is easy to assume that children with a lower socioeconomic background, already being at risk for obesity, would show more weight gain in such an extreme situation as the pandemic.

The pandemic and the associated restrictions enhanced behaviors connected to poor weight development, such as a lack of movement and increased caloric intake in the form of snacks and meals due to more available time or simply out of boredom (10, 11). Families of a lower socioeconomic status and with less education were less resilient to these risk factors. Before the pandemic, families with a lower socioeconomic status already showed poorer food choices for various reasons, such as affordability or knowledge about healthy food. They bought foods higher in fat and calories and with little nutritional value (12, 13). We hypothesized that these patterns did not change during the pandemic. Additionally, we hypothesized that, during the pandemic, many children replaced their relatively healthy meals eaten in school or at daycare with home-cooked meals or daytime snacks.

To date, no data have been presented to support this hypothesis. Furthermore, it is unknown how children's weight developed in the phase after the restrictions were lifted. We also analyzed whether age played a role in weight development.

The primary aim of this study was to find clear evidence regarding whether classically recognized socioeconomic factors linked to obesity, like education or income (6, 14), exerted additional effects on weight and BMI changes during and after the pandemic restrictions.

Secondarily, additional pandemic-relevant factors, such as the availability of an outside area during lockdowns or regular organized group activities in sports, were to be analyzed. The hypothesis was that the availability of outdoor activities would have a protective effect on intra-pandemic weight changes and that membership in a sports team would change the children's behavior, manifesting in outcomes such as better food choices and higher activity levels due to individual training. The secondary goal of the study was to answer these questions.

Additionally, pre-pandemic weight classifications according to BMI and changes regarding that classification were analyzed. A further aim of this study was to analyze the sustainability of changes after the period of restrictions ended.

Abbreviations: HAK, Handelsakademie/Vocational school with higher education entrance qualification in Austria; *z*-score, standard deviation score.

2. Methods

2.1. Study design

This study was designed as a cross-sectional survey study in a pediatric population. It was carried out at a pediatric practice in Vienna, Austria.

2.2. Inclusion criterion

The single inclusion criterion was the availability of anthropometric data, specifically on weight, height, and therefore BMI, in the period 6 months before the start of the first lockdown in Austria (before March 2020). These data were measured and collected on a regular basis during pediatric consultations, routine check-ups, and vaccinations at the doctor's practice. The measurements closest to the beginning of the restrictions were chosen. If no data were available in the 6-month period before the restrictions, the inclusion period could be expanded to 1 year before the lockdown if the last three BMI values were on a stable percentile.

2.3. Data collection

All children who attended planned, non-emergency appointments during the collection period were screened for suitability. When the inclusion criterion was met, available data within the restriction period between March 2020 and March 2022 were screened. The investigators aimed to obtain one pair of data points per year, as far as was available during this period. When more pairs of data points were available in the given time period, the highest values were chosen. Finally, available data after the end of the restrictions (March 2022) were included in the analysis. The restrictions in Austria were reduced in a stepwise manner, but in March 2022, nearly all of them had been lifted. The collection of data for this study took place between August 2022 and November 2022.

As the pairs of data points during the restriction period from March 2020 until March 2022 were not standardized in terms of time points, gaps between the two sets of data points differed, and some patients only had one set of data in the relevant time period, in-depth analysis of the intra-pandemic phase was not viable. Therefore, interindividual comparability was not reached.

All available data [sex, weight, height, and age (in months) at every included measurement performed at the pediatric practice] were anonymously transcribed to a survey sheet before it was handed out to parents who came to a planned appointment at the pediatric practice with their child within the data collection period. Information about the study was provided orally and in written form on the study sheet. It was both stated on the study sheet and orally communicated that the study was completely voluntary and that consent was given upon returning the completed survey to

a locked post box within the pediatric practice. The survey was available in German, Bosnian/Serbian/Croatian, and Turkish to ensure high-quality responses even from non-native speakers. This study was performed with the approval of the ethics committee of the Medical University Vienna (EK Number 1450/2022).

2.4. Data sheets

The socioeconomic factors analyzed were the number of adults and children per household; height of the living space; the availability of an outdoor area during restrictions, such as a garden, a playground, or access to free space; affiliations with any organized sport before, during, and after the restrictions; total household income; and the highest level of education in the household. Answers were to be given using prebuilt ordinal-scaled categories.

2.5. Data evaluation and statistical methods

After all the sheets were collected, the study data were transcribed to a data sheet and double-checked by another investigator. For every measurement, we recorded the age-dependent percentile for height, weight, and BMI, as defined by Kromeyer-Hausschild et al. (15) and calculated using the online PEDz calculator (16), in the data sheet. Children were categorized as normal weight, overweight, or obese based on the 2019 AWMF guidelines by Wabitsch et al. (1). Specifically, overweight was defined as a BMI higher than the 90th percentile and obesity as a BMI above the 97th percentile by age, a common standard in Austria and most European countries. Dystrophy was defined as a BMI below the 3rd percentile (1, 3).

Statistical analysis was performed using IBM SPSS (version number 27) and PSPP (version 1.6.2). Descriptive statistics, cross tables with chi-square tests, and paired *t*-tests for different time points were used. Non-parametric tests were conducted for ordinal variables, including the Mann–Whitney U test and the Kruskal–Wallis test; the Dunn–Bonferroni test was used for further analysis. Statistical significance was set to <0.05. A Sankey diagram was produced using the web application Sankeymatic (17).

3. Results

3.1. Descriptive data

A total of 403 surveys were distributed. In total, 388 surveys were included in the data analysis. The missing surveys either were not returned by the parents or had to be excluded due to missing data. Included patients were aged from 1 week to 14.4 years (mean: 4.34 ± 3.01 years). Ages at the end of the study ages spanned between 2.3 and 16.8 years (mean: 7.06 ± 3.04 years). This study included 208 male and 180 female participants. During the observation period, *z*-scores for BMI changed significantly. The mean BMI *z*-score changed from 0.036 ± 1.199 before COVID-19 to 0.224 ± 1.279 after the end of the restrictions. Maximum values were reached during the restrictions, with a BMI *z*-score of 0.453 ± 1.4, resulting in a mean *z*-score change of 0.403 ± 0.699 between the beginning of the observation period and the maximum value reached during the lockdowns. A difference of 0.187 ± 0.808 occurred between the period before the restrictions and after the restrictions. The *z*-score decreased by 0.221 ± 0.607 from its maximum during the restriction phase to the phase after the limitations were lifted. All of these changes were significant ($p < 0.001$).

Figure 1 shows the changes in categorizations throughout the measured time points. In total, the number of patients who were categorized as overweight or obese increased from 65/388 (16.7%) to 80/387 (20.7%), with a maximum of 94/379 (24.8%) during the restrictions. There was a statistically significant difference in the distribution between the groups before, during, and after the pandemic ($p < 0.001$). Gender did not contribute to the classification of weight before ($p = 0.36$), during ($p = 0.26$), or after the restrictions ended ($p = 0.67$).

Age played a subordinate role. The only significant difference in Δ *z*-scores for BMI was seen pre- to post-pandemic for children up to the age of 1 year (0.165 ± 0.85) as compared to those above this age (0.436 ± 0.669); $p = 0.041$. No significant differences were found for older children or other age categories. In particular, there were no differences in Δ *z*-scores between the preschool age group (<5) and school-aged children (>5), in the case of either pre-to-post or intra-pandemic changes in BMI *z*-score.

Significant changes in BMI during and after the restrictions, according to the original category of the patients, are presented in Table 1.

3.2. Socioeconomic factors

The answers to the questions asked in the survey sheet are presented in Table 2. The effects of these factors were analyzed for significance regarding BMI *z*-score before, during, and after the restrictions and corresponding Δ *z*-scores.

3.2.1. Outdoor area

The availability of a private outdoor area was correlated with a lower BMI before the pandemic. This effect persisted throughout the restriction period. However, no protective effect against weight gain was observed (Table 3).

3.2.2. Organized sport

A total of 53 patients participated in sports in the form of regular organized activities before the appearance of pandemic restrictions. Interestingly, 26 children were younger than 5 years of age at that time and were already participating in organized sport. A total of 268 patients were never part of any organized sport, and 62 children started to participate at some point during the pandemic. Participation in organized sport, and the point at which participation began, showed influence on BMI distribution. Children who were part of a regular activity before the lockdowns had significantly lower BMI *z*-scores pre-pandemic (−0.31 ± 1.18) than children who were never part of any sports team (0.09 ± 1.19,

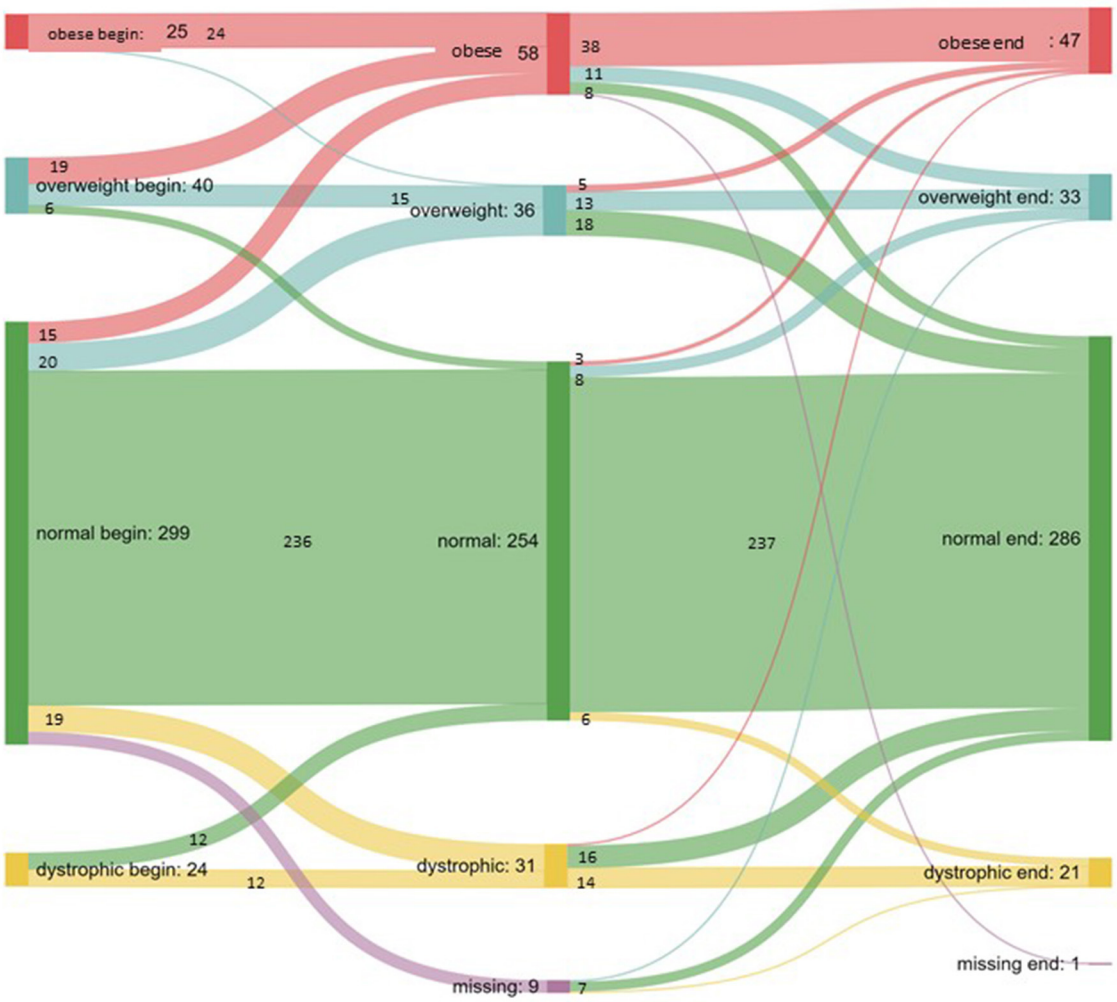

FIGURE 1
Sankey diagram illustrating changes in weight class and the flow between the groups.

$p = 0.026$). This significant difference continued throughout the pandemic (0.13 ± 1.02 vs. 0.55 ± 1.30; $p = 0.015$) and was present at the end of the study period as well (-0.27 ± 1.18 vs. 0.32 ± 1.32; $p = 0.004$). Nonetheless, Δ z-scores during ($p = 0.59$) and after the pandemic ($p = 0.22$) did not differ significantly.

However, BMI changes from the intra-pandemic maximum to the period after the restrictions differed significantly between these groups. Children who were already part of a team before the lockdowns reduced their BMI z-score (-0.36 ± 0.55). Differences compared to patients who stopped participating in sports teams were significant, as the latter group continued to gain weight even after the restrictions were lifted (0.31 ± 0.44; $p = 0.014$). A tendency toward higher weight loss was observed compared to children who never participated in any team sport (-0.23 ± 0.63; $p = 0.08$), but this difference did not reach significance. Children who stopped their team membership during the pandemic performed worse in terms of weight loss than children who never participated in any team sport ($p = 0.04$).

3.2.3. Education

Parental education was classified as low (no education or mandatory school), medium (vocational training and high school diploma), or high (university). The resulting correlations with BMI can be seen in Table 4.

3.2.4. Income

Income had small effects on BMI distribution and changes in BMI distribution. Tendencies were found toward a lower BMI pre-pandemic for the highest-income group as compared to the lowest-income group, but significance was not reached according to the Kruskal–Wallis test ($p = 0.06$). Overall income was not associated with any relevant differences in Δ z-score.

4. Discussion

As expected, weight and BMI percentile among the study population increased throughout the pandemic, which is consistent

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TABLE 1 Changes in *z*-score according to the original classifications present at the beginning of the study period.

Weight classification before COVID-19 restrictions		Maximum Δ BMI *z*-score during COVID-19 restrictions	Δ BMI *z*-score before–after restrictions	Δ BMI *z*-score during–after restrictions
Dystrophic	Mean	0.880	0.935	0.074
	SD	0.866	0.884	0.731
Normal	Mean	0.392	0.150	−0.252
	SD	0.686	0.782	0.617
Overweight	Mean	0.342	−0.045	−0.387
	SD	0.712	0.883	0.453
Obese	Mean	0.165	0.213	0.048
	SD	0.437	0.450	0.396
Overall	Mean	0.403	0.187	−0.226
	SD	0.699	0.808	0.607
Kruskal–Wallis test	*p*	<0.001	<0.001	0.005
Dunn–Bonferroni test				
Dystrophic–normal	*p*	<0.001	<0.001	0.146
Dystrophic–overweight	*p*	0.001	<0.001	0.028
Dystrophic–obese	*p*	<0.001	0.008	0.345
Normal–overweight	*p*	0.891	0.188	0.124
Normal–obese	*p*	0.078	0.664	0.005
Overweight–obese	*p*	0.176	0.221	0.001

with global studies (8, 9, 18). Throughout the period of restrictions, the rate of obesity increased from 6.4% (25/388) to 15.2% (58/379). At the peak, nearly 25% of the children were classified as overweight or obese. Interestingly, the number of overweight children did not increase, as can be seen in Figure 1, but approximately half of overweight children (19/40) became obese during the pandemic. Only a small proportion of overweight children (6/40) moved to the normal weight classification. The general trend among our study population indicated increased BMI and weight gain, leading to relevant changes in classification. This finding is comparable to data from America (19) and throughout Europe (2). Our intra-pandemic maximum Δ *z*-score (0.403) was even higher than those reported in other studies, such as Kang et al. (20).

In contrast to that change, 6.4% of the patients initially classified as normal weight (19/299) moved to the dystrophic group. Thus, there was a categorical shift from normal weight toward both edges of the classification system during the lockdown period. Overall, 23.7% (92/388) of the patients changed their classification. Stress and anxiety were high during the pandemic; these issues are connected to pathological behavior patterns, including unhealthy eating behaviors (21, 22) and eating disorders (23, 24). In contrast, approximately 50% of initially dystrophic children (12/24) gained enough weight to be classified as normal. Although there is no proof, such weight gain could be based on reduced stress in children with social anxiety or simply on the stress that occurs in school and social environments. The avoidance of daily peer pressure and ongoing social competition could have felt like a relief for some children (25).

In terms of change in BMI *z*-scores during the pandemic, children in all categories gained similar amounts of weight, with the exception of dystrophic children, who gained more than those in all the other categories. Children categorized as normal weight showed a tendency to gain more weight than obese patients, but the p-value was above the significance threshold ($p = 0.078$). This finding contrasts with that of Brooks et al. (26), who found that BMI changes showed an especially strong positive trend in children who were already obese. On the other hand, Kang et al. (20) stated that most weight gain was observed in children primarily classified as having a normal weight, which is loosely in alignment with our findings.

Regarding the persistence of changes in the post-pandemic period, we showed that the general study population showed signs of beginning to return to normal, seen as a tendency toward weight loss, with *z*-scores slowly declining, compared to the maximum *z*-scores reached during the pandemic. At the end of the study period, values were still far above pre-pandemic levels. Categorically speaking, the rate of obesity was nearly twice as high as it was during the pre-pandemic period (47/387), with a total increase of 5.7% ($p < 0.001$). The rates of overweight (−1.8%) and dystrophy (−0.8%) nearly reached their pre-pandemic levels.

When looking at the initial classification again, it was clear that the weight loss trend was present for patients originally classified as normal or overweight, not for those classified as having dystrophy

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TABLE 2 Socioeconomic factors and their occurrence in the study population.

Adults	*N*	Children	*N*
1	18 (4.6%)	1	86 (22.1%)
2	340 (87.6%)	2	191 (49.2%)
3	10 (2.6%)	3	77 (19.8%)
4	11 (2.8%)	4	17 (4.4%)
5+	4 (1%)	5+	14 (3.6%)
Missing	5 (11,3%)	Missing	3 (0.8%)
Income	***N***	**Education**	***N***
<1,300 €	26 (6.7%)	No school qualifications	10 (2.6%)
1,300–1,600 €	22 (5.7%)	Mandatory school	59 (15.2%)
1,600–2,000 €	48 (12.4%)	Apprenticeship	85 (22%)
2,000–2,400 €	57 (14.7%)	HAK	34 (8.8%)
2,400–3,000€	78 (20.1%)	High school	82 (21.1%)
>3,000 €	134 (34.5%)	University	111 (28.6%)
Missing	23 (6%)	Missing	7 (1.8%)
Organized sport	***N***	**Outdoor area**	***N***
Never participated in organized sport	268 (69.1%)	Yes	303 (78%)
Part of organized sport before restrictions	49 (12.6%)	No	74 (19%)
Started an organized sport during restrictions	62 (16%)	Missing	11 (2.8%)
Stopped participating in organized sport during restrictions	4 (1%)		
Missing	5 (1.3%)		

HAK (Handelsakademie): Vocational school with higher education entrance qualification.

or obesity. Children in the groups at both extremes gained weight during the pandemic and did not lose it after the pandemic restrictions were lifted. While the change to a normal weight for many of the patients classified as dystrophic was a favorable outcome, the lack of improvement among already-obese patients was a problem. They were as strongly affected by the pandemic as the rest of the population; however, after the restrictions were lifted, the return to their pre-pandemic activity level and lifestyle was insufficient to alter their direction of change toward weight loss. Risky behaviors were aggravated by the pandemic, and even if the children returned to their pre-pandemic lifestyle, they lacked strategies and resources to halt or even reverse their weight gain. In children who were normal or overweight, the return to pre-pandemic activity levels affected weight and BMI positively. Weight loss among these children was significantly greater compared to obese children. Their strategies and lifestyles promoted a trend toward pre-pandemic levels.

The lack of an effect of age on changes in BMI *z*-scores was a highly interesting point. According to our data, no differences by age were seen in the population other than the increased change among children older than 1 year of age. Prior to this study, we expected that schoolchildren would be affected differently than preschool children, but this hypothesis was not borne out in our data. In fact, the intra-pandemic restrictions and associated lifestyle changes seem to have affected our study population regardless of their specific age. Contrary to our study, although they also showed that preschool children gained extra weight during the COVID-19 pandemic, Li et al. (27) stated that there was an increase in weight gain with increasing age among preschoolers in China. Unlike our study, they did not follow individual patients but compared given age groups through the years, which makes direct comparison rather difficult.

To date, few data are available dealing with the long-term effects of the pandemic and the period afterward. To our knowledge, this study is the first to follow the course of weight development after the pandemic and to analyze the long-term impact on children's BMI in Austria. Bond et al. (28) analyzed weight development in Australian children over a period of 21 months. Overall, their results were aligned with those of our study. They showed increased rates of obesity, with an increase of around 6.3% immediately after the start of restrictions, which is slightly smaller than our maximum increase of 8.8% during the pandemic restrictions. They stated that, after these first changes, the situation normalized within 1 year and the rate of obesity returned to nearly pre-pandemic levels. In our study population, the general trend toward normalization was also present, but BMI percentiles and categories did not reach pre-pandemic levels (before March 2020) throughout the study period (from March 2020 until March 2022) or afterward.

Socioeconomic factors had a relatively small effect on weight gain in our study group. The single factor with a relevant effect on weight development during the pandemic was parental education, with higher parental education levels leading to less weight gain during the pandemic restrictions compared to that among children with lower parental educational levels. In other studies, screen time and activity time were strongly connected to weight gain, as shown by Robinson et al. (29). It is known that these behaviors are more strongly regulated in families with higher levels of education, as found by Pedersen et al. (30). This difference, although diminished when comparing Δ *z*-scores from pre- to post-pandemic, may be a result of the general adaptation of society or the slowly reduction in compliance with the regulations in society and the effects of these regulations. This observation aligns with the findings of Bond et al. (28) and Fäldt et al. (31), who both showed increased weight gain in groups of lower socioeconomic status shortly after the onset of restrictions.

We could see that access to an outdoor area was associated with lower BMI scores before the pandemic. A significant difference on this basis remained present throughout the pandemic (Table 3). After the restrictions, there was a slight tendency toward higher BMI *z*-scores among children without access to an outdoor area (0.ut15 vs. 0.37), but the difference was not statistically significant ($p = 0.186$). This is due to the surprising fact that children without access to an outdoor area showed a significantly higher tendency toward weight loss after the restrictions. The survey design did not take the actual time spent outside into consideration. Thus, this pattern could have

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TABLE 3 Relevance of an outside area for children and correlations with weight change.

	Outside area	*n*	Mean	SD	*p*
BMI *z*-score before COVID-19 restrictions	Yes	303	−0.047	1.199	0.032
	No	74	0.282	1.098	
Maximum BMI *z*-score during restrictions	Yes	294	0.346	1.245	0.006
	No	74	0.784	1.154	
BMI *z*-score after COVID-19 restrictions	Yes	302	0.15	1.269	0.186
	No	74	0.37	1.264	
Maximum Δ BMI *z*-score during COVID-19 restrictions	Yes	294	0.377	0.692	0.173
	No	74	0.501	0.720	
Δ BMI *z*-score before–after restrictions	Yes	302	0.19	0.771	0.29
	No	74	0.089	0.924	
Δ BMI *z*-score during–after restrictions	Yes	294	−0.190	0.550	0.021
	No	74	−0.412	0.767	

TABLE 4 Role of education in BMI and BMI changes.

		BMI *z*-score before restrictions	Maximum BMI *z*-score during restrictions	BMI *z*-score after restrictions	Maximum Δ BMI *z*-score during restrictions	Δ BMI *z*-score before–after restrictions	Δ BMI *z*-score during–after restrictions
Low level of education	Mean	0.39	0.90	0.64	0.49	0.24	−0.25
	N	69.00	68.00	68.00	68.00	69.00	68.00
	SD	1.40	1.31	1.36	0.70	0.94	0.76
Medium level of education	Mean	0.02	0.48	0.23	0.45	0.21	−0.25
	N	201.00	195.00	201.00	195.00	201.00	195.00
	SD	1.18	1.29	1.29	0.73	0.78	0.55
High level of education	Mean	−0.16	0.13	−0.07	0.26	0.08	−0.19
	N	111.00	109.00	111.00	109.00	111.00	109.00
	SD	1.05	1.03	1.14	0.61	0.75	0.60
Kruskal–Wallis	*p*	0.006	<0.001	0.002	0.03	0.314	0.65
Dunn–Bonferroni test							
Low compared to medium	*p*	0.02	0.01	0.04	0.39	0.60	0.529
Low compared to high	*p*	0.002	<0.001	<0.001	0.02	0.16	0.96
Medium compared to high	*p*	0.21	0.02	0.04	0.03	0.23	0.41

Education levels: low, no education or mandatory school; medium, vocational training or high school degree; high, university.

occurred because children without such access spent more time engaging in outdoor activities after the restrictions were lifted to compensate for their long period without this opportunity. Regardless of this, solely the availability of an outdoor area was not sufficient to protect children from changes in BMI *z*-score, but put them in a better position before any restrictions were

brought in. Other groups have found similar results and showed that activity levels and overall time spent outdoors decreased significantly during the pandemic, significantly influencing weight gain (32–35).

Participation in any form of organized sport before the pandemic correlated to lower BMI levels before any restrictions took place, but showed no protective value throughout the pandemic. Children who were participants in organized sport lost their regular activity and gained weight, as did other children. There was no sign of any better performance in terms of weight gain during the pandemic. When restrictions were placed on sports and activities, it seems that significant weight gain was inevitable. Loss of activity levels and regular sports activities have been generally accepted as obesogenic factors in the COVID-19 pandemic (36). Interestingly, a rather large number of children under the age of 5 years participated in organized sport, but it has to be stated that there are many different activities, such as mother–child gymnastics and toddler swim classes, that are performed regularly in Austria, as can be seen in our study population. To define these activities in more detail was outside the scope of this study.

In the post-pandemic period, children who stopped participating in these organized activities during the pandemic and did not return to sport had significantly lower weight loss after the restrictions were lifted, and even gained more weight, compared to those children who returned to participation in their teams. They also performed worse in terms of weight loss than children who never participated in any organized sport. As a symbol of a return to regular activity, the return to sport seemed to fall among the most significant influences on the return to normalization.

Interestingly, there was no significant difference in weight loss between children who participated in organized sports and those who never participated in a team throughout the course of the entire study, although there was a tendency toward increased weight loss among participating children. That can be explained by the fact that regular activity does not require participation in any kind of organized activity or team and that regular leisure activities, like hiking or running alone, can also be highly demanding. However, this study did not collect information regarding weekly hours of activity or similar data. Participation in an organized activity was used as a surrogate marker for regular activity, which was correlated with lower BMI levels and lower obesity rates before the COVID-19 pandemic. Prolonged reduction of activity, as is likely to have occurred in the children who left their team or classes, led to increased weight gain. Therefore, regular sports activity seems to have been one of the strongest protective factors against weight gain in the pandemic. Additionally, it is the socioeconomic factor that could be influenced the most easily. This recommendation aligns with that of Jarnig et al. (9), who stated that gym classes should be a fixed part of any study plan, even in distance learning.

In our study, parental income did not protect against changes in BMI and played no significant role in the children's BMI. However, answers were only to be chosen from the given options, and approximately half of the parents selected the highest possible answer of $>$ 3.000 €/month. Splitting up the answers into more categories, including higher categories, would have provided more insight and possibly significant results.

As we performed a single-center study, our study population was rather small. Some small effects might have been missed due to the lack of power and scaling issues with the factors.

As the study was designed in the form of an anonymous survey, missing data was an issue, as not all parents answered all questions. In particular, the question on income was the single answer with the most missing values. Another factor is the possibility that some answers might not have been completely correct, despite having been given anonymously: some people might have reported higher incomes and larger living spaces due to feelings of shame.

5. Conclusion

The obesity rate among the pediatric population increased during the COVID-19 pandemic by 8.8% and remained at a higher level even after the restrictions were lifted. A general trend of normalization in terms of BMI percentiles was visible in our population, but values were still above pre-pandemic levels.

Being obese before the pandemic increased the chances of poor performance in the aftermath. While most children showed a positive trend after the pandemic, obese children lacked strategies to fight their enhanced weight gain.

Regarding the role of socioeconomic factors, the family's education level, participation in an organized form of sport or activity, and having access to an outdoor area to engage in activity were associated with a lower BMI percentile before the pandemic. Nonetheless, only families with the highest level of education showed signs of lower weight gain during the pandemic restrictions. The presence of an outdoor area or membership in a sports team alone had no protective effect regarding weight gain during the pandemic.

A very striking finding was that returning to organized sport led to rapid and effective weight loss compared to prolonged inactivity after the restrictions.

We can conclude that children do not only need enough space to engage in activity but also profit enormously from groups and teams. It was not the availability of space and outdoor areas, but rather the re-starting of regular group activities and training, that affected weight development.

It is of the utmost importance to stimulate regular sporting activity in children, ideally in the form of team and group activities, and to keep activity levels high for as long as possible in the case of a future lockdown to prevent increasing obesity rates and to put the children in the best possible position beforehand. Actions directly targeting obese children are of the utmost importance, as they are the most vulnerable group of children in an obesogenic environment, such as the COVID-19 pandemic and its associated restrictions and limitations.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Medical University Vienna (EK Number: 1450/2022). Written informed consent from the patients/participants was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

SI: Conceptualization, Formal analysis, Investigation, Project administration, Writing—original draft, Writing—review and editing. JB: Data curation, Writing—review and editing. JE: Conceptualization, Supervision, Writing—review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Trends in the numbers of SARS-CoV-2 infections among students: a prospective cohort study comparing students in sports boarding schools with students in day schools during early COVID-19 pandemic

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Introduction: During the first months of the COVID pandemic it emerged that facilities where people gather or live together in cohorts, such as nursing homes or schools, were particularly at high risk for becoming hotspots of virus transmission. German political and health institutions responded with far-reaching interventions and preventive strategies to protect the population from infection with SARS-CoV-2. In this context, it remains unclear whether boarding schools for sports particularly pose a risk of infection to their residents.

Methods: In a single-center prospective cohort study, numbers of SARS-CoV-2 infections of students in sports boarding schools ($n = 11$) vs. students attending regular day schools ($n = 22$) in the region Freiburg/Hochschwarzwald in Germany were investigated over a period from October 2020 to January 2021 via regular virus and antibody screening (German Clinical Trials Register; Study ID: DRKS00021909). In addition, individual and behavioral risk factors for infection were stratified via questionnaire, which provide an indication of cohort specific risk factors for infection and the success of the implementation of hygiene concepts, as well as other infection prevention strategies, within the respective facilities.

Results: Regarding SARS-CoV-2 infection numbers, the screening detected no significant group difference between sports boarding schools vs. day schools.

Discussion: The study results provide indications that sports boarding schools did not pose an increased risk of infection, assuming that the facilities prevent virus transmissions with appropriate preventive strategies and hygiene measures. In future pandemic scenarios larger-scale and multicenter studies are necessary to achieve more comprehensive epidemiological data in this field.

KEYWORDS

COVID-19, SARS-CoV-2, athletes, students, schools, prevention, sports

1 Introduction

Since the beginning of 2020, the spread of SARS-CoV-2 has affected the lives of billions of people. First detected in Wuhan (Hubei, China) in December 2019, the pathogen spread mainly via aerosol transmission all around the world (1, 2). On March 11, 2020, the World Health Organization (WHO) classified the outbreak of SARS-CoV-2 infections as a pandemic and by that time 118,319 confirmed cases and 4,292 deaths from the disease had been reported worldwide. The novel pathogen also spread rapidly in Germany and soon it became evident that cohort-housed facilities in particular were at high risk for viral transmission (3). Faced with nationwide increasing infection rates and in the absence of sufficient vaccination rates, the German federal government and all 16 German state governments adopted far-reaching interventions and preventive strategies to protect the population from infection with SARS-CoV-2, which resulted in a general lockdown and closure of several public facilities. In this context, the state government of Baden-Württemberg in southwest Germany decided to close schools from March 17, 2020. In some cases, the school closures were maintained for several months, depending on regional incidence and grade levels. Consequently, the students' and adolescents' circumstances changed significantly and their new daily routine between homeschooling, complying with hygiene procedures and prevented extracurricular activities turned into a major challenge (4).

At the end of September 2020 a second wave of infections with SARS-CoV-2 occurred in Germany reaching its highest incidence level in December 2020 with up to 32,195 new daily infections on December 24, 2020. With the onset of the second COVID-19 wave another debate emerged in Germany as to whether school lockdowns were an appropriate instrument for containing the incidence of infection and whether the students could be expected to go through another school lockdown with all its challenges. According to the epidemiological bulletin of the German Robert Koch Institute, data on the infection environment of registered cases within Germany were published on August 11, 2020 (3). Here, infections in private households formed the largest proportion, followed by senior citizens and nursing homes as well as refugee and residential homes. The working space formed the second largest infection environment followed by shared residences (3). However, no robust data existed on how the infection distributed in the collective of students in schools and to what extent the infection numbers develop after reopening of schools. It was also unclear whether there were differences in certain types of schools, for example differences between boarding schools and regular day schools.

In this context, the Institute of Exercise and Occupational Medicine of the University Medical Center of Freiburg, Germany, aimed to provide information on whether attending sports boarding schools (SBS) poses an increased risk of infection with SARS-CoV-2 compared to regular day schools (DS), assuming that SBS students would be at higher risk for infection due to cohort accommodation and increased sport-related interpersonal contacts. In addition, the question arose as to whether a corresponding closure of SBS should occur in analogy to the day schools in terms of infection prevention. At the same time, possible individual and institutional risk factors for infection and resulting prevention measures were investigated. The study wanted to gain experiences and possible differences in the occurrence and transmission of infection with SARS-CoV-2 within a SBS or a DS. This may potentially prompt further cohort-specific information, which could lead to more sophisticated recommendations in an epidemic or pandemic situation for respective student facilities.

2 Materials and methods

2.1 Study design and procedure

A single-center, non-interventional, prospective cohort study was chosen as an appropriate observational study design. Two age-matched cohorts of students were observed regarding the occurrence of SARS-CoV-2 infections. Cohort 1 (SBS group) consisted of competitive sports students residing in sports boarding schools in the region Freiburg/Hochschwarzwald in southwest Germany. Cohort 2 (DS group) consisted of students attending regular day schools in the same region. The cohorts were observed in parallel over a period from October 2020 to January 2021. The chosen period corresponded to the second wave of COVID-19 diseases in Germany. The study was registered in the German Clinical Trials Register under the corresponding Study ID: DRKS00021909. After recruitment, informed consent, and study inclusion, subjects received a baseline visit (t0) and additional follow up examinations after 4 ($\pm$1) and 8 ($\pm$1) weeks (t1 and t2). A time buffer of $\pm$1 week was tolerated to avoid scheduling conflicts and, if possible, to invite all study participants within a group together for follow-up investigations. Initial appointments were arranged individually with the students from the corresponding SBS and DS. Follow-up appointments were organized according to the defined interval starting from the timepoint of the first visit. In both cohorts, the respective diagnostic and survey procedures were applied equivalently (see Table 1). The primary outcome parameter was defined as the detection of SARS-CoV-2 infection at timepoints t0, t1, and t2. In addition, secondary endpoints were surveyed at each time point to gain insights into individual and institutional risk factors for infection. Thereby, the subjects were asked via interview and questionnaire about symptoms of illness, social contact activities in the private and sporting setting, exposures to infected individuals, travel behavior and compliance with hygiene regulations, preventive strategies and their subjectively assessed effectiveness. The sport boarding schools' own preventive and hygienic concepts for infection prophylaxis was provided by the participating institutions. Their preventive concept included, in addition to the generally applicable hygiene rules (wearing facemasks, adhere the distance rules and regular hand hygiene) a query of infection symptoms as well as an obligatory hand disinfection upon entry into the institution, a daily disinfection of potentially contaminated surfaces (e.g., door handles), a general prohibition of visits, the drafting of an individual daily schedule of the athletes, the relocation to single rooms, the recommendation to avoid direct physical contact and to maintain a minimum distance of 1.5 m, as well as a distance maintenance when serving meals. Furthermore, it was decided that athletes with symptoms

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TABLE 1 Schedule of data collection and diagnostic procedures with respect to cohorts and study timepoints.

	Cohort 1			Cohort 2		
Timepoints	t0	t1	t2	t0	t1	t2
Time period	10/2020–11/2020	11/2020–12/2020	12/2020–01/2021	10/2020–11/2020	11/2020–12/2020	12/2020–01/2021
Assessments/data collection and sampling						
- Verification of written informed consent	X			X		
- Screening and study inclusion	X			X		
- Acquisition of master data	X			X		
- Survey of sports activity	X			X		
- Oropharyngeal swab	X	X	X	X	X	X
- Venous blood sampling	X	X	X	X	X	X
- Questionnaire	X	X	X	X	X	X
Diagnostics						
- RT-PCR	X	X	X	X	X	X
- ELISA based antibody diagnostics	X	(X)	X	X	(X)	X

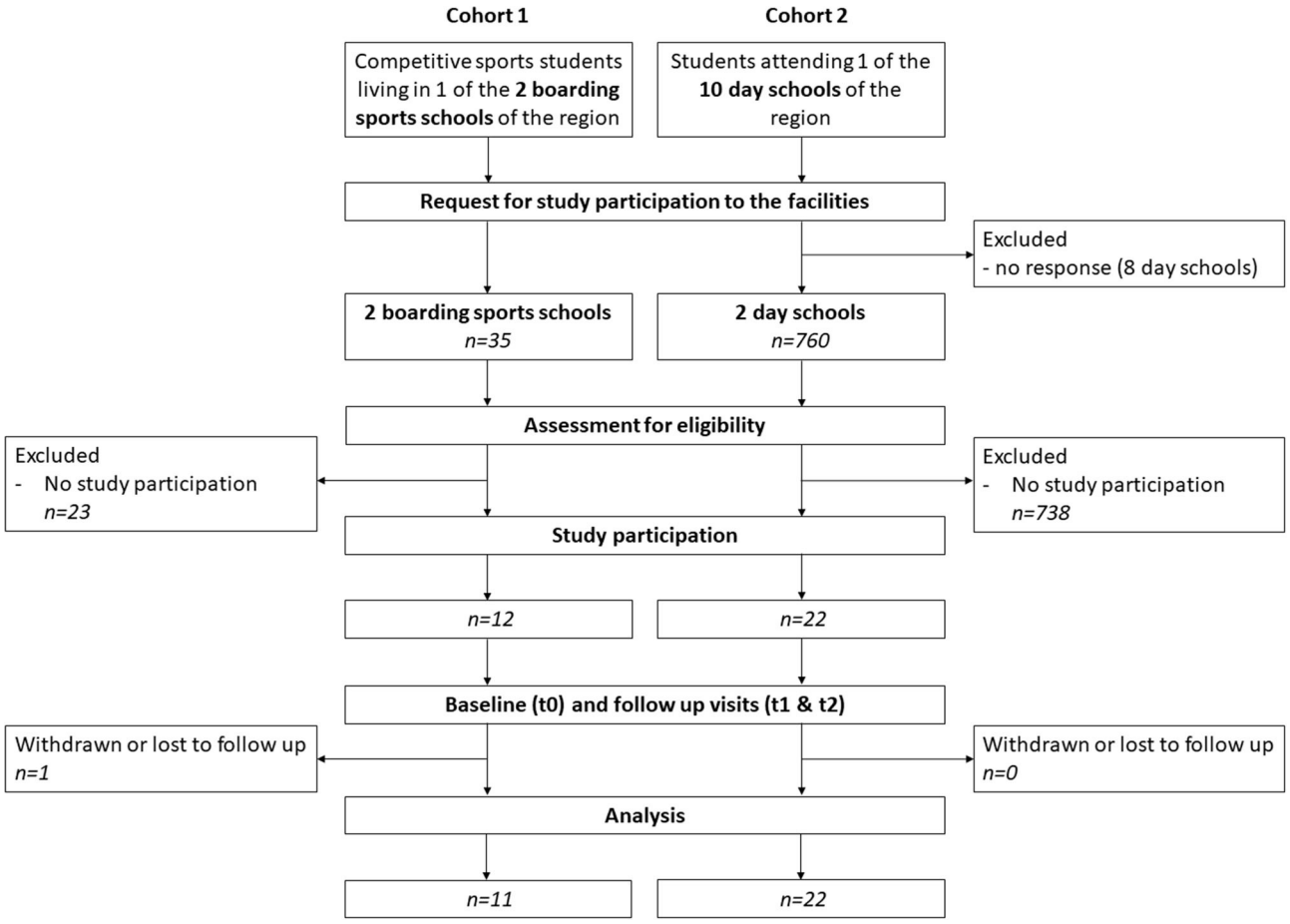

FIGURE 1
Study flow chart.

TABLE 2 Inclusion and exclusion criteria.

	Cohort 1	Cohort 2
Inclusion criteria	- Students residing in a sports boarding school	- Students attending a day school
	- Date of birth between 01. November 2000 and 01. November 2004	- Date of birth between 01. November 2000 and 01. November 2004
	- Absence of signs of infection (e.g., fever)	- Absence of signs of infection (e.g., fever)
	- Unrestricted suitability for sports	- Unrestricted suitability for sports
Exclusion criteria	- Known previously experienced SARS-CoV-2 infection.	- Known previously experienced SARS-CoV-2 infection.
		- Participation in a club sport according to the ACSM ("American College of Sports Medicine") of more than 2 times per week.

of infection would have to be immediately quarantined in their single rooms until a medical consultation, including a decision on the further procedure, was made. The detection and diagnosis of a SARS-CoV-2 infection had to be reported immediately to the competent health authority, which had to decide on the further procedure, up to a temporary closure of the respective facility.

2.2 Study population, recruitment and screening

The study population consisted of students of a certain age (16–20 years old), who either lived in SBS (cohort 1) or attended DS (cohort 2) (see Figure 1). The inclusion and exclusion criteria are noted in Table 2. Students in cohort 1 (SBS group) were all competitive athletes, who spent most of their extracurricular time practicing different sports activities in their training groups. Due to the pandemic situation, a bubble principle was performed in the training groups in such a way that all members of a training group were instructed to avoid contacts in the non-sporting area as much as possible. Symptomatic athletes were not allowed to attend ongoing training sessions. Due to the profile of the SBS, these were primarily winter sports (cross-country skiing, biathlon, ski jumping), which are mostly practiced outdoors as individual sports, but were also exercised in training groups of several persons. On the weekends, SBS students usually were either at competitions or went home to visit their families. Beyond study participation athletes received PCR diagnostics regarding SARS-CoV-2 infection in case of symptoms and before and after competitions. Students in cohort 2 (DS group) lived at home with their families and spent their leisure time doing different activities. Beyond study participation and in accordance with the official regulations at the time, students in this cohort had to undergo PCR testing if they were symptomatic.

In a preliminary step, potential institutions in the region were screened via web-based research. In this process, ten DS and two SBS could be identified for possible study participation. Subsequently, heads and administrations of the respective institutions were informed in written form about the planned study project and asked about the possibility of conducting the study within the institution. The request included an offer for a study information session for teachers, students and parents at the respective facilities. According to the guidelines of the Declaration of Helsinki, participation in the study was explicitly advertised as voluntary. With this strategy, two SBS and two DS could be won for study participation. In case of positive feedback from the facilities, a verbal and written study information was provided for interested students and parents. In order to avoid unnecessary contacts of the study personnel with the institutions, responsible teachers/guardians in the institutions took over the information transfer about the study project. Prospective students who matched the age range were invited to participate in the information session with the study personnel at the respective facilities. Whenever there was an entry of study personnel into the facilities, the study personnel excluded an own COVID-19 infection by PCR testing in advance and entered the facilities only in appropriate protective clothing in order not to cause virus transmission into the facilities. In a next step, interested students were screened according to inclusion and exclusion criteria (see Table 2). Only students who met the inclusion criteria and had given written informed consent to participate in the study were included. For minors, the signature of a legal guardian was obligatory. Due to pre-selection through the school's internal procedures and without the finding of other exclusion criteria, no prospective student had to be excluded in the screening process.

2.3 Data collection and data management

Data collection was either conducted at the study center or at the respective facilities. In this case, a mobile study team headed by a physician from the study center was sent to perform the data collection and diagnostics for the corresponding visits (see Table 1) according to the transmission prevention measures described in Study population, recruitment and screening. Analog case report files (CRFs) were used to record and save the subjects' master data (date of birth, gender, body weight in kg and height in cm), health-related data (previous illnesses, smoking habits) and study-specific data and documents (results from SARS-CoV-2 screening via RT-PCR, SARS-CoV-2 antibody diagnostics, paper-based questionnaire). CRFs were reviewed for legibility, completeness, and consistency via an internal monitoring at the study center.

After study inclusion, each study participant received a specific three-digit ID for pseudonymization. By means of two subsequent numerical digits, the collected biospecimens could be coded in a timepoint-related manner, which ensured pseudonymization to the sample processing Institute of Virology at the University Hospital Freiburg. Only the study director was given the authority to decipher the personal data to contact the appropriate local health department if a positive sample was detected. All other persons involved in the further processing of the specimens and data were only granted pseudonymized access to the data. The

pseudonymized data were transferred to an electronic database for statistical analysis.

2.3.1 SARS-CoV-2 virus diagnostics

Oropharyngeal swabs (Sigma Virocult® swab kit, Medical Wire&Equipment Corsham, Wiltshire, SN13 9RT, UK, REFMW950S) were taken at each time point of the study for direct detection of infection with SARS-CoV-2. Realtime-PCR (RT-PCR) analyses of the swabs were performed at the Institute of Virology of the University Hospital Freiburg using the AltoStar® SARS-CoV-2 RT-PCR Kit 1.5. The detection limit for SARS-CoV-2 in UTM®-containing simulated nasal matrix was 0.014 PFU/ml (95% confidence interval: 0.008–0.032 PFU/m) according to the manufacturer's instructions.

2.3.2 SARS-CoV-2 antibody diagnostics

Venous blood sampling from the cubital vein was performed at each visit for indirect detection of an acute or past SARS-CoV-2 infection via antibody diagnostics. After storage on ice, centrifugation (Eppendorf brand centrifuge, model 5810 R for 15 min at 3,000 rpm), pipetting of the serum supernatant, its alliquoting and biobanking in−28°C (temperature-controlled Liebherr brand freezer), antibody analyses were performed at the Institute of Virology of the University Hospital Freiburg. All serum samples were analyzed at the end of the study using SIEMENS brand ADVIA Centaur COV2T assay. Total SARS-CoV-2 antibodies (including IgM and IgG) were evaluated. Samples with an index of <1 were considered negative for SARS-CoV-2 antibodies. Samples with an index >1 were considered positive for SARS-CoV-2 antibodies. The measurement range of the test was an index value of 0.05–10.00. According to the manufacturer, the sensitivity of the ADVIA Centaur COV2T test is 97.5% 7–13 days after a positive PCR test and 100% after 14 days. The specificity is 99.8%. In order to save analysis capacity and costs, serum samples from t0 and t2 were analyzed primarily. Only if the serum sample from t2 was positive for SARS-CoV-2 antibodies, serum sample from t1 was further analyzed in order to draw conclusions about the timepoint of infection if it were unclear. If positive antibodies had been detected at timepoint t0, this would have led to retrospective exclusion from the study and further analysis according to the exclusion criteria.

2.3.3 Questionnaire

At all timepoints a questionnaire had to be completed by the study participants. The questionnaire was designed explicitly for the actual students' living conditions to assess an individual and institutional risk profile for SARS-CoV-2 infection. It considered topics and risk factors for SARS-CoV-2 infection, such as COVID-19 related symptoms, exposure to other persons in the sporting and family setting, out-of-school activities, adherence to hygiene regimens and travel behavior. The original questionnaire with its answer options and corresponding scale levels can be found in detail in Table 3.

2.4 Statistical analysis

Statistical analyses were performed using SPSS Statistics 29 software (IBM, Armonk, New York). Data sets were examined regarding normal distribution using Shapiro-Wilk test. Nonparametric tests were used for calculation of statistical relationships. Exploratory statistical analyses were performed in dependence of group comparisons or the observation between different study time points. Mann-Whitney-U test (MWU) was applied for at least ordinally scaled, unrelated variables. Chi square test (χ^2) or Fisher's Exact Test were applied for unrelated categorical scale samples. Cochranes Q or Friedmans test were used for connected samples. Furthermore, secondary outcome parameters were analyzed descriptively. Percentages were calculated to one decimal. All reported p-values are exploratory in nature. Significance level was set with $p < 0.05$.

2.5 Ethics approval statement

We adhered to the ethical principles of the World Medical Association's Declaration of Helsinki in the preparation of the study design as well as in the conduct of the study. An ethics application was submitted for the study, which was approved on 12/05/2020 (application no. 280/20). The study was reviewed and approved by: Research Ethics Committee, University of Freiburg, 79106 Freiburg, Germany. The students of full age provided their written informed consent to participate in this study. For all underage students, parents or guardians provided their written informed consent for their children to participate in the study.

3 Results

In the study region of the city and district of Freiburg/Hochschwarzwald two SBSs and two DSs showed interest in participating in the study. After screening of inclusion and exclusion criteria and verification of written informed consent, 12 students could be included in cohort 1 (SBS group) and 22 students in cohort 2 (DS group). During the study period one lost to follow up case was recorded in cohort 1 between timepoint t1 and t2 due to scheduling conflicts, which was excluded from statistical analysis. In cohort 2, all 22 study participants could be observed over the entire duration of the study.

3.1 Study population demographics

The study population consisted of two age-matched groups. The mean age of the participants was 17 years on average. Cohort 1 (SBS group) differed significantly from cohort 2 (DS group) in the characteristics of gender distribution, body height and weight and the weekly performed physical activity. No significant differences were found in relation to previous illnesses, usage of regular medication, smoking behavior, the number of family members or number of high-risk patients in the families (see Table 4).

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TABLE 3 Questionnaire for the assessment of individual risk factors for SARS-CoV-2 infection of students in sports boarding schools and day schools.

Topic	Questions	Answer options	Scale level
Symptoms	Did you have symptoms of illness in the last 4 weeks?	Yes, no	Nominal
	- Which symptoms occurred?	No symptoms, fever, rhinorrhea, cough, sore throat, taste or smell disorders, headaches, earaches, dizziness, diarrhea, nausea/vomiting, other (free answer option)	Nominal
Meetings with friends	How often did you meet with friends outside the facility for recreational activities in the last 4 weeks?	Not at all, <5 times, <10 times, >10 times	Ordinal/Interval
	- Did you wear a facemask when you met your friends?	Yes, partially, no	Nominal
	- Did your friends wear a facemask during the meeting?	Yes, partially, no	Nominal
	- Did you keep the minimum distance of 1.5 meters during the meetings?	Yes, partially, no	Nominal
	- Where did you meet with your friends?	Indoor, outdoor	Nominal
Out-of-school activities	How often have you met with friends for sport sessions in the last 4 weeks?	Not at all, <5 times, <10 times, >10 times	Ordinal/Interval
	- What was the maximum number of persons you were at the sport sessions?	Number of persons	Rating
	- How many hours per week did you spend on sport sessions?	Number of hours	Rating
	Do you engage in regular after-school activities apart from sports (e.g., driving school, music lessons)?	Yes, no	Nominal
	- How many hours per week?	Number of hours per week	Rating
Public transport and travel behavior	How often have you used public transportation in the last 4 weeks?	Not at all, <5 times, <10 times, >10 times	Ordinal/Interval
	Have you been traveling in the last 4 weeks?	Yes, no	Nominal
	- If yes, how many days in total?	Number of days	Rating
Subjective assessment of hygiene measures	In your opinion, are the hygiene and distance rules (frequent hand hygiene, minimum distance of 1.5 m, wearing a facemask) being observed within the facility?	No, rarely, usually, always	Ordinal
	How useful do you consider the current pandemic-related restrictions?	Not at all useful to very useful (0–10 cm)	Rating

3.2 SARS-CoV-2 infections during the observation period

Results of detected SARS-CoV-2 infections in the respective cohort are shown in Table 5. A total of 33 oropharyngeal swab specimen and 33 venous blood samples could be obtained over the entire study period in the SBS group (cohort 1) for RT-PCR and antibody analyses. In the DS group (cohort 2), 66 oropharyngeal swab specimen and 66 venous blood samples were obtained. According to the diagnostics performed, only one positive SARS-CoV-2 infection could be detected in the SBS group by RT-PCR at timepoint t1, which could be confirmed by ELISA-based antibody diagnostics at timepoint t2. In contrast, no evidence of infection was detected in the DS group throughout the study period. In this context, the performed antibody analyses could not reveal any other hidden infection. Thus, with respect to the numbers of SARS-CoV-2 infections, no statistically significant difference could be determined between the study cohorts (Fisher's Exact Test, $p = 0.333$, $\phi = 0.143$).

3.3 Symptoms of disease

Survey results are presented graphically in Figure 2 and in tabular form in Table 6. Considered the entire study period Fisher's Exact Test showed no significant difference in the occurrence of symptoms of illness between the study groups ($p > 0.05$). A closer look across the temporal course of the study showed a timepoint related decrease in the occurrence of one or more symptoms during the last 4 weeks in the SBS group [27.3% (t0) vs. 18.2% (t1) vs. 9.1% (t2)], while in the DS group the occurrence of one or more symptoms during the last 4 weeks remained fairly equal [45.5% (t0)

TABLE 4 Demography of the study population.

Parameter	Cohort 1	Cohort 2	Significance
Age (years)	17.45 (±2)	17.09 (±1)	0.955
Gender			0.024*
- Male	$n = 8$ (72.7%)	$n = 6$ (27.3%)	
- Female	$n = 3$ (27.3%)	$n = 16$ (72.7%)	
- Divers	$n = 0$	$n = 0$	
Body height (cm)	181.78 (±9.79)	171.39 (±9.76)	0.011*
Body weight (kg)	70.58 (±8.67)	62.25 (±9.19)	0.024*
At least one pre-existing illness (yes)	$n = 1$ (9.1%)	$n = 8$ (36.4%)	0.212
Regular medication (yes)	$n = 1$ (9.1%)	$n = 4$ (18.2%)	0.643
Smoking (yes)	$n = 0$ (0%)	$n = 1$ (5%)	1.000
Family members (number)	3.54 (±1.3)	3.18 (±0.9)	0.560
At-risk patients in family (yes)	$n = 10$ (90.9%)	$n = 17$ (77.3%)	0.637
Sports activity (hours/week)	13.0 (± 4.2)	3.3 (± 2.4)	<0.001*

*Significance level $p < 0.05$.

TABLE 5 Results of primary outcome parameters throughout the entire study period.

	Cohort 1/ SBS group ($n = 11$)	Cohort 2/ DS group ($n = 22$)	p-Value
SARS-CoV-2 infections	$n = 1$	$n = 0$	0.333*
• Positive RT-PCR	$n = 1$	$n = 0$	
• Positive antibodies	$n = 1$	$n = 0$	

*Significance level $p < 0.05$.

vs. 50.0% (t1) vs. 45.5% (t2)]. But, Chochran's Q Test did not reveal a statistical significant difference in the data distribution between the timepoints within the respective study cohorts.

3.4 Survey results evaluating risk factors for infection

3.4.1 Expositions and compliance with hygiene measures in meetings with friends and out-of-school activities

Survey results are presented graphically in Figures 3, 4. Regarding the number of meetings with friends for recreational activities in the last 4 weeks before the respective visits, DS students were significantly more likely to meet with friends than SBS students (MWU, $p < 0.001$, $r = 0.43$). In this context, the frequency of meetings with friends showed a significant difference among the distributions between the study timepoints ($\chi^2_{(2)} = 11.902$, $p = 0.003$). Here Friedman's pairwise tests revealed a significant decrease of meetings in the DS group between t0 and t2 ($p = 0.035$). With regard to the place of meetings, SBS students met friends significantly more often outdoor than indoor ($\chi^2_{(1)} = 6.428$, $p = 0.011$, $\phi = 0.471$). Regarding the wearing of a facemask in the context of the meetings, there were no significant differences between the study groups, with respect to the students and their met friends. In the SBS group, athletes wore a facemask permanently in only 5.6% of the cases and no mask was worn in 44.4% of the cases. In the DS group it was stated in 6.3% of the cases that a facemask was worn and in 53.1% no facemask was worn during the meetings. With respect to the adherence to the general rule of recommended minimum meeting distance of 1.5 m, there was a significant difference between the study cohorts. (Fish-er-Freeman-Halton Exact Test = 19.137, $p < 0.001$, $\phi = 0.535$). SBS students kept the minimum distance in 50.0% of the cases, whereas DS students kept the distance in only 4.6% of the cases.

With regard to the performed sport sessions, SBS students met significantly more often with other people than DS students (MWU, $p < 0.001$, $r = 0.66$). A closer examination of the groups across the study time points indicated a significant change in the frequency of meetings for sport sessions within the DS group ($\chi^2_{(2)} = 17.098$, $p < 0.001$). Here, Friedman's pairwise comparisons showed a significant decrease of the frequency of meeting for sports sessions between t0 and t1 ($p = 0.004$) and t0 and t2 ($p = 0.010$). On top, athletes met significantly longer with friends for sport sessions than DS students (MWU, $p < 0.001$, $r = 0.70$). In this context, SBS students spent an average of 12.7 h per week training with friends, whereas DS students met with others for an average of only 1.6 h per week for sports sessions. In terms of the number of training partners during exercise sessions, there was a significant difference between both study cohorts (MWU, $p < 0.001$, $r = 0.47$). In this regard, athletes met with a median of 10 other individuals. In contrast, DS students met with a median of three other persons. According to the place of the sport sessions both study groups showed no significant difference between indoor vs. outdoor locations (Fisher's Exact Test, $p > 0.05$). Regarding the practice of other out-of-school activities, such as music sessions, driving lessons, part-time jobs or church activities, no significant difference between both groups could be observed, both in terms of activities performed at all ($\chi^2_{(1)} = 1.370$, $p > 0.05$) and the number of hours spent for activities (MWU, $p > 0.05$).

3.4.2 Use of public transportation and travel behavior

Survey results are presented graphically in Figure 5. In daily life, DS students used public transportation significantly more often than SBS students (MWU, $p < 0.001$, $r = 0.41$). They stated that they had "not at all" used public transport in the last 4 weeks before the visits in 30.3% of the cases (<5 times: 33.3%, <10 times: 12.1%, >10 times: 24.2%). In the SBS group, in 72.7% of the cases students stated that they had "not at all" used public transport in the last 4 weeks before the visits (<5 times: 21.2%, <10 times: 0.0%, >10 times: 6.1%). Regarding the overall performed travels

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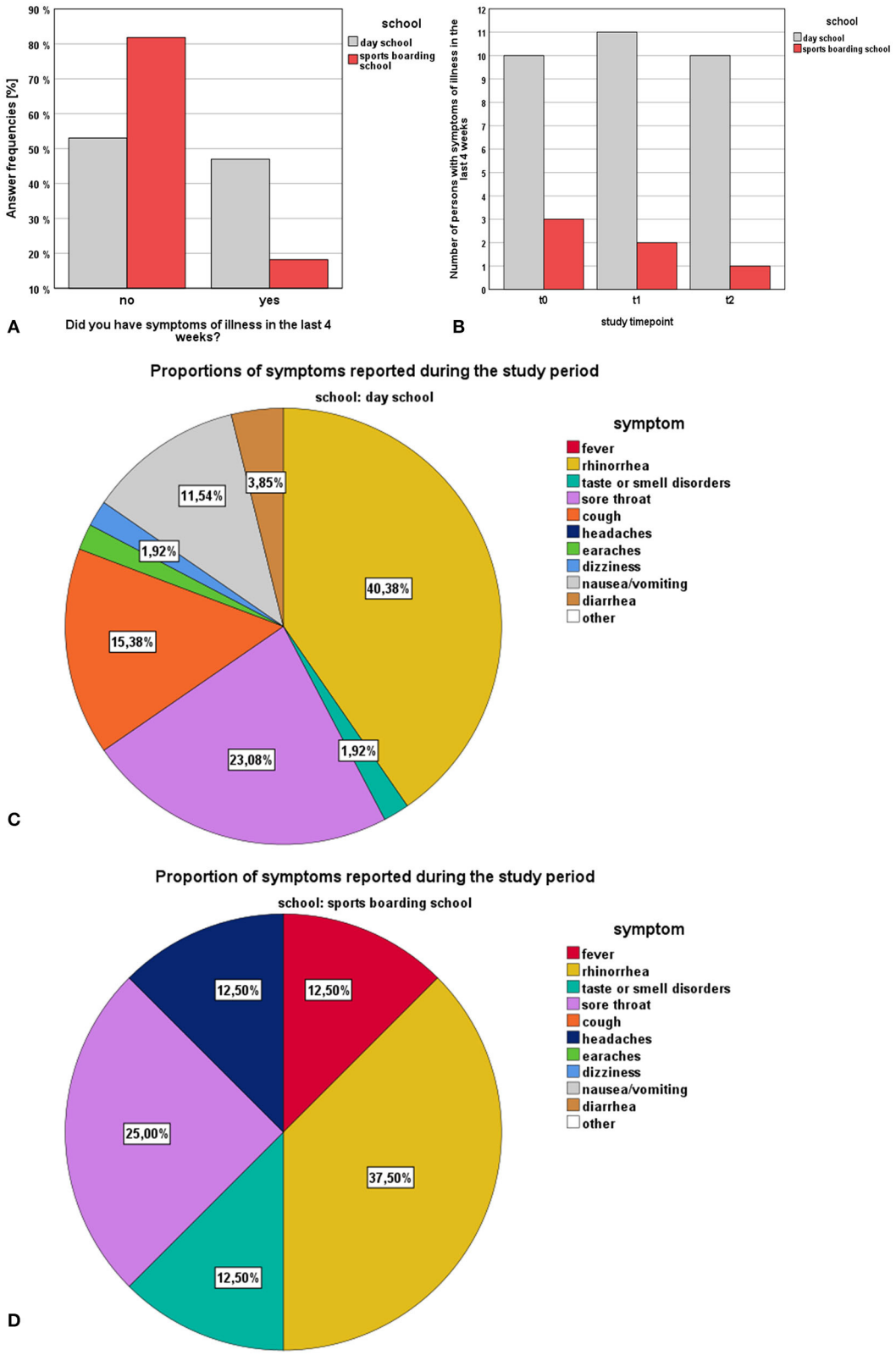

FIGURE 2
Survey results (SBS vs. DS) regarding the topic "symptoms": **(A)** answer frequencies of SBS and DS students regarding the general occurrence of symptoms, **(B)** number of persons with symptoms during the last 4 weeks stratified by timepoints, **(C)** proportional distribution of symptoms encountered in DS students, **(D)** proportional distribution of symptoms encountered in SBS students.

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TABLE 6 Survey results on the occurrence of symptoms in the last 4 weeks according to study time points.

	Cohort 1/SBS group ($n = 11$)			Cohort 2/DS group ($n = 22$)		
Timepoints	t0	t1	t2	t0	t1	t2
Symptoms						
Fever	-	$n = 1$	-	-	-	-
Rhinorrhea	$n = 1$	$n = 1$	$n = 1$	$n = 9$	$n = 7$	$n = 5$
Taste or smell disorders	-	$n = 1$	-	$n = 1$	-	-
Sore throat	$n = 2$	-	-	n = 5	$n = 4$	$n = 3$
Cough	-	-	-	$n = 4$	$n = 3$	$n = 1$
Headaches	-	$n = 1$	-	-	-	-
Nausea/vomiting	-	-	-	$n = 2$	$n = 3$	$n = 1$
Diarrhea	-	-	-	-	$n = 1$	$n = 1$
Dizziness	-	-	-	-	-	$n = 1$
Earaches	-	-	-	-	-	$n = 1$

during the entire study period no significant difference between the groups could be evaluated ($\chi^2_{(1)} = 2.228$, $p > 0.05$). With respect to the last study timepoint (t2), a significant difference between the groups could be revealed. Here, athletes traveled significantly more often in the last 4 weeks (Fisher's Exact Test $p = 0.030$, $\phi = 0.447$). Furthermore, it was noticed that the frequency of travels in the DS cohort decreased significantly in comparison between the timepoints (Cochranes Q, $p < 0.001$). Here a significant decrease between t0 and t1 ($p = 0.001$) as well as between t1 and t2 ($p < 0.001$) could be observed. In the SBS group, there were no significant differences between the study timepoints (Cochranes Q test, $p > 0.05$). In terms of the median travel duration, a significant difference between the study cohorts could be revealed (MWU, $p = 0.018$, $r = 0.48$). Here SBS students traveled longer (6 days) compared to DS students (4 days).

3.4.3 Subjective assessment of hygiene measures

Survey results are presented graphically in Figure 5. With regard to the subjective assessment of the usefulness of the applicable preventive and hygiene measures, no significant difference could be observed in between the study groups (MWU, $p > 0.05$). On a scale from 0 = "not useful" to 10 = "very useful," SBS students rated the usefulness of the interventions with a median of 7.6 points and DS students rated with a median of 8.0 points. Looking at the students' assessments of the extent to which hygiene measures were adhered to in their facilities, no significant difference between the groups could be shown (MWU, $p > 0.05$). In the SBS group only 9.4% of the athletes stated that the hygiene rules are "always" followed (90.6% "usually," 0.0% "rarely"), whereas in the DS group only 6.1% of the students stated, that the rules are "always" followed (83.3% "usually," 10.6% "rarely").

4 Discussion

The study primarily investigated the number of SARS-CoV-2 infections in students of two age-matched cohorts during the second wave of COVID-19 diseases in Germany, a time when widespread vaccination was not yet available and the pandemic had to be combated primarily by conservative hygiene measures and far reaching preventive strategies (e.g., lockdowns). During the study period, regular testing of students was not yet scheduled. For students the official pandemic recommendations at the time were to stay away from school if they showed symptoms of the disease and to undergo a PCR test performed at accredited centers. If the diagnostic test was negative, students could return to school. If SARS-CoV-2 infection was confirmed, students would have been quarantined at home for at least 10 days. The detected SARS-CoV-2 infections had to be reported to the regional health department, which decided when to end the quarantine. In this context, we asked for the registered infection numbers of all 16–20 year-olds in the city and district of Freiburg/Hochschwarzwald ($n = 25.501$) recorded by the public health department. In this age cohort, 549 new cases were recorded during the study period. In addition, the health office recorded infection outbreaks at schools in the region. Here, a total of 30 infections were recorded at 7 different schools during the study period.

In this context, the present study evaluated for the first time, based on infection numbers, whether or not living in a sports boarding school-a facility in the sense of a cohort accommodation-turned out to be an additional risk factor for infection with SARS-CoV-2. To the best of our knowledge, it is the only study that investigated the spread of SARS-CoV-2 in this kind of a student concerning setting. Due to insufficient evidence of how SARS-CoV-2 infections behaved in student collectives during the early time of the COVID-19 pandemic the study attempted to contribute and to improve our understanding of the institutional role of day schools and sports boarding schools in the pandemic situation. Furthermore, the investigation considered the behavior of students in their everyday life, so that cohort-specific risk stratifications could be derived. The study compared SBS students with students in regular day schools. With regard to the recorded epidemiological data, it can be determined that the study groups did not differ significantly in terms of age, preexisting illnesses, smoking behavior, family members or at-risk patients in the family, what

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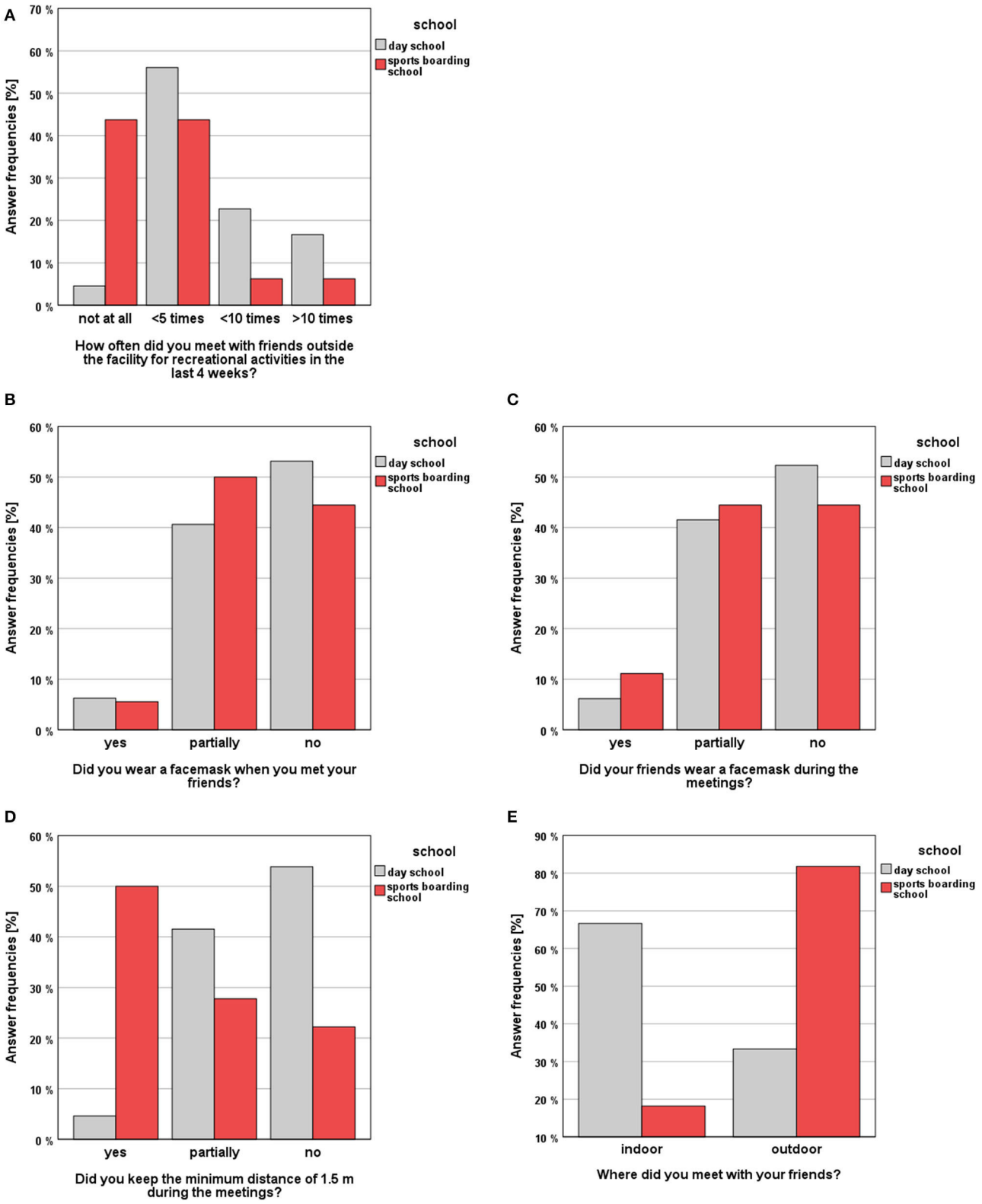

FIGURE 3
Survey results (SBS vs. DS) regarding the topic "Meetings with friends": **(A)** answer frequencies regarding the frequency of meetings with friends, **(B)** answer frequencies regarding the wearing of facemasks of the students **(C)** and their friends, **(D)** answer frequencies regarding the compliance with minimum distance rules, **(E)** answer frequencies regarding the place of meetings.

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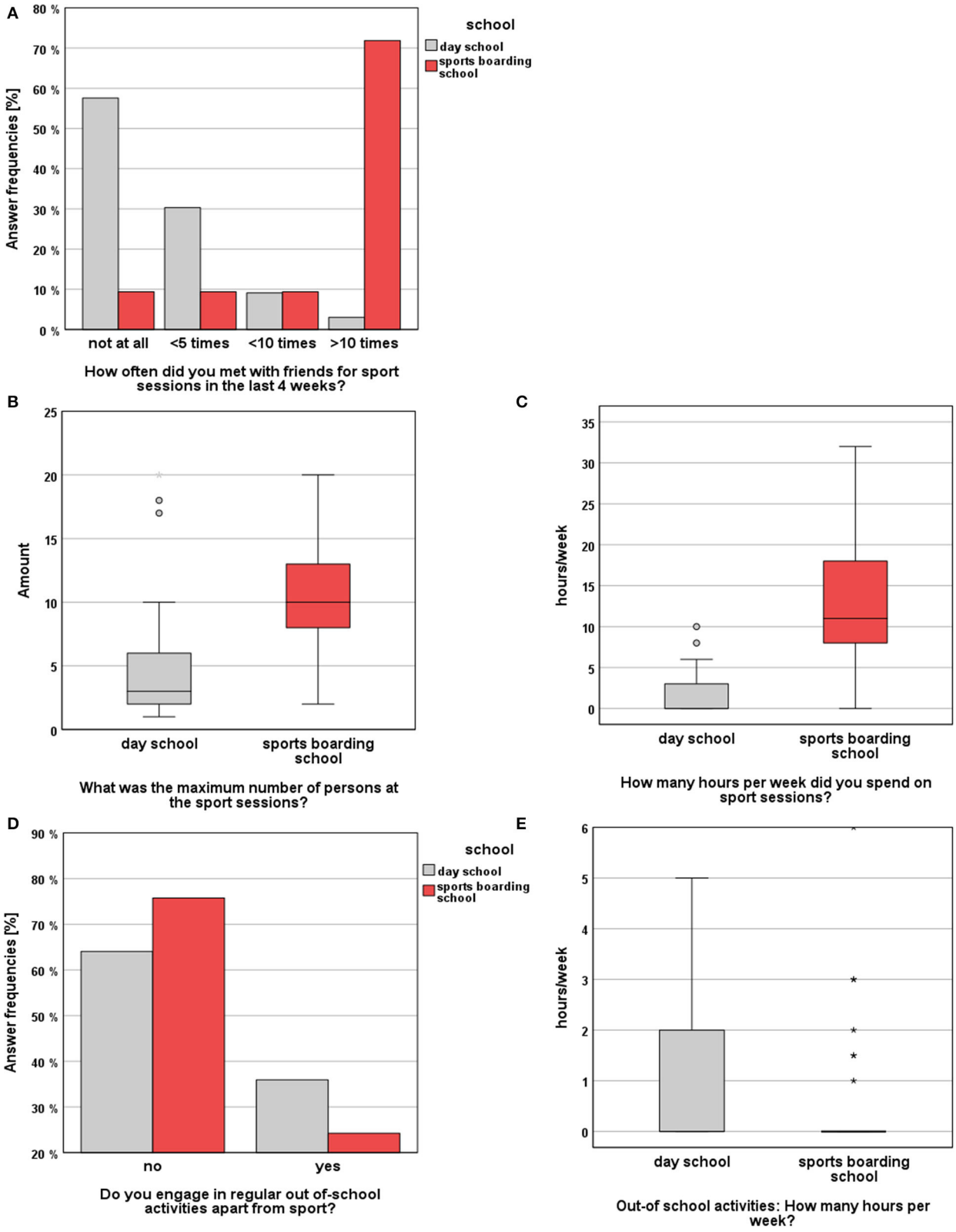

FIGURE 4
Survey results (SBS vs. DS) regarding the topics "Out-of-school activities": **(A)** answer frequencies concerning the frequency of meetings for sport sessions, **(B)** maximum number of persons during sport sessions, **(C)** hours spent for sport sessions per week, **(D)** answer frequencies regarding the participation in out-of-school activities apart from sport, **(E)** hours spent for out-of-school activities per week.

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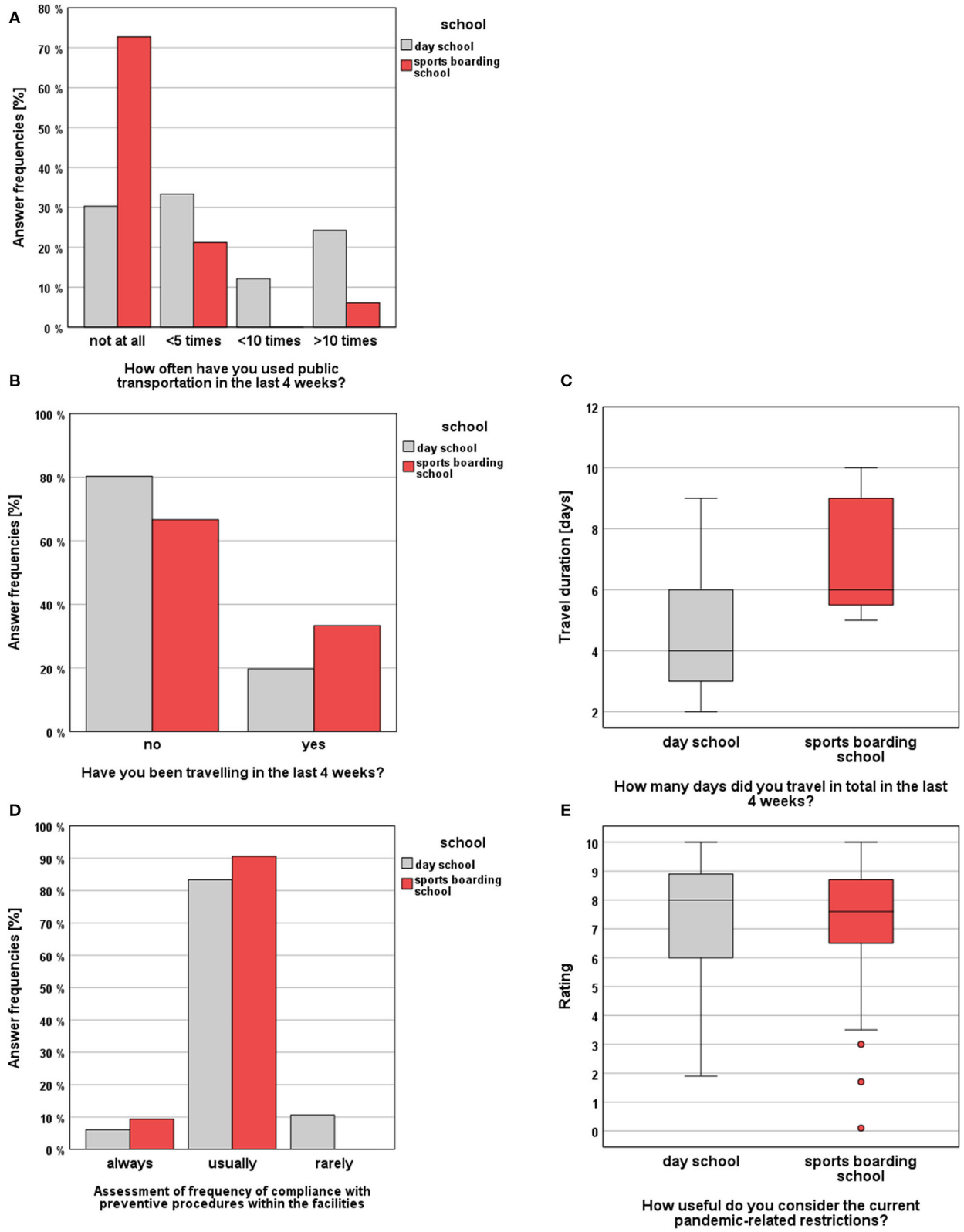

FIGURE 5
Survey results (SBS vs. DS) regarding the topics "Public transport and travel behavior" and "Subjective assessment of hygiene measures": **(A)** answer frequencies regarding the frequency of public transportation uses, **(B)** answer frequencies regarding travels, **(C)** and travel durations, **(D)** students' evaluations of their institution's compliance with hygiene measures, **(E)** students' subjective assessments of the usefulness of the measures.

allowed comparability. However, there was a disparity between the groups in terms of gender distribution and anthropometric data (body weight, body height). In this context, no evidence could be found that body height influences the risk of becoming infected with SARS-CoV-2. But, Vahidy et al. (5) showed that males have an increased risk of testing positive for SARS-CoV-2 compared with females. Furthermore, there is evidence that male gender indicates a risk factor for more severe disease progression with SARS-CoV-2 (6, 7). Within the present study, the SBS group showed an increased proportion of male subjects, but due to the small number of participants, a gender-related risk for infection could not be drawn. Studies with a larger number of subjects would be necessary in order to be able to draw further conclusions here. With regard to body weight, an increased risk for severe courses of COVID-19 diseases has been shown, but there is no sufficient evidence that overweight also increases the probability of infection (8).

However, to ensure objective detection of SARS-CoV-2 cases, RT-PCR was used, which represents the gold standard for the diagnosis of SARS-CoV-2 infection (9, 10). For motivational reasons, and to avoid discouraging potential study participants, oropharyngeal swabs were chosen as an adequate sampling method because they were more tolerable to the students than nasopharyngeal swabs. Although some data suggest that oropharyngeal swabs have lower sensitivity than nasopharyngeal swabs, the argument of better tolerance was considered more important to improve the willingness to participate in the study (11, 12). In addition, both types of sample collection are considered to deliver adequate results (13). By obtaining venous blood samples for antibody diagnostics, it was possible to objectively record any asymptomatic infections that had occurred. Thus, it was possible to ensure recording of hidden infections, which were not detected by RT-PCR diagnostics, as it also could be shown by Buntinx et al. (9) in the setting of a nursing home.

In comparing SBS students with DS students, no significant difference in infection numbers (objectified by RT-PCR and antibody diagnostics) was found. Overall, infection counts remained very low in both groups. During the entire study period, only one SARS-CoV-2 positive case presented in the SBS group. In this cohort, it could have been assumed, that further (secondary) infections would occur due to cohort-like accommodation and increased interpersonal contacts during sports activities, for example. The cohort-like coexistence of athletes within SBS with shared use of living and dining areas could additionally be considered a particular risk factor for infection or viral transmission. This form of cohabitation can be compared to a larger household. According to several studies, most infections occur in the domestic setting, which could argue for an increased risk of secondary infections within the SBS cohort (14–16). Presumably, due to consistent implementation of hygiene and isolation measures and the consequent application of the bubble principle in the training groups, further spread of infections within the institution could be prevented. According to the hygiene rules of the SBS, the only infected person went into quarantine immediately after the onset of symptoms. Starting from this case and on the basis of the collected study data, no other infection occurred in study participants from the same sports boarding school. According to the information provided by the responsible sports boarding school director the other residents were also spared. Thus, it can be concluded that the hygiene concept and bubble principle, developed and implemented by the SBS management and coaches, was effective regarding the control of an in-house virus spread. The immediate performed quarantine seemed to prevent further SARS-CoV-2 infections, which was also shown by Li et al. (17) who could demonstrate in 105 index patients that an immediate implementation of a quarantine for an infected individual with symptom onset resulted in 0.0% secondary infections within the household compared to 16.3% without quarantine. However, the role of secondary infections in the school setting is discussed controversial. In this context, an increasing number of studies concluded that schools were not major transmission sites of SARS-CoV-2. For example, Ehrhardt et al. investigated the sources of infection of 557 children and adolescents aged 0–19 years after the reopening of schools and kindergartens in Baden-Württemberg (Germany) after the first lockdown in May 2020. They were able to show that infections in schools and in the context of childcare accounted for only 3.3% of all detected infections (18). Similarly, in the present study, no evidence was found that the participating facilities represented a particular risk factor for infection with SARS-CoV-2 or its onward spread. Here, the corresponding hygiene programs of the facilities in particular could have made a significant contribution to infection control.

Moreover, the study was intended to shed light on the living conditions and preventive behavior of students in DS and SBS and thereby identify age and cohort specific behavioral and attitudinal risk factors for infection via questionnaire, which was explicitly designed for the study population. Validated questionnaires from previous surveys that involved an increased risk of infection with SARS-CoV-2 in the context of the students' living conditions and activities were lacking. Thus, the questionnaire was designed mainly based on two superordinate factors in order to provide an assessment regarding the risk of infection with SARS-CoV-2: first, interpersonal contacts and second, compliance with infection-preventive hygiene measures. Further factors based on the current state of research and on reflections about everyday life from the students' point of view were included. On top, questions about COVID-19 related symptoms were implemented based on the main clinical symptoms of SARS-CoV-2 known at this time and mentioned by Huang et al. (19). In addition, a free-text option was implemented to cover any symptoms of infection with SARS-CoV-2 not yet reported in the literature at this point. The number of interpersonal contacts in the domestic environment was surveyed by asking for the number of people living in the household, as Koh et al. (16) reviewed that household transmission of SARS-CoV-2 has been identified as a significant route of infection. Although a correlation of the number of family members and the risk of infection had not been investigated until then, it was likely that a higher number of persons in the same household is accompanied with a higher number of interpersonal contacts and thus an increased risk of infection with SARS-CoV-2. Further questions were aimed at interpersonal contacts outside the families (friends, training partners, etc.). By means of questions about meetings with friends, it was intended to get an overview of the number and type of peer group contacts in the students' leisure time. In this

context, it was not only the frequency of meetings that was of interest, but also the compliance with general hygiene regulations during the meetings (maintaining a minimum distance of 1.5 m and wearing a facemask) since previous studies had shown that these points had an influence on the risk of viral transmission (16, 20–24). In addition, the location of meetings and sporting activities were surveyed, as it is described in the literature that the risk of virus transmission and infection is less likely to occur outdoors than indoors (15, 23). Furthermore, a question was asked about at-risk patients in the family environment (persons over 60 years of age, persons with chronic underlying diseases, immunosuppressed persons) (8, 25), since in any cases greater prudence and compliance with hygiene regimens by students can be assumed to protect their at-risk family members. However, this had not yet been scientifically investigated. Therefore, the study participants were additionally asked about their opinions about the generally applicable hygiene guidelines to get insights into the question whether a low assessment of the usefulness of hygiene measures is associated with an increased risk of infection with SARS-CoV-2 within the cohorts. The last set of questions dealt with the use of public transportation and travel behavior, two factors that could mean an unmanageable number of interpersonal contacts and thus represent a possible additional risk factor for infection. Thus, the aim of the questionnaire was to screen symptoms and risk factors for infection and to assess whether the two cohorts differed in these aspects. Of course, the retrospective recording of the questions could have led to a recall bias. Nonetheless, important insights into cohort-specific characteristics were gained. In this context, the symptoms of illness surveyed over the study period differed only slightly between the study groups in terms of type and frequency. The decrease in symptom frequency over the study period in the SBS group is most likely explained by an increasing compliance of the athletes with hygiene measures, which could be related to the upcoming competition period in the winter months. It is also conceivable that athletes did not truthfully undertake the reporting of symptoms of illness, as this might possibly have led to quarantine-related exclusion from sport and competitions. This factor did not play a role in the DS group, which may be why the reported occurrence of disease symptoms remained rather constant in this group. Nevertheless, despite the occurrence of disease symptoms, the infection numbers with respect to SARS-CoV-2 remained very low. Of course, other pathogens may have played a role here, which were not assessed by the study design. With respect to the risk stratification for SARS-CoV-2 infections, extracurricular activities, frequency of travels, and subjective ratings of the usefulness of infection prevention measures did not highlight cohort-specific differences. Across all study participants, an overall increased risk of infection might have been expected because of poor adherence to wearing facemasks when meeting other persons, which is considered an effective infection prevention method (26–29). In addition, presumably the living conditions of the students pose a higher risk of infection compared with the general population, since school-related class communities and sports-related training groups are difficult-to-avoid circumstances in which many persons and close spatial contacts occur. In this context, the Christmas holidays, which fell within the study period, posed another unavoidable risk factor for SARS-CoV-2 infection for the students and athletes, who mostly spent the holidays with their families. The recommendations in Germany stipulated that no more than 10 people should gather for family celebrations and travel abroad was discouraged. Nevertheless, many interpersonal contacts presumably remained unavoidable during the Christmas vacations.

With regard to the risk of virus spread during sport sessions, a higher risk of infection cannot be assumed generally, since different types of sport differ significantly from each other in terms of risk factors for infection. In this context, a differentiation between individual and team sports is mandatory. Based on current research, team sports appear to have an increased risk of infection with SARS-CoV-2 compared to individual sports (30–32). The participating athletes at the sports boarding schools were all practicing individual sports, which is due to the sports profile of the sports boarding schools. Here, predominantly individual winter sports such as cross-country skiing, biathlon and ski jumping were represented and thus sports that are practiced primarily outdoors. Therefore, a comparatively lower risk of virus transmission and infection with SARS-CoV-2 could be associated in comparison with the practice of team sports, which should be considered in a comprehensive risk stratification for sports boarding schools. In this context, future investigations of differences between sport boarding schools hosting team athletes vs. sports boarding schools hosting individual athletes would represent an interesting question. However, the group comparison presented here compared a sports boarding school cohort of individual sports vs. a day school cohort that differed significantly in terms of frequency and intensity of physical activity in general. Thus, the study design does not allow comparisons between team athletes and individual athletes.

But, based on the present survey, cohort specific risk factor patterns emerged between the two study groups. For example, DS students met more often with other persons than SBS athletes. Compared to the SBS students, DS students would have an increased risk profile because they were more likely to meet people in private settings and indoor areas, less likely to consistently maintain the recommended minimum distance of 1.5 m and more likely to use public transportation. When meetings with friends occurred in the SBS group, infection prevention measures were more likely to be observed (meeting outside, keeping sufficient distance between each other) than in the DS group. This indicates an overall better compliance with preventive measures of the SBS group and suggests that there was a better awareness of the consequences of SARS-CoV-2 infections. It seems plausible that athletes are intrinsically motivated to continue their sporting activities and that this leads to greater compliance with infection prevention procedures. However, the fact that athletes tended to adhere to hygienic measures during meetings with friends could also be based on better education and the fact that an infection with consecutive quarantine and sports prohibition would have prevented the practice of competition and training activities, which can lead to serious disadvantages in competitive sports (e.g., loss of squad status, missing qualification for international competitions, etc.). On the other hand, SBS students showed an elevated risk profile for infection with SARS-CoV-2 compared to DS students because they were exposed to others without facemasks more frequently and for longer periods of time due to sports and training

activities. Additionally, they traveled for longer periods of time mostly to attend competitions or training camps. In this context, the performed bubble principle of the training groups tried to avoid a higher risk of infection in sport related circumstances. But, the only SARS-CoV-2 infection that could be evaluated in this study happened in the SBS group. A closer analysis of the individual source of infection most likely suggested an infection among a meeting with out-of-sports friends. The individual assessment of the meaningfulness of the preventive measures showed that the affected athlete did not consider the measures to be very meaningful at the beginning of the study and may not have paid particular attention to the preventive measures. This individual assessment was significantly lower than the ratings of the other subjects in the group, but increased significantly after the infection occurred. The overall survey of the assessment of the meaningfulness of the measures showed that the cohorts did not differ significantly on this point. Regardless of the possibly stronger motivation of the athletes, this could probably indicate that the general educational measures of the population achieved adequate effects also for DS students as the topic had disproportionate relevance in everyone's daily life at this time. However, there could also be a selection bias that induced anyway prevention-motivated students to voluntarily participate in the study. Based on the survey results, there would nevertheless be potential for improvement in both groups regarding adherence to infection prevention measures. For example, deficits were found in adherence to the facemask regimen in the context of gatherings. In addition, according to the students' assessment, there were only a limited number of students who strictly adhered to the hygiene rules, which suggests an overall rather insufficient adherence to the hygiene rules within the facilities. Thus, it can be concluded that in the future students should be provided with enhanced information on the usefulness and necessity of compliance with facility specific infection prevention measures. If necessary, more individual and age-related educational measures could be implemented to promote understanding and even more consistent implementation of the hygiene measures (e.g., avoidance of interpersonal contact in the recreational area, consistent wearing of the facemask, adherence to the minimum distance). However, this should only be done with thorough consideration of the accompanying impact on the psychosocial situation of the students. In this context, already performed school closures and contact restrictions placed particular demands on children and adolescents. Social contacts with peers represent an important factor for young people in finding their identity, social development and general wellbeing (33–35). Negative consequences of the pandemic situation on the psychological and physical wellbeing of young people in Germany were investigated as part of the nationwide COPSY study. Decreased quality of life and health behaviors were observed. There was also a significant increase in mental health problems among children and adolescents (36). The long-term effects of the pandemic on children and adolescents and any educational gaps, that may have occurred, will not be fully understood yet. In sports boarding schools, cases of SARS-CoV-2 temporarily led to boarding school closures and training cancellations. This could lead to career disadvantages for athletes if the quarantine affected important training camps, selection games and viewings or if there were setbacks in performance due to training absences, for example. The appearance of new virus variants will probably necessitate a new evaluation of the situation and an adaptation of hygiene concepts. In the long term, efficient hygiene plans and concepts for educating students and guardians must be further developed to guarantee continuous school and boarding school operation.

However, it is important to consider that only a small number of subjects could be recruited for this study, which cannot be considered representative of an entire population. Therefore, the results can't be transferred to larger student cohorts due to the small number of cases and the single-center design. This represents an important limitation of the study, which was based on a lack of willingness to voluntarily participate in the study, especially within the day school institutions, their students or their parents. But, on an institutional level it should be mentioned that schools were particularly burdened by the pandemic situation and the need to develop and implement hygiene concepts. Furthermore, the fear of school closures and negative media image due to SARS-CoV-2 cases discovered during the study may also have played a role in the decision not to participate. Another reason for refusal could have been that day schools did not want to subject their students to more measures, whose benefits were not yet foreseeable, especially since most of the students were in their high school graduation preparations. On an individual level, low assessment of the benefits of the study or the fear of an additional time burden due to study participation could have played a role not to participate. An aversion to venous blood sampling and oropharyngeal swabs could also have led to a refusal, especially since most students were already regularly swabbed in other settings.

In conclusion, this study examined that sport boarding school students had a cohort-specific risk constellation for infection with SARS-CoV-2 due to their living circumstances. But, living in a cohort accommodation, such as the participating sports boarding schools, did not present itself as a particular risk factor for SARS-CoV-2 infection compared to attending regular day schools. In this context, the implementation, consistent adherence to and enforcement of specific infection prevention measures within student-caring institutions may ensure the continuation of school and sports operations even in pandemic situations. But, the study results cannot be generalized to other athlete facilities due to the sport profile of the institutions and the small number of study participants. Therefore, in future pandemic scenarios larger-scale, multicenter studies and larger cohorts would be desirable parameters of study designs to address these circumstances and attract more institutions to respective research questions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Research Ethics Committee, University of Freiburg, 79106 Freiburg, Germany. The studies were conducted in accordance

with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

Conceptualization and funding acquisition: SP and PD. Methodology: VP, PD, and DH. Validation and data curation: PD and PM. Formal analysis: FB, VP, and PM. Investigation: FB, VP, OM, and OK. Resources: PD and DH. Writing—original draft preparation and visualization: FB and VP. Writing—review and editing: PM, OM, SP, and PD. Supervision and project administration: PD. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

VP declares that this work was developed in the context of her doctoral thesis.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Influencing factors of early childhood teachers' disaster preparedness

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Background: The risk of disasters and infectious diseases continues to persist in modern times. Children are a vulnerable group in disaster prevention and management due to their limited ability to cope on their own. Hence, the role and disaster preparedness capacity of early childhood teachers (ECTs) is vital for children's protection.

Objectives: This study aims to explore how ECTs can improve their personal resilience to adapt to and overcome disasters as part of early childhood education and care (ECEC). To this end, this study examined the effects of ECTs' self-efficacy, resilience, disaster awareness, COVID-19 stress, and work-related stress on their disaster preparedness.

Results: According to the outcomes of disaster preparedness of ECTs based on their general and job characteristics, full-time employees and principals scored significantly higher in work-related disaster preparedness (WrDP) compared to part-time workers and general and assistant teachers, respectively. Resilience and WrDP were identified as influencing factors of general disaster preparedness (GdP), with an explanatory power of 26.4%. GdP and self-efficacy were identified as influencing factors of WrDP, with an explanatory power of 25.7%.

Discussion: According to the findings, ECTs' self-efficacy and GdP must be improved, followed by developing strategies to strengthen their resilience and WrDP. Doing so would ensure the safety and disaster preparedness of ECTs and infants who have low self-care capacity.

KEYWORDS

early childhood, early childhood education and care, self-efficacy, resilience, COVID-19, teachers

Introduction

Disasters entail widespread losses and often exceed people's capacity to cope with the aftermath. Depending on the severity and scope of disasters, they can involve human, material, economic, and environmental losses that require support at the global level (1). To minimize damages, disasters must be mitigated and recovery made possible through pre-preparation and appropriate responses (2).

When disaster prevention, preparedness, response, and recovery activities occur along a continuum, the negative impacts of a disaster are minimized; prevention and preparedness are the most cost-effective approaches in terms of invested manpower and resources (3, 4).

Populations that are vulnerable to disaster prevention and response are high-risk groups whose safety and life support are threatened in the event of a calamity. Infants, children, older people, and people with disabilities are among the most in danger. In particular, infants and children lack self-management capacities owing to their lifecycle characteristics, and they therefore need efficient planning and strategies (5). In addition, children with poor connectivity are left with irreversible aftereffects in the event of a disaster, so effective preventative intervention is needed to enhance children's connectedness (6).

Industrialization has altered the structure of the family, changing the family lifecycle and family functions. In South Korea, industrialization has led to the nuclearization of the family, a decrease in the number of family members per household, and recently, the expansion of various family types, such as single-parent families. Such adjustments are transforming the care and family functions of infants and young children within families.

The importance of early childhood education and care (ECEC) is increasing due to the growing number of children receiving care at child daycare centers. In this regard, the childcare activities and responsibilities of these centers are emphasized, and there is a growing interest in promoting the safety and health of infants and young children (7, 8). Given that infants and young children are a vulnerable group in terms of disaster awareness and response, early childhood teachers (ECTs) are an important resource when it comes to preventing disasters that could affect them (9) In disasters, ECTs complement the role of families, form bonds with children, and take responsibility for childcare activities and facilities (8). Through their role, ECTs can help children buffer the shock of disaster situations (6). In other words, being unprepared for a disaster has a negative impact on the well-being of ECTs as caregivers, which, in turn, affects children negatively. This can also be inferred from the Family Stress Model (10).

Disaster preparedness refers to all proactive planning and efforts that take place before a disaster strikes. ECTs' awareness and competence in disaster preparedness not only allows them to protect themselves, but also infants and young children from the negative effects of disasters (6, 11, 12). Therefore, identifying factors that influence ECTs' disaster preparedness lays the foundation for establishing effective strategies.

Infectious diseases are a social issue that has persisted since the beginning of humanity. In particular, the outbreaks and epidemics of severe acute respiratory syndrome (SARS) in the early 2000s, the Middle East respiratory syndrome (MERS) of 2015, and the COVID-19 pandemic and its variants since December 2019 have been—and still are—social disasters. The threat of various infectious diseases (including zoonotic diseases) continues to exist along with the possibility of natural catastrophes and the danger of multiple crises. Under such circumstances, resilience enables a person to adapt well in emergencies, and self-efficacy raises the efficiency of adaptation and response in stressful situations. Hence, the level of self-efficacy and resilience of ECTs are important factors in responding to and acting efficiently in stressful circumstances like disasters. However, the reality of disaster-related education and research concerning ECTs is that studies are limited to ECTs' perceptions of disaster preparedness safety education (13), the relationship between infectious disease prevention knowledge and self-efficacy, emotional labor and infection prevention (14), ECTs' COVID-19 situations and stress (15), as well as their perceptions and experiences and disaster preparedness (12). There is a lack of research that identifies the correlations between ECTs' self-efficacy, resilience, stress, and disaster preparedness. As such, this study aims to determine the correlations between ECTs' self-efficacy, resilience, disaster awareness, COVID-19 stress, and work-related stress. The study also intends to confirm the influencing factors of ECTs' disaster preparedness and offer basic data that can be used to develop a program that improves ECTs' disaster preparedness capacity. The availability of basic data will help to develop programs to build ECTs' disaster management capacity, which in turn will benefit the health of infants, families, and communities.

Methods

Study design

This study has a descriptive design and was conducted to determine the impacts of ECTs' self-efficacy, resilience, disaster awareness, COVID-19 stress, and work-related stress on their level of disaster preparedness.

Participants

The participants of this study selected 7 out of 25 districts in Seoul and conducted convenience sampling to choose target daycare centers. The participants were ECTs working at public or *metropolitan* daycare centers in Seoul, South Korea, responsible for the care of children aged 3 to 7 years old. They understood the study's objectives and gave written consent to take part in the survey. Using the G*Power (Version 3.1) program, the number of participants was based on a significance level of 0.05, a test power of 0.95, a moderate effect size of 0.15, and eight predictor variables. The calculated minimum sample size was 160, and considering a 10% dropout rate, data were collected from 176 participants. Excluding data from nine incomplete responses, data from 167 participants were analyzed.

Measures

Self-efficacy

Self-efficacy was measured using Sherer et al.'s (16) tool modified by Kim (17). It has been modified and supplemented to align with the emotional aspects of Koreans, and it is frequently used to assess the specific self-efficacy of Korean adults. This tool inquiries about the level of confidence individuals have in their ability to successfully perform various activities, including daily life, and includes a self-efficacy variable related to problem-solving.

It is a 14-item tool with a scale that ranges from 1 for *not at all confident* to 10 for *completely confident*, with a minimum score of 14 and a maximum score of 140. Higher scores indicate a greater level of self-efficacy. In Kim's (17) study, the reliability of the tool had a Cronbach's α of 0.98, while in the present study, the Cronbach's α was 0.96.

Resilience

Resilience was measured using the California Psychological Inventory (CPI) adapted by Klohnen (18) from the California Adult

Q-Set (CAQ) by selecting 48 items that had a correlation of 0.20 or higher with items on self-resilience, and excluding one item that had a correlation with another CPI subscale. The final 29 items, translated by Park (19), were used. This tool was employed in a study that yielded results confirming the resilience of Korean. ECTs (20), and its statistical reliability and validity were verified, and its applicability to ECEC in Korea was confirmed. The tool used in this study consists of four subfactors—self-confidence (9 items), interpersonal effectiveness (8 items), optimism (10 items), and anger (2 items)—and each item is measured on a 5-point scale. Scores range from a minimum of 29 points to a maximum of 145 points, where a higher score indicate a greater level of self-resilience. In Park's (19) study, the Cronbach's α was 0.91, while in the present study, the Cronbach's α was 0.92.

COVID-19 stress

The COVID-19 stress scale in this study involved all but one of the 21 items from the COVID-19 stress scale developed by Kim et al. (21). The original scale consists of three factors: Factor 1 is about fear of infection with 9 items, Factor 2 is about difficulty with social distancing with 6 items, and Factor 3 is about anger toward others with 6 items. This study used a modified version with 20 items that combined questions about rallies and gatherings under Factor 3. The reliability (Cronbach's α) of Kim et al.'s (2021) tool was 0.914, while that of this study was 0.89.

Work-related stress

Work-related stress was measured using 23 items adapted from Lee et al. (7) to gage work-related stress in ECTs. These 23 items were taken from the 43 translated items (translated by the Korea Institute of Occupational Safety and Health), originally provided in the work-related stress measurement tool developed by the U.S. National Institute for Occupational Safety and Health (NIOSH). The tool includes a 4-point scale consisting of various sub-factors—job demands (4 items), job autonomy (4 items), interpersonal conflict (3 items), job insecurity (2 items), the organizational system (4 items), inadequate compensation (3 items), and work culture (3 items)—where a higher score implies a greater level of work-related stress. In Lee et al. (7), the reliability of the instrument had a Cronbach's α of 0.90, while in the current study, the Cronbach's α was 0.84.

Disaster preparedness

General disaster preparedness

The tool used in this study to measure general disaster preparedness (GdP) was developed by the Japanese government to investigate adults' general preparedness in the face of calamities (22). This study modified and supplemented 16 questions used by Han and Kwon (23), and added four questions on typhoons, traffic accidents, infectious diseases, and earthquakes, taking into account the frequency of natural catastrophes in South Korea. A total of 20 items on a scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) were used, with a minimum score of 20 points and a maximum score of 100 points, where a higher score indicates a greater level of disaster preparedness. The Cronbach's α of this study's tool coincided with that of Han and Kwon's (23) study at 0.83.

Work-related disaster preparedness

The work-related Disaster Preparedness Evaluation Tool (DPET) is currently widely used in Asia, including Japan and China (24–26). DPET is a disaster preparedness evaluation tool that classifies different phases of a crisis into the pre-disaster preparation phase, the disaster mitigation and response phase, and the disaster evaluation (recovery) phase (27); it consists of 46 questions. Among the 25 DPET items related to disaster preparedness translated by Han et al. (28), this study selected and revised 14 items relevant to ECTs and added one item on infectious diseases. Hence, a total of 15 questions were used for measurement. Each question was scored from 1 (*strongly disagree*) to 5 (*strongly agree*), with a total minimum score of 15 and a maximum score of 75, and a higher score indicating a greater level of disaster preparedness. The Cronbach's α for each domain of the original DPET ranged from 0.91 to 0.93, while those of Han et al. (28) ranged from 0.94 to 0.96; that of this study was 0.92.

Ethical considerations and data collection

The data were collected between October and December 2021 after receiving approval from the Institutional Review Board of the one of the authors' institution (#202106-HR-010-03). The researcher gathered the data with the cooperation of 16 daycare centers that are licensed and operated as public or Seoul-based daycare centers. In accordance with the national social distancing policy, the researcher personally provided information on the study's purpose and methods along with an explanation of the study to the directors, assistant directors, and nurses at the daycare centers. Afterward, the survey was administered to ECTs who gave written consent to participate. Participants were informed that they could discontinue the survey at any time, even after completion. The survey took about 20 min to complete.

Data analysis

The collected data were analyzed using SPSS-win 21.0. The general and job-related characteristics of the ECTs were determined by frequency, percentage, mean, and standard deviation. Self-efficacy, resilience, COVID-19 stress, work-related stress, and disaster preparedness were established by mean and standard deviation. Differences in the level of disaster preparedness according to the general and job-related characteristics were analyzed through a t-test, analysis of variance, and a Scheffé test. Correlations between self-efficacy, resilience, COVID-19 stress, work-related stress, and disaster preparedness were examined using Pearson's correlation coefficient, and factors affecting disaster preparedness were explored using stepwise multiple regression analysis.

Results

The general and job-related characteristics of the participants

In terms of the participants' general characteristics, all were female, with an average age of 37.5 years (age range: 20–62), with 53 (32.7%) in the 20–29 age group, 43 (26.5%) in the 40–49 age

group, 40 (24.7%) in the 30–39 age group, and 26 (16.1%) in the 50 and older age group. In terms of marital status, 82 (50.3%) were married. Regarding work-related characteristics, regarding certifications, 109 (66.1%) participants were Level 1 ECT-certified and 56 (33.9%) were Level 2 ECT-certified. Further, 126 (76.8%) were full-time employees, while 38 (23.2%) were part-time workers. By rank, 101 (60.8%) were general teachers, 36 (21.7%) were assistant teachers, 17 (10.3%) were head teachers, and 12 (7.2%) were directors. In addition, 56 (33.7%) had more than 10 years of on-the-job teaching experience, followed by 50 (30.1%) with 5–10 years of experience. Moreover, 138 (82.6%) had disaster preparedness training. The most common type of required disaster preparedness training was fire evacuation training with 85 respondents (57.4%), followed by infectious disease prevention training with 40 respondents (27.0%), and natural disaster (e.g., earthquakes and floods) evacuation training with 17 respondents (11.8%).

As for the types of support needed, 154 participants (92.2%) said they needed support from their national and local governments to improve preparedness and response to the pandemic, with 45 participants (29.2%) saying they needed vaccines and drugs, followed by 42 (27.3%) for personal protective equipment (PPE) and supplies, 31 (20.1%) for detailed guidance, and 25 (16.2%) for response training (see Table 1).

Self-efficacy, resilience, work-related stress, COVID-19 stress, and disaster preparedness of ECTs

The score for self-efficacy averaged 105.75 ± 19.18 points out of 140 (61–140 points). The score for resilience averaged 109.93 ± 16.50 points out of 145 (69–145 points), with its sub-factors displaying the following scores: self-confidence at 34.54 ± 5.76 points (19–45 points), interpersonal effectiveness at 29.46 ± 6.17 points (14–40 points), optimism at 38.91 ± 5.97 points (23–50 points), and anger management at 7.02 ± 1.88 points (3–10 points). ECTs suffered from COVID-19 stress and work-related stress. The score for COVID-19 stress averaged 27.28 ± 10.90 points out of 80 (4–60 points), with its sub-factors demonstrating the following scores: fear of infection at 10.70 ± 6.73 points (0–33 points), difficulty with social distancing at 12.29 ± 4.57 points (0–24 points), and anger toward others at 4.29 ± 3.39 points (0–15 points). The score for work-related stress averaged 49.84 ± 7.94 points (28–76 points) out of 92, with its sub-factors displaying the following scores: job demands at 10.82 ± 2.64 points (4–23 points), job autonomy at 10.02 ± 1.31 points (6–15 points), relationship conflicts at 5.76 ± 2.14 points (3–27 points), job insecurity at 3.70 ± 1.40 points (2–8 points), the organizational system at 7.60 ± 1.78 points (3–13 points), inadequate compensation at 6.23 ± 1.33 points (3–10 points), and workplace culture at 5.71 ± 1.69 points (2–10 points).

The degree of disaster preparedness was classified into general and work-related disaster preparedness (WrDP). The score for GdP averaged 61.10 ± 9. Seventy two points out of 100 (41–98 points), and that for WrDP averaged 57.85 ± 8.77 points out of 75 (28–75 points), with its sub-factors demonstrating the following scores: the preparation phase at 25.46 ± 3.45 points (13–30 points), the response phase at 13.24 ± 3.35 points (4–20 points), and the evaluation (recovery) phase at 19.15 ± 3.26 points (11–25 points) (see Table 2).

Differences in disaster preparedness among ECTs according to their general and job-related characteristics

There were no significant differences in GdP according to the general and work-related characteristics of ECTs. There were, however, significant differences in WrDP with respect to employment type and rank. Full-time teachers scored an average of 58.66 ± 8.75 points, which was significantly higher than part-time teachers, who scored 55.29 ± 8.70 points ($t = 2.08$, $p = 0.039$). Moreover, directors of childcare centers scored an average of 65.33 ± 7.09 points, which was significantly higher than the scores of general teachers at 57.81 ± 8.48 points and assistant teachers at 55.06 ± 8.08 points ($F = 4.51$, $p = 0.005$) (see Table 1).

Correlations between disaster preparedness and ECTs' self-efficacy, resilience, disaster awareness, COVID-19 stress, and work-related stress

This study examined the correlations between disaster preparedness and ECTs' self-efficacy, resilience, disaster awareness, COVID-19 stress, and work-related stress, and found that GdP was positively associated with higher self-efficacy ($r = 0.220$, $p = 0.004$), stronger resilience ($r = 0.352$, $p < 0.001$), and lower work-related stress ($r = -0.249$, $p = 0.001$). WrDP was associated with higher self-efficacy ($r = 0.309$, $p < 0.001$), stronger resilience ($r = 0.286$, $p < 0.001$), lower work-related stress ($r = -0.209$, $p = 0.007$), and increased GdP ($r = 0.471$, $p < 0.001$) (see Table 3).

Factors influencing the disaster preparedness of ECTs

A stepwise multiple regression analysis was performed on the variables of self-efficacy, resilience, work-related stress, and WrDP—which were determined to be correlated to ECTs' GdP—to identify the factors influencing GdP. According to analysis, WrDP and resilience were found to be influencing factors with an explanatory power of 26.4% ($F = 30.76$, $p = <0.001$) (see Table 4). Upon verifying the assumptions of the independent variables in the multiple regression analysis, the tolerance limit was determined to be 0.918 (less than 1.0) and the variation inflation factor (VIF) was 1.089 (less than 10), demonstrating no multicollinearity problems. Furthermore, the Durbin-Watson value was 1.727, indicating that the autocorrelation of errors was mutually independent.

Likewise, a stepwise multiple regression analysis was carried out on the variables of self-efficacy, resilience, work-related stress, and GdP—all of which were correlated to ECTs' WrDP—in order to identify the factors influencing WrDP. According to the analysis, disaster preparedness and self-efficacy were influencing factors with an explanatory power of 25.7% ($F = 29.71$, $p = <0.001$). When checking the assumptions of the independent variables in the multiple regression analysis, the tolerance limit was determined to be 0.952 (less than 1.0) and the VIF was 1.051 (less than 10), demonstrating no multicollinearity problems. Moreover, the Durbin-Watson value was 1.681, indicating that the autocorrelation of errors was mutually independent (see Table 5).

TABLE 1 Differences in disaster preparedness based on participants' general and job-related characteristics.

						(*N*=167)
		n (%)	General disaster preparedness		Work-related disaster preparedness	
			Mean ± SD	*t*/*F* (ρ)	Mean ± SD	*t*/*F* (ρ)
Age[†] (year)	20–29	53 (32.7)	60.79 ± 10.16	1.47	56.57 ± 9.16	1.78
	30–39	40 (24.7)	59.40 ± 9.98	(0.224)	56.40 ± 9.68	(0.154)
	40–49	43 (26.6)	61.86 ± 9.04		59.81 ± 7.92	
	50 or older	26 (16.1)	64.31 ± 8.64		59.54 ± 7.82	
Marital status[†]	Married	82 (50.3)	60.61 ± 10.07	−0.93	57.48 ± 9.04	−0.78
	Single	81 (49.7)	62.04 ± 9.32	(0.349)	58.54 ± 8.47	(0.438)
Certification types[†]	Level 1 childhood educator	109 (66.1)	61.49 ± 9.26	−0.77	58.17 ± 8.38	−0.67
	Level 2 childhood educator	56 (33.9)	60.27 ± 10.18	(0.441)	57.21 ± 9.24	(0.502)
Employment types[†]	Full-time	126 (76.8)	61.69 ± 9.93	1.25	58.66 ± 8.75	2.08
	Part-time	38 (23.2)	59.42 ± 9.19	(0.211)	55.29 ± 8.70	(0.039)
Position[†]	Director	12 (7.2)	63.08 ± 10.00	5.27	65.33 ± 7.09[ab]	4.51
	Head teacher	17 (10.3)	60.24 ± 9.37	(0.845)	59.12 ± 8.31	(0.005)
	General teacher	101 (60.8)	61.25 ± 9.99		57.81 ± 8.48[a]	
	Assistant teacher	36 (21.7)	60.42 ± 9.45		55.06 ± 9.08[b]	
On-the-job teaching experience[†] (years)	< 1	8 (4.8)	57.88 ± 16.44	0.29	54.25 ± 10.58	1.12
	1 ≤, < 3	31 (18.7)	61.52 ± 9.22	(0.883)	57.42 ± 9.12	(0.350)
	3 ≤, <5	21 (12.7)	60.57 ± 8.96		56.33 ± 9.70	
	5 ≤, < 10	50 (30.1)	60.96 ± 9.72		57.56 ± 8.13	
	≤ 10	56 (33.7)	61.66 ± 9.44		59.64 ± 8.40	
Experience in disaster preparedness education	Yes	138 (82.6)	61.38 ± 9.71	0.81	57.97 ± 8.76	0.39
	No	29 (17.4)	59.76 ± 9.85	(0.417)	57.28 ± 8.95	(0.699)
Need for disaster preparedness education	Yes	148 (88.6)	61.03 ± 9.79	−0.26	57.39 ± 8.81	
	No	19 (11.4)	61.63 ± 9.43	(0.799)	61.47 ± 7.74	
Types of necessary disaster preparedness education	Fires	85 (59.0)				
	Natural disasters	17 (11.8)				
	Maritime accidents	2 (1.4)				
	Infectious diseases	40 (27.8)				
Necessary government support	Yes	154 (92.2)	61.22 ± 9.89	0.57	57.60 ± 8.78	−1.29
	No	13 (7.8)	59.62 ± 7.60	(0.569)	60.85 ± 8.38	(0.200)
	Education	11 (7.2)				
	Response training	25 (16.2)				
	Equipment, supplies	42 (27.3)				
	Vaccines, drugs	45 (29.2)				
	Detailed guidance	31 (20.1)				

[†]Included missing data.
[ab]Scheffe *t*-test.

Discussion

COVID-19 has profoundly impacted individuals and workplaces, but its impact on ECTs is unclear (29). The pandemic has influenced ECTs' work practices, leading to work-related stress and burnout (30). In response, multidimensional efforts are recommended to increase understanding of work-related stress and promote resilience. This research was conducted as a preliminary study to identify the influencing factors for ECTs when adapting to and overcoming disaster situations as part of carrying out ECEC, while also providing measures to promote individual resilience.

To this end, the study classified factors that affect ECTs' disaster preparedness into two main areas, and discussed problems identified during the analysis.

First, through the examination of disaster preparedness based on general and job characteristics, it was found that there were differences in the degree of preparedness depending on employment type and rank. Full-time teachers and directors displayed higher WrDP than part-time teachers and general or assistant teachers, respectively. This finding is consistent with that of previous research, which suggests that less experienced educators are less capable of managing adversity experienced by children compared to their more experienced counterparts (31). The sudden onset of COVID-19 left ECTs unprepared in both personal and professional domains (32), and has led to a significant spike in ECTs' workload due the high likelihood of infections in the workplace, increased number of tasks, and greater responsibility regarding children's safety (32). Under such circumstances, full-time teachers with relatively higher work stability and directors with more experience may have been able to adapt more easily to sudden changes that followed the COVID-19 pandemic. Disaster management capacity is the ability to respond immediately to disasters and minimize

TABLE 2 The degree of self-efficacy, resilience, work-related stress, COVID-19 stress, and disaster preparedness of ECTs.

				(*N*=167)
		Mean ± SD	Minimum	Maximum
Self-efficacy		105.75 ± 19.18	61.0	140.0
Resilience		109.93 ± 16.50	69.0	145.0
	Self-confidence	34.54 ± 5.76	19.0	45.0
	Interpersonal effectiveness	29.46 ± 6.17	14.0	40.0
	Optimism	38.91 ± 5.97	23.0	50.0
	Anger management	7.02 ± 1.88	3.0	10.0
COVID-19 stress		27.28 ± 10.90	4.0	60.0
	Fear of infection	10.70 ± 6.73	0.0	33.0
	Difficulty with social distancing	12.29 ± 4.57	0.0	24.0
	Anger toward others	4.29 ± 3.39	0.0	15.0
Work-related stressors		49.84 ± 7.94	28.0	76.0
	Job demands	10.82 ± 2.64	4.0	23.0
	Job autonomy	10.02 ± 1.31	6.0	15.0
	Relationship conflicts	5.76 ± 2.14	3.0	27.0
	Job insecurity	3.70 ± 1.40	2.0	8.0
	Organizational system	7.60 ± 1.78	3.0	13.0
	Inadequate compensation	6.23 ± 1.33	3.0	10.0
	Workplace culture	5.71 ± 1.69	2.0	10.0
General disaster preparedness		61.10 ± 9.72	41.0	98.0
Work-related disaster preparedness		57.85 ± 8.77	28.0	75.0
	Preparation phase	25.46 ± 3.45	13.0	30.0
	Response phase	13.24 ± 3.35	4.0	20.0
	Evaluation phase	19.15 ± 3.26	11.0	25.0

TABLE 3 Correlations between disaster preparedness and ECTs' variables.

						(*N*=167)
	Self-efficacy	Resilience	Disaster awareness	COVID-19 stress	Work-related stressors	General disaster preparedness
			r(*p*)			
General disaster preparedness	0.220	0.352	0.146	0.007	−0.249	
	(0.004)	(< 0.001)	(0.059)	(0.924)	(0.001)	
Work-related disaster preparedness	0.309	0.286	0.142	−0.113	−0.209	0.471
	(< 0.001)	(< 0.001)	(0.066)	(0.147)	(0.007)	(< 0.001)

damage, and it is essential for ECTs, who need to respond promptly to calamities and reduce children's and their own vulnerability to hazards (7). It is believed that groups with a fairly high level of stability and more experience manifest greater adaptability by setting goals and planning in stressful situations.

Second, resilience and WrDP were identified as influencing factors of ECTs' GdP, with an explanatory power of 26.4%. A study of Italian teachers found that those with lower baseline resilience experienced more COVID-19-related symptoms of anxiety, depression, stress, and burden than those with higher resilience (33). Self-resilience refers to the ability to respond appropriately in unfamiliar situations, and it is believed that resilience acts as a force that enables people to flexibly cope with diverse stressful circumstances, thereby minimizing physical and mental symptoms. Furthermore, self-efficacy and GdP were identified as influencing factors of ECTs' WrDP, with an explanatory power of 25.7%. This finding is consistent with that of a previous study (12), which determined that greater self-efficacy and GdP among ECTs revealed a higher level of WrDP. Resilience and self-efficacy are beliefs in one's ability to successfully perform a task, and they are deemed to act as moderating factors in improving disaster management capabilities.

Third, a lack of institutional support that encourages resilience and self-efficacy prevents the implementation of practical capacity-building training. Tension caused by the COVID-19 pandemic has

TABLE 4 Influencing factors of general disaster preparedness of ECTs.

								(*N*=167)
	B	*S.E*	*β*	*t(ρ)*		Adj R^2	*F*	*ρ*
	19.94	5.39		3.70	(< 0.001)	0.264	30.76	< 0.001
Work-related disaster preparedness	0.45	0.08	0.40	5.80	(< 0.001)			
Resilience	0.14	0.04	0.24	3.40	(0.001)			

TABLE 5 Influencing factors of work-related disaster preparedness of ECTs.

								(*N*=167)
Independent variables	*B*	*S.E*	*β*	*t(ρ)*		Adj R^2	*F*	*ρ*
	24.08	4.48		5.37	(< 0.001)	0.257	29.71	< 0.001
General disaster preparedness	0.38	0.06	0.42	6.17	(< 0.001)			
Self-efficacy	0.10	0.03	0.22	3.16	(0.002)			

had a significant impact on the emotional well-being and mental health of ECTs (34), acting as a major stressor. Compared to a preceding study conducted with the same ECTs in 2021 (12), there was a slight increase in resilience, but a dip in self-efficacy. As the pandemic became prolonged, the resilience of ECTs—who had gotten used to changing circumstances—increased. Nonetheless, their sense of self-efficacy declined somewhat because they felt inadequate when responding to disasters and experienced difficulties in their disaster response capabilities in comparison to the beginning of the COVID-19 pandemic. The reasons behind such reactions may be inferred from Quinones (35). Some ECTs perceived that most disaster response manuals were structured around schoolteachers, and that their work was not as worthy and that they were treated with less value than schoolteachers (35). This may have served as an extrinsic motivation for ECTs in lowering their self-belief during emergency situations, which in turn contributed to lower self-efficacy. The present study confirmed that most ECTs in such a scenario are in need of disaster preparedness training and active forms of state support. In addition to human and material resources for disaster preparedness, these teachers also need detailed guidelines for disaster response.

While the emotional health and well-being of infants and young children during COVID-19 have been discussed (36), there has been a lack of research on the health and protection of ECTs, who are responsible for the care and education of these children (37). According to this study, when ECTs' emotional health and wellbeing are given higher priority than those of infants and young children, quality care and education will be provided, and their disaster response capacity will also increase. Hence, disaster response capacity training that strengthens the self-efficacy and resilience of these teachers should be implemented. This study also asserts that increasing disaster response capacity is not limited to the health and safety of infants and young children; it also plays a crucial role in managing the health of the general population through the national infection control system. In this regard, modifications should be made to the current direction of education and mental health promotion of disaster response in South Korea, which focuses on students and young children. The Ministry of Health and Welfare and related organizations have prepared disaster response manuals and psychological support plans for infants and young children and distributed them to frontline organizations. The major issue, however, is that there is an absence of protection and capacity-building support policies for ECTs, who protect and educate these children in difficult situations. As such, this study calls for active training and support to enhance the self-efficacy and resilience of ECTs working in ECEC settings to reduce disaster stress. This study highlights the necessity of stockpiling emergency medications, as well as the provision of PPE and supplies requested by those in ECEC settings, in addition to strengthening disaster response capacity at schools. The CDC recommends tailored guidance for teachers of young children (38). In line with this advice, this study calls for the development of specific disaster response guidelines for ECTs working with infants and toddlers in ECEC settings, as well as enhanced on-site response drills that may be practiced in the presence of infants and toddlers. Strategies for disaster preparedness capacity building should be tied to community settings, such as the availability of resources, the health status of infants and toddlers, and the community's demographic composition (39). Enhanced prevention strategies may also be necessary in ECCE settings (39).

The participants in this study were selected using convenience sampling and ECTs working in Seoul, South Korea, which has a relatively well-established disaster response system, so the results cannot be said to represent the situations of all ECTs across the country. Hence, the findings cannot be generalized, and future research should be conducted by recruiting participants through nationwide random sampling. Moreover, this study is limited in that it used self-reported data based on a cross-sectional survey design, which makes it difficult to identify a causal relationship between the variables. In addition, unexamined variables were not controlled for.

Future research should collect qualitative data through focus group interviews and quantitative studies should be performed that include diverse variables to derive comprehensive impact variables in order to not only examine disaster preparedness from an ecological standpoint, but also look more closely into the influencing factors to specifically identify responses at the individual, community, and national levels. Nevertheless, this study is meaningful in that it calls attention to ECTs, who are the caregivers of infants and toddlers and manage their health in the context of South Korea, where disaster response training and healthcare are carried out at childcare centers. In particular, it is significant because it offers an opportunity to

reevaluate the limitations of disaster response management after a disaster by conveniently selecting and confirming the capital city that is best managed by the country. Based on the outcomes, this study also explored ways to strengthen ECTs' disaster response capacity.

Conclusion

The findings stress the importance of actively providing education and support to increase self-efficacy and resilience in individual ECTs in order to strengthen their capacity to respond to disasters. They also highlight the significance of having numerous discussions about lowering disaster-related stress. The education and mental health promotion policies for disaster response in South Korea, which are currently only implemented for infants and toddlers, must also include ECTs.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Institutional Review Board of the Seoul Women's College of Nursing (#202106-HR-010-03). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by Y-RL, S-NP, M-RL, and EN. The first draft of the manuscript was written by Y-RL and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Effect of school lockdown due to the COVID-19 pandemic on screen time among adolescents in Hungary: a longitudinal analysis

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Introduction: Studies indicate that due to school lockdown during the Coronavirus Disease 2019 (COVID-19) pandemic, screen time increased more steeply than pre-pandemic years. The aim of our study was to examine changes in screen time and its components (screen time spent on videos, games, homework, and other activities) of adolescents affected by COVID-19 school closures compared to controls from pre-pandemic years and to assess the effect of family structure and family communication.

Methods: Two sets of ninth-grader boys and girls transitioning into 10th grade were included in the analysis. The 'pre-COVID classes' (controls) completed the baseline survey in February 2018 and the follow-up survey in March 2019. 'COVID classes' (cases) completed the baseline survey in February 2020 (1 month before the COVID-19-related school lockdowns) and the follow-up survey in March 2021. Linear mixed models stratified by sex were built to assess the change in screen time over one year adjusted for family structure and communication.

Results: Our study population consisted of 227 controls (128 girls, 99 boys) and 240 cases (118 girls, 122 boys). Without COVID-19, overall screen time did not change significantly for boys, but there was a decrease in screen time for gaming by 0.63 h, which was accompanied by an increase of 1.11 h in screen time for other activities (consisting mainly of social media and communication). Because of the pandemic, all components increased by 1.44–2.24 h in boys. Girls' screen time and its components remained stable without school lockdown, while it increased for videos and homework by 1.66–2.10 h because of school lockdown. Living in a single-parent household was associated with higher, while better family communication resulted in lower screen time.

Discussion: Our results indicate that COVID-19-related school lockdowns modified the age-specific increase in screen time for boys and girls as well. This trend, however, may be counterbalanced by improving communication between family members.

KEYWORDS

screen time, lockdown, COVID-19, adolescent, longitudinal studies, quarantine, school closure

1 Introduction

During the Coronavirus Disease 2019 (COVID-19) pandemic, countries worldwide introduced different non-pharmaceutical measures to reduce and delay the surge of COVID-19 cases and mortality (1, 2). One such intervention was the initiation of school lockdowns and the provision of online education. As a result, face-to-face classes were replaced with online education from home, and families had to adapt abruptly to these drastically new circumstances (3).

Cross-sectional studies and their meta-analysis suggest that screen time was higher among students during the COVID-19 pandemic compared to pre-pandemic years (4, 5). However, cross-sectional studies suffer from limited power and are unable to differentiate between cohort and period effects. Thus, longitudinal studies examining changes before and during the COVID-19 pandemic are required to more precisely describe school closure-related changes in screen time. One such longitudinal study conducted among Canadian school-aged students, who were followed over multiple years, found a steady increase in screen time before the pandemic and a much steeper increase during COVID-19-related school closures, corroborating cross-sectional studies (6).

Screen time habits seem to show certain sex differences. For example, girls are more likely to be active on social media, while boys are more likely to engage in gaming (7). Increased screen time has been extensively associated with a wide variety of negative outcomes, such as obesity, inadequate amount of physical activity, poor sleep quality, depressive symptoms, suicidal thoughts, or not meeting certain developmental milestones (8–10).

Several determinants of screen time among adolescents are well described in the literature. Family structure seems to be an especially important factor related to screen time. Children in single-parent households and reconstituted families tend to have longer screen times (11). Communication between parents and their offspring may also play a key role, as certain communication styles are more successful than others in regulating the duration of screen time (12). Even though negative behaviors during adolescence may persist into adult life (13), certain factors, such as family, peer, or school support, may prevent the continuity of these unhealthy behaviors into adulthood (13).

Since screen time is associated with deleterious consequences on both physical and mental health of adolescents, it is extremely important to elucidate how pandemic-related factors, such as school lockdowns, modify screen time habits. Furthermore, as screen time changes with aging during adolescence (14), the best setting to investigate the effect of the pandemic-related school closures on screen time involves a longitudinal study design with a historical reference group unaffected by the pandemic. Thus, we aimed to examine school lockdown-related changes in overall screen time and its components (watching videos, playing games, doing homework, or other activities [e.g., social media]) by comparing two sets of ninth-grader boys and girls transitioning into 10th grade: one set not affected by COVID-19 and another affected by COVID-19 lockdowns. Furthermore, we also aimed to examine whether family structure or family communication modify the observed effect on screen time.

2 Materials and methods

2.1 Study design

The present study is a secondary analysis of data collected during a school-based health education program (Balassagyarmat Health Education Program [BEP]) that aimed to improve health literacy and focused on sexual health, substance use, basic life support, infection control, nutrition, and physical activity but did not cover screen time as a topic. The program was described in detail previously (15). In short, consecutive ninth graders were recruited in BEP from all five secondary schools (three grammar schools and two vocational secondary schools) in a northern Hungarian town (Balassagyarmat, approximately 15,000 inhabitants) in 2018–2020. Participants first completed a baseline survey, then participated in the health education program that spanned over a year. After completing the program, students filled in a follow-up survey, approximately one year after the baseline survey in 10th grade.

For the present analysis, we selected nineth-grade participants who completed their baseline assessment in either 2018 or 2020 (not 2019). For controls (baseline in 2018, unaffected by the COVID-19 pandemic), both baseline and follow-up surveys were filled in online under the supervision of research assistants (teachers were not present during the survey process) during school hours. For cases (baseline in 2020, affected by the COVID-19 pandemic during follow-up), baseline assessment took place in circumstances identical to controls, while the follow-up survey was filled in at home because of the school closures. Students were asked to complete the survey during specified school hours, and they could contact a research assistant online in case of any questions. Students recruited in 2019 were excluded from the current analysis because their follow-up survey was conducted during the early, transitional phase of school lockdown. The questionnaire and methodology for this study was approved by the Institutional Review Board of Semmelweis University (SE TUKEB: 276/2017). Parental approval of the participants was sought with an opt-out procedure.

2.2 Participants

All ninth-grader students were invited to participate. In 2018, out of the 454 ninth-grade students of the 'pre-COVID classes' (defined as controls), 332 agreed to participate at baseline resulting in a 0.73 sampling fraction. The baseline survey was completed in February 2018, while the follow-up survey was completed in March 2019. In the control group, 98 students were lost to follow-up. In 2020, out of the 446 ninth-grade students in the 'COVID classes' (defined as cases), 334 agreed to participate at baseline, resulting in a 0.75 sampling fraction. Cases completed the baseline survey in February 2020 (approximately 1 month before the COVID-19-related school

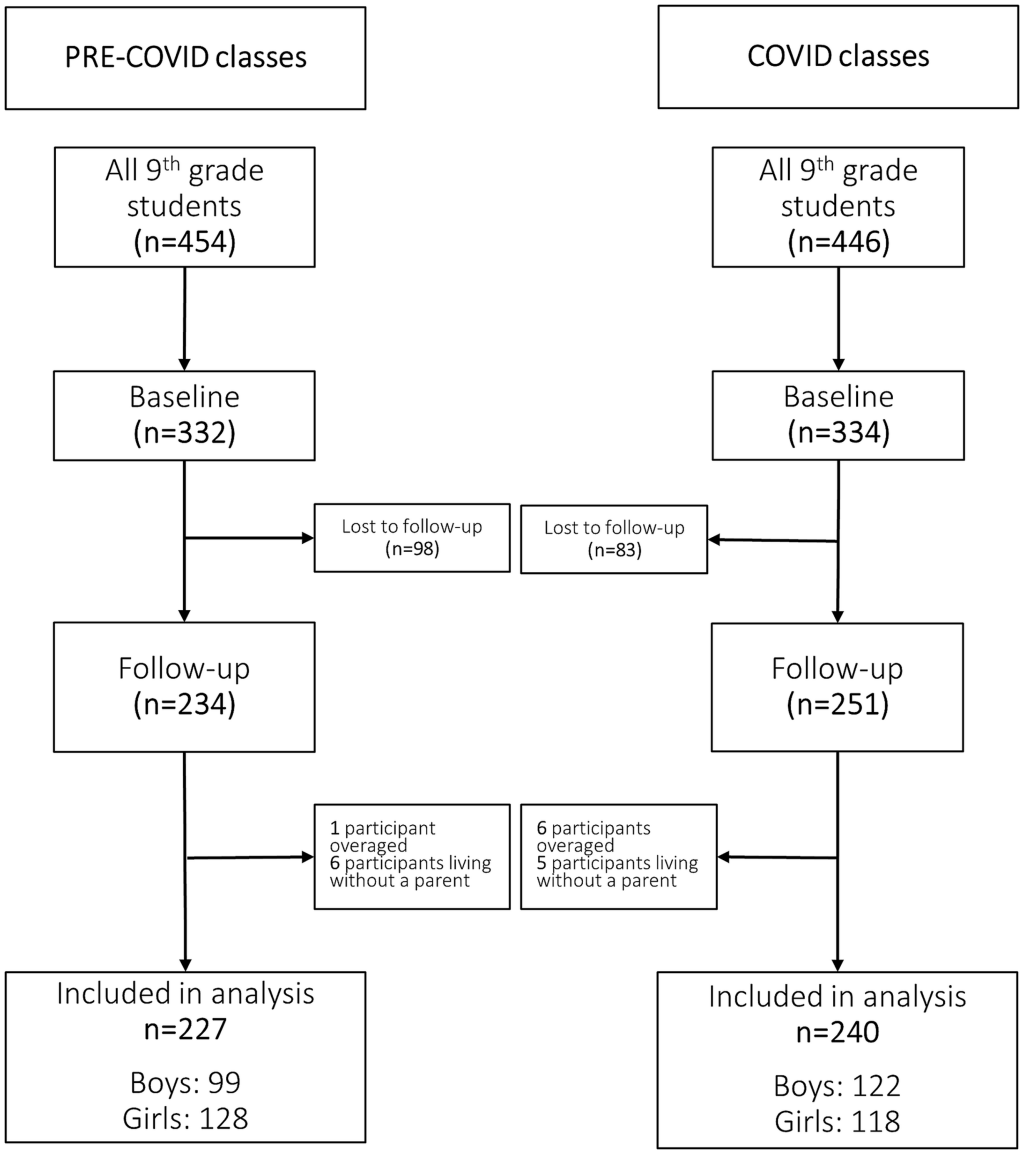

FIGURE 1
Flowchart of study participants.

lockdowns in Hungary) and the follow-up survey in March 2021. In the case group, 83 students were lost to follow-up. Flowchart of participants is presented in Figure 1. During the study period, school lockdowns affected students from 16 March 2020 to 2 June 2020 and then from 11 November 2020 to the end of study. According to the Organization for Economic Co-operation and Development (OECD) report, Hungarian secondary schools were fully closed for 164 days (excluding school holidays, public holidays and weekend) between 1 January 2020 and 20 May 2021 (16). Overaged students (mean age + 3 SD) and those living without a biological or stepparent were excluded.

2.3 Outcomes

To evaluate screen time, we used four questions based on the Hungarian version of the Health Behavior in School-aged Children study (HBSC 2014) (17, 18): (1) *'How many hours a day, in your free time, do you usually spend watching TV, videos (including YouTube or similar services), DVDs, and other entertainment on a screen?'* (2) *'How many hours a day, in your free time, do you usually spend playing games on a computer, games console, tablet (like iPad), smartphone or other electronic device (not including moving or fitness games)?'* (3) *'How many hours a day, in your free time, do you usually spend using electronic devices such as computers, tablets (like iPad) or smart phones for other purposes, for example, homework, emailing, tweeting, Facebook, chatting, surfing the internet?'* (4) *'How many hours of this do you spend on doing homework?'*. Students were required to express the amount of time spent on each activity as hours and fractions of an hour. The items resulted in five outcome variables: overall screen time (sum of Question 1, 2 and 3), screen time for watching videos (Question 1), playing games (Question 2), doing homework (Question 4), and screen time for other purposes (derived as the difference between data provided in Questions 3 and 4) representing time spent mainly on social media activities and communication).

2.4 Covariates

Since studies indicate that family support is an important protective factor against unhealthy behaviors among adolescents (13), we adjusted our results for family structure (living with two parents, with one parent, or in a stepfamily) and family communication [short version of the Clear Communication Scale from Family Dynamics Measure II [FDMII] (18, 19)] in our analyses. To assess family communication, we used the Hungarian version of the FDMII implemented in the Hungarian HSBC study 2014 (Cronbach-alfa: 0.74) (17). The questionnaire consists of four Likert items with a maximum score of 20. A higher score represents more positive judgement on family communication (17).

2.5 Statistical analysis

All analyses were conducted stratified by sex. Descriptive baseline data of pre-COVID vs. COVID classes and follow-up data of pre-COVID vs. COVID classes were compared with Chi-squared tests for categorical variables and independent samples *t*-tests for continuous variables. Descriptive baseline vs. follow-up data within pre-COVID and COVID classes were compared with marginal homogeneity tests for categorical variables and paired *t*-tests for continuous variables. Linear mixed models were built to assess the effect of COVID-19-related school lockdowns on overall screen time and on its individual components. *Model 1* includes case/control status as predictor, while Model 2 is adjusted for time-varying family structure and family communication. In our models, only family communication was treated as a continuous variable. To exclude the potential for a non-linear relationship, we tested whether adding a quadratic term of family communication would improve our models. Given that these quadratic terms were non-significant, we removed them from the final model to achieve parsimony. All other variables were categorical variables, and thus non-linearity was not investigated. Given that we had a sufficient number of cases (>200 individuals for each analysis) and only 2 time-points in a *random slope, random intercept* model, we decided to use the unstructured covariance matrix with the least number of assumptions, as it only increased the number of parameters in the model minimally (by one) compared to other frequently used covariance structures (e.g., variance component or autoregressive). Furthermore, we also tested the information criteria (AIC, BIC) of the above covariance structures, and the unstructured covariance structure had the lowest values. All statistical analyses were performed using IBM SPSS Statistics version 28.0.0.0. Statistical significance was set at $p < 0.05$.

3 Results

A total of 234 controls and 251 cases were eligible for our analysis. We excluded seven participants due to being overaged, and 11 students due to living without a parent. Thus, the final analytical sample consisted of 467 pupils: 227 pre-COVID controls (128 girls and 99 boys) and 240 cases affected by COVID-19 (118 girls and 122 boys) (Figure 1).

Few differences were present between pre-COVID and COVID classes. Female students were 0.22 years older in the COVID classes compared to pre-COVID classes. Furthermore, the family structure of girls in the pre-COVID and COVID groups was different at baseline: the proportion of two-parent families was lower in the COVID group. As for males, there were no differences between the pre-COVID and COVID groups in age, family structure, or family communication (Table 1).

TABLE 1 Descriptive statistics of pre-COVID and COVID classes.

	Pre-COVID classes		COVID classes	
	Baseline	Follow-up	Baseline	Follow-up
Boys				
n	99		122	
Age, mean ± SD	16.08 ± 0.60	–	16.16 ± 0.63	–
Family structure, *n* (%)				
Two-parent	71 (71.7%)[b]	66 (66.7%)[b]	85 (69.7%)	83 (68.0%)
Single-parent	17 (17.2%)[b]	19 (19.2%)[b]	20 (16.4%)	21 (17.2%)
Stepfamily	11 (11.1%)[b]	14 (14.1%)[b]	17 (13.9%)	18 (14.8%)
Family communication, mean ± SD	17.53 ± 2.61[b]	16.44 ± 3.56[b]	16.97 ± 3.26	16.79 ± 3.56
Girls				
n	128		118	
Age, mean ± SD	15.92 ± 0.68[a]	–	16.14 ± 0.64[a]	–
Family structure, *n* (%)				
Two-parent	94 (73.4%)[a]	92 (71.9%)	78 (66.1%)[a]	73 (61.9%)
Single-parent	25 (19.5%)[a]	26 (20.3%)	19 (16.1%)[a]	27 (22.9%)
Stepfamily	9 (7.0%)[a]	10 (7.8%)	21 (17.8%)[a]	18 (15.3%)
Family communication, mean ± SD	17.43 ± 2.56[b]	16.02 ± 4.15[b]	17.00 ± 3.11[b]	16.38 ± 3.84[b]

COVID: Coronavirus Diseases 2019; SD: standard deviation.

[a]$p < 0.05$ (Baseline data of pre-COVID vs. COVID classes and follow-up data of pre-COVID vs. COVID classes were compared with Chi-squared tests for categorical variables and independent samples *t*-tests for continuous variables).

[b]$p < 0.05$ (Baseline vs. follow-up data within pre-COVID and COVID classes were compared with Marginal Homogeneity tests for categorical variables and paired samples *t*-tests for continuous variables).

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TABLE 2 Results of liner mixed models for overall screen time expressed in hours.

	Model 1		Model 2[b]	
	Estimate (95% CI)	*p* value	Estimate (95% CI)	*p* value
Boys				
Intercept	8.46 (7.51–9.40)		8.35 (7.34–9.36)	
Classes				
pre-COVID	ref.			
COVID	**1.35 (0.12–2.57)**[a]	**0.032**	1.17 (−0.06–2.40)	0.063
pre-COVID*Time				
Baseline	ref.		ref.	
Follow-up	0.81 (−0.32–1.93)	0.158	0.53 (−0.59–1.66)	0.349
COVID*Time				
Baseline	ref.		ref.	
Follow-up	**3.27 (2.25–4.29)**[a]	**<0.001**	**3.29 (2.29–4.29)**[a]	**<0.001**
Family structure				
two-parent	–	–	ref.	
single-parent	–	–	0.66 (−0.69–2.01)	0.335
stepfamily	–	–	1.45 (−0.02–2.92)	0.053
Family communication	–	–	**−0.78 (−1.32 – −0.24)***	**0.005**
Girls				
Intercept	8.31 (7.55–9.07)		8.18 (7.37–8.99)	
Classes				
pre-COVID	ref.		ref.	
COVID	**1.52 (0.43–2.60)***	**0.007**	**1.53 (0.44–2.62)**[a]	**0.006**
pre-COVID*Time				
Baseline	ref.		ref.	
Follow-up	0.20 (−0.63–1.05)	0.646	−0.02 (−0.88–0.84)	0.969
COVID*Time				
Baseline	ref.		ref.	
Follow-up	**2.47 (1.57–3.38)**[a]	**<0.001**	**2.27 (1.37–3.18)**[a]	**<0.001**
Family structure				
two-parent	–	–	ref.	
single-parent	–	–	**1.16 (0.02–2.31)**[a]	**0.046**
stepfamily	–	–	−0.19 (−1.68–1.30)	0.804
Family communication	–	–	**−0.64 (−1.11 – −0.16)**[a]	**0.009**

95% CI: 95% Confidence Interval; COVID: Coronavirus Disease 2019. Bold values indicate significant results.

[a]$p < 0.05$.

[b]Adjusted for time-varying family structure and family communication.

Similarly, we observed some changes over the one-year follow-up. The FDMII score significantly decreased in case and control girls during follow-up. As for boys, the FDMII score as well as the proportion of two-parent families decreased in controls during follow-up. We observed no similar change in cases (Table 1).

3.1 Changes in screen time of boys

According to *Model 1*, cases' overall screen time was higher by 1.35 (95% CI: 0.12–2.57) hours compared to controls. This difference became non-significant after adjustment for family structure and family communication (MD: 1.17 [−0.06–2.40]; 9.06 [95% CI: 8.03–10.08] vs. 10.23 [95% CI: 9.35–11.09] hours) (Table 2; Figure 2). As *Model 1* and *Model 2* yielded similar results for the individual components of screen time, we only provide detailed description of *Model 2* in the following. According to *Model 2*, at baseline cases spent 0.79 (95% CI: 0.13–1.45) hours more on watching videos compared to controls (3.49 [95% CI: 2.93–4.04] vs. 4.28 [95% CI: 3.80–4.76] hours), while screen time of controls and cases was similar for playing games (3.08 [95% CI: 2.59–3.58] vs. 3.11 [95% CI: 2.68–3.54] hours), doing homework (0.79 [95% CI: 0.53–1.04] vs. 0.91 [95% CI: 0.70–1.12]

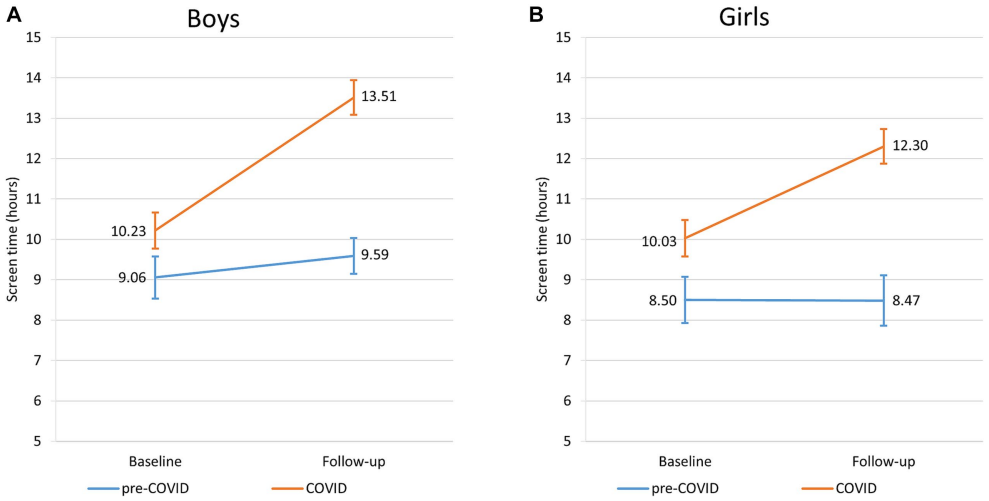

FIGURE 2
Changes of overall screen time of pre-COVID and COVID classes for boys **(A)** and girls **(B)**.

hours), and other purposes (3.00 [95% CI: 2.41–3.59] vs. 3.63 [95% CI: 3.13–4.14] hours) (Table 3; Figure 3).

In controls, with aging overall screen time did not show a significant change (9.06 [95% CI: 8.03–10.08] vs. 9.59 [95% CI: 8.55–10.63] hours) (Figure 2), however the pattern of its components was altered. Screen time for watching videos remained stable (3.49 [95% CI: 2.93–4.04] vs. 3.46 [95% CI: 2.81–4.11] hours), playing games decreased by 0.63 (95% CI: −1.12 – −0.14) hours (3.08 [95% CI: 2.59–3.59] vs. 2.45 [95% CI: 1.87–3.04] hours), doing homework also remained stable (0.79 [95% CI: 0.53–1.04] vs. 0.84 [95% CI: 0.46–1.22] hour), while screen time for other purposes increased by 1.11 (95% CI: 0.25–1.97) hours (3.00 [95% CI: 2.41–3.59] vs. 4.11 [95% CI: 3.36–4.87] hours) (Table 3; Figure 3).

In the COVID classes overall screen time increased by 3.29 (95% CI: 2.29–4.29) hours (10.23 [95% CI: 9.35–11.09] vs. 13.51 [95% CI: 12.49–14.53] hours) during the follow-up period (Table 2; Figure 2). All components of screen time also increased. Screen time spent on watching videos increased by 1.56 (95% CI: 1.05–2.08) hours (4.28 [95% CI: 3.80–4.76] vs. 5.84 [95% CI: 5.25–6.44] hours), playing games – as opposed to controls – increased by 1.44 (95% CI: 1.02–1.85) hours (3.11 [95% CI: 2.68–3.54] vs. 4.55 [95% CI: 4.01–5.09] hours), homework increased by 1.38 (95% CI: 1.02–1.73) hours (0.91 [95% CI: 0.70–1.12] vs. 2.29 [95% CI: 1.94–2.62] hours), and other purposes increased by 2.24 (95% CI: 1.49–2.99) hours (3.63 [95% CI: 3.13–4.14] vs. 5.87 [95% CI: 5.18–6.56] hours) (Table 3; Figure 3).

Furthermore, we found that boys living with only one parent spent more screen time on watching videos and playing games. We also found that boys who scored higher on family communication had lower overall screen time and screen time for watching videos and playing games (Table 2; Table 3).

3.2 Changes in screen time of girls

Similarly to boys, *Model 1* and *Model 2* yielded similar results in girls. According to *Model 2*, we detected that cases' overall screen time at baseline was higher by 1.53 (0.44–2.62) hours than that of controls (8.50 [95% CI: 7.62–9.38] vs. 10.03 [95% CI: 9.19–10.87] hours) (Table 2; Figure 2). As for the individual components, screen time spent on watching videos was higher in cases by 0.62 (95% CI: 0.06–1.17) hours than in controls (3.51 [95% CI: 3.05–3.96] vs. 4.13 [95% CI: 3.69–4.55] hours], there was no significant difference in screen time for playing games (1.51 [95% CI: 1.10–1.93] vs. 1.79 [95% CI: 1.40–2.19] hours) and doing homework (1.08 [95% CI: 0.92–1.24] vs. 1.03 [95% CI: 0.88–1.17] hours), but screen time for other purposes was also higher by 1.28 (95% CI: 0.57–2.00) hours in cases compared to controls (3.71 [95% CI: 3.14–4.29] vs. 4.99 [95% CI: 4.45–5.54] hours) (Table 4; Figure 4).

During follow-up, control girls' overall screen time remained stable (8.50 [95% CI: 7.62–9.38] vs. 8.47 [95% CI: 7.56–9.41] hours) (Table 2; Figure 2). Unlike boys', control girls' screen time did not show any significant change in the individual components with aging. They spent 3.45 h (95% CI: 2.85–4.04) on watching videos, 1.14 h (95% CI: 0.70–1.59) on playing games, 1.02 h (95% CI: 0.71–1.32) on doing homework and 4.18 h (95% CI: 3.56–4.80) for other screen time purposes (Table 4; Figure 4).

On the other hand, classes affected by COVID increased their overall screen time by 2.27 (95% CI: 1.37–3.18) hours (10.03 [95% CI: 9.19–10.87] vs. 12.30 [95% CI: 11.35–13.25] hours) (Table 2; Figure 2). As for the individual components, time spent on watching videos increased by 1.66 (95% CI: 1.13–2.19) hours (4.13 [95% CI: 3.69–4.55] vs. 5.79 [95% CI: 5.18–6.37] hours), playing games remained stable (1.80 [95% CI: 1.40–2.19] vs. 1.76 [95% CI: 1.32–2.19] hours), doing homework increased by 2.10 (95% CI: 1.80–2.40) hours (1.03 [95% CI: 0.88–1.17] vs. 3.13 [95% CI: 2.81–3.43] hours), and screen time spent on other activities increased by 1.49 (95% CI: 0.87–2.12) hours (4.99 [95% CI: 4.45–5.54] vs. 6.48 [95% CI: 5.87–7.10] hours) during follow-up (Table 4; Figure 4).

Living in a single-parent household was associated with higher overall screen time and screen time spent on social media. Higher score on family communication was associated with lower overall screen time in girls, however, it showed no association with the individual components of screen time (Table 2, 4).

TABLE 3 Results of liner mixed models for the individual components of boys' screen time expressed in hours.

	Video				Game				Homework				Other purposes			
	Model 1		Model 2[b]		Model 1		Model 2[b]		Model 1		Model 2[b]		Model 1		Model 2[b]	
	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p
Intercept	3.24 (2.74–3.75)		3.10 (2.56–3.65)		2.69 (2.24–3.15)		2.58 (2.09–3.06)		0.79 (0.56–1.01)		0.77 (0.52–1.03)		2.79 (2.26–3.33)		2.71 (2.12–3.30)	
Classes																
pre-COVID	ref.		ref.		ref.		ref.		ref.		ref.		ref.		ref.	
COVID	**0.83 (0.16–1.49)[a]**	**0.015**	**0.79 (0.13–1.45)[a]**	**0.019**	0.12 (−0.48–0.72)	0.685	0.03 (−0.57–0.62)	0.931	0.12 (−0.17–0.42)	0.413	0.12 (−0.18–0.42)	0.425	0.68 (−0.02–1.38)	0.055	0.63 (−0.08–1.34)	0.081
pre-COVID*Time																
Baseline	ref.		ref.		ref.		ref.		ref.		ref.		ref.		ref.	
Follow-up	0.07 (−0.52–0.67)	0.811	−0.03 (−0.63–0.58)	0.930	−0.46 (−0.95–0.03)	0.066	**−0.63 (−1.12 – −0.14)[a]**	**0.012**	0.05 (−0.36–0.45)	0.827	0.05 (−0.36–0.47)	0.800	**1.18 (0.33–2.04)[a]**	**0.007**	**1.11 (0.25–1.97)[a]**	**0.012**
COVID*Time																
Baseline	ref.		ref.		ref.		ref.		ref.		ref.		ref.		ref.	
Follow-up	**1.59 (1.07–2.10)**	**<0.001**	**1.56 (1.05–2.08)[a]**	**<0.001**	**1.47 (1.05–1.89)[a]**	**<0.001**	**1.44 (1.02–1.85)[a]**	**<0.001**	**1.37 (1.02–1.73)[a]**	**<0.001**	**1.38 (1.02–1.73)[a]**	**<0.001**	**2.25 (1.50–3.00)[a]**	**<0.001**	**2.24 (1.49–2.99)[a]**	**<0.001**
Family structure																
two-parent	–	–	ref.		–	–	ref.		–	–	ref.		–	–	ref.	
single-parent	–	–	**0.94 (0.18–1.70)[a]**	**0.015**	–	–	**0.78 (0.10–1.46)[a]**	**0.025**	–	–	0.13 (−0.22–0.48)	0.479	–	–	0.52 (−0.27–1.30)	0.197
stepfamily	–	–	0.22 (−0.63–1.07)	0.608	–	–	0.75 (−0.02–1.52)	0.057	–	–	−0.09 (−0.47–0.29)	0.635	–	–	0.37 (−0.50–1.24)	0.404
Family communication	–	–	**−0.32 (−0.62 – −0.02)[a]**	**0.040**	–	–	**−0.41 (−0.66 – −0.15)[a]**	**0.002**	–	–	0.10 (−0.06–0.26)	0.223	–	–	−0.07 (−0.42–0.29)	0.722

95% CI: 95% Confidence Interval; COVID: Coronavirus Disease 2019. Bold values indicate significant results.

[a]$p < 0.05$.

[b]Adjusted for family structure and family communication.

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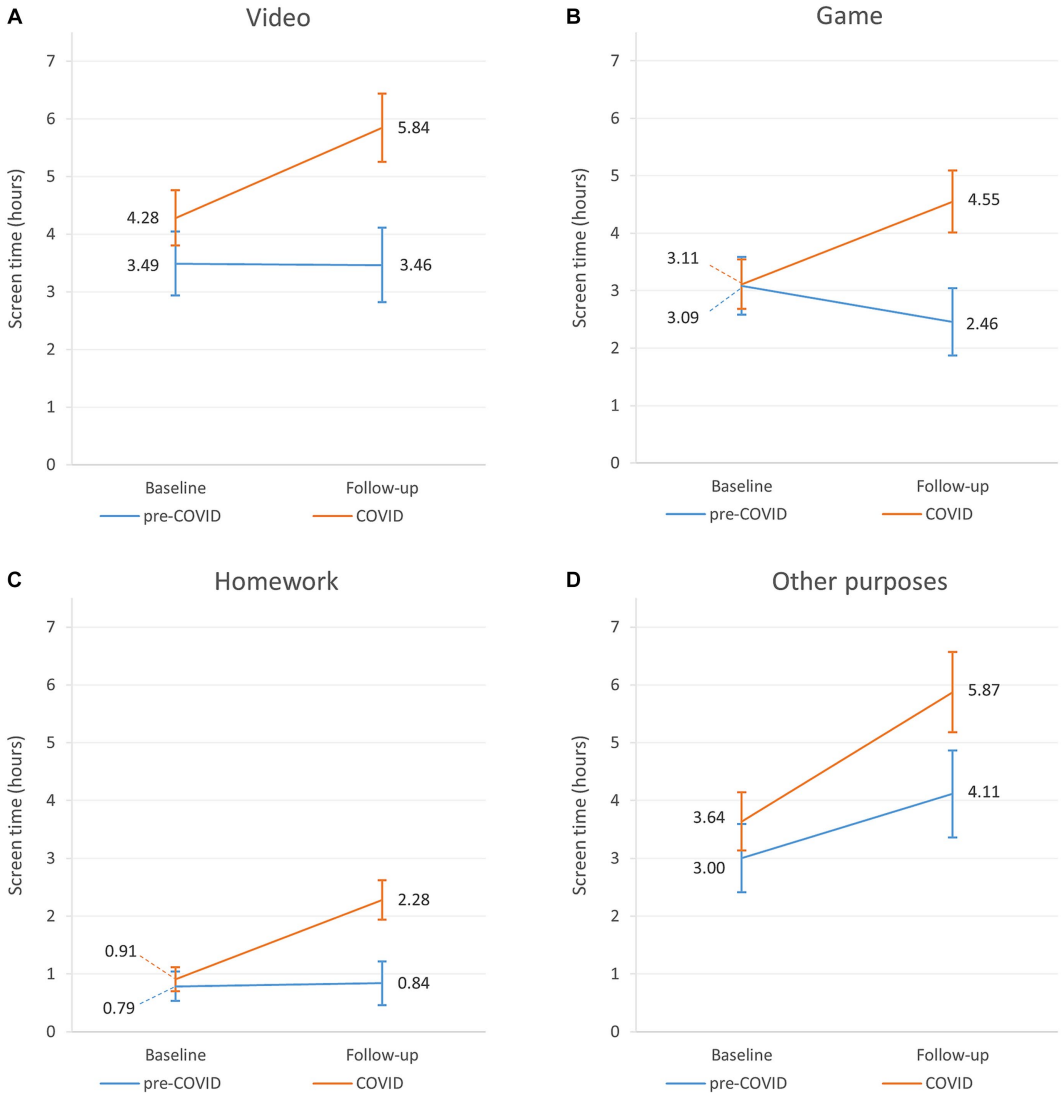

FIGURE 3
Changes of the individual components of screen time of pre-COVID and COVID classes for boys: screen time on watching videos **(A)**, playing games **(B)**, doing homework **(C)**, and other purposes **(D)**.

4 Discussion

Our study offers insight into adolescents' screen time habits before the COVID-19 pandemic and how it changed due to school lockdown. In our sample, overall screen time was around 9–10 h at baseline which is markedly higher than the recommendations (20). Both control and case boys spent the most screen time on watching videos at baseline. Without the presence of lockdown, aging of boys was associated with an increase in screen time for other purposes and a decrease in that for playing games, but the overall screen time remained stable. As for girls, the highest screen time was measured for other purposes – which consisted of mainly social media and communication – at baseline, and aging had no significant effect on their overall screen time and screen time habits. Based on our results, the COVID-19 pandemic modified these age-related trends. Boys affected by lockdown increased their overall screen time and screen time in every examined activity among which screen time for other activities showed the greatest increase. During the COVID-19 pandemic, girls also increased their overall screen time and its individual components, except for screen time for playing games, which did not change. As for family-related variables, we found that living with only one parent was associated with higher screen time for watching videos and playing games for boys and for overall screen time and social media for girls. Better family communication resulted in lower screen time for watching videos and playing games for boys and with overall screen time for girls. However, these family-related variables had no effect on the overall direction and size of the observed associations.

Several studies have reported that adolescents' screen time had been higher than the recommended amount of two hours/day recreational screen time for children and adolescents (5–17 years) (20) even before the COVID-19 pandemic and that it increased significantly during lockdown (6). Two recent meta-analyses found that total daily screen time of adolescents increased by around

TABLE 4 Results of liner mixed models for the individual components of girls' screen time expressed in hours.

	Video				Game				Homework				Other purposes			
	Model 1		Model 2[b]		Model 1		Model 2[b]		Model 1		Model 2[b]		Model 1		Model 2[b]	
	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p	Estimate (95% CI)	value of p
Intercept	3.38 (2.99–3.76)		3.35 (2.93–3.76)		1.54 (1.18–1.90)		1.63 (1.25–2.02)		1.05 (0.92–1.18)		1.04 (0.90–1.19)		3.48 (2.97–3.99)		3.25 (2.72–3.78)	
Classes																
pre-COVID	ref.		ref.		ref.		ref.		ref.		ref.		ref.		ref.	
COVID	**0.65 (0.10–1.20)**[a]	**0.021**	**0.62 (0.06–1.17)**[a]	**0.030**	0.31 (−0.20–0.82)	0.231	0.28 (−0.24–0.80)	0.288	−0.04 (−0.23–0.14)	0.633	−0.05 (−0.25–0.14)	0.593	**1.27 (0.54–2.00)**[a]	**<0.001**	**1.28 (0.57–2.00)**[a]	**<0.001**
pre-COVID*Time																
Baseline	ref.		ref.		ref.		ref.		ref.		ref.		ref.		ref.	
Follow-up	0.05 (−0.46–0.56)	0.860	−0.06 (−0.58–0.46)	0.834	−0.31 (−0.76–0.15)	0.183	−0.37 (−0.82–0.08)	0.110	−0.06 (−0.33–0.21)	0.651	−0.06 (−0.36–0.23)	0.677	0.52 (−0.08–1.13)	0.090	0.47 (−0.15–1.08)	0.135
COVID*Time																
Baseline	ref.		ref.		ref.		ref.		ref.		ref.		ref.		ref.	
Follow-up	**1.73 (1.20–2.26)**[a]	**<0.001**	**1.66 (1.13–2.19)**[a]	**<0.001**	−0.03 (−0.49–0.43)	0.889	−0.04 (−0.50–0.42)	0.862	**2.10 (1.82–2.38)**[a]	**<0.001**	**2.10 (1.80–2.40)**[a]	**<0.001**	**1.59 (0.97–2.21)**[a]	**<0.001**	**1.49 (0.87–2.12)**[a]	**<0.001**
Family structure																
two-parent	–	–	ref.		–	–	ref.		–	–	ref.		–	–	ref.	
single-parent	–	–	0.33 (−0.31–0.97)	0.310	–	–	−0.23 (−0.77–0.31)	0.399	–	–	0.02 (−0.21–0.26)	0.842	–	–	**0.92 (0.16–1.67)**[a]	**0.017**
stepfamily	–	–	0.14 (−0.67–0.96)	0.729	–	–	−0.12 (−0.81–0.56)	0.720	–	–	0.08 (−0.21–0.37)	0.589	–	–	0.47 (−0.49–1.42)	0.338
Family communication	–	–	−0.27 (−0.55–0.01)	0.059	–	–	−0.12 (−0.35–0.11)	0.320	–	–	0.01 (−0.11–0.12)	0.972	–	–	−0.29 (−0.61 – −0.03)	0.080

95% CI: 95% Confidence Interval; COVID: Coronavirus Disease 2019. Bold values indicate significant results.

[a]$p < 0.05$.

[b]Adjusted for family structure and family communication.

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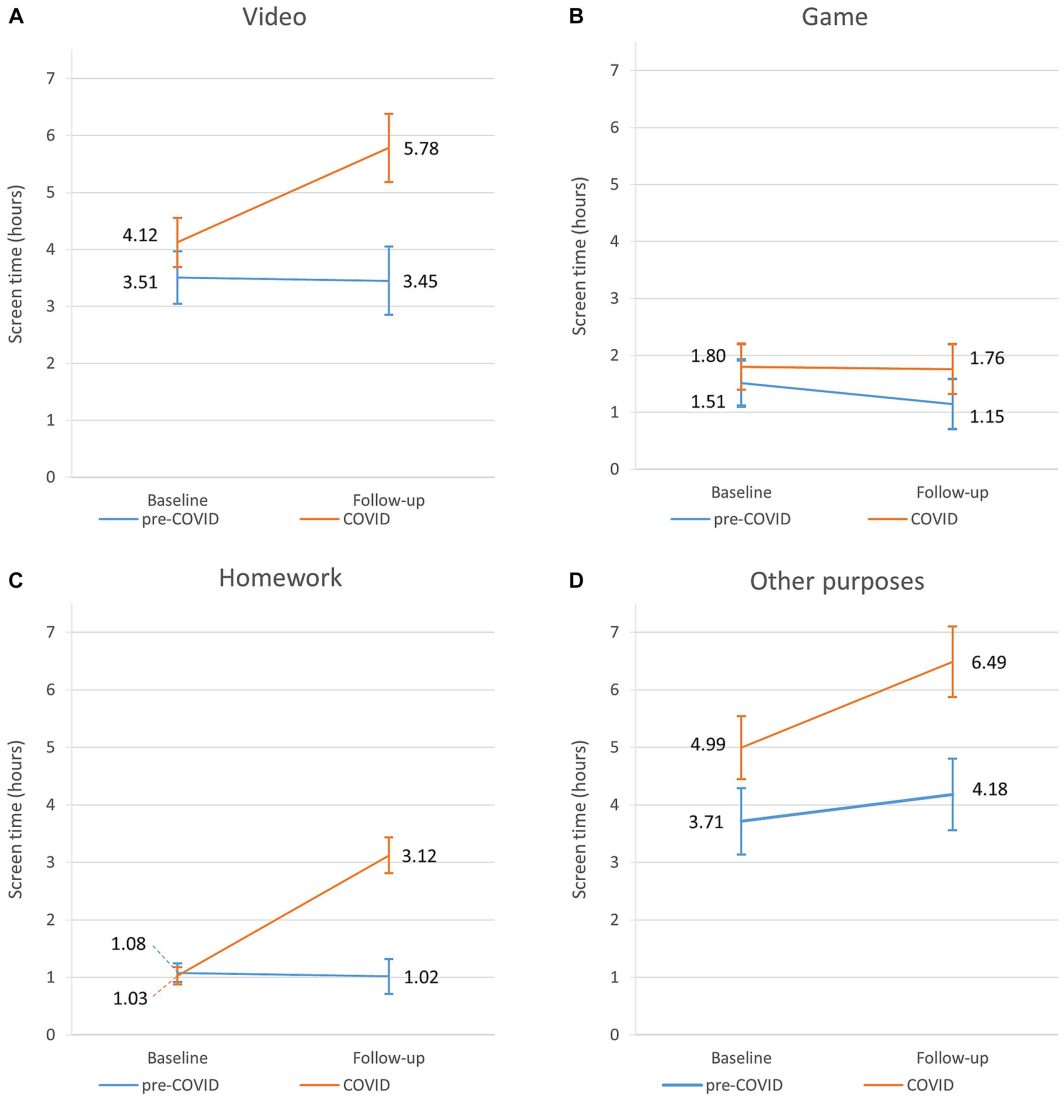

FIGURE 4
Changes of the individual components of screen time of pre-COVID and COVID classes for girls: screen time on watching videos **(A)**, playing games **(B)**, doing homework **(C)**, and other purposes **(D)**.

0.9–1.8 h/day during the COVID-19 pandemic (5, 21), which is lower than our results of 3.3 h increase for boys and 2.3 h for girls. Even though screen time tends to increase with age in adolescents (14, 22, 23), this is not supported by our results. It must be noted, however, that our study examined changes in screen time over a relatively shorter period. On the other hand, our results do corroborate the few longitudinal studies that found that the increase was much more substantial during the pandemic compared to the pandemic-free period (6, 24). Furthermore, we extend previous observations by the finding that except for time spent on gaming in girls, all forms of screen time increased significantly both in girls and boys during the pandemic. In our sample, all kinds of device use (except for homework) already exceeded the recommendations at baseline, and the lockdown added a further 1–2 h to each dimension. This is alarming as higher screen time is associated to several negative outcomes on physical health (high blood pressure, obesity, low HDL cholesterol, disrupted stress regulation, insulin resistance, impaired vision, lower bone density, poor sleep) and mental health (depression, suicidal thoughts, electronic devices dependency, antisocial behavior) (9).

The experienced negative effects may differ by the type of activity adolescents pursue on electronic devices. In our study, boys were more engaged in playing games, while girls spent more screen time for other activities, which consisted of social media and communication activities in our case. These are parallel with the results of other studies (25–27). Furthermore, even the same type of screen time could have different effects on boys and girls. Girls, for instance, are more likely to develop symptoms of depression, anxiety, loneliness, and physical symptoms, such as headache and stomachache than boys as a consequence of social media use (28, 29). Moreover, social media use may also have a detrimental effect on the overall wellbeing of girls and may also predispose girls to the development of negative body image (28, 30–33). It has also been suggested that the risk of mental health problems increases at a lower threshold of screen time (two hours/

day) in girls compared to boys (five hours/day) (34). This difference may be explained by the fact that girls are more concerned about social comparison, feedback, being accepted, and having intimate friendships (30, 35, 36).

In contrast to girls, boys spent more time on playing games in our study, which has been linked to unwanted consequences, such as depressive symptoms and lower life satisfaction (34, 37). These effects are more likely to appear after excessive amounts of gaming (34). A study found that anxiety-like symptoms appear after six or more hours of gaming, and this effect was observed only in boys, not in girls (38). This further supports that adolescents of different sexes react differently to different types of screen time. This is corroborated by a study that found greater activation in the medial frontal gyrus, the bilateral middle temporal gyri, and thalamic regions of men compared to women after gaming (37). This may explain why men are more likely to develop craving-like symptoms as a result of gaming and why they are more prone to develop gaming disorders (37). A study conducted on male internet gamers found that the reasons for gaming are entertainment, getting along with friends, stress relief, and habitual gaming. This study also found that habitual gamers are more likely to develop gaming disorder, indicating that apart from sex the reason for gaming also influences the appearance of disorders (39).

In our study, we found that adolescent boys living in single-parent households spend more time watching videos and play more games, while adolescent girls in single-parent households spend more time on social media. This is corroborated by another study that found that youth in single-parent households are more likely to exhibit unfavorable patterns of physical activity, participation in sports, and screen time behaviors (11, 40). Possible explanations to this may be the lack of time of single parents, which may be barrier for imposing restrictions on screen time, and the lack of financial resources to involve their children in extracurricular activities (11). This increased screen time, however, may be counterbalanced (at least in boys) by better communication, as seen in our study. This is in line with the results of a study that found that autonomy-supportive style of communication is more successful than controlling styles of communication, which was associated to increased screen time of children (12). Autonomy-supportive parenting aims to encourage the child's volitional functioning by allowing choice and offering relevant rationale tailored to the child's specific situation when introducing rules (12). Controlling style of communication on the other hand tries to impose the parent's own will on the child and requires the child to feel and act in a certain way (12). These results emphasize that the communication style is a key factor for parents, who want to achieve changes in their child's particular behavior, such as screen time.

4.1 Strengths and limitations

A major strength of our study is its longitudinal design, which enabled us to observe within participant trends of screen time. Studies indicate that longitudinal studies have much more statistical power and thus result in a more precise assessment of screen time, as shown by a study in which retrospective assessment was compared to longitudinal assessment (21). As observed by the authors, retrospective assessment tended to overestimate the true amount of screen time (21). Furthermore, our design allowed us to differentiate and compare the effect of aging and the pandemic. Another strength is that we examined the different dimensions of screen time, and thus were able to analyze how engagement in different screen time categories changed as a result of lockdown. A subsequent strength is that both case and control students came from the same settlement, and controls preceded cases by only two years reducing the potential of time period effects. Moreover, our study is one of the first to offer a deeper insight in screen time in Balassagyarmat, a typical city of a deprived region in central Europe.

A limitation of our study is that answers of student were not cross-referenced by parents. A study similar to ours found, however, that the estimation of screen time by students tends to be similar to the assessment of parents (6). Another limitation of our study is that we were not able to account for double screen time, for instance watching TV while scrolling social media. Our questions also did not focus exclusively on social media and had to be calculated *post hoc* from the HBSC 2014 questions. We also experienced baseline difference in males' screen time on watching videos and females' screen time on watching videos and other activities, which may be explained by the different time periods of the baseline and follow-up surveys (February vs. March) with different weather patterns and daylight hours. This, however, is less likely to have severely biased the observed trends between baseline and follow-up. Finally, our study did not contain information on other sedentary behaviors and level of physical activity.

5 Conclusion

In our study, we observed that during the study period screen time remained stable without the COVID-19 pandemic, but it increased as a result of school lockdown. With aging, in pandemic-free circumstances, girls' screen time habits remained consistent, while boys decreased their time spent on games and caught up to girls in their time spent on social media and communication activities. Lockdown modified these trends. All individual components increased in both sexes, except for playing games for girls, which remained stable. As increased screen time may result in detrimental effects on physical and mental health, it is crucial to identify risk and protective factors that may influence the amount of screen time. We found, for instance, that children in single-parent households exhibited higher screen time, which may be attributed to the lack of time and financial resources of single parents. This, however, can be counterbalanced by better family communication, especially for males, who exhibited less time watching videos and playing games as a result of better family communication in our study. Public health programs implemented to decrease screen time should target families as a whole and promote improved family communication instead of solely focusing on adolescents. These interventions should help parents familiarize themselves with communication styles, as communication in itself does not necessarily lead to decreased screen time. It must be noted, however, that our observation related to family communication may be confounded by reverse causation, as more screen time may also result in worse communication between family members. Finally, since online homework is becoming more widespread, schools should also try to come up with assignments that require physically active involvement of students instead of passive activities, such as watching videos, which may further increase passive screen time of students unnecessarily.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board of Semmelweis University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

DM, DE, DÁ, and ZU contributed to the conceptualization of the study. VF-P, AdT, and DM performed the statistical analysis. KP, VF-P, and DM wrote the first draft of the manuscript. AnT and AdT supervised the study. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Autonomous motivation, social support, and physical activity in school children: moderating effects of school-based rope skipping sports participation

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Purpose: Recent studies have shown that physical activity (PA) levels are low among children and adolescents globally. In order to reverse this trend, PA interventions are increasingly favoured. The school setting is the ideal place to address the issues that many children face. The purpose of this study was to (a) The primary focus of this study is to delve into the mediating role played by school-based rope skipping sports participation (SRSP) in the connection between social support and moderate to high-intensity physical activity (MVPA) among school children. (b) Additionally, this research aims to examine the moderating effect of within this pathway.

Methods: We conducted a survey involving 721 adolescents residing in Changsha City. The participants' ages ranged from 8 to 12 years, with an average age of 9.84 $\pm$ 1.535 years. Out of these participants, 406 were boys, and 315 were girls. To assess variables such as social support and autonomous motivation, we employed standardized measurement scales. Subsequently, we analyzed the collected data using various statistical methods, including independent s-amples t-tests, bivariate correlation analysis, descriptive statistical analysis, structural equation modeling (SEM), and the Johnson-Neyman method.

Results: An independent samples t-test revealed a statistically significant difference in MVPA between genders ($p = 0.003 < 0.05$), with boys exhibiting a higher level of engagement in MVPA compared to girls, Correlation analysis revealed significant positive associations among several key variables. Specifically, social support demonstrated a noteworthy positive correlation with autonomous motivation ($r = 0.331$, $p < 0.01$) as well as school children's engagement in MVPA ($r = 0.308$, $p < 0.01$). Moreover, autonomous motivation displayed a significant positive correlation with school children's involvement in MVPA ($r = 0.459$, $p < 0.01$). The moderating analysis revealed a significant influence of the interaction between increased participation in and social support on school children's engagement in MVPA.

Conclusion: Social support and autonomy support have been proven effective in enhancing school children's engagement in MVPA. They exert their influence indirectly by fostering autonomous motivation. Notably, robust social support can significantly benefit MVPA school children with high activity requirements, particularly those regularly engaged in MVPA during the school day.

KEYWORDS

interaction, moderate to high intensity physical activity, structural equation modelling school children, rope skipping, school children

1 Introduction

In our rapidly evolving modern society, significant shifts in lifestyles have led to a concerning trend among school children—an insufficient level of physical activity (PA), especially in the realm of moderate to high-intensity physical activity (MVPA) (1, 2). This trend gives rise to a host of issues affecting their physical and mental well-being (3, 4). Research has compellingly demonstrated the intricate connection between school children's engagement in MVPA and their overall health, social aptitude, academic performance, and mental health (5–7). Participation in MVPA offers a multitude of advantages for school children, including enhancements in cardiorespiratory fitness, muscle strength, bone development, psychological well-being, and cognitive abilities (8–11). Regrettably, the advent of modern technology and shifts in societal dynamics have profoundly transformed the lifestyles of school children. The widespread prevalence of technological devices like televisions, mobile phones, and computers has lured them into spending more time on indoor electronic leisure pursuits, leaving limited room for outdoor sports and PA (12, 13). Simultaneously, escalating academic pressures and the weighty burden of schoolwork have compelled school children to allocate more of their time to studies, subsequently reducing the time available for physical exercise (14). These converging factors have precipitated a decline in the PA levels of school children, and the adverse repercussions on their health and development are gradually becoming increasingly evident (15).

Youth participation in PA is not only determined by individual characteristics and choices, but more importantly is related to environmental factors. The campus environment is being influenced by some of the options related to exercise and the various opportunities to use physical education time for exercise (16).

It has been suggested that the school environment explains an important part of the variation in PA in school children (17, 18). In addition, the inability of school children to carry out or participate in activities at school is an important factor affecting their participation in PA (19). Therefore, PA facilities and the provision of extra-curricular activities in schools are key factors to be considered in promoting PA among school children.

Schools, being the primary environment for school children, bear the crucial responsibility of nurturing their comprehensive development (20). Within this framework, physical education stands out as a pivotal avenue for providing these students with opportunities for PA (21). Nonetheless, the degree to which school children engage in MVPA is subject to numerous influencing factors, with autonomous motivation and social support emerging as vital moderating elements (22, 23). Research has convincingly underscored the importance of self-regulation and external support in fostering MVPA among school children (24). Autonomous motivation, representing an intrinsic form of motivation, encompasses both autonomous intrinsic motivation and autonomous extrinsic motivation (25). Autonomous intrinsic motivation stems from an individual's genuine interest in an activity and their sense of personal value, Autonomous intrinsic motivation is the only predictor of moderate-intensity physical activity in school children (26), while autonomous extrinsic motivation is rooted in external rewards and acknowledgment (25). The level of autonomous motivation exhibited by school children directly relates to their motivation, persistence, and effectiveness in engaging in PA (27). Moreover, social support plays an instrumental role in influencing MVPA among school children (28). Social support (SS) is a key reinforcer of the children and young people's PA promotion (YPAP) model, and participation in PA with a range of supportive behaviors is essential to promote PA in children and young people (29). Social support encompasses emotional understanding, encouragement, recognition, and the provision of practical feedback, assistance, and resources (17). At the same time, social support may influence autonomous motivation in school children. Previous research suggests that autonomy support from a significant other may influence a person's motivation to be autonomous (30). When school children receive guidance and support from their social circles during PA, it significantly bolsters their motivation and drive to participate. Nonetheless, it is imperative to identify integrated measures that can synergistically harness the powers of autonomous motivation and social support to foster PA among school children (31). Therefore, there is a need to better understand the factors influencing school children's participation in PA and the mechanisms involved in order for interventions to provide insights.

School-based rope skipping sports participation (SRSP) offers a straightforward, cost-effective, and inclusive approach to PA, with distinct advantages (32). Through rope skipping exercises, school children can enhance their cardiorespiratory function, boost muscle strength and coordination, improve physical fitness, foster teamwork, and cultivate perseverance (33, 34). It boasts a low entry barrier, making it easy for school children of varying ages and physical fitness levels to engage in, and is well-suited for widespread adoption in schools (35). Research has demonstrated that not only bolsters school children's enthusiasm for sports but also elevates their engagement in MVPA (36). This suggests that SRSP might encourage participation among school children due to its affordability, accessibility for families of lower socio-economic backgrounds, and its interactive nature, which garners support from peers in the same class (35). However, limited research has explored the moderating effects of SRSP. Therefore, this study aims to investigate the moderating influence of SRSP on the relationship between autonomous motivation and social support, as well as MVPA among school children. It seeks to construct a conceptual model using a sample of school children to shed light on these dynamics.

In summary, this study tested a structural equation modelling (SEM) with a sample of school children. The study hypothesised that (1) there is a positive correlation between social support and autonomous motivation and MVPA in school children, effectively increasing MVPA engagement. (2) Social support enhances school children's autonomous motivation, thereby increasing MVPA. i.e.,

autonomous motivation mediates the relationship between social support and MVPA. (3) SRSP moderates' school children's autonomous motivation and social support and the relationship between the two and MVPA. Our aim was to examine in depth the relationships between autonomous motivation, social support, and MVPA in school children. In addition, we aimed to investigate the moderating effects of these relationships. By analysing these factors in depth, we hope to lay a scientific foundation for strengthening physical education in schools and promoting the overall health and development of school children.

2 Research methodology

2.1 Study design and participants

Between September and December 2022, we conducted comprehensive testing and surveys. To ensure a representative sample, we employed a whole cluster random sampling method, taking into account both urban and suburban areas. Specifically, we selected six key urban districts in Changsha City, Hunan Province, and identified one primary school (comprising grades 3 to 5) in each district. Within these selected schools, we randomly designated one class per grade as our research subjects. This process resulted in a total of 20 classes, encompassing 800 students. Following the principle of voluntary participation, our research team distributed informed consent forms to both students and their caregivers. These documents outlined the study's purpose, procedures, potential benefits, and any inconveniences that might arise. Ultimately, 750 students and their caregivers voluntarily signed the informed consent form to participate in the study. To assess PA levels, we employed accelerometers to monitor the PA of these 750 students over a one-week period. Additionally, we administered questionnaires to both the students and their caregivers. Out of the 750 questionnaires distributed, 735 were returned. After careful evaluation, 706 of these were deemed valid, resulting in a robust 96% valid return rate.

2.2 Data acquisition

2.2.1 Accelerometer

MVPA time was measured using a GT3X Human Movement Energy Monitor (ActiGraph, Pensacola, FL). Accelerometers are highly effective instruments for assessing PA levels and estimating energy expenditure in children and adolescents (37). Their widespread utilization is evident in numerous national and internation. During the study, school children were instructed to wear the accelerometers securely fastened to their hips continuously for seven consecutive days. The device should be worn for a minimum of 10 h per day, as the definition of the effective wearing time will have an impact on the PA measurements, and the devices were only removed during water-related activities and sleep. Data collection, initialization of the devices, data retrieval, and data processing were all conducted using ActiLife software (version 15.60, Pensacola, FL), with an epoch time set at 10 s. Periods where consecutive zeros exceeded 8 min were identified as non-wear time. To be included in the analyses, subjects had to provide at least 5 h of measurements on at least 24 weekdays and at least 7 h of measurements on at least 2 weekends. The accelerometer data were recorded in "count" units of measurement, and PA was categorized into different intensity levels based on these count values (38). The intensity classification standard developed by Zhu et al. for Chinese school children and adolescents was applied to categorize PA into four levels: "sedentary physical activity" (SPA), "light physical activity" (LPA), "moderate physical activity" (MPA), and "vigorous physical activity" (VPA).

3 Questionnaire design

3.1 Social support (SS) scales

Referring to Daijun et al. (39). The social support dimension of the scale, which assesses its influence on adolescents' exercise and health behaviors from the perspective of social ecology theory, comprises 4 question items (e.g., "I often participate in PA with my peers"). Participants rated these items on a 7-point Likert scale. The reliability of these items, as measured by Cronbach's alpha, was found to be 0.711 in this study. Additionally, the validated confirmatory factor analysis (CFA) metrics indicated a very good model fit: $\chi^2/df = 0.464$, RMSEA = 0.000, RMR = 0.006, GFI = 1, AGFI = 0.997, and CFI = 1.

3.2 Autonomous motivation (AM) scales

We used an adapted version of the Spanish (40) of the Exercise Behavior Modification Questionnaire (41) which contains both internal and external motivation.The scale was independently translated into Chinese by the translator, and then the translated questionnaire was discussed until a consensus was reached, resulting in a preliminary Chinese questionnaire with a reliability of 0.817, which is a good reliability, and was therefore chosen for this study. In our study, we focused on intrinsic motivation as a measure of autonomous motivation (e.g., "Because I feel pleasure and satisfaction when I do exercise," etc.). Participants rated these items on a 7-point Likert scale. The factor analysis (CFA) results indicated a good model fit: $\chi^2/df = 3.923$, RMSEA = 0.064, RMR = 0.019, GFI = 0.995, AGFI = 0.973, and CFI = 0.993.

3.3 Procedures and data analysis

Initially, we employed SPSS 26.0 (SPSS Inc., Chicago, IL, USA) to input and manage the collected data. Subsequently, we conducted Harman's one-way method test to assess any potential common method bias. Following this, we performed bivariate correlation analysis to examine relationships among different dimensions and to gauge the strength of correlation between variable factors. Descriptive statistics were used to present the data, expressed as the mean and standard deviation ($M \pm SD$). Subsequently, we employed SEM to assess the relationship between high-intensity PA, potential influencing factors, and pathways in MVPA. Given that there is only one variable for MVPA, it will not be computed when incorporated into structural equation modeling. To address this, we will establish the error variance of the single variable MVPA, which can be determined using the following formula: Error Variance of MVPA = (1 - reliability coefficient) (S2). This approach allows us to account for the single-variable nature of MVPA in the structural

equation modeling analysis. If the reliability of scores for X1 is 0.85 with a standard deviation of 5.00, then the error variance of X1 = (1–0.85)(5.00)2 = 0.15(25) = 3.75 (42). In this study, the potential variance single indicator measure MVPA reliability was set at 0.8, and using SPSS descriptive statistics, the MVPA variance (S2) was calculated as 0.328, so the error variance of MVPA in this study = (1–0.8)*0.328 = 0.067. λ0.51 was calculated from the error variance, and then the calculated results were substituted into the model (see Figure 1).

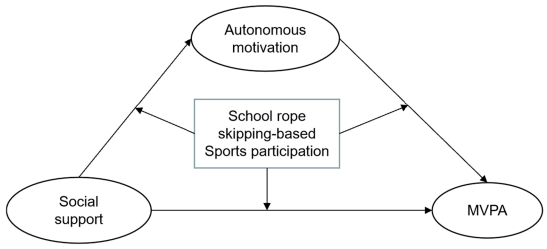

FIGURE 1
Research architecture.

SEM was conducted using AMOS 24.0 (SPSS Inc., Chicago, IL, Unite States) with maximum likelihood estimation. Model fitness was assessed using various indices, which encompassed the ratio of the minimum difference to the degrees of freedom (CMIN/DF), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), the comparative goodness-of-fit index (CFI), and the standardized mean root mean square residual (SRMR) (43, 44). The Bootstrap 5,000 method was employed to perform mediation model tests (refer to Figure 2 and Table 1). These tests encompassed the examination of model direct effects, indirect effects, and total effects. The syntax for direct effects in the structural equations was constructed to evaluate whether social support has a direct impact on school children's MVPA behavior. Additionally, the syntax for indirect effects was formulated to investigate whether social support indirectly influences school children's MVPA through autonomous motivation. Confidence intervals obtained from the estimation method were assessed to ascertain whether they contained zero at the 95% confidence level.

To conduct the moderated effects analysis, we initially computed the standardized values of the variables and the product coefficients of the interaction terms. These standardized values and interaction terms were subsequently incorporated into the model to assess the presence of moderating effects. Specifically, we aimed to determine whether the interaction terms significantly influenced the path

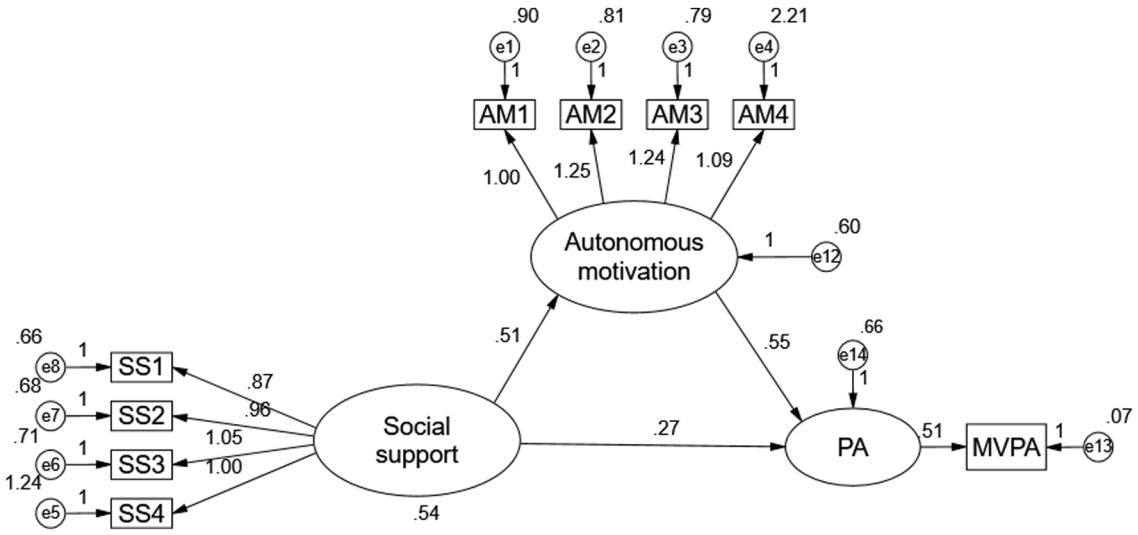

FIGURE 2
Diagram of a mediated model of PA in school children.

TABLE 1 Analysis of the effectiveness of brokering.

Form	Estimate valuation	Product of coefficients		Bootstrapping			
				bias-corrected 95 per cent CI		Percentile 95 per cent CI	
		Z	SE	Lower	Upper	Lower	Upper
Overall effect	0.547	6.924	0.079	0.390	0.707	0.392	0.709
Indirect effect	0.282	5.127	0.055	0.180	0.405	0.179	0.403
Direct effect	0.265	3.118	0.085	0.097	0.435	0.097	0.435

TABLE 2 Independent samples t-test of different genders and dimensions.

Dimension	Mean equivalence *t*-test				Gender	Number of cases	M	SD
	T	DF	*p*	Mean difference				
Social support					Girl	315	4.628	0.700
	−1.209	717	0.227	−0.074	Boy	406	4.702	0.947
Autonomous motivation	−0.297	719	0.767	−0.025	Girl	315	4.683	1.058
					Boy	406	4.708	1.169
MVPA	−2.935	719	0.003	−0.125	Girl	315	2.759	0.522
					Boy	406	2.884	0.603
SRSB	−2.495	719	0.013	−0.185	Girl	315	3.041	0.056
					Boy	406	3.226	0.048

TABLE 3 Correlation and descriptive statistics of variables in the prediction model.

Dimension (math.)	Social support	Autonomous motivation	MVPA	SRSB	M	SD
Social support	1	0.331**	0.308**	0.103**	4.670	0.848
Autonomous motivation		1	0.459**	0.155**	4.697	1.121
MVPA			1	0.198**	2.893	0.573
SRSB				1	3.146	0.993

**Correlations are significant at the 0.01 level (two-tailed) and the upper triangle is the Pearson correlation of dimensions, $N = 721$.

coefficient (γ) of the dependent variable and whether the value of p was less than 0.05, indicating statistical significance. The moderated effects plots were generated using the Johnson-Neyman's method, implemented as an SPSS plug-in within the PROCESS framework. This approach allows for a comprehensive visualization and interpretation of the moderating effects in the analysis.

3.4 Standard

This study received approval from the Ethics Committee of Xiangya School of Public Health, Central South University (project number XYGW-2022-44, issued on 20 July 2022). The research was carried out in full compliance with the principles outlined in the Declaration of Helsinki. Before participating in the survey, students were provided with clear information that their responses to the questionnaires would remain anonymous, and participation was entirely voluntary. The content of the questionnaires was treated with utmost confidentiality, and the collected data was exclusively employed for scientific research purposes. All questionnaires were collected in person, and all participants were duly informed about the study's objectives and characteristics. Furthermore, each participant willingly signed an informed consent form to formally acknowledge their agreement to participate in the study.

4 Results and analyses

4.1 Basic statistical information

In this study, independent samples t-tests were employed to investigate potential differences between genders concerning social support, autonomous motivation, and MVPA. The findings revealed that gender did not yield statistically significant differences in the dimensions of social support and autonomous motivation at the 0.05 significance level. However, notable disparities emerged among school children in MVPA and SRSP ($p = 0.003 < 0.01$, $p = 0.013 < 0.05$). Specifically, it was observed that boys exhibited a higher level of engagement in PA compared to girls (refer to Table 2).

4.2 Common methodological controls and tests

To mitigate potential common methodological biases in the gathered data, a systematic approach was implemented to oversee the measurement process. The Harman one-factor method was specifically employed to examine the presence of common bias. The results of this analysis revealed the existence of two factors with eigenvalues exceeding 1. However, it's noteworthy that the first factor accounted for only 26.96% of the total variance, which fell below the critical threshold of 40%. This outcome indicates that there was no substantial evidence of common method bias affecting the study's findings (45).

4.3 Correlation analysis of variables

Pearson correlation analyses were diligently executed for each variable, and the resulting correlations are meticulously presented in Table 3. These findings reveal noteworthy patterns of association among the variables. Specifically, it was observed that social support exhibited a significantly positive correlation with autonomous motivation, MVPA, and SRSP ($r = 0.331$, $p < 0.01$, $r = 0.308$, $p < 0.01$,

r = 0.103, $p < 0.01$). Furthermore, autonomous motivation demonstrated a significant positive correlation with MVPA and (r = 0.459, $p < 0.01$, r = 0.155, $p < 0.01$). Additionally, exhibited a significant positive correlation with MVPA (r = 0.198, $p < 0.01$). These correlations underscore the interconnectedness of these variables within the study's context.

4.4 Analysis of mediating effects of autonomous motivation

As shown in Figure 2, the fit indices of the mediation model are as follows: $\chi^2 = 39.807$, df = 43, $\chi^2/df = 1.592$, GFI = 0.988, AGFI = 0.979, CFI = 0.991, NFI = 0.975, TLI = 0.986, RMSEA = 0.029, RMR = 0.024, and the prediction γ of the social support on the autonomous motivation is 0.51, $p < 0.001$. The predicted γ for social support was 0.51, $p < 0.001$, the predicted γ for social support on MVPA was 0.27, $p < 0.001$, and the predicted γ for autonomous motivation on MVPA was 0.55, $p < 0.001$, predicting that autonomous motivation mediates the relationship between social support and children's MVPA. In order to calculate the mediating effect more accurately, this paper tested the mediating effect with structural equation modelling analysis, firstly using Bootstrap 5,000 estimation technique to estimate the standard error of the mediating effect, and then further calculating the significant level of the mediating effect. The results showed (Table 1) that the total effect of social support on children's MVPA was 0.547, with a standard error of 0.079 and a Z-value of 6.924, which meets the criterion of greater than 1.96.

At 95% confidence level, the lower limit of the confidence interval obtained by the Bias-corrected estimation method is 0.390, and the upper limit is 0.707, the lower limit of the confidence interval obtained by the Percentile estimation method is 0.392, and the upper limit is 0.709, which does not include zero, so the total effect is established. Similarly, the indirect and direct effects are also valid. The value of indirect effect is 0.282, accounting for 51.6%, and the direct effect is 0.265, accounting for 48.4%. Therefore, autonomous motivation has a mediating effect on social support and MVPA.

4.5 A mixed model test of the moderating effects of SRSP

SEM was used to examine the mechanisms of social support, SRSP, the interaction between the two aforementioned, and autonomous motivation on children's MVPA, using great likelihood estimation to test the hypothesised model shown in Figure 3. In this, the interaction terms were standardised and then the multiplication of the interaction terms was calculated and brought into the SEM, if the interaction terms were significant then an interaction existed. In Figure 3, the fit indices of the mixed model are as follows: $\chi^2 = 54.098$, df = 43, $\chi^2/df = 1.258$, GFI = 0.988, AGFI = 0.978, CFI = 0.994, NFI = 0.970, TLI = 0.990, RMSEA = 0.019, and RMR = 0.022, which are within the good range of the fit indices. Within the range, so it can be concluded that the data fit the model well. The results showed that the path coefficient γ of the interaction term (social support × SRSP) on children's MVPA was 0.09, CR = 2.17, $p = 0.03 < 0.05$, indicating that the direct moderating effect of SRSP was significant. The path coefficient γ of the interaction term (social support × SRSP) on autonomous motivation was 0.05, CR = 1.49, $p = 0.14 > 0.05$, indicating that the moderating effect of SRSP on the relationship between social support and children's MVPA was not established, i.e., the effect of SRSP on the relationship between social support and children's MVPA could not be achieved through the mediation of autonomous motivation in the first half of the interaction term. Mediated by the first half of the The path coefficient γ of the interaction term (autonomous motivation × SRSP) on children's MVPA was-0.03, CR = −0.74, $p = 0.46 < 0.05$, indicating that the moderating effect of SRSP on autonomous motivation and children's MVPA was not established. The path coefficient γ of SRSP on children's MVPA was 0.13, CR = 3.38, $p = 0.00 < 0.05$, and the path coefficient γ of SRSP on autonomy motivation was 0.09, CR = 2.71, $p = 0.01 < 0.05$. This result verified that the effect of social support on children's MVPA was moderated by SRSP.

4.6 Johnson-Neyman's diagram of moderating effects

To better understand the moderating effect in the relationship between social support and MVPA in school children and identify the conditions under which this moderating effect occurs, the Johnson-Neyman test method was employed. The results, as illustrated in Figure 4, indicate that the moderating effect starts at a value of minus 2.105. Within this interval, there is no significant difference observed on the left side, suggesting that lower levels of SRSP do not significantly moderate the relationship between social support and MVPA in school children.

However, on the right side of the interval, concerning higher levels of SRSP, there is a significant moderating effect observed in the relationship between social support and MVPA in school children. This implies that when school children engage in higher levels of SRSP, the interaction between this participation and social support significantly affects their MVPA.

5 Discussion

5.1 Social support, autonomous motivation directly explains school children's MVPA

The findings of this study reveal several significant relationships within the context of school children's PA. Specifically, the study highlights that both social support and autonomous motivation are positively linked to school children's MVPA. Moreover, the quality of teacher-student relationships, peer relationships, parental support, and the degree of autonomy school children perceive within their school environment directly impact their emotional experiences. These emotional experiences, in turn, play a pivotal role in shaping school children's commitment to engaging in MVPA. We found multiple studies examining the relationship between teacher influence and school children's PA participation. For example, teacher support positively predicted school children's PA participation, and physical education teacher support in particular positively promoted school children's participation in PA (46–48). Furthermore, the study suggests that friendships among school children can exert a noteworthy influence on their participation in MVPA. Friends communicate through various means, such as social norms and dialogues related to MVPA. These interactions can involve positive messages, including

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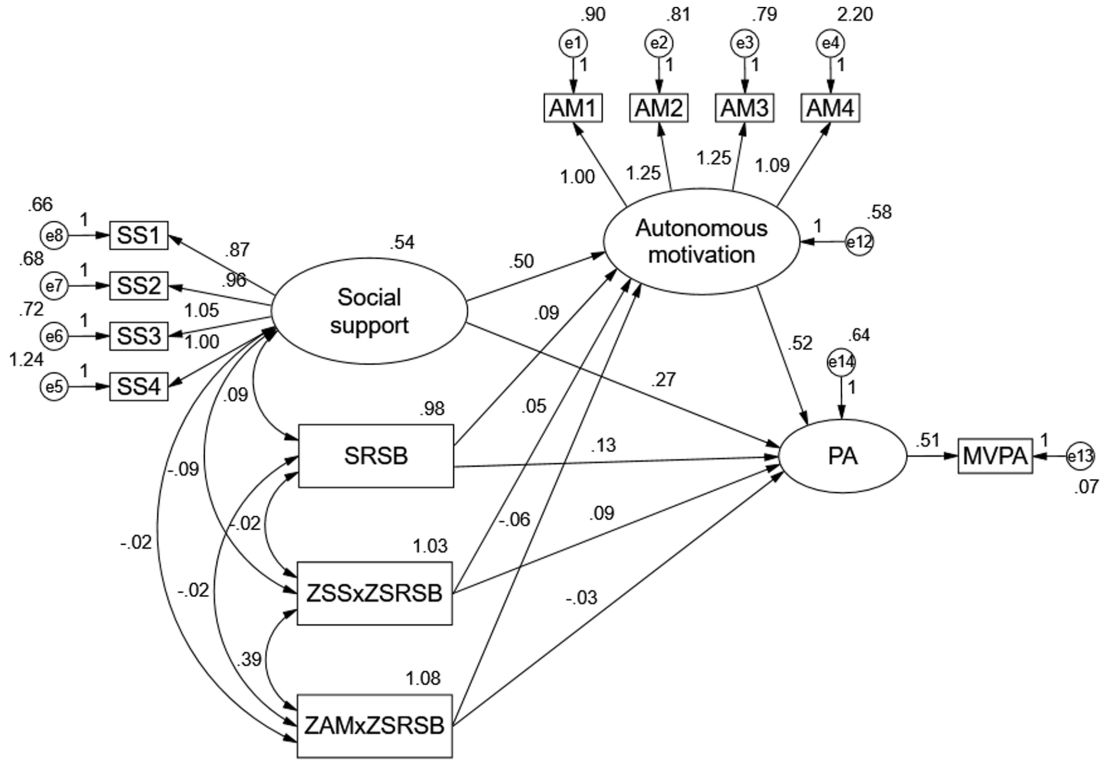

FIGURE 3
Mixed model of school children's PA.

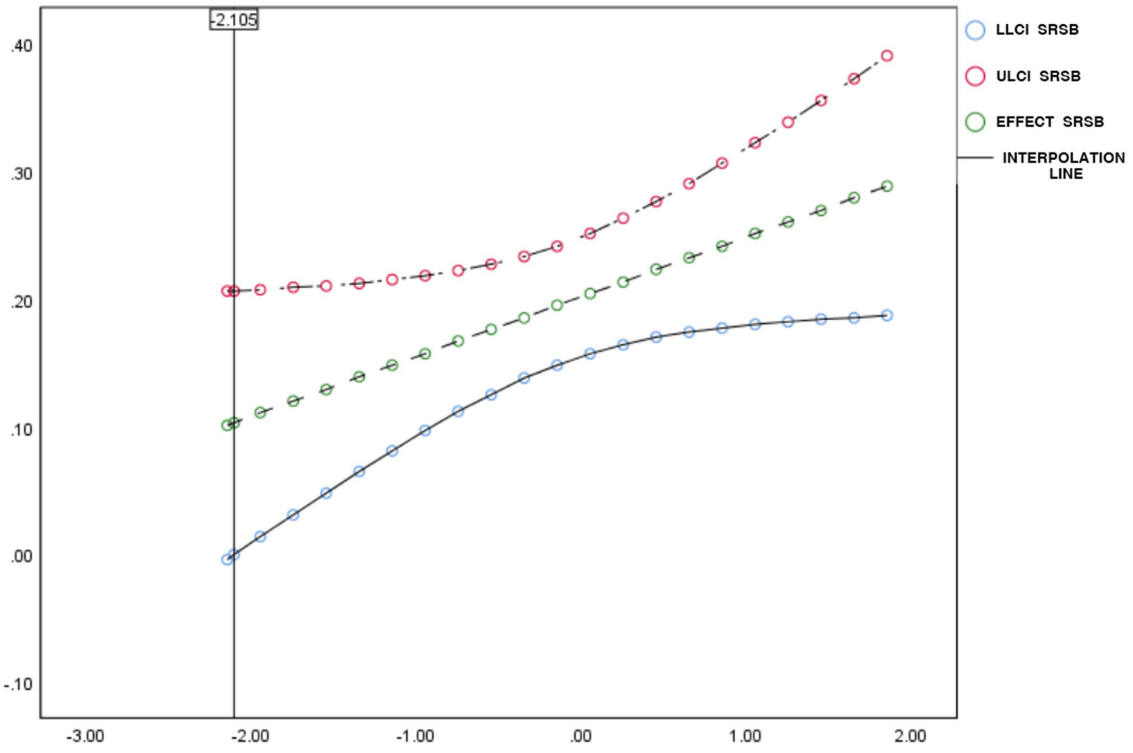

FIGURE 4
Johnson-Neyman's test for moderating effects interpolation line. LLCI and ULCI are the lowest and highest values of the confidence interval, respectively, and the interpolation line refers to the dotted line connecting the dots.

encouragement and support, which contribute to shaping school children's attitudes and behaviors towards PA (49–52). The conduct of friends, which can provide guidance to their peers (53–56), includes participating in MVPA with friends, such as organized sports and recreational activities in their company. These activities are considered positive behaviors (55, 57–59). Communication regarding MVPA frequently involves friends providing support and encouragement. This support can be assessed through factors that gauge social support. These factors may include friends reminding individuals to engage in exercise, encouraging them to take part in MVPA, praising their involvement in such activities, or engaging in discussions with them on topics related to MVPA (60). In models exploring communication about MVPA or social support, all twenty-five items exhibited significant positive correlations (57, 60–64). Autonomous motivation has been demonstrated to be linked to increased levels of MVPA in school children and adolescents (65–68).The motivation for MVPA is progressively emerging as a significant factor influencing school children's mental health. When individuals are autonomously motivated, they tend to achieve better physical and mental outcomes naturally (69, 70). Research has demonstrated that greater levels of autonomous motivation are predictive of increased positive affect in adolescents (71). This study illustrates the beneficial effect of autonomous motivation on sustaining MVPA (72). In this study, the favorable effects of autonomous motivation on the maintenance of MVPA were showcased. Additionally, social support and autonomous motivation played crucial roles in enhancing MVPA levels. To promote MVPA participation in school children and adolescents, interventions aimed at fulfilling psychological needs and fostering positive affective experiences are essential.

5.2 Autonomous motivation mediates the relationship between social support and school children's MVPA

In this study, we assessed and analyzed the mediating role of autonomous motivation in the connection between social support and the MVPA levels of adolescents. Our findings confirm the presence of this mediating relationship. We observed that social support not only has a direct impact on school children' MVPA but also exerts an indirect influence through autonomous motivation. Notably, there was a significant difference in the indirect effect ($Z = 5.127$), with a bias-corrected 95% confidence interval [0.180, 0.405] and a percentile-based 95% confidence interval [0.179, 0.403]. This mediation effect amounted to 0.282 or 51.6%. Relevant studies suggest that parental support plays a pivotal role in enhancing school children's MVPA and influencing their choices and behaviors (73). Encouraging family members to engage in MVPA alongside their school children promotes an increase in MVPA among the school children (74). It has been suggested that social support such as family support (75, 76)and peer support influence motivation to exercise (77), and that social support plays an important role in promoting autonomous motivation for healthy exercise (78) and social support plays an important role in promoting autonomous motivation for healthy exercise. In accordance with the principles of self-determination theory, autonomous motivation encompasses both internal and fully internalized external sources of motivation. It represents an individual's intrinsic drive to consistently strive towards their exercise-related goals (79). A comprehensive meta-analysis comprising 46 studies that met the specified inclusion criteria revealed a positive correlation between overall levels of autonomous motivation and engagement in MVPA (80), and that motivation is an important correlate and potential determinant of MVPA (81). The current study further corroborated the significant impact of autonomous motivation on MVPA (with a γ coefficient of 0.55, $p < 0.001$). In MVPA scenarios, students exhibit a strong desire to achieve goals related to reducing anxiety, enhancing mood, and fostering both physical and mental well-being through MVPA. They possess an intrinsic and compelling need for MVPA. Conversely, social support assumes a pivotal role as an external catalyst. School children with robust social support tend to experience higher exercise efficacy and a heightened sense of accomplishment. This support allows them to reinforce internal motivational elements, such as the desire for exercise and interest in MVPA, thereby sustaining their motivation and behavior for exercise. In essence, when school children recognize that engaging in MVPA contributes to their competence and self-confidence, they develop an increased need for competence, a heightened interest in exercise, and are more likely to maintain frequent and enduring exercise routines. This, in conjunction with their innate desire for MVPA and external triggers provided by social support, stimulates their autonomous motivation to engage in MVPA.

5.3 Moderating effects of SRSP on the relationship between social support and MVPA in school children

The findings of this study revealed that participation in SRSP had a direct moderating influence on the relationship between social support and school children's engagement in MVPA. This suggests that as the level of SRSP increased, the positive impact of social support on school children's MVPA became more pronounced. When school children perceived adequate social support, they tended to make optimal choices during MVPA, especially when engaging in SRSP, provided they experienced happiness and excitement throughout the process and were content with the resulting outcomes. Consequently, for these school children who are particularly sensitive to social support due to their urgent psychological need for satisfaction and encouragement during exercise, effective social support exerted a more significant influence on their participation in MVPA.

5.4 Significance and limitations of the study

The findings of this prospective study hold significant implications. Firstly, the study underscores the substantial relevance of social support and autonomous motivation in enhancing school children's MVPA. Factors such as family support, peer support, and intrinsic motivation are all closely tied to school children's MVPA levels. Therefore, it is important to educate schools and families in order to increase the level of autonomous motivation of schoolchildren and their active participation in MVPA. Secondly, the mediation model analysis offers valuable insights into the pivotal role played by autonomous

motivation in mediating the relationship between social support and school children's MVPA. This insight lays the foundation for potential interventions aimed at boosting autonomous motivation, consequently improving school children's MVPA behaviors. Therefore, the creation of relevant courses or activities can foster and increase the level of autonomous motivation and promote the adoption of positive strategies to promote the active participation of schoolchildren in MVPA. Lastly, the study validates that SRSP is more likely to impact school children's engagement in MVPA. Therefore, it is advisable to prioritize interventions targeting groups with higher levels of SRSP to enhance school children's MVPA levels. The results of the study make it important that social support and autonomous motivation enhance the behavioral impact of school children's MVPA and, more notably, help school children to raise their level of self-motivation and, consequently, their level of behavior.

In future research, demand-supportive behaviors can be used to improve motivation and levels of PA. In a recent study by Ahmadi et al. a classification system for motivational behaviors was proposed which could serve as an important basis for future research (82). When a person's psychological needs are met in an activity, the development of intrinsic motivation towards that activity is promoted. This suggests that in order to promote PA in children, interventions can be used to support their basic psychological needs in the context of PA (83).

This study has several limitations. Firstly, its cross-sectional design restricts the ability to establish causality, as causal relationships cannot be inferred. Future research should employ a longitudinal research design to further validate the causal hypotheses proposed in this study. Secondly, the study exclusively focused on the impacts of social support and autonomous motivation on school children's MVPA. It did not consider other potential mediating factors such as sensation seeking and psychological resilience, which might also influence school children's MVPA. Therefore, future research should explore the interplay between these variables to gain a more comprehensive understanding of their relationships. Lastly, this study employed whole cluster random sampling and collected data from only one district. Consequently, the results may not be readily generalizable to a broader population. To enhance the generalizability of the findings, future studies should employ more diverse and representative sampling methods to encompass a broader spectrum of school children, including those from different regions in China.

6 Conclusion

Social support and autonomous motivation were both direct predictors of school children's MVPA. Additionally, social support exerted an indirect influence on school children's MVPA through the intermediary role of autonomous motivation. And autonomous motivation played a crucial "bridging" role in mediating the relationship between social support and school children's MVPA. Besides, the interaction between social support and participation in SRSP had a moderating effect on the levels of MVPA in school children. Improvements in social support and autonomous motivation are conducive to an environment that enhances healthy behaviors and overall MVPA for school children, and future efforts should be directed at continuing to improve social support and autonomous motivation for school children, and enhancing psychological access for school children. Overall, this study provides ideas for the future development of physical education policies in schools.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Xiangya School of Public Health, Central South University (No XYGW-2022-44; 20 July 2022). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

YQ: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Validation, Writing – original draft. YY: Data curation, Formal analysis, Software, Writing – original draft. XW: Investigation, Visualization, Writing – review & editing. YZ: Resources, Supervision, Visualization. BL: Resources, Funding acquisition, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Associations between social network addiction, anxiety symptoms, and risk of metabolic syndrome in Peruvian adolescents—a cross-sectional study

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Background: The link between physical and mental health and screen time in adolescents has been the subject of scientific scrutiny in recent years. However, there are few studies that have evaluated the association between social network addiction (SNA) and metabolic risk in this population.

Objective: This study determined the association between SNA and anxiety symptoms with the risk of metabolic syndrome (MetS) in adolescents.

Methods: A cross-sectional study was conducted in Peruvian adolescents aged 12 to 18 years, who completed a Social Network Addiction Questionnaire and the Generalized Anxiety Disorder 2-item scale (GAD-2), between September and November 2022. A total of 903 participants were included in the study using a non-probability convenience sample. Sociodemographic and anthropometric data were also collected. Binary logistic regression was used to explore the association between SNA and anxiety symptoms with MetS in a cross-sectional analysis.

Results: Males were more likely to have MetS than females (OR = 1.133, $p = 0.028$). Participants who were 16 years of age or older and those with excess body weight were 2.166, $p = 0.013$ and 19.414, $p < 0.001$ times more likely to have MetS, respectively. Additionally, SNA (OR = 1.517, $p = 0.016$) and the presence of anxiety symptoms (OR = 2.596, $p < 0.001$) were associated with MetS.

Conclusion: Our findings suggest associations between SNA, anxiety symptoms, and MetS among youth. However, more studies are needed to better understand this association and to deepen the possible clinical and public health implications.

KEYWORDS

adolescents, anxiety symptoms, cardiometabolic risk, metabolic syndrome, obesity, social network addiction

Introduction

Metabolic syndrome (MetS) also known as "insulin resistance syndrome" or "syndrome X" refers to the set of conditions that increase the likelihood of developing cardiovascular and metabolic diseases, including type 2 diabetes mellitus, hypertension, and cardiovascular disease (1). Central obesity, which can be measured through anthropometric parameters, such as waist and hip circumferences and waist-hip ratio (WHR), constitutes one of the main components of the MetS (2). In recent decades, the prevalence of obesity in adolescents has increased significantly worldwide (3), which has been associated with an increased risk of developing cardiometabolic diseases at an early age (4). In fact, since 1975, obesity rates have increased considerably and have almost tripled in the general population, and in the particular case of children and adolescents, this increase is even greater, reaching almost a five-fold increase (3). In the national context, in recent years, there has been a steady increase in the number of Peruvian adolescents at high and very high risk of cardiometabolic diseases, as measured by the WHtR (5), which, in turn, increases mortality risk. In Peru, there is a double burden of morbidity due to, on the one hand, problems associated with infectious diseases and malnutrition by deficit and/or excess, and on the other hand, a progressive increase in non-communicable diseases (6).

Social networks are online platforms that allow users to create personal profiles and establish connections with other users in their network (7). In recent years, the use of social networks has become an increasingly frequent and popular activity among adolescents (8). Social network platforms such as TikTok, Facebook, Twitter, among others, can represent a valuable opportunity to connect and engage adolescents with messages related to the adoption of healthy lifestyles, such as proper diet and physical activity, which can be a preventive element against MetS (9). However, excessive exposure to these digital platforms could have negative consequences on the physical and mental health of this population group (8). There are few studies that examine the relationship between SNA and MetS. However, we found a recent study that evaluated the link between adolescent social networks and health in adulthood, suggesting that adolescents' social network position has lasting consequences for MetS in adulthood (10). However, most studies have focused on body mass index (BMI), pointing to a possible relationship between social media addiction, excessive use of media, and an increased risk of developing obesity in adolescents (11–13), which is related to cardiometabolic problems (1, 4).

Anxiety symptoms are one of the most prevalent psychiatric conditions in adolescence, affecting approximately 1 in 4 adolescents (14). These symptoms may represent risk factors for anxiety disorders encompassing various conditions such as agoraphobia, panic disorder, specific phobias, separation anxiety disorder, social anxiety disorder, and generalized anxiety disorder (15). Studies have shown that anxiety symptoms are associated with an increased risk of cardiovascular disease and other metabolic problems in young adults (16, 17). Although there is less research examining these connections in adolescents, a study recently found a statistically significant relationship between anxiety and some metabolic risk factors in this population (18). Another study conducted in adolescents reported a relationship between anxiety symptoms and insulin resistance (19), which may lead to worsening metabolic outcomes in at-risk youth.

Therefore, considering the above, it is important to deepen our understanding of this relationship and explore the possible clinical and public health implications. In this context, the present study aims to examine the association between SNA, anxiety symptoms, and MetS in adolescents, with the intention of contributing to a better understanding of these phenomena and to the implementation of effective preventive and therapeutic interventions.

Materials and methods

Design and study participants

A descriptive cross-sectional study was conducted during September and November 2022. The sample was selected using non-probabilistic sampling (20, 21). The researchers chose to use non-probabilistic purpose sampling because it is relevant to obtain data from respondents for this study (21–23). Data were collected using a survey consisting of the following: (a) sociodemographic data (e.g., age, sex, origin, place of residence, among others); (b) a validated questionnaire and scale to assess symptoms of SNA and anxiety symptoms, respectively; (c) in addition, information was collected on body weight status, height, and waist circumference, to subsequently estimate BMI, height-for-age (H/A), and waist-to-height ratio (WHtR).

The survey was distributed to participants enrolled in two public schools in the districts of Reque and Morrope, located in the city of Chiclayo, Peru. Data collection was possible due to the support of the directors of both schools and the teachers of each of the classrooms we selected. The sample size was calculated using Free Statistic Calculators version 4.0 (24). For the multiple regression analysis, an effect size of 0.10, a statistical power of 0.80, 5 explanatory variables and a probability level of 0.05 were considered. According to this calculation, a minimum sample size of 134 participants was required. However, in this study, a total of 903 students participated voluntarily, which far exceeds the calculated sample size. Participants of both sexes, those without any pathology, and those within the selected age range (12–18 years) were included. However, adolescents whose parents did not give their written informed consent were excluded from the study. Furthermore, 23 records were excluded due to missing data. The final sample was 903 participants.

Ethical aspects

The study was carried out after receiving the approval of the Research Ethics Committee of the Universidad Señor de Sipán (Registration and reference number: 0085-17052022-CIEI). Subsequently, the directors of both schools were contacted to request and obtain permission to meet with the parents of potential participants. This meeting was to explain to all parents the purpose of the study. Furthermore, considering that the participants were minors, a procedure was implemented to guarantee participation with the consent of the parents or legal guardians. After providing initial explanations about the purpose of the study, an informed consent question was included to be answered by parents or legal guardians as a prerequisite for adolescents to participate in the survey. Therefore,

informed consent was obtained from all subjects prior to their participation in the study.

Measurement instruments

Social network addiction questionnaire

This instrument was originally developed by Escurra and Salas in 2014 and was constructed using a sample of 380 participants (36.3% men and 63.7% women) in Lima, Peru (25). This questionnaire is made up of 24 items on a 5-point Likert scale ranging from never to always (assigned scores from 0 to 4). In addition, it has 23 direct items and 1 inverse item. A higher score indicates a higher level of SNA. The validity and reliability of the instrument was analyzed, showing a Cronbach's Alpha coefficient (α) = 0.95, therefore, it has adequate internal consistency. Additionally, the instrument evaluation was carried out on a sample of 744 adolescents aged 17 to 19 years, reporting a reliability of α = 0.86 (26). In the current study, the internal consistency of the instrument was also tested, evidencing α = 0.89.

Generalized anxiety disorder (GAD-2)

The Generalized Anxiety Disorder 2-item Scale was used to measure emotional state. This instrument is composed of item 1 of the GAD-7 "Feeling of nervousness, anxiety, or being on edge" and by item 2 "Not being able to stop worrying or controlling worries" and is assessed through the question: "Indicate how often you have experienced the following problems in the last 15 days" (27, 28). These items have 4 response options where never = 0, less than half of the days = 1, more than half of the days = 2, and almost every day = 3. A cutoff score greater than or equal to 3 on GAD-2 is an indicator of a probable clinically relevant anxiety disorder, while a score less than 3 indicates the absence of anxiety symptoms (29). Total scores range from 0 to 6 (28, 30, 31). In this study, the version adapted and validated for the Peruvian population was used and presented an adequate Cronbach's α coefficient (α = 0.81) (32).

Sociodemographic data

Sociodemographic and economic data were collected through a registration form, which is composed of sociodemographic factors such as age in years (11–12 and 16–18), sex (male and female), residence (urban and rural), level of education of parents (elementary, technical, and university), marital status of parents (married, cohabiting, single, divorced, and widowed), family income in "soles (PEN)" (<2,149.00 PEN, 2,149.00 PEN–10,746.00 PEN, and > 10,746.00 PEN), among others.

Anthropometric data

BMI

Weight and height were measured using a calibrated SECA 700 mechanical column scale with a capacity of 220 kg and a measuring range of 60 to 200 cm (SECA®, Hamburg, Germany). Anthropometric evaluation was performed by a professional nutritionist in the early hours of the day for one week. Furthermore, the measurements were performed with the participants walking barefoot and wearing the minimum amount of clothing. The BMI was calculated, and the classification was made according to the parameters established by the World Health Organization. A BMI z score was determined and classified as follows: "underweight," BMI z-score < −1; "normal," BMI z score −1 to 1; and "overweight" (z > 1) (33).

Height/age (H/A)

Furthermore, H / A was calculated and classified based on the reference data corresponding to the Peruvian standards in the public health system: >2 standard deviation (SD), "normal or adequate" (H/A ≥ −2 to ≤2 SD), "low" (H/A < −2 to −3 SD), and "severe low" (H/A < −3). For the purposes of the current study, it is necessary to specify that short and very severe height was recategorized as short height (34, 35).

Waist-to-height ratio (WHtR)

Waist circumference (WC) was measured in triplicate using a Cescorf (Cescorf Equipamentos Para Esporte Ltda—Epp, Brazil) self-retractable metallic steel tape measure. Measurement of the WC was made considering the midpoint of the axillary line, in the distance that goes from the ridge of the last rib to the iliac spine (36).

Outcome

After obtaining WC measurements, WHtR was determined by dividing the waist circumference of each participant by their respective height. This anthropometric parameter is valued for its ability to provide an accurate indication of the distribution of adipose tissue in the body (33, 37). It is a simple index that offers immediate identification and interpretation, being particularly useful in the early identification of abdominal obesity in children (38). As a result, it makes it possible to anticipate potential risks related to cardiometabolic disorders (2, 37, 39). In the evaluation process, a cutoff point of 0.5 was identified. That is, participants who had a WHtR index greater than 0.5 were classified as adolescents at risk of MetS (2, 33, 37, 39, 40).

Statistical analysis

A Microsoft Excel spreadsheet was used for data collection and coding. Then, for data processing and analysis, the IBM SPSS statistical software package, version 26 (SPSS Inc., Chicago, IL, United States) was used. Descriptive analysis of the variables was performed using tables of absolute frequencies and percentages. To explore whether sociodemographic data, anthropometric data, SNA, and anxiety symptoms were different according to sex and MetS, the chi-square statistical test was used. Finally, an exploration of the association of the factors influencing MetS (dependent variable) was carried out using a binary logistic regression model. We considered sex, age, overweight, SNA, and anxiety symptoms as independent variables. These variables had a probability value (p-value) of less than 0.05 in a preliminary bivariate analysis, and therefore were incorporated in the bivariate logistic regression analysis.

Results

A total of 903 schoolchildren voluntarily decided to participate in the study; of these, 56% were female. The highest proportion (68.8%) were between 12 and 15 years of age. Regarding the level of education of parents, 76.6% of mothers and 69.2% of fathers reported basic

TABLE 1 Sociodemographic characteristics of the participants ($N = 903$).

Variable		*n*	%
Sex	Female	497	55.0
	Male	406	45.0
Age	12–15	621	68.8
	16–18	282	31.2
Mother's education	None	107	11.8
	Basic	692	76.6
	Technical	67	7.4
	University	36	4.0
Father's education	None	109	12.1
	Basic	625	69.2
	Technical	92	10.2
	University	77	8.5
Parents' marital status	Married	419	46.4
	Cohabitant	208	23.0
	Single	139	15.4
	Divorced	105	11.6
	Widowed	31	3.4
With whom you live	With mother and father	499	55.3
	Only with father	94	10.4
	Only with mother	201	22.3
	With another family member	103	12.2
Monthly income	<2,149.00 PEN*	674	74.6
	2,149.00–10,746.00 PEN	168	18.6
	>10,746.00 PEN	60	6.6
Number of children	One son	140	15.5
	Two sons	240	26.6
	More than two sons	523	57.9

*The ISO code for Peruvian currency is PEN, a standardized 3-letter code according to the ISO-4217 currency code standard.

education. Most parents were married (46.4%), had a monthly income <2,149.00 (74.6%), and reported having more than two sons (57.9%). More than half of the respondents reported that they live with their parents (55.3%). The sociodemographic characteristics of the participants are shown in Table 1.

The results of the association between H/A, BMI, SNA, and anxiety symptoms are shown in Table 2. MetS was generally observed among men (67.1%, $p = 0.046$), in the age range of 16–18 (78.3%, $p < 0.001$), in those with excess body weight (90.1%, $p < 0.001$), SNA (85.5%, $p = 0.039$) and anxiety symptoms (63.2%, $p = 0.007$).

A binary logistic regression model was used to explore the variables that predict the probability that adolescents will present MetS and the results are shown in Table 3. In this analysis, males were more likely to present MetS than females (OR = 1.133, $p = 0.028$). Participants who were 16 years of age or older and those with excess body weight were 2.166, $p = 0.013$ and 19.414, $p < 0.001$ times more likely to have MetS, respectively. Furthermore, SNA (OR = 1.517, $p = 0.016$) and the presence of anxiety symptoms (OR = 2.596, $p < 0.001$) were associated with the risk of MetS.

Discussion

In this cross-sectional study, we determined the association between SNA and anxiety symptoms with the risk of MetS in Peruvian adolescents aged 12 to 18 years. The main findings were as follows: Male sex, participants who were 16 years of age or older and those who had excess body weight were more likely to present MetS. Furthermore, it is highlighted that SNA and anxiety symptoms were associated with MetS.

Previous studies have documented the influence of sex and age on the anthropometric profile, more precisely MetS, measured through the WHtR (4, 41–43). The results of the logistic regression analysis of the current study revealed that men were more likely to have MetS compared to females; furthermore, we found that a higher proportion of men had MetS. It should be noted that the current study used WHtR to determine MetS. Similarly, the findings of the research conducted in Brazilian adolescents showed that boys had a higher mean WHtR and a higher WHtR at the 95th percentile (41). Similarly, other studies in adolescents reported that boys were more likely to report MetS factors, such as high blood pressure, elevated cholesterol,

TABLE 2 Chi-square analysis of MetS.

Variables	MetS		Non MetS			
	n	%	*n*	%	χ^2	*p*-value
Sex						
Female	50	32.9	436	58.1	0.421	0.046*
Male	102	67.1	315	41.9		
Age (years)					15.440	<0.001*
12–15	33	21.7	412	54.8		
16–18	119	78.3	339	45.2		
H/A						
Inadequate H/A	52	34.2	286	38.1	0.809	0.368
Adequate H/A	100	65.8	465	61.9		
BMI						
Normal	15	9.9	479	63.8	148.290	<0.001*
Excess body weight	137	90.1	272	36.2		
SNA						
Yes	130	85.5	90	12.0	0.721	0.039*
No	22	14.5	661	88.0		
Anxiety symptoms						
Yes	96	63.2	246	32.8	0.948	0.007*
No	56	36.8	505	67.2		

*Statistically significant, $p < 0.05$ [Chi-square (χ^2)]. *p* represents the probability that MetS is associated with sociodemographic and anthropometric data, social network addiction, and anxiety symptoms. H/A, height/age; BMI, body mass index; MetS, Metabolic syndrome; SNA, Addiction to social networks.

TABLE 3 Binary logistic regression analysis of factors associated with MetS.

Variables				95% CI	
	B	OR_B	*p*	Lower	Upper
Sex (0 = female, 1 = male)	0.125	1.133	0.028	0.770	1.667
Age (year) (0 = <16, 1 = ≥16)	0.773	2.166	0.013	1.386	3.387
Excess body weight (0 = no, 1 = yes)	2.966	19.414	<0.001	10.911	34.544
SNA (0 = no, 1 = yes)	0.417	1.517	0.016	0.844	2.727
Anxiety symptoms (0 = no, 1 = yes)	0.954	2.596	<0.001	1.713	3.933

$\chi^2 = 173{,}114$, df = 5, $p < 0.001$; Cox and Snell R-squared = 0.174, Nagelkerke R-squared = 0.293.
B, Beta coefficient; *p*, probability; OR_B, Odds ratio; 95% CI, 95% confidence interval; SNA, social network addiction.

glucose, and triglyceride levels (42, 43). Although in some studies MetS patterns do not differ in both sexes (44), however, there are mechanisms that support evidence of sex differences (42, 43, 45, 46). In general, it has been found that men have higher visceral adipose tissue, intramyocellular and intrahepatic lipids than women, which could partly explain why they have a higher MetS (46). On the other hand, males tend to have higher blood pressure and cholesterol levels than women from puberty onward, which can also contribute to a higher cardiovascular risk (42, 43). In hormonal terms, it has been found that testosterone levels in men can negatively affect glucose metabolism and increase the risk of insulin resistance and type 2 diabetes, which are considered cardiometabolic complications (45).

Chronological age remains one of the strongest predictors of cardiometabolic events (47). In the present study, we found that participants who were 16 or older tended to report MetS; furthermore, an age ≥ 16 years was significantly associated with MetS. These findings are similar to the results reported in a recent study conducted in Peruvian adolescents where the highest proportion of those with MetS, measured by WHtR, were aged 15 to 17 years vs. 12 to 14 years (4). In addition, these results confirm the findings of research that measured waist circumference and WHtR in US children and adolescents (48). This study showed that the relative changes in WHtR increased with increasing age, and that the greatest relative change was observed in men and women between 18 and 19 years of age (48). Chronological age is an important determinant of health, since it coincides with the critical moments of increasing body fat and, therefore, of the development of diseases (49). In fact, as age increases, the risk of developing various chronic cardiometabolic diseases and conditions increases (48, 50). In addition, the physical and mental changes that occur with age can affect the quality of life and a person's ability to perform daily activities (51). However, it is important to note that the premature onset of age-related diseases in younger people suggests a discrepancy between

chronological and biological age, pointing out that chronological age is not always representative of true biological age, because several disease/morbidity factors may be related to biological age (50). Beyond this discrepancy, it is important to consider age as an important factor in assessing adolescent health and in planning long-term disease prevention and treatment strategies.

Global obesity and MetS, measured using WHtR, are two anthropometric factors that are associated with the onset and development of noncommunicable diseases (1). The measurement of both factors is particularly important in adolescents, since adolescence is a high-risk stage and one of the most critical periods of life, due to constant changes in lifestyle (52). Evidence for the association between global obesity and MetS has been demonstrated in both adolescents and the general population (4, 49, 53, 54). In our study, we found that those who had excess body weight were more likely to present MetS. These results are consistent with the findings of a study conducted in Spanish schoolchildren aged 6 to 15 years, showing a relationship between excess body weight and abdominal obesity, a metabolic risk factor (49). Similarly, the results of a recent study conducted in 506 adolescents aged 10 to 19 years of age from different schools in Brazil reported that normal weight obesity, which is defined as excess body fat in normal weight individuals, is associated with MetS, assessed through waist circumference (53). Some possible justification why obesity is related to increased waist circumference in adolescents is the fact that excess body fat accumulates predominantly in the abdominal region (1). It is worth mentioning that abdominal fat, also known as visceral fat, is metabolically active and can release pro-inflammatory fatty acids and adipokines, which contribute to the development of insulin resistance, dyslipidemia and other MetS factors (53, 54). Therefore, assessment of MetS measured through WHtR in obese and normal weight adolescents can be useful to identify those with a higher risk of developing cardiovascular and metabolic diseases.

Another relevant finding of this study is the fact that SNA is associated with MetS. This connection is especially relevant in the current times since the use of social networks has become a widespread and popular activity among adolescents (8). Although there is a paucity of research analyzing the relationship between SNA and MetS, our findings are in line with a recent study that evaluated the relationship between adolescents' social networks and their health in adulthood suggesting that their position in their social network during adolescence has lasting implications for MetS in adulthood (10). It should be noted that most studies have focused on BMI, pointing to a possible relationship between SNA and excessive media use with an increased risk of developing obesity in children and adolescents (11–13, 55), which is related to cardiometabolic problems (1, 4). Therefore, it is important to highlight that excessive exposure to digital platforms could have negative effects on the cardiovascular health of this population group through the onset of obesity (56). This suggests that the effect of SNA on MetS could be mediated by obesity. Although it is important to note that structural equation modeling was not used in this study to explore these relationships in depth, our findings provide a clear picture of how cardiometabolic disease is influenced by SNA and obesity. This sets the groundwork for future research using mediation models, which will help to better understand these relationships. The mechanism for this association may be that excessive and sedentary use of social networks reduces the time that would be devoted to physical activities (57). Studies that have provided evidence to support this theory show that when the amount of time adolescents spend in front of screens is reduced, their level of physical activity increases (12). Another reason for this relationship is the fact that it has been suggested that the consumption of hypercaloric foods can increase in parallel with the time spent on the media and social networks (58, 59). This hypothesis is supported by research showing that high use of social networks among adolescents is associated with unhealthy dietary behaviors (60), and that energy intake in adolescents decreases when sedentary behaviors are reduced (59).

Finally, in this study, we found that anxiety symptoms are associated with MetS. Although little research has been done on the relationship between anxiety and metabolic risk factors in adolescents, however, a recent study has found a significant association between anxiety and some metabolic risk factors in this population group (18). Similarly, another study conducted in adolescents reported a relationship between anxiety symptoms and insulin resistance (19), which may lead to worsening metabolic outcomes in at-risk youth. Furthermore, studies have shown that anxiety symptoms are associated with an increased risk of cardiovascular disease and other metabolic problems in young adults (16, 17). Anxiety is a common affective disorder in children and adolescents, affecting approximately 1 in 12 children and 1 in 4 adolescents, and is one of the most common mental health problems in these populations (14). One of the possible reasons why anxiety symptoms are associated with MetS is that this disorder can contribute to increased intake of unhealthy foods and decreased physical activity (61). In particular, it is possible that people with anxiety are more likely to have a sedentary lifestyle, increasing the risk of obesity and cardiovascular disease (61). Furthermore, anxiety symptoms can increase the release of stress hormones, such as cortisol, which can promote abdominal fat gain and insulin resistance (19, 62).

Limitations and future research

When interpreting the results of this study, certain limitations should be taken into account, which will benefit future lines of research. First, the study was a cross-sectional design; therefore, it does not allow establishing the possibility of causality, that is, it cannot be considered that having SNA, anxiety symptoms, or excess body weight can lead to an increase in WHtR; therefore, longitudinal studies that follow participants over time are needed to determine whether the initial presence of SNA, anxiety symptoms, or overweight predicts future increases in WHtR. Second, in relation to the anthropometric data, this is cross-sectional information, where a single measurement was taken for each student and there is no follow-up data to evaluate the evolution of weight and height over time. Therefore, the results presented are based on single measurements taken in different age groups. Considering this, we cannot evaluate how these anthropometric parameters evolve with age. However, in the specific case of WHtR, an advantage of using this index is that it does not appear to be age dependent at certain levels and therefore it may be possible to use a single cut-off value for all children (63). Nonetheless, it is important to point out that there is no consensus on a single WHtR cut-off point to predict the risk of MetS risk in adolescents (64). Given the lack of consensus on a single WHtR cut-off point for predicting the risk of MetS in adolescents, further studies are needed to explore and validate uniform criteria. This could include comparative analyses of different cut-off values in different adolescent populations to identify those that are most predictive of

MetS risk. Third, data on SNA and anxiety symptoms were self-reported, which may lead to measurement errors. However, both instruments were validated in the Peruvian population. Therefore, future research on anxiety symptoms could be based on medical diagnoses rather than self-report alone. Medical diagnoses provide a more objective and detailed assessment of anxiety status by combining clinical observations, medical records, and, in some cases, psychometric tests administered by professionals (65). Finally, it is important to note that the inability to generalize the findings to a larger population, due to the type of sampling used and the number of participants involved, is an obvious limitation in the current study. Therefore, it is important to interpret the results with caution and within the specific context of the selected sample group. In addition, studies using probability sampling methods are suggested to verify and expand on the findings of the current study.

Public health implications

Despite these limitations, we believe that the current study is of public health relevance due to its potential impact on the long-term health of adolescents. Adolescents are a vulnerable and growing population; therefore, habits and behaviors acquired at this stage can influence their health in adulthood. In addition, SNA, anxiety symptoms, and obesity are mental and physical health problems that have been increasing in the adolescent population in recent years. If these problems are related to an increased risk of MetS, they need to be addressed early and effectively. Therefore, it is important to conduct further research to confirm the relationship between these factors and to develop and implement preventive and treatment interventions targeting this vulnerable population. Furthermore, it is essential that health professionals, educators, and public health authorities inform and educate both adolescents and their parents about the importance of a healthy and balanced life, including responsible use of social networks, management of stress and anxiety, and maintaining a healthy weight.

Conclusion

The findings of this cross-sectional study suggest that men were more likely to have MetS compared to females; furthermore, we found that a higher proportion of men had higher MetS. Furthermore, it is notable that participants 16 years or older tended to report a higher level of MetS; furthermore, an age $\geq$ 16 years was significantly associated with the risk of MetS. Similarly, excess body weight, SNA, and anxiety symptoms were associated with the risk of MetS. Given the impact of MetS on health, more efforts are needed to better understand the associated factors for the implementation of effective preventive and therapeutic interventions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Research Ethics Committee of the Universidad Señor de Sipán (Registration and reference number: 0085-17052022-CIEI). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

JS: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. SO-G: Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Resources, Writing – original draft. GL-T: Conceptualization, Methodology, Project administration, Resources, Visualization, Writing – original draft. IL-D-M: Conceptualization, Data curation, Funding acquisition, Writing – original draft. FB-C: Funding acquisition, Investigation, Methodology, Writing – original draft. EL-L: Conceptualization, Funding acquisition, Methodology, Project administration, Writing – review & editing. YC-M: Conceptualization, Data curation, Investigation, Project administration, Visualization, Writing – original draft, Writing – review & editing. AS-B: Investigation, Methodology, Validation, Visualization, Writing – review & editing. CR-V: Formal Analysis, Investigation, Methodology, Supervision, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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Listening to the community: identifying obesity prevention strategies for rural preschool-aged children

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Multi-level interventions promoting healthy weight in rural preschool children aged 2–5 years are limited. With the goal of developing a community-informed obesity prevention intervention for rural preschool-aged children, the purpose of this descriptive study was to identify: (1) community settings and intervention strategies to prioritize for an intervention; (2) potential implementation challenges and solutions; and (3) immediate interventions the study team and community partners could collaboratively implement. Workshops occurred in two rural communities in Indiana (2 workshops) and North Carolina (2 workshops), with high obesity rates. A guide was developed to moderate discussions and participants voted to rank community settings and intervention strategies. There were 9–15 participants per workshop, including parents, childcare providers, and representatives of community organizations. Community settings identified as priorities for child obesity prevention included the home, educational settings (preschools), food outlets, recreational facilities, and social media. Priority intervention strategies included providing nutrition and physical activity education, increasing access to healthy foods and physical activity in the built environment, and enhancing food security. Potential intervention implementation challenges centered on poor parental engagement; using personalized invitations and providing transportation support to families were proffered solutions. Immediate interventions to collaboratively implement focused on making playgrounds esthetically pleasing for physical activity using game stencils, and nutrition education for families via quarterly newsletters. This participatory approach with community partners provided insight into two rural communities' needs for child obesity prevention, community assets (settings) to leverage, and potential intervention strategies to prioritize. Findings will guide the development of a multi-level community-based intervention.

KEYWORDS

childhood obesity, multi-level interventions, community engagement, rural, preschool-aged children

1 Introduction

Childhood obesity rates in the United States (U.S.) are high. From 2010 to 2020, obesity prevalence in children aged 2–5 years increased from 10 to 13% (1). This public health concern is more acute in rural communities, with studies reporting 26% higher odds of obesity in rural versus urban children (2). Obesity prevention is preferrable to treatment in rural children (3), but often difficult to achieve because of multiple risk factors (4, 5) occurring at the child (e.g., child diet/physical activity [PA]), family (e.g., socioeconomics), organizational (out-of-home care settings), community (e.g., built environment), and policy levels (6, 7). Interventions targeting a single level of influence demonstrate mixed results in terms of effects on child weight (8). To effectively address child obesity in rural areas requires that interventions simultaneously target multi-level influences. The Socioecological Model, which posits that child obesity is influenced by factors at multiple levels of influence, including individual, interpersonal (family), organizational, community, and policy levels (9), provides a framework for understanding the critical need for multi-level child obesity prevention interventions.

Multi-level community-based interventions (e.g., Shape Up Somerville, Romp & Chomp) have been shown to promote sustainable improvements in child weight (10–16). This type of intervention exposes entire communities to obesity prevention efforts and simultaneously targets change at multiple levels that influence child obesity (e.g., child and family) (16, 17). Applying this intervention approach requires that researchers engage with persons having first-hand knowledge about communities to ensure applicability, effectiveness, and sustainability of an intervention (18, 19). To the authors' knowledge, there is one multi-level, childhood obesity prevention intervention that has targeted rural U.S. communities, with results unpublished (20, 21), but no such studies have targeted rural children aged 2–5 years.

Although rural communities have strengths, including the tightknit social ties among residents, strong cultural traditions, and proximity to natural landscapes that offer opportunities for outdoor activities (22–25), lack of access to resources that support wellbeing can make it difficult to implement and sustain interventions in rural communities. From June 2019 to July 2021, the current study team conducted formative research in two rural communities in Indiana (IN) and North Carolina (NC) to identify barriers, facilitators, and opportunities to address obesity in preschool children aged 2–5 years (published elsewhere) (26). Guided by the formative research, with the goal of developing a community-based intervention for preschool-aged children, the study team conducted workshops to engage with partners from the two rural communities (e.g., parents, representatives of community organizations) in the identification of: (1) community settings to prioritize for a child obesity prevention intervention; (2) intervention strategies at multiple levels of influence (e.g., child, family) to prioritize; (3) challenges that might be encountered while implementing an intervention, with potential strategies for navigating challenges; and (4) immediate interventions the study team and community partners could begin to implement collaboratively with little or no funding. This paper describes results from the workshops.

2 Methods

2.1 Study setting and participants

This descriptive study occurred in spring of 2022 in two rural counties ("communities" hereon) in IN and NC. Rurality was defined using U.S. Department of Agriculture's Rural–Urban Commuting Area Codes (27). Both communities are considered high-need, with child poverty levels (18–32%) (28, 29) that exceed the national poverty average (16%) (28, 30), and high child and/or adult obesity (20–39%). Both communities differ in racial/ethnic make-up; the IN community is predominantly (96%) non-Hispanic White (31), while the NC community is diverse, with Black/African-Americans comprising 52% and Hispanic/Latino, 9% (32). Study participants included parents of children aged 2–5 years, childcare providers, representatives of community organizations serving children/families, and community residents interested in improving child health.

To recruit participants, two study team members (KP, TE) participated in a meeting for an existing coalition of community leaders in each community. At each meeting, the study team shared initial results from the formative research conducted to learn about barriers, facilitators and opportunities to promote healthy weight in children aged 2–5 years in both communities (26). The study team invited coalition members to participate in community workshops, sought insight from coalition members about how to structure the workshops (e.g., where/when to host workshops, incentives to offer), and enlisted their assistance with participant recruitment. Thereafter, personalized invitations were sent to coalition members, other community leaders who were not members of the coalitions (e.g., librarians, faith-based leaders), and persons from the formative research (26). Coalition members and other community leaders received several copies of the invitation to distribute to community residents in their network. Persons interested in participating in the workshops were instructed to notify the study team by telephone/email.

Overall, 110 invitation cards (65 in IN, 45 in NC) were mailed, with the goal to recruit up to 15 participants per community, a threshold that would allow for robust discussions among participants based on the study team's prior experiences with conducting community workshops (33, 34). The study team aimed to recruit a diverse representation of participants, including parents, childcare providers, and representatives of community organizations that serve families, but there were no set quota requirements. Two workshops were held per community. In IN, 15 persons participated in the first workshop, while 11 participated in the second workshop. In NC, there were 9 persons in the first workshop, and 13 in the second workshop. Study procedures were approved by the Institutional Review Board at Indiana University Bloomington. Written informed consent was obtained from participants before each workshop.

2.2 Overview of the community workshops

Community workshops occurred on Saturday mornings at publicly accessible community facilities. Short breaks were incorporated, refreshments were provided, and participants received a thank-you gift. The first workshop was 3 h and participants received $75 upon completion, versus $50 for the second workshop lasting 2 h.

The study team developed a discussion guide (Supplementary Table 1) for the workshops that was informed by the formative research in the two communities (26) and similar studies that used community workshops to design community-based interventions (18, 33, 34). The Socioecological Model (9) and previous multi-level obesity prevention studies (10, 11, 13, 18, 35, 36) provided a theoretical framework to understand influencing factors, and prioritized community settings and strategies to promote healthy dietary intake and PA at the child, family/peer, organizational (e.g., childcare settings), community (e.g., built environment), and policy levels. The workshops were intended to be interactive and participatory. Each workshop began with a description of the purpose of the workshop, completion of informed consent and a demographic survey by participants, and an ice-breaker activity. Facilitation of each workshop was led by the same study team member (TE), with assistance from another team member (KP/AL). Flip charts displayed in the meeting room were used to record participants' responses, and discussions were audio-taped.

2.3 Data collection at the community workshops

Guided by prior childhood obesity prevention studies (11–15), data collection for this study focused on two behavioral targets, to: (i) promote healthy dietary intake (specifically, increase fruits and vegetables; reduce fast food; reduce sweet/salty snacks; reduce sugar-sweetened beverages; and promote water consumption) and (ii) promote PA (Figure 1). Similar contents were covered at each workshop across both communities using the discussion guide, however, where necessary, the facilitator combined behavioral targets for discussions because of time constraints. Data collection began with a discussion among participants about factors influencing the choice to engage in the target dietary and PA behaviors in families with children aged 2–5 years in various settings (home, childcare). While related information was collected in the formative research, discussions around influencing factors that impact child healthy weight behaviors helped to set the stage for ensuing discussions about settings and strategies to prioritize in an intervention. Participants' responses were recorded on flip charts and then reflected back at the end of the discussion.

Next, participants were asked to specify community settings in which to intervene to promote each behavioral target. After this discussion was exhausted, four sticky dots were provided to each participant so they could vote on settings they thought should be prioritized in an intervention. Votes were tallied and reported back to participants. During the next phase of discussions, participants were asked to specify potential intervention strategies for each behavioral target. Given time constraints, some behavioral targets were combined for discussion (e.g., strategies to reduce sugar-sweetened beverages combined with strategies to promote water consumption). After the discussion was exhausted, participants received 4 to 6 sticky dots to vote on intervention strategies that they thought should be prioritized for each behavioral target. Votes were tallied and restated to participants. The moderators then asked participants to specify challenges they thought the study team might encounter in implementing a potential intervention and strategies that might help to navigate challenges. Given time constraints in IN, the discussion about challenges occurred only in NC, and participants' responses were captured on flip charts.

Final discussions centered on identifying immediate interventions from the priority list that the study team and community partners could begin to work on with little or no funding, and how the community and academic partners could begin to work together collaboratively to develop a multi-level obesity prevention intervention for children aged 2–5 years and families in their community. The study team shared workshop summaries with participants by email about

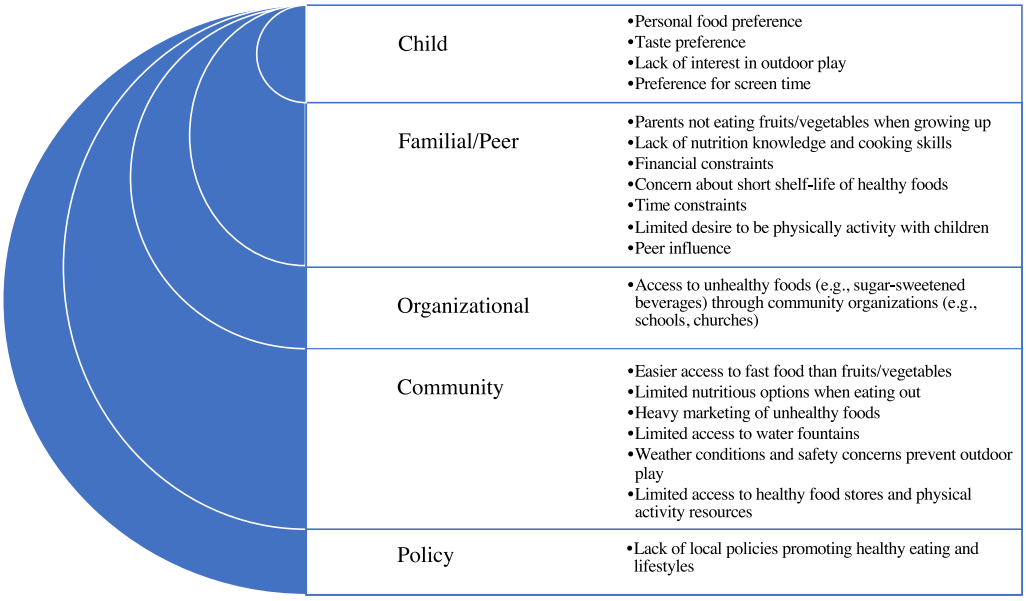

FIGURE 1
Factors influencing the consumption of unhealthy foods and physical inactivity among families with children aged 2–5 years in two rural communities in Indiana and North Carolina: summary of results from community workshops.

10 days after each workshop and also provided a printed copy of the summary from the first workshop at the second workshop. Email and in-person communications included requests for participants to check that the summaries accurately reflected discussions held, and report related concerns.

2.4 Data analysis

Audio-taped recordings from each workshop were transcribed without identifiers and were reviewed for accuracy and completeness. Data coding and content analysis were conducted by study team members trained in qualitative analysis (TE, KP) using the transcripts, supplemented with flipchart notes. Differences in the application of codes and content analyses were discussed by the coders and resolved by consensus. Notably, participants' responses about factors that influence the choice to engage in the target dietary and PA behaviors were coded into five descriptive categories, guided by the Socioecological Model (9) and prior multilevel child obesity prevention research (10, 11, 13, 18, 35, 36): child; family; organizational; community; and policy. Community settings with the four highest votes for each behavioral target were coded into descriptive categories based on similarities in function (e.g., educational, recreational settings) by state. A similar process was used to code and summarize responses about potential intervention strategies to prioritize. Responses about challenges the study team might encounter in implementing a potential intervention, strategies for navigating challenges, and immediate interventions to begin to implement were described. Demographic characteristics of participants were summarized using frequencies and percentages in R (version 4.2.1, Vienna, Austria), a software for quantitative analyses.

3 Results

Demographic characteristics of participants are shown in Table 1. There were 9–15 participants per workshop. The second workshop included some of the persons who had participated in the first workshop (5 in IN, 7 in NC) and new participants (5 in IN, 6 in NC). Participants described themselves as parents, grandparents, child-care providers, representatives of community organizations (e.g., healthcare, business, government, youth service), or a combination of those roles. Participants were predominantly female, with more racial diversity in NC compared to IN.

Participants listed examples of factors that influence the choice to engage in the target dietary and PA behaviors but did not prioritize or rank factors in order of importance (Figure 1). At the child level, these included child preference for unhealthy foods, peer influence, lack of interest in outdoor play, and preference for electronic media. A participant said: "*I really want her [child] to eat healthy, but at the same time, I want her to eat. She's literally… her food choices, she will eat chicken nuggets. She will eat French fries. She will eat ramen, carrots, and grapes. That's it.*" Familial and peer influences included parental perception that healthy foods are expensive with short shelf-life, limited knowledge about how to obtain, prepare or preserve fruits/vegetables, and lack of time to prepare nutritious meals and/or be active with children. A participant described: *"I think it's the balance, but I'm really blessed to have the life where I can do this. We are very intentional when we eat at home. Everything is healthy at home… when we go to grandparents, that's kind of the time for the treat… Not everyone has that option.*" Organizational factors centered around perceptions that unhealthy foods were easily accessible through community organizations (e.g., schools, churches).

Community influences included lack of access to outlets that carry healthy foods (supermarkets) and resources that promote PA (parks), marketing of unhealthy foods to children, outdoor weather, and concern about child safety while playing outdoors. Describing the lack of access to PA resources, a participant said: "*One really sad thing that happened with the little kid basketball program was they used to have a preschool and kindergarten little boys' basketball, biddy ball. Then this year, because it had to get serious, you had to try out as a first grader. Kindergarten and preschool was dropped.*" Additionally, lack of policy to support healthy eating and PA was cited as a challenge. Describing this, a participant said: *I do think there's a role for the community as a whole. And that would be the government to make the rules of how we are exposed, to make our decisions… If we recognize there's a problem, there's only one way that we can step forward as a community to do that: to set some principles and rules that guide us in that.*"

Community settings that participants ranked highest as the top places to promote healthy dietary intake and PA in children are described in Table 2. For the promotion of healthy dietary intake, settings that overlapped between the IN and NC communities included educational settings (e.g., childcare centers), food outlets (e.g., grocery stores), youth sports, community gathering places (e.g., churches), and social media. Also, participants prioritized the home (NC), recreation facilities (IN), and other locations (e.g., community events) (NC) as settings to promote healthy dietary intake in their communities. In terms of promoting PA, settings that overlapped across both communities were educational and recreation facilities (e.g., parks, trails). Additional settings for promoting PA that participants prioritized were the home (NC), social media (IN), and community gathering places (IN).

Intervention strategies that participants ranked highest are shown in Table 3. Strategies for promoting healthy dietary intake overlapped between the two communities, focusing on: providing nutrition education opportunities (e.g., nutrition education for parents, fruit and vegetable gardening with children at preschools); enhancing access to healthy foods in the built environment (e.g., via community gardens); and enhancing food security through access to food programs (e.g., backpack buddy programs at childcare settings to provide children from food-insecure households with take-home meals). Partnerships with community organizations to increase healthy food offerings in childcare settings were also recommended (NC). For PA promotion, an intervention strategy that overlapped between both communities centered on providing PA education opportunities for children/families (e.g., PA lessons at childcare, organized community events that promote PA). Additional strategies that participants prioritized included: providing enhanced access to PA-promoting resources in the built environment (e.g., adding game stencils to playgrounds) (IN); offering incentives (e.g., free passes to bounce houses) (IN); and leveraging community facilities and local organizations to offer PA to families (NC).

Due to time constraints, discussions about challenges the study team might encounter in implementing an intervention and potential navigation strategies occurred only in NC. The major challenge that was discussed centered around low parental

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TABLE 1 Demographic characteristics of participants in community workshops conducted in two rural communities in Indiana and North Carolina[1].

	Indiana community		North Carolina community	
	Workshop 1 (n = 15)	Workshop 2 (n = 11)	Workshop 1 (n = 9)	Workshop 2 (n = 13)
	n (%)	n (%)	n (%)	n (%)
Sex				
Female	14 (93)	10 (91)	8 (89)	10 (77)
Male	1 (7)	1 (9)	1 (11)	3 (23)
Age				
18–35 years	4 (27)	2 (18)	3 (33)	5 (38)
36–55 years	7 (47)	6 (55)	4 (44)	4 (31)
55 years or older	4 (27)	3 (27)	2 (22)	4 (31)
Race				
Black/African-American	0 (0)	0 (0)	4 (44)	10 (77)
White	13 (87)	11 (100)	3 (33)	3 (23)
Other	2 (13)	0 (0)	2 (22)	0 (0)
Ethnicity				
Hispanic	1 (7)	0 (0)	0 (0)	0 (0)
Non-Hispanic	14 (93)	11 (100)	9 (100)	12 (100)
Employment status				
Full-or part-time	12 (80)	9 (82)	7 (78)	9 (69)
Not currently employed	3 (20)	2 (18)	2 (22)	4 (31)
Self-identified roles[2]				
Parent	5	3	2	4
Grandparent	1	0	1	2
Childcare provider	3	2	0	1
Youth Service	2	3	3	3
School	4	2	0	0
Business/Media	1	0	2	1
Law enforcement/ government	0	0	1	1
Civic, volunteer, or religious	3	2	2	2
Healthcare	3	1	2	3
Other	0	0	0	2

[1]The total number of participants in each workshop across the Indiana and North Carolina community were not calculated in this table because some participants took part in both workshops, while others participated in a single workshop. To preserve participant anonymity, the study team asked each participant to complete a demographic survey at the start of each workshop, even if they had participated in the previous workshop. Thus, the study team was unable to differentiate demographic characteristics of persons who participated in a single workshop versus both workshops.
[2]When reporting self-identified roles, participants could "select all that apply." Therefore, this table is not indicative of the total count of participants, but rather, the roles that were represented at the workshops., hence the reason for not combining categories or including percent counts.

engagement in an intervention that might occur because of parents' busy schedules (lack of time) and limitations with transportation given the community's lack of a public transit system. Participants suggested using personalized invitations to enhance parental engagement. Organizing intervention activities to occur at community settings where parents typically spend time with children (e.g., childcare centers, parks) was also suggested. Another concern that was discussed centered on the transience of community partners and health initiatives that made it difficult to create sustainable health promotion programs, but no solutions were proffered.

Participants identified immediate interventions they could begin to implement with the study team with limited funding. In IN, the immediate intervention was to install game stencils at public playgrounds/parks to promote PA in children, whereas in NC it was to create a quarterly newsletter about healthy lifestyles to disseminate to families. Participants shared examples of local agencies [e.g., REMC Electric Company (IN), Triangle North Healthcare Foundation (NC)] from which grant funding could be sought to support the immediate interventions. Participants indicated willingness to continue to engage with the study team via quarterly meetings to advance the obesity prevention efforts identified from this study.

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TABLE 2 Community settings that workshop participants in the two rural communities in Indiana and North Carolina ranked highest for the promotion of healthy dietary intake and physical activity in children aged 2–5 years.

	Indiana community			North Carolina Community		
	Settings that ranked as top 4 places to promote healthy eating and PA			Settings that ranked as top 4 places to promote healthy eating and PA		
Setting to promote:	Setting category	Specific setting	# of votes	Setting category	Specific setting	# of votes
Fruits/vegetables	Educational	Preschools	10	Educational	Child care centers	7
	Youth sports	Concession stands	10	Home	Home	6
	Social media	Social media	6	Social media	Social media	5
	Food/beverage outlets	Farmers' markets	6	Food/beverage outlets	Grocery stores	4
	Food/beverage outlets	Grocery stores	6	Community events	Community events	4
Less fast food	Youth sports	Concession stands	14	Educational	Child care centers	7
	Where parents are	Where parents are	13	Community gathering	Library	5
	Recreational	Parks	10	Community gathering	Churches	4
	Educational	Schools/cafeteria	5	Food/beverage outlets	Grocery stores	4
Less sweet/salty snacks	Recreational	Pools	15	Educational	Schools	7
	Youth sports	Concession stands	14	Other	Afterschool	7
	Educational	Schools	14	Home	Home	6
	Recreational	Parks	7	Youth sports	Youth sports	4
Healthy beverages[1]	Food/beverage outlets	Water fountains	10			
	Recreational	Parks	8			
	Educational	Schools/cafeteria	8			
	Educational	Preschools	8			
Physical activity	Community gathering	Library	12	Educational	Child care centers	8
	Educational	Schools/preschools	8	Educational	Schools	8
	Social media	Social media	4	Home	Home	7
	Recreational	Walking trails	4	Recreational	Recreation centers	6
	Community gathering	Churches	4			

PA represents physical activity.
[1]Given time constraints, discussions about setting to promote less consumption of sweet and salty snacks, and healthy beverages were combined at the workshop in the North Carolina community.

4 Discussion

This paper describes results from four workshops with community partners to guide the development of a rural multi-level community-based intervention to promote healthy weight in children aged 2–5 years. In the current study, participants described factors influencing the choice to engage in healthy weight behaviors in their community. They cited several factors at the child (e.g., child preference), familial/peer (e.g., financial and time constraints), organizational (e.g., limited access to healthy foods and PA opportunities through organizations), community (e.g., food deserts), and policy levels (lack of nutrition and PA-promoting policies). Participants' responses about factors that influence the choice to eat healthy and be physically active were consistent with the initial formative research conducted by the current study team in both communities (26) and other studies of rural communities (4, 7, 37).

Discussions at the workshops were used to identify community settings to prioritize in a rural, obesity prevention intervention for children aged 2–5 years. Rural areas vary widely with regards to the availability of resources that can support healthy lifestyles (37) (e.g., supermarkets, recreation centers), but existing community-identified settings can serve as trusted, anchor organizations that can be leveraged in the implementation of community-based child obesity prevention interventions (37, 38). Community settings that participants identified align with studies of children and adults that report social media, rural social networks (e.g., social or family gatherings) (10, 11, 18, 37), food outlets (10, 11, 18, 35–37, 39), and shared community spaces (e.g., schools, faith-based/civic organizations) (10, 11, 13, 18, 37, 40) as natural settings to reach and engage with rural children/families. Notably, representatives of healthcare organizations were present at the workshops and discussions about services/programs available at healthcare settings

TABLE 3 Intervention strategies that workshop participants in the two rural communities in Indiana and North Carolina ranked highest for the promotion of healthy dietary intake and physical activity in children aged 2–5 years.

	Indiana community			North Carolina community		
	Intervention strategies that ranked as top 4 ways to promote healthy eating and PA			Intervention strategies that ranked as top 4 ways to promote healthy eating and PA		
Ways to promote:	Intervention Category	Specific Intervention	# of votes	Intervention Category	Specific Intervention	# of votes
Fruits/Vegetables[1]	Nutrition education	Hands-on gardening	12	Nutrition education	Nutrition education	8
	Enhance access in the built environment	Turn on water fountains (COVID-19 related)	7	Enhance food security	Backpack buddy programs	7
	Nutrition education	Provide seeds to kids to grow	6	Enhance access in the built environment	Community gardens	5
	Enhance food security	Provide meals kits	6	Nutrition education	Farm tour/field trips	5
Less Fast Food				Enhance food security	Grocery store coupons	8
				Enhance food security	"Pay as you can" at farmers' markets	7
				Nutrition education	Sampling of foods at grocery stores	6
				Enhance food security	Gift cards to farmers' markets	6
Less sweet/salty snacks and Sugary beverages				Enhance access in the built environment	Pop-up fruit & vegetable markets	13
				Nutrition education	Community events	10
				Nutrition education	Promote healthy celebration foods	10
				Community partnerships	Partnerships to increase healthy offerings	10
Physical activity	Enhance access to PA in the built environment	Install game stencils at community locations	11	PA education	Use local personal trainers	8
	PA education	PA lesson in preschool	7	Community partnerships	Use organization to bring in activities	8
	Enhance access to PA in the built environment	Library of "things" to increase PA	7	PA education	Yoga for kids	7
	Provide incentives	Passes to PA locations	6	PA education	Community PA events and classes	6
	PA education	Use social media to promote PA	6			

PA represents physical activity.

[1]Given time constraints, discussions about intervention strategies centered around healthy foods in the Indiana community, as opposed to focusing on specific nutrition behavioral targets as was done in the North Carolina community.

in the community occurred, however, participants did not prioritize healthcare settings as places to reach or intervene with families.

Intervention strategies identified by study participants can be implemented across several of the settings they prioritized. Providing nutrition and PA education opportunities to children/families and offering incentives to promote healthy lifestyles were recommended by participants. Given the paucity of nutrition and PA resources in most rural areas (26), it not a surprise that participants recommended the need to increase access to healthy foods and PA-promoting resources in their community's built environment. With many rural areas' high levels of food insecurity (41), it is also not a surprise that participants recommended enhancing food security in their community through access to food programs. Going forward, the goal of the study team is to work collaboratively with community partners to develop a multi-level intervention that incorporates the community-identified priorities for obesity prevention for children aged 2–5 years, and then seek grant funding to pilot-test the intervention.

Using a community-engaged approach, as was done in the current study, helps researchers build trust with partners in rural communities

(18, 37, 42, 43) and allows researchers and community partners to work together in a collaborative manner to design child obesity prevention interventions that are culturally-appropriate, relevant, and acceptable to communities (18, 34, 42). This community-engaged approach is crucial for creating community-based interventions that are likely to be impactful and sustainable in the long-term (18, 38, 44).

At the workshops, participants discussed the installation of game stencils at public playgrounds/parks to promote PA in children (IN) and the dissemination of a quarterly newsletter about healthy lifestyles to families (NC) as immediate interventions that could be implemented with limited funding. To implement these, in IN, the study team collaborated with a community partner (Greene County Foundation, IN) to apply for two small grants that were awarded in the fall of 2022 by the South Center Indiana REMC and the Bloomington Board of Realtors. Using the grant funds, the study team and community partners have painted playground stencils for use by children at three public libraries and two childcare centers. For NC, the study team is working with community partners to develop a series of electronic newsletters, the first of which was shared with community partners in the spring of 2023 to distribute to families served through their respective organizations' communication channels.

This study has some limitations. Because rural areas differ with regards to resources available to promote healthy weight behaviors, the findings of this study may not be generalizable to all rural communities. While the study team spread the word about the workshops throughout the communities, it is possible that the sample was biased toward persons most interested/passionate in promoting health in their community. Additionally, workshops occurred in the main townships of both counties, thus, excluding participation by interested community members without access to a means of transportation. Childcare support was not provided at the workshops, limiting attendance by parents who could not afford or find childcare. Nevertheless, a strength of this study is the sizable number of participants (9–15) with varied demographic characteristics that allowed for the inclusion of diverse perspectives at the workshops. Additionally, the use of a participatory approach in which community partners and the study team collaboratively identified community priorities for preventing obesity in children aged 2–5 years is a strength.

Results from each workshop were summarized and shared with participants and other community partners via a factsheet. The study team will use the results to work collaboratively with community partners to develop a rural multi-level community-based obesity prevention intervention for children aged 2–5 years.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Human Research Protection Program (HRPP) Office for Research Compliance Indiana University Bloomington. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KP: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. AL: Writing – original draft, Writing – review & editing, Data curation, Conceptualization. LH: Writing – review & editing, Writing – original draft, Conceptualization. DG: Writing – review & editing, Writing – original draft, Conceptualization. JG: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. DW: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. TH: Writing – review & editing, Writing – original draft. TE: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1372890/full#supplementary-material

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Examining the association of family environment and children emotional/behavioral difficulties in the relationship between parental anxiety and internet addiction in youth

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Introduction: Associations between parental anxiety and adolescent internet addiction have been documented in the literature; however, few studies have analyzed the role of the family environment in this relationship. This study aims to explore the relationship between parental anxiety and adolescent internet addiction while also investigating the indirect relationships involving multiple dimensions of the family environment and child emotional behavior issues.

Methods: Surveys were conducted among 6,296 parent-child pairs. We administered SDQ, CIAS-R, and FES-CV to assess adolescents' issues and internet addiction, and evaluate family environment. Additionally, parents completed GAD-7 to assess parental anxiety levels.Results: Correlation analysis revealed that the family environment and adolescent emotional behavior issues played an indirect relationship in the link between parental anxiety and internet addiction.

Discussion: The findings emphasize the importance of addressing parental anxiety and fostering a positive family environment as effective measures to alleviate adolescent emotional behavior problems and reduce the risk of internet addiction.

KEYWORDS

internet addiction, parental anxiety, family environment, emotional, teenager

1 Introduction

Adolescents' engagement in online activities plays a vital role in their leisure, entertainment, and social interactions. However, internet addiction has become one of the most prevalent maladaptive behaviors worldwide, with internet gaming disorder being recognized in the DSM-5 (1). These behaviors pose substantial threats to the psychological and physical well-being of adolescents and may impact their future developmental paths (2, 3). Epidemiological studies, primarily focusing on male patients, have linked internet addiction to psychosocial challenges, psychopathological disorders, compromised physical health, and diminished quality of life (4). Furthermore, the COVID-19 pandemic has led to significant shifts in the lifestyles and learning routines of adolescents. Spending more time at home has resulted in increased usage of electronic devices. For adolescents with weaker self-management abilities, this newfound opportunity may be utilized for recreational activities, potentially reinforcing their reliance on the internet (5, 6). These changes may intensify adolescents' propensity for internet usage, rendering them more vulnerable to the perils of internet addiction. Consequently, internet-related issues among adolescents have become a prominent societal concern, carrying significant implications for families and society as a whole (7). Hence, conducting a comprehensive investigation into the potential predictive factors of adolescent internet addiction is of paramount importance to devise effective intervention measures.

Numerous studies have identified certain predictive factors for internet addiction, such as sleep quality (8), psychopathological disorders (9), and social support (10). Several studies have established a link between parental emotional difficulties (including anxiety, depression, behavioral and psychological controls), and internet addiction (11, 12), but the impact of family environment remains worthy of further study. Based on the family systems theory and ecological systems theory, this study aims to explore the relationship between parental anxiety and adolescent internet addiction, while also examining the role of multidimensional family environment (including intimacy, conflict, achievement orientation, cultural orientation, recreational orientation, organization, and control), as well as child emotional and behavioral issues in this association.

1.1 Parental anxiety and internet addiction

In recent years, there has been widespread concern about the parental anxiety and its adverse effects on the mental health of adolescents. Research findings show that approximately 66.8% of parents in China experience elevated levels of anxiety (13). Studies underscore the possibility that parental anxiety may lead to behavioral and psychological control, deterioration in parent-child relationships, and neglect, particularly as these factors are closely intertwined with smartphone and internet addiction among adolescents (14–18). Furthermore, anxious parents may manifest specific behaviors related to their emotional state (for example, excessive worry, nervousness, and manifestation of negative emotions), this process may lead children to adopt similar ways of coping with stress and handling emotions as their parents (19). It could be a key mechanism contributing to adolescent addictive behaviors, such as internet addiction. While the exact mechanisms are not fully understood, we believe that parental anxiety may influence the family atmosphere and shape children's emotional coping mechanisms through various pathways. Firstly, anxious parents may create a tense and uneasy atmosphere within the family, which could hinder communication among family members and escalate internal tensions and conflicts (20). Secondly, anxious parents may exhibit excessive worry, nervousness, and negative emotions, which could be transmitted to their children, impacting their emotional state and regulation abilities (21). For instance, when parents display anxiety and tension, children may experience feelings of unease and fear, and may adopt similar emotional coping strategies. Additionally, anxious parents may tend to employ overly protective or controlling parenting styles, which could limit children's autonomy and self-development, impeding their ability to effectively manage emotions and cope with stress (22). Therefore, by researching the potential correlation between parental anxiety and adolescent "addictive behaviors," we can gain a deeper understanding of this phenomenon and provide more targeted recommendations for intervention measures.

1.2 Family environment and internet addiction

Regarding family factors, family relationships have been proven to be a key mediating factor in transmitting parents' emotional problems to children's emotional and behavioral issues. Academic research emphasizes that family and parenting environments, as a dynamic system, impact various aspects of adolescents (23–25). Internet addiction is closely related to the internalizing and externalizing problems in adolescents. Firstly, internet addiction is often categorized as an externalizing problem, thus it is likely influenced by parental anxiety (26). On the other hand, internalizing problems involve individual's internal emotions and psychological states, where internet addiction may serve as a coping mechanism to escape or alleviate negative emotions (27, 28). However, previous studies often discuss the family environment as a whole or focus on specific aspects of it (29). The ecological systems theory and family systems theory both emphasize the importance of the environment in individual development. The ecological systems theory focuses on the interaction between individuals and their surrounding environment, highlighting the influence of environmental factors on individuals, and considers the family as one important ecological system. Within this framework, individual behavior, emotions, and development are influenced by the family environment, and the interactions and dynamics among family members have an impact on individual growth (30, 31). On the other hand, family systems theory views the family as a holistic system, emphasizing the interactions and interrelations among

family members. The behavior, emotions, and relationship quality of parents affect the stability and functioning of the family system. Parental anxiety may disrupt the balance of the family system. Anxious parents may exhibit more tension and negative emotions, which can affect the interactions and emotional connections among family members. They may demonstrate excessive control, detachment, or conflict, leading to a tense and unstable family atmosphere, which could negatively impact the emotions and behaviors of adolescents (32, 33). If the family environment is characterized by tension, instability, or other negative features, it may have adverse effects on a child's development. Parental anxiety can manifest within the family atmosphere, influencing the emotions and behaviors of the child (33). During the COVID-19 pandemic, one study focused on investigating the overall impact of the family environment on children's diet and nutritional status (34). In contrast, research examining the role of family intimacy in collaborative esports using the Switch device concentrated on the dimension of family relationship intimacy (35), aiming to understand its specific effects on the gaming experience. This type of study, which delves into specific family dimensions, holds significant importance as it helps us comprehend how a particular family factor can have a comprehensive impact on individual behavior and health in diverse contexts. By exploring multiple dimensions of the family environment, this paper aims to precisely grasp the mechanisms through which the family influences individuals in specific situations, providing more targeted recommendations and strategies for future family-based interventions. For example, if research reveals that the way a family resolves conflicts is related to the psychological well-being of adolescents, intervention measures can focus on providing training in conflict resolution skills to help family members effectively address conflicts and stressors. Similarly, if it is found that family cohesion is associated with adolescents' adaptability, interventions may involve strengthening communication and support networks among family members to enhance adolescents' emotional stability and social adaptation skills. Therefore, through targeted intervention measures, different needs within the family can be better addressed, leading to specific improvements in family dynamics and individual health. This study employs a multidimensional conceptualization of the family environment, incorporating multiple subscales to comprehensively assess various aspects within the family. These subscales cover dimensions such as cohesion, emotional expression, conflict resolution, individual independence, achievement orientation, cultural interest, recreational activities, moral-religious orientation, organization, and control among family members. By meticulously examining the impact of each family environmental construct, we aim to provide a more profound and comprehensive understanding of the relationship between family factors and adolescent internet addiction. For example, in families characterized by low intimacy and high conflict, adolescents may opt for online social interactions as an alternative to communicating with their parents, resulting in spending more time on the internet. In families characterized by low intimacy and high conflict, adolescents often opt for online social interactions as a substitute for communication with their parents, consequently spending more time on the internet. In such scenarios, the social circle of adolescents plays a crucial role in the development of their addictive behaviors. Research indicates that associating with peers and friends who exhibit addictive behaviors significantly increases the risk of adolescents developing their own addictive tendencies (36). These adolescents are more likely to encounter peers already addicted to the internet, and they are influenced by the behaviors and attitudes of their peers (37). They may emulate their peers' behaviors or be influenced by them, thereby exacerbating their own internet usage and addiction. Additionally, with low parent-child intimacy and frequent family conflicts, parents often lack adequate guidance in helping their children establish healthy friendships. This contributes to the difficulty in correcting these adolescents' poor socializing tendencies. Similarly, in households with limited engagement in recreational activities, where parents spend less time playing with their children, adolescents may be more inclined to use the internet to fulfill their entertainment needs (38). In such an environment, if the family lacks organization and rules are unclear, adolescents may feel a lack of guidance and structure (39), thus more likely to become immersed in the online world to seek self-organization and rules. Simultaneously, we will also explore the relationship between family environment and adolescent internet addiction in the dimensions of cohesion (40), conflict resolution (41), achievement orientation (42), cultural interest (43), and recreational activities (44). Therefore, this paper also aims to investigate the relationship between family environment and adolescent internet addiction across these dimensions, seeking to identify family environmental factors that predict adolescent internet addiction.

1.3 Adolescent emotional and behavioral issues and internet addiction

Previous studies have demonstrated a strong relationship between internet addiction and the mental well-being of adolescents. For instance, internet addiction may increase susceptibility to depression and anxiety (45), negatively impact academic performance, physical exercise, and sleep, and even have a moderate correlation with Attention Deficit Hyperactivity Disorder (ADHD) (46). Adolescents facing emotional challenges, such as academic pressure, family issues, and social challenges, may resort to excessive internet use to escape reality and alleviate emotional distress (47). Prolonged immersion in the online world may also lead to social isolation in adolescents, leading to a lack of emotional and interpersonal skills in facing real-life situations, thereby increasing the risk of emotional problems (48, 49). Most previous research has primarily examined the relationship between internet addiction and the mental health of adolescents, however, this study will assess five aspects, including emotional symptoms, conduct problems, hyperactivity, peer problems, and prosocial behavior, to explore the connection between adolescent emotions and behaviors and internet addiction from the perspectives of internalizing and externalizing issues.

1.4 Parental anxiety, family environment, and adolescent emotional and behavioral issues

Regarding individual factors, numerous studies have confirmed that parental anxiety and depression may significantly influence the anxiety and depression of adolescents, potentially fostering internet addiction. Parents with anxiety may excessively focus on negative events (50), leading to intensified parenting stress and resulting in internalizing and externalizing problems in their children (51). The family environment is inseparable from emotional and behavioral challenges in adolescents. Families with mental health issues often exhibit weakened cohesion, diminished adaptability, and increased conflict, making children more susceptible to disturbances in psychosocial functioning and stress response systems (52, 53). The literature on the relationship between parental parenting styles and family environment suggests that adolescents with higher levels of parental anxiety may experience increased levels of family conflict. Additionally, findings indicate that adolescents with higher levels of anxiety tend to perceive their parents as more isolated within the family environment, excessively concerned with others' opinions, and feel ashamed of their own perceived inadequacies (54). While previous studies often focused solely on either parental individual factors or family environmental factors, our research simultaneously considered both of these influencing factors, thoroughly exploring their associations with adolescent emotional and behavioral issues.Additionally, we conducted meticulous analysis to thoroughly study the relationships among these factors. Although cross-sectional data cannot provide causal evidence, our emphasis is on elucidating the correlations between these factors. This comprehensive approach aids in better identifying factors that are more predictive of the severity of internet addiction.

1.5 The current study

In summary, the escalating recognition of the detrimental impact of parental anxiety on adolescent mental health parallels the growing global concern over the increasing prevalence of internet addiction among this demographic. However, a research gap exists, notably the lack of a detailed categorization of the family environment into different dimensions to explore their relationships with other factors separately. Additionally, previous studies using small samples may have compromised the credibility and statistical significance of the findings. To address this gap, we propose the following specific research questions and hypotheses. Hypothesis one suggests that family environment variables (including closeness, conflict, achievement orientation, cultural orientation, recreational orientation, organization, and control) play an indirect role in the impact of parental anxiety on adolescent internet addiction. Hypothesis two anticipates that adolescent emotional and behavioral issues will generate an indirect relationship between family environment variables and internet addiction. Through the study of these factors, our aim is to explore the relationship between parental anxiety, family environment, adolescent emotional and behavioral issues, and internet addiction. It is hoped that this research will provide support for the establishment of intervention measures to address adolescent internet addiction, further improve family environments, and enhance the overall well-being of adolescents.

2 Method

2.1 Participants

We conducted a questionnaire survey among students aged 10-18 and their parents in Taizhou, Yixing, and Sheyang in Jiangsu Province, China. Prior to the survey, we obtained informed consent from all participants. To ensure representation, we selected 1-2 primary schools, 1-2 middle schools, and 1-2 high schools in each location, using a cluster stratified random sampling method. Utilizing a convenient and efficient online self-monitoring system, we assessed the psychological health status of individual students and the overall well-being of the student community through self-assessment questionnaires completed by both students and parents. We collected a total of 6,296 valid questionnaires, among adolescents, there are 2,884 females and 3,412 males, and among parents, there are 5,294 mothers and 1,002 fathers.

2.2 Measures

We administered the Strengths and Difficulties Questionnaire (SDQ), the Revised Chen Internet Addiction Scale (CIAS-R), and the Family Environment Scale-Chinese Version (FES-CV) to assess adolescents' emotional and behavioral issues, measure the extent of internet addiction, and evaluate the family environment, respectively. Additionally, for parents, we utilized the Generalized Anxiety Disorder-7 scale (GAD-7) to assess the level of parental anxiety.

2.2.1 Strengths and difficulties questionnaire

SDQ was a self-report questionnaire with 25 items that was developed by Goodman (55) with the aim of measuring the mental strengths manifested in children and the difficulties faced by the children, we administered this questionnaire as a self-report for adolescents. It had five subscales, including subscales of emotional symptoms (e.g., Many worries, often seems worried), conduct problems (e.g., Often lies or cheats), hyperactivity (e.g., Thinking things out before acting), peer problems (e.g., Rather solitary, tends to play alone), and prosocial scale (e.g., Kind to younger children). Participants responded to each item via a three-point scale (1 = "not true," 2 = "somewhat true," and 3 = "certainly true"), and high scores indicate high levels of mental strengths and difficulties. The Chinese version of the SDQ had good reliability and validity (56, 57), and the Cronbach's alpha of the total four subscales was 0.71. In calculating adolescent emotional and behavioral issues, we utilized the total scores of emotional symptoms, conduct problems,

hyperactivity symptoms, and peer problems. The total difficulty score, with a range from 0 to 40, was categorized as follows: scores equal to or less than 13 were considered within the normal range, scores from 14 to 16 were categorized as borderline, and scores ranging from 17 to 40 were considered abnormal.

2.2.2 The revised Chen internet addiction scale

CIAS-R was a modified version of the Chinese Internet Addiction Scale (CIAS) developed by Taiwanese scholars (57), including Chen Shu-Hui. It consisted of 26 items grouped into "Core Symptoms of Internet Addiction" and "Internet Addiction-Related Problems." Adolescent participants completed self-reports of the CIAS-R. The "Core Symptoms of Internet Addiction" factor comprised three sub-factors: Compulsive Use of the Internet, Withdrawal Symptoms of Internet Addiction, Tolerance Symptoms of Internet Addiction. The "Internet Addiction-Related Problems" factor included two sub-factors: Interpersonal and Health-Related Problems of Internet Addiction, Time Management Problems. Participants rate each item on a 4-point scale (1 = "Not at all," 2 = "Slightly," 3 = "Moderately," and 4 = "Severely"). The score for each factor was the sum of the scores of the items it contains. In the calculation, we summed up the scores of these two factors to assess the severity of internet addiction, higher scores indicated a more severe level of Internet addiction. Adopting the recommended cutoffs for adolescents (58), respondents with CIAS-R scores of 64 or above were classified as Internet addicted. Cronbach's alpha of the total score of CIAS-R was reported to range from 0.90 [10] to 0.95 (59) in university students, and was 0.97 in the present study.

2.2.3 Family environment scale-Chinese version

FES-CV was a self-report questionnaire introduced and revised by Fei Lipeng et al. in 1991 (60), adapted from the FES developed by Moss et al. in 1981 (61), this was a self-report questionnaire for adolescents. It aimed to assess 10 different family environmental characteristics and explore the impact of the family on individuals. This questionnaire encompassed ten subscales aimed at evaluating various relational characteristics within the family environment. These subscales included Cohesion, which measured the commitment and support among family members; Expressiveness, which gauged the encouragement of emotional expression within the family; Conflict, which assessed the openness of anger expression and conflict resolution; Independence, which examined the level of esteem, self-confidence, and independence among family members; Achievement Orientation, which appraised the family's perspective on achievement and competition in general activities; Intellectual-Cultural Orientation, which indicated the family's interest in political, intellectual, and cultural pursuits; Active-Recreational Orientation, which assessed family involvement in recreational activities; Moral-Religious Orientation, which measured the emphasis on ethnicity, religion, and values among family members; Organization, which evaluated the planning and responsibility allocation for family activities; and Control, which determined the extent to which rules and procedures were used by family members to structure their lives (62). The scale consisted of 90 true/false items divided into 10 subscales. However, it was found that the subscales measuring Independence, Moral-Religious Emphasis, and Expressiveness demonstrated relatively poor internal consistency reliability, possibly due to their content being less suitable for Chinese culture. Therefore, for the purpose of this screening, 7 subscales (Closeness, Conflict, Achievement Orientation, Cultural Orientation, Recreational Orientation, Organization, and Control) with better reliability and validity were selected, resulting in a total of 63 true/false items utilized. The FES-CV demonstrated good reliability and validity, except for three subscales: expressiveness, independence, and moral-religious orientation. These subscales were excluded from our study; thus, a total of seven subscales were utilized. The Cronbach's α coefficients for the cohesion, conflict, intellectual-cultural, organization, achievement, active-recreation, and control subscales were 0.813, 0.807, 0.798, 0.764, 0.712, 0.726, and 0.708, respectively, indicating satisfactory internal consistency reliability for the measurement instrument (63).

2.2.4 Generalized anxiety disorder-7 scale

GAD-7 was a self-report screening tool developed by Stanley Rachman (64) with the aim of measuring parent's anxiety symptoms, this was also the sole self-report applied to parents. This scale comprised 7 items (worry, tension, irritability, muscle pain, fatigue, difficulty concentrating, and irritability), each assessing various aspects of anxiety symptoms. Participants rated each item on a four-point scale ranging from "0 =not experienced at all" to "3 =experienced almost every day".The scale had a total score of 21 points, achieved by adding up the scores from each item given by the test taker, and a higher score indicates a greater level of anxiety.The assessment criteria for anxiety were as follows: A score of 0-4 indicates no symptoms of anxiety; 5-9 points suggest possible mild anxiety symptoms; 10-13 points may indicate moderate anxiety symptoms; 14-18 points could suggest moderately severe anxiety symptoms; and a score of 19-21 may indicate severe anxiety symptoms.The Chinese version of GAD-7 was widely used in research and clinical practice, and had a Cronbachs alpha of 0.89.

2.3 Data analysis

The current study employed a series of well-defined steps for data analysis. Firstly, a total of 10,232 pairs of parents and children completed the questionnaire survey. To meticulously clean the data, the author implemented rigorous measures to exclude outliers. During this process, it was noted that some participants provided answers in demographic questions that did not match the given options. Consequently, these outliers were removed by the author to ensure the accuracy and reliability of the data. Subsequently, data from participants who did not complete questions related to parental anxiety, family environment, adolescent emotional behavior, and teenage internet addiction were further excluded. The final dataset comprised 6,296 valid responses. A descriptive analysis of demographic characteristics was then conducted,

wherein the participants were grouped based on the levels of parental anxiety. The family environment was categorized into seven dimensions, and a direct model was employed to explore the intricate relationships between all variables. For the purpose of conducting indirect association analysis, one independent variable (parental anxiety), one dependent variable (adolescent internet addiction), and two intermediary variables (family environment and adolescent emotional and behavioral difficulties) were utilized. We categorized parental anxiety into three levels and conducted analysis of variance (ANOVA) among these levels. Additionally, we employed Pearson product-moment correlation analysis to explore the relationships between each variable. Each dimension of the family environment underwent separate analysis for indirect associations. To perform the data analysis, SPSS and the PROCESS computational macro were employed, facilitating indirect association and moderation analyses within SPSS. Additionally, the indirect association model was analyzed using AMOS. To ensure the robustness of the indirect association effects, a bootstrapping procedure with 5,000 bootstrap samples was employed to estimate the 95% confidence intervals.Control variables such as age, gender, and grade were carefully included in the model as covariates to account for potential confounding factors. Significance assessment was conducted using two-tailed tests, with a p-value set at 0.05.Furthermore, it is important to note that all analyses were conducted using SPSS 24.0 for Windows, ensuring standardized and reliable data processing.

3 Results

3.1 Demographic characteristics

In the survey, 6296 pairs of adolescents and parents took part. Among the adolescents, 3412 (54.2%) of them were male, and 2884 (45.8%) of them were female, with an average age of 13.45 years (SD=2.07). There are 650 individuals addicted to mobile and electronic products, with a detection rate of 10.3% for mobile and electronic product addiction. Table 1 classified parents into groups based on their anxiety levels and compared their differences in family environment, emotional and behavioral issues of adolescents, and internet addiction. The analysis revealed significant variations among the groups, indicating the potential impact of parental anxiety on these aspects.

3.2 Preliminary correlation analyses

The results reveal significant positive correlations between parental anxiety, adolescent emotional and behavioral issues, and adolescent internet addiction variables (Table 2). These three factors show negative correlations with family environment's intimacy, entertainment, achievement, culture, and organization, while they exhibit positive correlations with its control and conflict. These correlations align with our expectations, indicating support for our hypotheses that there is a close association between parental anxiety, adolescent emotional and behavioral issues, and adolescent internet addiction. Furthermore, these correlations are statistically significant in some instances, further emphasizing their importance and influence. It is worth noting that no significant correlation was found between parental anxiety and adolescent emotional and behavioral issues in the dimension of family environment control.

3.3 Indirect relationship analysis

We conducted an analysis of indirect relationships using regression analysis and bootstrapping, following Hayes' (65) method, to examine the indirect influence of various dimensions of the family environment and emotional behavioral issues in adolescents on the relationship between parental anxiety and internet addiction. The results of the analysis are presented in Table 3 and Figure 1. After accounting for sociodemographic variables (age, gender, grade), the direct effects, indirect effects, and total effects of the model were found to be statistically significant. Additionally, the non-parametric bootstrapping method confirmed the statistical significance of the indirect effects of each factor.

The relationship analysis regarding family environment intimacy and adolescent emotional/behavioral issues revealed significant effects between parental anxiety and adolescent internet addiction. The calculated indirect effect was 0.3573, with a confidence interval of [0.2140-0.5005], excluding 0, accounting for 36.87% of the total effect (0.9690) of parental anxiety on adolescent mobile internet addiction. Importantly, the indirect effect comprises three pathways, all of which are statistically significant. The first pathway, facilitated by parental anxiety - family environment intimacy - adolescent internet addiction, accounted for 9.45% of the total effect, with a confidence interval of [0.0595-0.1281]. The second pathway, influenced by parental anxiety - adolescent emotional/behavioral issues - adolescent internet addiction, accounted for 27.46% of the total effect, with a confidence interval of [0.1888-0.3471]. Lastly, the third pathway, involving parental anxiety - family environment intimacy - adolescent emotional/behavioral issues - adolescent internet addiction, accounted for 26.21% of the total effect, with a confidence interval of [0.1956-0.3167]. These findings indicate that family environment intimacy and adolescent emotional/behavioral issues play an indirect role in the connection between parental anxiety and adolescent internet addiction.

Moreover, the findings for other family environment dimensions, such as entertainment, achievement, cultural, and organizational aspects, exhibited a similar negative correlation with parental anxiety. In contrast, family environment conflict displayed a positive correlation with parental anxiety. These findings corroborate our initial hypothesis that family environment intimacy, entertainment, achievement, cultural, conflict, and organizational aspects, along with adolescent emotional and behavioral problems, may play a role in the association between parental anxiety and adolescent internet addiction. We also compared the overall magnitude of indirect effects for each model (see Table 3). Given that we compared the influence of family dimensions across models, and the confidence

TABLE 1 Analysis of differences among three groups of parents: no anxiety, mild anxiety, and moderate to severe anxiety.

	No anxiety (n=5698)		Mild anxiety (n=574)		Moderate to severe anxiety (n=24)		F	*P*
	Mean	SD	Mean	SD	Mean	SD		
EBP	10.24	5.90	12.80	6.63	13.92	8.64	12.25	0.00
INT	4.92	3.24	6.21	3.67	6.42	4.60	10.86	0.00
EXT	7.51	4.10	9.19	4.73	9.75	6.00	11.35	0.00
Intimacy	7.66	1.89	6.92	2.36	6.13	2.98	-10.95	0.00
Entertainment	5.09	2.24	4.42	2.26	4.67	2.37	-7.92	0.00
Achievement	4.57	1.40	4.36	1.52	4.17	1.40	-4.16	0.00
Control	3.39	2.00	3.47	1.96	3.08	1.67	0.50	0.62
Cultural	4.95	2.18	4.41	2.15	3.83	2.30	-7.02	0.00
Conflicts	2.26	1.95	2.96	2.26	3.54	2.59	9.64	0.00
Organization	6.53	1.93	5.92	2.13	5.21	2.47	-9.12	0.00
IA	42.27	16.41	48.68	19.19	52.50	23.97	11.22	0.00

EBP, emotional and behavioral problem; INT, internalizing problems; EXT, externalizing problems; IA, Internet addiction; intimacy, entertainment, achievement, control, cultural, conflicts, organization are all dimensions of the family environment.

intervals for ind1 and ind3 of the family environment control model encompassed 0, we excluded it from consideration. We observed that family environment achievement had the largest magnitude of indirect effects, suggesting that adolescent emotional and behavioral problems and family environment achievement may have the greatest impact on the relationship between parental anxiety and adolescent internet addiction.

4 Discussion

The aim of this study was to examine the indirect impact of parental anxiety on internet addiction in adolescents. The results indicated a significant statistical association between parental anxiety and internet addiction through the indirect relationships of different dimensions of family environment and adolescent emotional and behavioral problems. These findings support the perspective of Family Systems Theory (66, 67), which posits that the behavior of each family member is influenced by others and, in turn, also affects the behaviors of other members within the family. This helps explain how parental anxiety may lead to internet addiction through the indirect relationships of different dimensions of family environment and adolescent emotional and behavioral problems. Among these factors, family environment intimacy seems to play a key role in influencing adolescent internet addiction. It is crucial for parents and adolescents to recognize the importance of family environment and work together to maintain a positive and beneficial family atmosphere. These results will be further discussed.

TABLE 2 Correlations between parental anxiety, family environment, teenage emotional and behavioral issues, and internet addiction.

Variables	Mean	SD	1	2	3	4	5	6	7	8	9
1 parent anxiety	1.06	2.432	–	–	–	–	–	–	–	–	–
2 EBP	10.48	6.031	0.153***	–	–	–	–	–	–	–	–
3 intimacy	7.58	1.958	-0.137***	-0.556***	–	–	–	–	–	–	–
4 entertainment	5.02	2.254	-0.100***	-0.394***	–	–	–	–	–	–	–
5 achievement	4.55	1.414	-0.052***	-0.123***	–	–	–	–	–	–	–
6 control	3.4	1.997	0.006	0.019	–	–	–	–	–	–	–
7 cultural	4.89	2.188	-0.088***	-0.359***	–	–	–	–	–	–	–
8 conflicts	2.33	1.992	0.121***	0.520***	–	–	–	–	–	–	–
9 organization	6.47	1.957	-0.114***	-0.493***	–	–	–	–	–	–	–
10 IA	42.89	16.827	0.140***	0.554***	-0.378***	-0.327***	-0.127***	-0.045***	-0.383***	0.338***	-0.389***

EBP, emotional and behavioral problem; INT, internalizing problems; EXT, externalizing problems; IA, Internet addiction; intimacy, entertainment, achievement, control, cultural, conflicts, organization are all dimensions of the family environment, ***p<0.001.

TABLE 3 Analysis of the pathway.

The pathway		Effect	SE	BootLLCI	BootULCI	% of contribution
Intimacy	Total effect	0.9690	0.0863	0.7997	1.1382 *	
	Direct effect	0.3573	0.0731	0.2140	0.5005 *	36.87%
	Ind1	0.0916	0.0178	0.0595	0.1281 *	9.45%
	Ind2	0.2661	0.0405	0.1888	0.3471 *	27.46%
	Ind3	0.2540	0.0310	0.1956	0.3167 *	26.21%
Entertainment	Total effect	0.9452	0.0879	0.7729	1.1175 *	
	Direct effect	0.3601	0.0740	0.2149	0.5052 *	38.10%
	Ind1	0.0890	0.0145	0.0624	0.1192 *	9.42%
	Ind2	0.3640	0.0473	0.2763	0.4613 *	38.51%
	Ind3	0.1320	0.0183	0.0970	0.1680 *	13.97%
Achievement	Total effect	0.9707	0.0863	0.8016	1.1398 *	
	Direct effect	0.3812	0.0731	0.2378	0.5245 *	39.27%
	Ind1	0.0210	0.0069	0.0090	0.0362 *	2.16%
	Ind2	0.5460	0.0562	0.4366	0.6571 *	56.25%
	Ind3	0.0225	0.0064	0.0105	0.0357 *	2.32%
Control	Total effect	0.9690	0.0863	0.7997	1.1382 *	
	Direct effect	0.3942	0.0731	0.2509	0.5375 *	40.68%
	Ind1	-0.0024	0.0047	-0.0121	0.0063	-0.25%
	Ind2	0.5768	0.0582	0.4643	0.6934 *	59.53%
	Ind3	0.0004	0.0010	-0.0014	0.0028	0.04%
Cultural	Total effect	0.9690	0.0863	0.7997	1.1382 *	
	Direct effect	0.3434	0.0713	0.2036	0.4831 *	35.44%
	Ind1	0.1274	0.0189	0.0919	0.1657 *	13.15%
	Ind2	0.3979	0.0463	0.3091	0.4911 *	41.06%
	Ind3	0.1002	0.0146	0.0726	0.1295 *	10.34%
Conflicts	Total effect	0.9690	0.0863	0.7997	1.1382 *	
	Direct effect	0.3737	0.0732	0.2302	0.5172 *	38.57%
	Ind1	0.0546	0.0131	0.0304	0.0820 *	5.63%
	Ind2	0.3228	0.0460	0.2365	0.4125 *	33.31%
	Ind3	0.2178	0.0268	0.1658	0.2715 *	22.48%
Organization	Total effect	0.9690	0.0863	0.7997	1.1382 *	
	Direct effect	0.3514	0.0724	0.2094	0.4934 *	36.26%
	Ind1	0.1185	0.0180	0.0848	0.1557 *	12.23%
	Ind2	0.3190	0.0424	0.2373	0.4061 *	32.92%
	Ind3	0.1800	0.0227	0.1358	0.2249 *	18.58%

PA, parent anxiety; EBP, emotional and behavioral problem; IA, Internet addiction. Taking Intimacy as an example, Ind1 is PA-Intimacy-IA, Ind2 is PA-EBP-IA, Ind3 is PA-Intimacy-EBP-IA. Similarly, for other dimensions and so forth.

SE stands for Standard Error, BootLLCI and BootUPCI are the lower and upper limit confidence intervals obtained through the Bootstrap method, the asterisk (*) represents significance in that pathway.

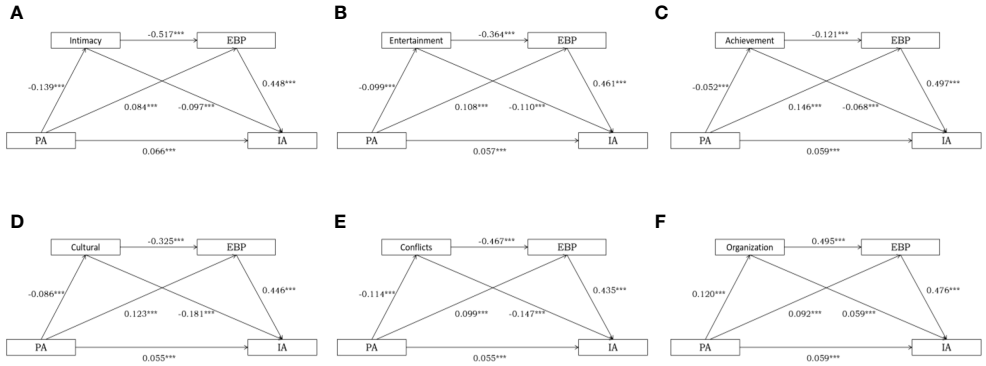

FIGURE 1
The relationship of family environment and children's emotional/behavioral difficulties in parental anxiety and adolescent internet addiction. **(A–F)** represent the model between parental anxiety (PA) and Internet addiction (IA) through family environment (intimacy, entertainment, achievement, cultural, conflicts, organization) and adolescent emotional and behavioral problems (EBP), respectively.

4.1 Correlation between parental anxiety and internet addiction

Firstly, in the data analysis of internet addiction prevalence, we paid particular attention to the differences in prevalence rates across various studies and found that this may be related to the methods of questionnaire administration and the characteristics of the study population. Some studies administered questionnaires through e-commerce websites such as JD.com, as well as social media platforms like WeChat and Weibo. This approach may not have adequately excluded participants who frequently use the internet in their daily lives, potentially leading to an overestimation of internet addiction prevalence in the results. We chose to conduct our survey in computer rooms at multiple schools, covering students from various grades, to enhance the credibility of the data and observe the general level of the study population. In our study, we found a significant association between parental anxiety and adolescent internet addiction in each model, which aligns with our previous hypotheses. Similar findings have been reported in previous research, indicating that parental anxiety is associated with various types of addictive behaviors, such as alcohol abuse (68), tobacco addiction (69), and food addiction (70). Some studies suggest that parents' high levels of anxiety can impact the development of parental control, potentially influencing both internal and external issues in adolescents (71). The Ecological Systems Theory suggests that when the needs of children and parents are not aligned, parental attempts at psychological control of their children's needs may lead to psychological imbalances, which in turn may result in emotional/behavioral problems and various substance addictions, especially internet addiction (72). Meanwhile, these relationships are considered to be partially mediated, implying that parental anxiety is not only directly associated with adolescent internet addiction but also indirectly influences adolescent internet addiction behavior through other variables (such as family environment intimacy). This study further illuminates the close association between parental anxiety and adolescent internet addiction, offering insights for a more in-depth understanding of this connection. It holds practical significance for the development of effective family support and educational programs, as well as the prevention and intervention of adolescent internet addiction behavior.

4.2 The effect of family environment

In line with our expectations, we found that parental anxiety not only directly influences internet addiction but also generates an indirect impact through the family environment. According to the Family Systems Theory, as a mutually interdependent entity, family environment can be affected by parental anxiety, thereby influencing the functioning and dynamics of the entire family system, which, in turn, may impact the child and make them vulnerable to substance dependence (73). In other words, in families where parental anxiety is present, the family environment undergoes negative changes, including increased instability, heightened conflicts, and reduced intimacy. These changes contribute to an escalation in adolescent emotional and behavioral problems, as well as an increase in internet addiction. A meta-analysis pointed out that when parents feel anxious, they may impose their own thoughts on their children in an abnormal way, intervening in their thoughts and behaviors, leading to a sense of insecurity and belongingness in children, which further contributes to a deteriorating family environment (74). Systemic relational approach emphasizes the interactions and influences among family members, highlighting the holistic and dynamic nature of the family system. In this approach, parental anxiety may disrupt the balance of the family system, affecting the stability and intimacy of internal family relationships, thereby negatively impacting the emotions and behaviors of adolescents (75). On the other hand, attachment theory focuses on the emotional bond between children and primary caregivers, suggesting that children's attachment experiences influence their emotional and behavioral development (76). In families with anxious parents, issues related to insecure attachment with parents may exist, potentially leading to an increased need for intimate relationships among adolescents, thereby influencing their internet addiction behavior. Additionally, adolescents may experience stress and a lack of confidence when confronted with challenges,

leading to a reduction in intimacy with family members. Research has revealed that this psychological state inclines adolescents to distance themselves from the family, making it challenging to establish profound emotional connections (77). Therefore, comprehending and supporting adolescents in times of adversity are crucial for maintaining family intimacy. Other research has also found a positive correlation between controlling family environment and adolescent frustration (78), and an increase in frustration can drive adolescents to seek refuge in the virtual world of the internet. Parental anxiety may lead to a poorer family environment, and the lack of security and belongingness may drive adolescents to seek the internet as a possible comfort, ultimately leading to internet addiction. Furthermore, entertainment-oriented and success-oriented characteristics may have positive effects on adolescents. A family environment rich in entertainment may encourage adolescents to seek healthy forms of entertainment, thereby reducing their reliance on the internet (79). Likewise, a success-oriented family may instill positive values of achievement, encouraging adolescents to pursue goals through tangible actions, thereby reducing reliance on the internet as a crutch (80). However, these positive influences may be weakened or even offset when there is conflict and chaos within the family environment. Internal family conflicts may lead adolescents to feel stressed and insecure, making them more prone to seeking ways to escape reality, such as getting lost in the internet (81). The disorderliness of family organization may weaken intimacy among family members, leaving adolescents feeling lonely and unstable, thus increasing the risk of internet addiction (82). On the other hand, family culture also influences adolescent internet addiction. A positive, healthy family culture may emphasize communication, mutual support, and personal development, providing a more conducive environment for adolescents' healthy growth. Conversely, a lack of clear values and cultural heritage in the family may lead to confusion and a lack of self-worth in adolescents, making them more susceptible to seeking solace in virtual worlds like the internet (83). In other words, parental anxiety has an indirect relationship with internet addiction in middle and high school students, with the family environment being the influencing factor. However, the potential lack of significance in the indirect pathways in the control model may be attributed to various complex factors. Firstly, the influence of family environment control on adolescent emotional and behavioral issues may be subject to moderation or interference from other factors, thereby diminishing the pathway's significance. Secondly, while family environment control acts as a mediating variable transmitting parental anxiety's impact on adolescent internet addiction, there could be other more substantial mediating factors overlooked in the current model. Additionally, other important factors such as individual characteristics of adolescents, social environment, mental health status, and socioeconomic status, which were not taken into account, may play pivotal roles in this relationship.

4.3 The effect of adolescent emotional and behavioral problems

Furthermore, parental anxiety also directly and indirectly predicted internet addiction through adolescent emotional and behavioral problems. In each model, the contribution of Ind2 is relatively high, suggesting that parental anxiety may directly affect adolescent emotional and behavioral issues, while also potentially indirectly influencing adolescents' tendency towards internet addiction through its impact on the family environment. The significant contribution of this pathway highlights the crucial influence of parental emotional state on both the family atmosphere and the behavioral development of adolescents. Studies have shown that adolescent depression symptoms are associated with genetic and environmental risk factors (84). Parental anxiety may lead to excessive expectations and attention towards their children's academic performance. This anxiety may stem from concerns about their children's future, fearing that they may not meet the standards set by the parents, thus affecting their future academic achievements and life development. Consequently, parents may attempt to address this anxiety by emphasizing and expecting their children's academic performance, ensuring that they achieve success and fulfill the desired accomplishments (85). A research (86) indicated that under the backdrop of COVID-19, parents with higher levels of anxiety and depression displayed worsened attitudes towards their children, which was closely associated with the increase in children's psychological problems. Conversely, in the family setting, if emotional support is high and conflicts are low, children and adolescents are more likely to feel protected, thereby reducing the incidence of emotional and behavioral problems (87). Therefore, maintaining positive and intimate relationships among family members is crucial. Studies on internet use have found a close association between internet addiction and psychological issues (88). A study on Singaporean university students found a significant correlation between emotional disorders and addictive behaviors, particularly in females (89). A meta-analysis indicates that during the pandemic, the impact of internet addiction on emotional issues has intensified (90). This could be attributed to the implementation of global social distancing and isolation policies, leading many individuals to experience isolation and anxiety. In such an environment, internet addiction may serve as a means for people to escape negative emotions, further exacerbating the association with emotional problems. Consequently, parental anxiety may contribute to emotional and behavioral issues in adolescents, prompting them to seek solace through the internet, ultimately resulting in internet addiction.This study deepens our understanding of the relationships between parental anxiety, family environment, adolescent emotional and behavioral issues, and internet addiction, providing substantive guidance for the development of effective family support and preventive intervention plans.

4.4 The multiple relationship model

Our research findings indicate that adolescent emotional and behavioral problems and family environment play an indirect role in the relationship between parental anxiety and adolescent internet addiction. Previous studies have shown that parental anxiety may be transmitted to adolescents through parenting styles or by

imitating parental behaviors, leading to emotional and behavioral problems in adolescents (91). Sell et al. (92) further found a close association between family environment and adolescent emotional and behavioral problems. Moreover, the results show that adolescent emotional and behavioral problems are negatively correlated with the intimacy, recreation, achievement, cultural orientation, and organization of the family environment, while positively correlated with conflicts. The above discussions suggest that parental anxiety is related to family environment, and adolescent emotional and behavioral problems are associated with internet addiction. Therefore, parental anxiety may lead to a poorer family environment, which, in turn, may cause emotional and behavioral problems in children, ultimately leading to internet addiction. In future research, we will integrate additional studies to provide targeted guidance aimed at improving family environments and addressing adolescent emotional and behavioral issues as well as internet addiction.

4.5 Limitation

There are several limitations in the current study. Firstly, the proportion of mothers in the sample was higher than fathers, with a ratio of approximately 2:1, leading to an imbalance in parental representation, making it difficult to distinguish the effects of each parent on adolescents. Mothers often serve as the primary caregivers for adolescents, which may contribute to this imbalance. However, further research is needed to delve deeper into the anxiety levels of fathers to comprehensively understand the influence of both parents on adolescents' development. Secondly, although the Bootstrap method was used, the cross-sectional design may not elucidate the causal relationship between parental anxiety and internet addiction and may lead to biased parameter estimates (93). Therefore, longitudinal studies are needed to further establish causality. Furthermore, there are certain limitations to the generalizability of this study, as our sample primarily consists of adolescents from middle school, high school, and elementary school, and the data is from Jiangsu Province, China. Due to the specificity of the sample, the generalization of research findings may be influenced by cultural or regional differences. Therefore, when extrapolating the study results, it is crucial to consider the unique background of this particular group to ensure broader applicability of the research. Finally, despite achievement having the highest coefficient in the family environment structure, we did not include it in the model when considering the variance of other family environment structures. Therefore, we plan to employ an incremental prediction model in future research to further explore this area.

5 Conclusion

This study investigated 6,296 parent-child pairs to delve into the intricate relationship between parental anxiety and adolescent internet addiction, while also examining the impact of child emotional and behavioral problems and family environment. Parental anxiety not only directly affects adolescent internet addiction but also indirectly influences it through factors such as family environment and child emotional and behavioral problems. This discovery underscores the significance of addressing parental anxiety proactively and nurturing a supportive family environment. In terms of family environment, our study investigated different dimensions of family dynamics. Therefore, our research not only contributes to understanding the overall impact of family factors on adolescent internet addiction but also provides specific insights into how various family constructs influence internet addiction. In future research, we will further explore the association between parenting dimensions and styles with externalizing problems in children and adolescents, in order to develop more targeted and scientifically effective intervention measures. This will not only help address emotional and behavioral issues in adolescents, but also aid in the prevention and treatment of internet addiction. In today's information age, the mental well-being of adolescents is of paramount importance, therefore, this study provides valuable insights into family dynamics, parent-child relationships, and mental health for society, offering a robust foundation for future policies and interventions.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding authors.

Ethics statement

The studies involving humans were approved by Medical Research Ethics Committee of the Affiliated Brain Hospital of Nanjing Medical University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

YuW: Writing – original draft, Writing – review & editing. KZ: Formal analysis, Writing – review & editing. YaW: Methodology, Supervision, Writing – review & editing. JZ: Writing – review & editing. YX: Writing – review & editing. XW: Writing – review & editing. WY: Writing – review & editing. XZ: Writing – review & editing. JY: Writing – review & editing. FW: Data curation, Funding acquisition, Investigation, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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The gap between parental knowledge and children practice of myopia control and challenge under COVID-19: a web-based survey in China

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Objective: To evaluate parental knowledge of myopia control, investigate its association with children's practice and refractive status, and explore their change under the outbreak of COVID-19 pandemic.

Methods: In this web-based survey, a self-administered questionnaire was made online available during the COVID-19 outbreak between February 1th, 2022 and August 31th, 2022 in China. Participants were recruited via social media by convenience and snowball sampling. Parents of both sexes whose children aged between 3 and 18 were eligible. The overall questionnaire was composed of four categories: demographic information, parental knowledge of myopia, children's myopia-related behaviors and their change after the COVID-19 pandemic, and children's refractive status. SPSS version 18.0 was applied to perform the statistics analysis and $p < 0.05$ was considered to be statistically significant.

Results: A total of 423 eligible families were included in our online survey. The average age of children was 11.37 ± 2.83y (male 46.1%; female 53.9%), with a myopia incidence of 83.9% (355/423). Both children's age (OR = −0.6; 95%CI = −1.12 to −0.07; $p = 0.026$) and family income (OR = 2.60; 95%CI = 1.13 to 4.07; $p = 0.001$) had independently significant impacts on parental knowledge. Unexpectedly, parental knowledge was negatively correlated with children's onset age of myopia ($p = 0.002$, $r = -0.165$) and positively correlated with spectacles wearing ($p = 0.014$, $r = 0.131$), and no correlation was found between parental knowledge and the occurrence of children myopia, current diopter, annual myopia progression and the diopter of the first glasses (all $p > 0.05$). We found discordance phenomenon between parents' knowledge and children's behaviors, with parental knowledge being irrelevant to children's sleeping time ($p = 0.159$, $r = 0.069$), the frequency of lying reading ($p = 0.462$, $r = -0.036$) and keeping nutrition diet ($p = 0.142$, $r = 0.072$), and positively correlated with daily homework time ($p = 0.012$, $r = 0.123$). After the outbreak of COVID-19, 77.8% (329/423) of parents admitted that their children's daily routine had been changed, with children spending more time on sleeping ($p < 0.001$) and electronic products ($p < 0.001$), and taking less time to do outdoor activities ($p < 0.001$).

Conclusion: The ideal interaction mode that establishing positive impact between parental knowledge and children practice has not been reached in China, which might be the result of insufficient parents' cognition and discordance phenomenon between parental knowledge and children's

behaviors. The pandemic of COVID-19 has obviously changed children's daily routine. More efforts should be made to narrow the gap between knowledge and behaviors of myopia control, and stay alert to the potential increased risk of myopia during COVID-19.

KEYWORDS

parental knowledge, children's behaviors, COVID-19, myopia control, refractive status

Why carry out this study?

- The association between parental knowledge of myopia control and children's refractive status has not been determined in China.
- The impact of COVID-19 pandemic and quarantine on children's eye health habits has not been explored.

What was learned from the study?

- The ideal interaction mode that establishing positive impact between parental knowledge and children practice has not been reached in China.
- Discordance was noted between parental knowledge and child behavior.
- The pandemic of COVID-19 has obviously changed children's daily eye health routine.

Introduction

With the dramatically increased prevalence in the past three decades, myopia, the most common ocular disorder characterized by a mismatch between ocular optical power and excessive axial length, is arguably reaching epidemic levels (1). It was recognized as a global twenty-first century public health problem and predicted to affect half of the world population by 2050 (2). In China, the prevalence of myopic children aged 7 to 18 years has been reported to increase from 47.5% in 2005 to 57.1% in 2014 (3). Children are becoming myopic at a younger age, with the degree of myopia increasing in magnitude over time (2–4). More than optical inconvenience, pathological myopia could also lead to irreversible vision loss due to serious pathological complications, including retinal tears, retinal detachment and myopic macular degeneration (1, 5). However, currently, the complicated mechanism and pathogenesis of myopia has not been fully elucidated yet, and the efficacy of existing prevention measures is still controversial, contributing to the dilemma of myopia control. Optical correction, which is the primary mode and most widely used treatment option for myopia correction, could not stop the progression of myopia and the occurrence of pathological complications. Therefore, it is necessary to propose more preventive measures to avoid the onset and progression of myopia.

Despite the recent progress in orthokeratology and pharmacologic interventions, it is still a common view that environmental factor plays a dominant role in myopia control practice, and behavior control including less near work time, limited screen time and sufficient outdoor activities strongly affects children refractive status (6). Hence, children's daily routine behaviors should be put more emphasis on, which can be modified to reduce environmental risk exposure and achieve prevention (7). Traditionally, parents are generally the sole guardians of children, and school-aged children are always inclined to agree to parents' arrangements (8). Parents can play an integral role given their particular influence on the lifestyle choices of children. Previous studies have revealed that parental knowledge and attitudes had an important influence on children's physical activities and screen time (9). Therefore, we hypothesized that parental knowledge about myopia control had a significant influence on children's myopia risk by guiding children's daily behaviors and rectifying their unhealthy visual habits. The success of any strategy that requires behavioral modification among children, including limited near work duration, encouraged outdoor activity, appropriate lighting environment, timely optical correction and prevention measures, will likely depend on parental awareness of the condition and their acceptance of the proposed interventions.

Thereby, the interaction mode that establishing positive impact between parental knowledge and children practice (PPP mode) was proposed and applied by governments in a few countries for implementing myopia control strategies, including Singapore and Germany (10, 11). However, the high prevalence and its dramatically increasing trend in China indirectly revealed that the ideal PPP mode of myopia control has not been achieved. Thereby, it is essential to investigate the association between parental knowledge and children practice to reveal the "real world" mode of myopia control in China. The association, to the best of our knowledge, has rarely been reported in China.

Moreover, with Corona Virus Disease 2019 (COVID-19) quickly spreading worldwide, governments have imposed unprecedented public measures such as school closure and home confinement to restrict individual contact. According to UNESCO, over 160 countries have closed schools in attempt to retard the spread of COVID-19, covering 87% of world's student population (12). Consequently, teenagers' daily routine has been dramatically changed. It has been proposed that the global incidence of myopia would be very likely to increase during the COVID-19 pandemic, provoking the concern of "quarantine myopia," which might become a secondary epidemic public health problem (13). Hence, it is desperately necessary to explore the alteration of children's behaviors under the pandemic and stay alert to the potential increased risk of myopia during COVID-19.

Our study aims, therefore, to evaluate parental knowledge of myopia control, investigate its association with children's practice and refractive status and reveal the "real world" interaction mode between them in China as a means to inform future health planning and policy.

Meanwhile, we also explored the change of children's behaviors under the outbreak of COVID-19 pandemic to remind us of the potential public health problem of "quarantine myopia" and the necessity of strengthening preventive strategies.

Methods

Recruitment and inclusion of participants

In this descriptive cross-sectional web-based survey, we developed an electronic survey via the Jinshuju survey platform (AdMaster, Beijing, China) openly accessible to Chinese population. A self-administered questionnaire evaluating parental perception of myopia, children's myopia-related behavior and current refractive status was made available online between February 26th, 2022 and March 12th, 2022. Before answering any research-related questions, participants would provide the informed consent. The project was approved by the medical ethics committee of Peking University Third Hospital and conducted according to the declaration of Helsinki.

Participants were recruited electronically via social media, mainly through social networking applications. The online convenience and snowball sampling were applied in our survey, and respondents were asked to pass on the survey link to more qualified participants. Parents of both sexes were eligible for inclusion if they could provide complete answers and their children were between 3 and 18 years old at the time of study. To prevent the disturbance of shared views within a family, only one parent from each family was invited to participate in our study. As exclusion criteria, we also excluded incomplete, duplicate, typing error and unrealistic answers before carrying out the analysis. All responses were anonymized at the time of data collection.

Web-based questionnaire

The structure and content of the web-based survey were designed by a team of expert optometrists and ophthalmologists. The questionnaire was pilot tested during an iterative process to assess the acceptability and feasibility, and subsequently modified until all designers agreed on the final version. The overall questionnaire was composed of four categories: demographic information, parental knowledge of myopia, children's myopia-related behaviors and their change after the COVID-19 pandemic, children's refractive status. Additionally, a preceding question was applied at the beginning of the questionnaire to screen out people without children who could also voluntarily provide their perception of myopia as respondents.

The demographic information included the age, educational, occupation, income and refractive status of parents and children's characteristics such as gender, age, place of residence, daily care people and regular place for visual acuity (4)/optometry examination. The number of children in each family was asked to be provided, and the questions about children should be answered on the basis of the eldest one in each family to avoid potential duplication. And children who stayed with the other family member (not parents) or in boarding schools were also excluded.

Parental knowledge about myopia was estimated by the questions described in the Supplementary materials. To quantitatively analyze parental knowledge, for each question, each participant would obtain 1 score for complete correct answer, 0.5 score for partly correct answer and 0 score for wrong answer. The total score of 16 questions was calculated and converted into 100 scale to assess the overall knowledge of myopia.

Children's current refractive status was evaluated by the diagnosis of myopia, initial age of myopia, diopter of the first prescribed spectacle, current refractive error (diopter) and annual progression of myopic diopter. The diagnosis of myopia was defined as spherical equivalent (4) of refractive error of less than −0.50 diopters (D) with the cycloplegic refraction. Children's myopia-related behaviors were assessed by the length of their daily time spend on reading, electronic screens and outdoor activity, the frequency of resting after continuous near work, lying reading, maintaining a distance over 30 centimeters when writing, keeping sufficient light when reading, more than 8-h sleeping, doing Chinese eye exercises and keeping a nutritionally balanced diet. The answers of these questions were divided into five ranks (i.e., always, usually, often, seldom and never) and scored from 1 to 5 according to their contribution of myopia development. Moreover, participants were asked whether their children's daily routine had been changed and the detailed alterations of children's behaviors after the COVID-19 pandemic.

Both closed and open-ended questions were used in an adaptive format. The type of answer was determined as single choice or multiple choice depending on the property of questions. The answer options for the multiple-choice questions were randomized to eliminate answer option order bias. No time limitation was set during the completion of the questionnaire by participants.

Data analysis

SPSS version 18.0 was applied to perform the statistics analysis. Continuous variables in our study were presented as the mean ± SD (standard deviation) and categorical variables were expressed as number and percentage. The chi-square analysis was performed to assess the differences in the characteristic of the categorical variables and t-test analysis for continuous variables. After univariate analysis of potential associations, we performed logistic regression model and multiple linear regression model to identify the independent risk factors for myopia and explore the association between parents' knowledge and children's behaviors. The correlation between parental knowledge and children's myopia status were calculated and adjusted by children age, sex, living place and family income through regression analysis. $p < 0.05$ was considered to be statistically significant. Odds ratios (OR) and 95% confidence intervals (95%CI) were calculated for risk factors that were independently associated with myopia in this population.

Results

Demographic information and myopia status

A total of 537 questionnaires were received online in our electronic survey, with 440 parents recruited and 67 participants without children enrolled. The flow of participant enrollment and screening in our study was illustrated in Figure 1. After the exclusion

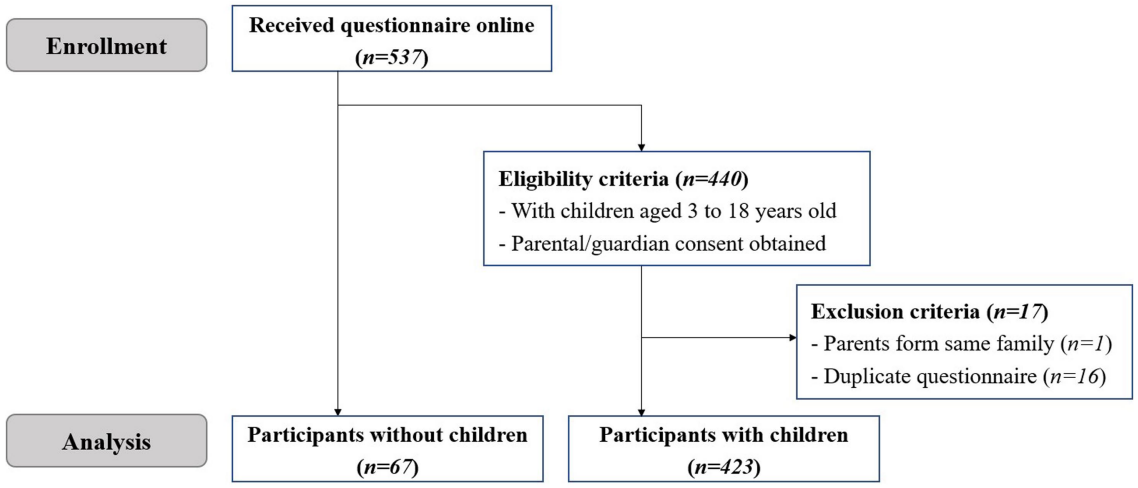

FIGURE 1
The flow diagram of enrolling and screening eligible participants through the study.

of one parent from the same family and 16 duplicate questionnaires, 423 parents whose children aged from 3 to 18 were eventually included in our analysis.

Table 1 showed the demographic characteristics of involved parents and their children. Among the 423 families, 76.1% (322/423) of them were one-child. 96.9% (410/423) of families lived in the urban area, compared with 3.1% (13/423) in the rural area. In terms of monthly income, more than 80 % of families earned more than 5,000 yuan per person, and 30 % of families made over 10,000 yuan per person. Of these parents, the mean ages of fathers and mothers were 43.44 ± 5.56y and 41.44 ± 4.26y, respectively. More than 80 % of parents' education background was bachelor degree or above. 80.9% (342/423) of fathers and 70.4% (298/423) of mothers were occupied in mentor labor, with 5.4% (23/423) of fathers and 13.0% (55/423) of mothers engaged in medicine and healthcare work. 68.3% (289/423) of fathers and 76.1% (322/423) of mothers were myopic, and 19.1% (81/423) of fathers and 22.9% (97/423) of mothers were highly myopic (more than −6.00 D). Among the children, 46.1% (195/423) of them were boys and the mean age was 11.37 ± 2.83y. 89.4% (378/423) of children were daily taken care of by their parents and 9.7% (41/423) were looked after by their grandparents. More than nighty percent of children had regular visual acuity or optometry examination in public hospitals (90.3%), optical shops (2.5%), private hospitals (1.3%), and schools (0.3%).

Children's myopia status was presented in Supplementary Table S1. Based on the reports of parents, 83.9% (355/423) of children were once diagnosed as myopia with a diopter of more than 0.50 D. Among these myopic children, the onset of myopia was developed at an average age of 9.02 ± 2.10y. According to the current diopter, 66.8% (237/355) of children were mild myopia (−0.50 D to −3.00 D), 31.5% (112/355) of children were moderate myopia (−3.00 D to −6.00 D) and 1.7% (20/355) of children were high myopia (more than −6.00 D). The annual progression of diopter was less than 1.00 D among three-fourths of myopic children and more than 2.00 D among 10 % of myopic children. 89.6% (318/355) of myopic children wore spectacles, and more than 80 % of them wore their first spectacles with a diopter between −0.50D to −2.00D.

The correlation analysis of demographic information and children's myopia onset was shown in Supplementary Table S2. The univariate analysis demonstrated that children's age (11.92 ± 2.43 vs. 7.93 ± 3.21; $p < 0.001$), female (55.7% vs. 39.1%; $p = 0.034$), urban residence (98.5% vs. 89.1%; $p = 0.003$), father's age (44.18 ± 5.31 vs. 39.67 ± 5.49; $p < 0.001$), and mother's age (42.15 ± 3.85 vs. 37.61 ± 4.32; $p < 0.001$) showed significant difference between myopia children and non-myopia children, which were subsequently included as possible risk factors in multivariate analysis. By conducting logistic regression model, we detected that increased children's age (OR = 1.86; 95%CI = 1.51 to 2.30; $p < 0.001$), female children (OR = 2.89; 95%CI = 1.27 to 6.58; $p = 0.11$), urban residence (OR = 16.8; 95%CI = 3.29 to 85.80; $p < 0.001$) and increased mother's age (OR = 1.198; 95%CI = 1.02 to 1.41; $p = 0.027$) were related to the increased risk of myopia.

Parental knowledge of myopia

Parents' answers to myopia knowledge questions were illustrated in Figure 2. The average false rate of these questions was 30.0%. Among them, the false rates of Question 1(41.1%), Question 4 (41.6%), Question 8 (65.7%), Question 10 (70.7%) and Question 13 (63.1%) were over the average value. In terms of the perception of myopia, only 58.9% (249/423) of parents regarded myopia as a pathological disease that could result in a series of severe complications, while 22.7% (96/423) considered only high myopia was pathological and 11.6% (49/423) thought myopia was just a harmless blurred-vision condition. When asked about the correction of myopia, only 58.4% (247/423) of parents thought myopia should be fully corrected, while 27.4% (116/423) held a view that myopia should be under-corrected. Nearly half of parents (203/423, 48.0%) considered that wearing eyeglasses could result in the deformation of eyes, such as "goldfish eyes." The inhibition effect of low-dose atropine on myopia progression was merely realized among 29.3% (124/423) of parents. Only 74.0% (313/423) of parents were aware that myopia cannot be cured once it occurs, and the others thought myopia was reversible or could be cured by eyeglasses and laser

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TABLE 1 Demographic information of involved parents and their children.

Demographic characteristics		mean ± SD or *n* (%)	
Parental characteristics			
		Father	Mother
	Age, mean ± SD (y)	43.44 ± 5.56	41.44 ± 4.26
	Education level, *n* (%)		
	Doctor and higher	69 (16.3%)	53 (12.5%)
	Master	133 (31.4%)	130 (30.7%)
	Bachelor	170 (40.2%)	188 (44.4%)
	College	33 (7.8%)	34 (8.0%)
	Technical school or less	18 (4.3%)	18 (4.3%)
	Occupation, *n* (%)		
	Medicine and healthcare	23 (5.4%)	55 (13.0%)
	Physical labor	11 (2.6%)	8 (1.9%)
	Mental labor	342 (80.9%)	298 (70.4%)
	Free occupation	35 (8.3%)	52 (12.3%)
	Else	12 (2.8%)	10 (2.4%)
	Myopia, *n* (%)	289 (68.3%)	322 (76.1%)
	High myopia, *n* (%)	81 (19.1%)	97 (22.9%)
	Children number, *n* (%)		
	One	322 (76.1%)	
	Two	97 (22.9%)	
	Three or more	4 (0.9%)	
	Income, *n* (%)		
	0–2000 yuan/month/person	8 (1.9%)	
	2000–5,000 yuan/month/person	50 (11.8%)	
	5,000–8,000 yuan/month/person	104 (24.6%)	
	8,000–10,000 yuan/month/person	96 (22.7%)	
	>10,000 yuan/month/person	165 (30.0%)	
Children characteristics			
	Age, mean ± SD (y)	11.22 ± 3.01	
	Gender, *n* (%)		
	Male	195 (46.1%)	
	Female	228 (53.9%)	
	Place of residence, *n* (%)		
	Urban	410 (96.9%)	
	Rural	13 (3.1%)	
	Daily care people, *n* (%)		
	Patents	378 (89.4%)	
	Grandparents	41 (9.7%)	
	Baby-sitter	2 (0.5%)	
	Him/herself	2 (0.5%)	
	Regular place for optometry examination, *n* (%)		
	Public hospital	287 (90.3%)	
	Private hospital	4 (1.3%)	
	Optical Shop	8 (2.5%)	
	School	1 (0.3%)	
	No regular examination	18 (5.7%)	

surgery. The detailed distribution of parental answers was shown in Supplementary Table S3. After being converted into one hundred scale, the average score of myopia knowledge among parents was 64.24 ± 16.32, which was significantly higher when compared with that of participants without children (57.35 ± 19.87; $p = 0.004$).

The results of correlation analysis between demographic information and parental knowledge score were tabulated in Supplementary Table S4. In simple linear regression, our analysis showed that children's age ($p = 0.009$), place of residence ($p < 0.001$), parental education level (both $p < 0.001$), parental occupation (physical labor: $p = 0.001$ for father and $p = 0.03$ for mother; mental labor: $p = 0.002$ for father and $p = 0.022$ for mother; free occupation: $p = 0.011$ for father and $p = 0.023$ for mother), parental myopia status ($p = 0.001$ for father and $p = 0.044$ for mother) and family income ($p < 0.001$) were all significantly correlated with parents' knowledge. The above variables were subsequently added into the multiple linear regression model, and the results demonstrated that only children's age (OR = −0.6; 95%CI = −1.12 to −0.07; $p = 0.026$) and family income (OR = 2.60; 95%CI = 1.13 to 4.07; $p = 0.001$) had an independently significant impact on parental knowledge of myopia.

Meanwhile, as shown in Table 2, the relationship of parental myopia knowledge and children's refractive status was determined by correlation analysis. The results showed that parental knowledge was negatively correlated with children's onset age of myopia ($p = 0.002$, $r = -0.165$) and positively correlated with spectacles wearing ($p = 0.002$, $r = 0.230$). There was no correlation between parental knowledge and the occurrence of children myopia, current diopter, annual myopia progression and the diopter of the first glasses (all $p > 0.05$). Based on the total knowledge score, parents were then divided into high and poor knowledge subgroups with a cut-off value of 60. Similarly, only children's onset age of myopia (8.81 ± 2.01 vs. 9.29 ± 2.19; $p = 0.007$) and spectacles wearing (92.6% vs. 85.6%; $p = 0.034$) showed significant difference between the two groups.

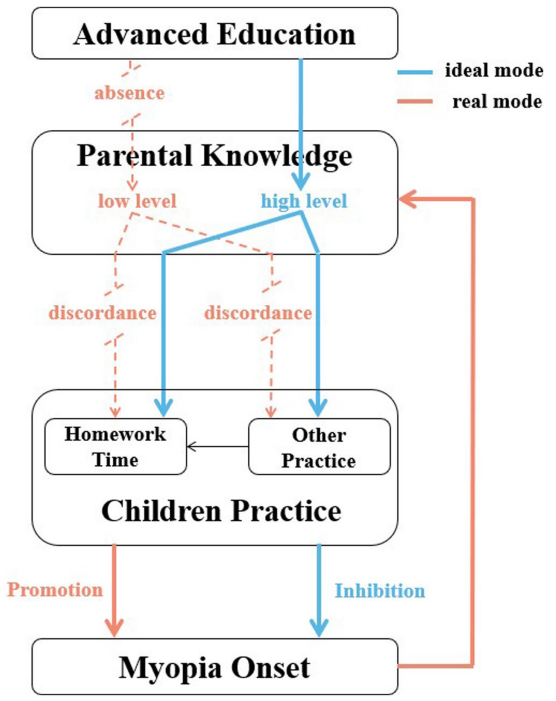

FIGURE 2
The ideal and realistic interaction mode between Parental Knowledge and Children Practice of Myopia Control in China.

Children's behaviors

The information of children's myopia-related behaviors was shown in Supplementary Table S5. According to the results, more than nighty percent (91.0%) of children could sleep at least 7 h a night. However, only less than 20% (19.1%) of children could finish their homework within 1 h, and nearly half of them spend more than 4 h on homework. Additionally, more than 2 h of daily outdoor activities could be ensured in just 3.5% (15/423) of children, and half of children (51.5%) took at least 1 h in electronic products. On the other hand, only 8.3% (35/423) and 5.2% (22/423) of children reported "always" for their daily frequency of "taking a break after using eyes continuously for 40 min" and "keeping the distance between eyes and books over 30 centimeters when reading," respectively.

The correlation analysis between parental myopia knowledge and children's behaviors were presented in Table 3. In the prevention of developing myopia, parental knowledge was correlated with increased outdoor activities time ($p = 0.028$, $r = 0.107$) and decreased time on electronic products ($p < 0.001$, $r = -0.191$). In addition, high parental knowledge was positively related to children's frequency of resting their eyes ($p < 0.001$, $r = 0.193$), keeping enough distance between eyes and books ($p = 0.462$,

TABLE 2 The correlation analysis between parental knowledge and children's myopia status.

Children's myopia status		Correlation with parental knowledge		Difference between high and poor knowledge subgroups
		p-value	*r* value	*p*-value
	Myopia	0.327	−0.077	0.191
	Onset age of myopia	0.002*	−0.165	0.007#
	Current diopter	0.296	0.056	0.250
	Spectacles wearing	0.002*	0.230	0.034#
	Diopter of the first glasses	0.642	−0.026	0.652
	Annual progression	0.434	0.044	0.237

* Significantly correlated with parental knowledge adjusted by children age, sex, living place and family income ($p < 0.05$). # Significantly different between high and poor knowledge subgroups ($p < 0.05$).

TABLE 3 The correlation analysis between parental knowledge and children's behaviors of myopia control.

Children's behaviors of myopia control		Correlation with parental knowledge		Difference between high and poor knowledge subgroups
		p-value	*r* value	*p*-value
	Daily time spent on			
	Sleeping	0.159	0.069	0.666
	Doing homework	0.012*	0.123	0.014#
	Outdoor activities	0.028*	0.107	0.034#
	Electronic products	<0.001*	−0.191	<0.001#
	Daily frequency of			
	Taking a break after using eyes continuously for 40 min	<0.001*	0.193	0.005#
	Lying down to do homework and read books	0.462	−0.036	0.584
	Keeping the distance between eyes and books over 30 centimeters when reading	0.031*	0.106	0.079
	Keeping enough bright light when reading and writing	0.015*	0.119	0.125
	Doing Chinese eye exercises	0.002*	0.150	0.006#
	Keeping a balanced nutrition diet	0.142	0.072	0.091

* Significantly correlated with parental knowledge ($p < 0.05$). # Significantly different between high and poor knowledge subgroups ($p < 0.05$).

$r = -0.036$), keeping bright environment ($p = 0.031$, $r = 0.106$) and doing Chinese exercises ($p = 0.002$, $r = 0.150$). However, our results showed that parental knowledge was irrelevant to children's sleeping time ($p = 0.159$, $r = 0.069$) and their frequency of lying reading ($p = 0.462$, $r = -0.036$) and keeping nutrition diet ($p = 0.142$, $r = 0.072$). Moreover, on the contrary, higher parental knowledge was correlated with more daily time on doing homework ($p = 0.012$, $r = 0.123$). Similarly, by comparing high and poor knowledge groups, we found that sleeping time ($p = 0.666$) and the frequency of lying reading ($p = 0.584$) and keeping nutrition diet ($p = 0.091$) showed no significant difference between different levels of knowledge, and high knowledge group spent more time on homework instead ($p = 0.014$).

The results of correlation analysis between children's behaviors and their myopia status were tabulated in Supplementary Table S5. The univariate analysis demonstrated that sleeping time ($p = 0.002$), homework time ($p < 0.001$), the frequency of resting eyes ($p < 0.001$), keeping enough distance between eyes and books ($p < 0.001$) showed significant difference between myopia children and non-myopia children, which were subsequently added as possible risk factors into multivariate analysis. By conducting logistic regression model, with the adjustment of children's age, gender, place of residence and mother's age, we detected that only increased homework time was a significantly independent risk factor of developing myopia (OR = 1.61; 95%CI = 1.01 to 2.58; $p = 0.046$).

With the outbreak of COVID-19, 77.8% (329/423) of parents admitted that their children's daily routine had been changed due to home quarantine, restricted traffic and online education. Compare with daily behaviors, as shown in Table 4, children spent more time on sleeping ($p < 0.001$) and electronic products ($p < 0.001$), and take less time to do outdoor activities ($p < 0.001$) during the pandemic. Nevertheless, daily time spent on homework did not change significantly after the outbreak ($p = 0.092$). The correlation analysis demonstrated that basic demographics and the change of daily routine were irrelevant (all $p > 0.05$). However, parental knowledge of myopia was positively correlated with the change of daily routine ($p = 0.002$, $r = 0.148$), and high knowledge group inclined to change their daily routine during the pandemic (81.0% vs. 72.1%; $p = 0.033$). We then performed the subgroup analysis based on parental knowledge in Supplementary Table S6. The results showed that homework time also remarkably lengthened in high knowledge group ($p = 0.034$), which did not significantly change in poor knowledge group ($p = 0.657$).

Discussion

With the sharp rise of prevalence, myopia "epidemic" is becoming a worldwide public health issue, which is considered to be related with both genetic and behavioral factors (1). Generally, given that parents are main child guardians, children's daily routine and behaviors are largely subject to their parents' arrangements (8). Therefore, we reasonably hypothesized that parental knowledge of myopia might be associated with children's behaviors and have a significant influence on children's myopia risk. Prevention measures for myopia control about behavioral modification will likely require parental precise knowledge and their acceptance of the proposed interventions, depending on the positive feedback mode between parental knowledge and children practice. Additionally, due to school closures and home confinement under the outbreak of COVID-19, children tend to spend longer screen time on online courses and less spare time on outdoor activities, which probably raises the incidence of myopia during COVID-19 pandemic (12). Thus, we conducted this web-based survey through online questionnaires to describe parental knowledge of myopia control, investigate the "real world" interaction mode between parental knowledge and children practice in China, and

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TABLE 4 The comparison of children's behaviors before and after the outbreak of COVID-19.

Children's behaviors	Routine	During pandemic	*p*-value
Daily time spent on			<0.001*
Sleeping			
<7 h	35 (10.6%)	20 (6.1%)	
7–8 h	116 (35.3%)	51 (15.5)	
8–9 h	127 (38.6%)	107 (32.5)	
9–10 h	46 (14.0%)	105 (31.9)	
>10 h	5 (1.5%)	46 (14.0)	
Doing homework			0.092
<1 h	16 (4.9%)	20 (6.1%)	
1–2 h	42 (12.8%)	49 (14.9%)	
2–4 h	112 (34.0%)	108 (32.8%)	
4–8 h	100 (30.4%)	104 (31.6%)	
>8 h	56 (17.0%)	48 (14.6%)	
Outdoor activities			<0.001*
<0.5 h	82 (24.9%)	256 (77.8%)	
0.5–1 h	125 (38.0%)	43 (13.1%)	
1–1.5 h	80 (24.3%)	19 (5.8%)	
1.5–2 h	34 (10.3%)	9 (2.7%)	
>2 h	8 (2.4%)	2 (0.6%)	
Electronic products			<0.001*
<0.5 h	63 (19.1%)	14 (4.3%)	
0.5–1 h	102 (31.0%)	31 (9.4%)	
1–1.5 h	57 (17.3%)	50 (15.2%)	
1.5–2 h	38 (11.6%)	49 (14.9%)	
>2 h	67 (20.4%)	185 (56.2%)	

* Significantly different after the outbreak of COVID-19 pandemic ($p < 0.05$).

explore the change of children's daily routine after the outbreak of COVID-19.

To the best of our knowledge, this is the first research to investigate the effect of parental knowledge about myopia risk on children's behaviors and myopia status in China. Our findings revealed that, unexpectedly, parental knowledge did not play a significantly positive role in myopia control, which might be the result of discordance phenomenon between parental knowledge and children's behaviors. Therefore, more efforts should be made to narrow the gap between parents' knowledge of myopia control and children's behaviors, thereby effectively establishing "PPP mode" and preventing the occurrence of myopia. Moreover, COVID-19 pandemic has obviously changed children's daily routine in China. Children inclined to spend more time on sleeping and electronic products, and take less time to do outdoor activities during home confinement. Therefore, it's necessary to stay alert to the potential increased risk of myopia during COVID-19 and institute preventive measures against "quarantine myopia."

According to the logistic regression model, increased children's age, female sex, urban residence and increased mother's age were related to the risk of myopia. In agreement with previous studies, we found that myopia was more common in older children. McCrann et al. demonstrated that, for older children, increasing academic burden and social contact were followed by more time spent on near work and visual displays coupled with a decline in outdoor time, thereby exerting both a direct and indirect influence on myopia development and progression (8). Meanwhile, in the present study, we found that female sex was associated with a higher risk of myopia, which was in accordance with several previous studies. Lyu et al. speculated that estrogen could regulate matrix metalloproteinase in the sclera and counted for myopia development in female adolescents (14). Apart from the physiological reason, another possible explanation could be that young girls always spend less time engaged in outdoor activities (14). Additionally, our result also verified that urbanization was linked to increasing prevalence of myopia. Urbanization is usually considered to be accompanied by lack of green spaces, less time outdoors, variable light exposure and changes in residents' lifestyle, diet, and stress in more densely populated areas, all of which could contribute to myopia development. Interestingly, although few studies have found the association between mother's age and children's myopia status, our research revealed that children were exposed to higher myopia risk with increasing mother's age. Similarly, a large-sample cohort study conducted in British by Rahi et al. concluded that, myopia was positively associated with greater

maternal age, indicating the fundamental importance of prenatal influences on the ocular growth, and the excessive elongation of myopic eyes might be determined *in utero* and amplified or cascaded during childhood (15). This unexpected association also suggested we should keep in mind that the trend of increasing births to older mothers, which had been identified as a novel putative risk factor of child health and growth, was consistent and possibly related with the global trends of increasing myopia, and further research could explore the potential impact of prenatal and early life factors on the abnormal ocular growth.

As the integral targets of numerous behavioral interventions, parents play an essential role in various aspects of myopia prevention, including the environments to which children are exposed, parenting styles, children's daily routine and behaviors, all of which were deemed critical in myopia management (8). Therefore, parental awareness of myopia causes and prevention strategies is of much importance in intervening and supervising their children's behaviors, thereby effectively decreasing the occurrence of myopia. Overall, in our survey, with an average false rate of 30.0%, parental knowledge of myopia did not reach the ideal level. However, compared to participants without children, parents in our survey showed significantly higher level of knowledge, suggesting that parents might be eager to acquire related knowledge about myopia control and seek effective measures to slow myopic progression. We detected most of parents were lacking knowledge about the pathology, irreversibility and intervention strategies of myopia. Myopia is characterized by typical degenerative changes in the sclera, choroid, and retinal pigment epithelium, which leads to elongated axis length, posterior staphyloma and choroidal neovascularization and also occurs in non-highly myopic eyes (5). Nevertheless, when asked about the perception of myopia, a number of parents only regarded myopia as an optical inconvenience instead of a pathological disease with visually threatening complications, and some of them thought myopia was reversible or could be cured by eyeglasses and laser surgery. The fail to realize its pathogenicity and irreversibility could delay regular optometry and ophthalmic examination and medical treatment, which might promote the progression of myopia and occurrence of complications. Moreover, nearly half of parents considered that wearing eyeglasses could result in the deformation of eyes, such as "goldfish eyes" that is actually the result of exophthalmos due to excessive elongated axial length. This wrong perception might reduce parental compliance of wearing children spectacles and accelerate myopia progression. On the other hand, atropine, a nonselective muscarinic antagonist, has been proved effective in several long-term cohort studies in preventing worsening of myopia in children (6). However, due to the uncertainty of exact mechanism and action site, safety concerns such as photophobia, poor near visual acuity and allergy are generally considered to be a barrier for the commercialization and clinical use of atropine in China, which could possibly explain the low awareness rate of the inhibition effect of atropine on myopia progression among parents in our research. A meta-analysis conducted by Ahnul et al. demonstrated that the adverse effects of atropine were dose dependent and the low dose of atropine (0.01%) seemed to decrease the adverse effects (16). Hence, we suggested that a large-scale clinical trial should be investigated further to explore a safety dose with enough efficacy in China. Furthermore, either pharmacological or optical, the role of parents in the acceptance of any interventional treatments needs to be recognized to make them practicable.

According to the multiple regression analysis, parents with younger children might be more deficient in knowledge about myopia control. However, it has been reported that the preschool period is crucial for the development of eyesight, implying that school-aged children would have a lower risk of myopia if parental knowledge can be promoted during preschool period (17). Therefore, it is necessary to strengthen health education for parents of young preschool children to avoid irreversible visual impairment. On the other hand, based on our results, low-income families tend to lack knowledge of myopia control, which suggested that both individual as well as community level socioeconomics play a role in determining parental knowledge. Thus, we propose that regular optometry examinations should be popularized and performed based on community hospitals. Moreover, there might be a relatively large difference in knowledge between fathers and mothers. However, due to the limitation of research design and data collection, the gender of participations who filled out the questionnaire was not acquired, which is needed to be corrected in the future study as a potential confounding variable.

Generally, it is believed that better knowledge and perception have a significant positive influence on the uptake of preventive measures and bridging the gap towards delivering of health information, reducing children's myopia risk by guiding children's daily behaviors and rectifying their unhealthy visual habits (9, 18). Nevertheless, our results revealed that higher parental knowledge failed to reduce the occurrence and slow the progression of myopia. On the contrary, parental knowledge was negatively correlated with children's onset year of myopia and positively correlated with spectacles wearing, suggesting that early-onset myopia and spectacles wearing attracted parental attention instead and enhanced their knowledge in turn by negative feedback. Another possible explanation for the earlier occurrence of myopia in highly cognitive parents could be that they were more aware of the hazards and thus took their children for eye assessments at an earlier age. On the other hand, we also detected that parental knowledge was at odds with several children's myopia-related behaviors, with parental knowledge being irrelevant to children's sleeping time, the frequency of lying reading and keeping nutrition diet, and even positively correlated with daily homework time. Therefore, we suspected that the discordance phenomenon between parental knowledge and children's behaviors might lag the influence of knowledge and contribute to the inconsistency between parents' knowledge and children's myopia status. There might be several reasons for the dissociation. First, according to the "KAP (knowledge-attitude-practice)" theory, attitude is a prominent intermediate factor between knowledge and practice, which could directly promote behavioral changes (18). However, in our current study, parents' attitude was not assessed and their knowledge might fail to be sufficiently transferred to their attitude thoroughly. On the one hand, positive attitude is mainly driven by the high level of knowledge and perceptions toward the harmfulness of myopia. Based on our results, although the overall level of parental knowledge of myopia control was moderate, a substantial part of parents had not recognized the pathology and irreversibility of myopia, thereby failing to consider myopia as a health risk and actively intervene children's daily behaviors. On the other hand, although parents might have a relatively higher level of knowledge regarding myopia control and prevention, other intrinsic factors which were beyond the assessment of our

research, might modify parental attitude toward myopia control and affect their final arrangements in children's behaviors. These intrinsic factors, including the confidence in the knowledge, the expectation on children's vision and the concern about the impact of prevention strategies on children's academic, vary individually and may be related to how the knowledge was received, processed, perceived and interpreted. Hence, we suggested that only enhancing parental knowledge is not enough to improve children's behaviors. More efforts should be paid to help parents form a distinct perception of the harm of myopia and turn their attitudes by emphasizing the threat of myopia to visual health and increasing the acceptability of prevention measures. Parents' attitude toward myopia control should be evaluated in the further research and addressed as part of the strategies for myopia prevention. Secondly, with the increase of age, children gradually step into their adolescence and tend to get more involved in schools and society, and their behaviors will consequently be more affected by their teachers, classmates and themselves instead of parents. In that case, more other variables, such as health education in school, teachers' supervision, classmates' habits and their own attitudes, will account for their daily behaviors which parental knowledge cannot completely predict. Given the influence schools and society have on children's lifestyle choices, these findings confirm that school supervision and public education about myopia are essential to generate a shift in individual behaviors. Teachers, schools and society are supposed to take their responsibility together to close the critical gap between parental knowledge and children's behaviors. However, during the COVID pandemic, the discordance could also be due to some quarantine-related situations where parents have to permit their children to use electronic devices to remain indoors. Therefore, in the future study, the discordance phenomenon should be verified in this post-COVID era.

Ideally, as shown in Figure 2, the ideal interaction mode that establishing positive impact between parental knowledge and children practice was most conducive to the implementation of myopia control strategies. The mode that better children practice derived from higher-level parental knowledge could inhibit myopia development has been widely applied in a few countries. In Singapore, by conducting the visual health screening, designing brochures and performing lectures about myopia knowledge, Singapore National Eye Center allied with schools and media to provide advanced education for parents to enhanced parental cognition level upstream, which has successfully disciplined children's behavior and decreased the incidence of myopia by 5% in the past 6 years (19). And Germany advocated the specially-designed application software for parents to communicate the risk and harm of myopia, encouraging them to restrict children's screen time and establish refraction development profile for children (11). However, our research reveals that the ideal positive mode has not been reached in China. Without enough cognition, the positive influence of parental knowledge on children's behavior has not been facilitated. The present state is that the worsening myopia in turn enhances parents' knowledge by negative feedback. Based on our results, we consider that the main problems are as follows: firstly, the actively-advanced education for parental knowledge is almost absent, and the passively-enhanced knowledge driven by exacerbated myopia lags behind children's key period of visual development; secondly, the level of cognition is not enough, especially for the irreversible and pathological characteristic of myopia; thirdly, the discordance phenomenon that parents' knowledge fails to be sufficiently transferred to children behavior completely. Therefore, we suggest that, in the future, parental knowledge should be actively strengthened upstream with the multi-channel approach, combining parents, teachers, schools, society, ophthalmologists and children themselves together. Myopia knowledge should be more popularized, especially in low-income and rural residents. More efforts should be paid to help parents turn their attitudes by emphasizing the threat of myopia to visual health.

During COVID-19 pandemic, less physical activity, longer screen time and irregular sleep pattern are very likely to increase the incidence of shortsightedness and contribute to the "quarantine myopia epidemic" (12, 13). According to our results, after the outbreak of COVID-19, 77.8% of parents admitted that their children's daily behaviors had been changed, with more time spent on sleeping and electronic products, and less outdoor activities. More sleep time is considered to be linked to less near work and screen time, and Jee et al. revealed an inverse relationship between sleep duration and myopia (20). Although our survey revealed the prolongation of sleep time, however, we did not explore the alteration of sleep rhythm. Due to the uncertainty of online class time and lack of school restrictions, children might have a disposition to get up and stay up late. Therefore, despite the longer sleep duration, the irregular sleep pattern and circadian rhythms cannot be ignored. Not only sufficient sleeping time but also regular sleep rhythms should be guaranteed to prevent children from developing myopia during the quarantine. Additionally, with the wide application of online classes, children get more access to electronic devices to read, write and finish their homework, which increases screen time, prolongates near work and limits outdoor time. Therefore, we suggested more break time between classes to allow children to rest their eyes and reduce accommodative stimulation. Meanwhile, when the usage of electronic screen devices is unavoidable, more attention could be paid to adjusting devices' parameters, including luminance ratio, brightness, contrast and softness which were associated with myopia. It is necessary to stay alert to the potential public health problem of "quarantine myopia" and strengthen preventive strategies focusing on children's visual habits. Meanwhile, post-pandemic myopia evaluation project and ophthalmological surveillance program for children are probably required. Patient education, including theoretical knowledge, practical experience, enhanced compliance and regular follow-up, are all of great importance.

There were several limitations in our research. Firstly, due to online platform and non-randomized sampling, participants in our research were preselected. For instance, urban participants might have more access to the social application and were more likely to participate our survey, and parents with myopia children would be more motivated to complete our questionnaire, which could contribute to potential selection bias. Selection bias may overestimate parents' mastery of myopia-related knowledge and affect subsequent correlation and regression analyses. Random selection strategy would be a better option for future studies. Secondly, children's behaviors were obtained from questionnaires and relied on reports of their parents, which could be subject to recall bias. Additionally, as a cross-sectional study, the cause or effect of parents' knowledge and children's behaviors toward myopia development was not clear. Therefore, a further cohort study with a larger sample size is required to give a better understanding of parental knowledge about myopia

control and demonstrate its real causal relationship with children's behaviors and myopia risk.

Conclusion

The ideal interaction mode that establishing positive impact between parental knowledge and children practice has not been reached in China, which might be the result of insufficient parents' cognition and discordance phenomenon between parental knowledge and children's behaviors. The pandemic of COVID-19 has obviously changed children's daily routine. More efforts should be made to narrow the gap between knowledge and behaviors of myopia control, and stay alert to the potential increased risk of myopia during COVID-19.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the project was approved by the medical ethics committee of Peking University Third Hospital and conducted according to the declaration of Helsinki. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HY: Writing – original draft. HL: Writing – original draft. XL: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1344188/full#supplementary-material

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Effectiveness of a program to lower unwanted media screens among 2–5-year-old children: a randomized controlled trial

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Background: Limited interventions exist on reducing unwanted screen time (ST) among children from low- and middle-income countries (LMICs), so we developed and assessed the effectiveness of the program to lower unwanted media screen time (PLUMS) among children aged 2–5 years in Chandigarh, Union Territory, North India.

Methods: An open-label randomized control parallel group trial per CONSORT guidelines was conducted among randomly selected 340 families with children aged 2–5 (±3 months) years in Chandigarh, India. PLUMS was implemented at the family level with a focus on modifying the home media environment and targeted individual-level interventions using parent and child modules for 2 months. A post-intervention (immediately) and a follow-up assessment after 6 months was done. During the follow-up period, the interaction was done passively via WhatsApp groups. The control group received routine healthcare services. Validated and standardized tools, including a digital screen exposure questionnaire with a physical activity component, preschool child behavior checklist, and sleep disturbance scale for children, were used to collect data at baseline, post-intervention, and follow-up periods. The primary outcome was the mean difference in ST (minutes/day) among children in the intervention group versus the control group. Generalized estimating equation (GEE) analysis was performed to adjust for clustering.

Results: An equal number of families ($n = 170$) were randomly assigned to the intervention and control arms. In the post-intervention assessment, 161 and 166 families continued while, at the follow-up assessment, 154 and 147 were in the intervention and control arm, respectively. The mean difference in ST on a typical day [27.7 min, 95% Confidence Interval (CI) 5.1, 50.3] at the post-intervention assessment significantly ($p < 0.05$) decreased in the intervention (102.6 ± 98.5 min) arm as compared with the control (130.3 ± 112.8 min) arm. A significant reduction in ST ($\beta = -35.81$ min, CI -70.6, –1.04) from baseline ($\beta = 123.1$ min) to follow-up phase ($\beta = 116$ min) was observed in GEE analysis. The duration of physical activity increased both at post-intervention ($\beta = 48.4$ min, CI = +6.6, +90.3) and follow-up ($\beta = 73.4$ min, CI = 36.2, 110.5) assessments in the intervention arm.

Conclusion: The PLUMS intervention significantly reduced the children's mean ST on a typical day and increased the physical activity immediately post-intervention and during the 6-month follow-up period. These results

might guide the policymakers to include strategies in the national child health programs in the Southeast Asia Region to reduce unwanted ST.

Clinical trial registration: https://clinicaltrials.gov/, identifier CTRI/2017/09/009761.

KEYWORDS

screen time, digital media, unwanted media screen, effectiveness, RCT

Introduction

Excessive Screen Time (ST) among young children is a significant public health problem globally, with implications for their growth and development (1). ST represents an individual's use of electronic devices (2) with or without the Internet. Since the 70s, the age at which children begin interacting with the electronic devices has shifted from the older children (4 years old) to the younger ones (4 months old), meaning they are born in a "dynamic digital ecosystem" (3). The early childhood phase (birth to 5 years) is crucial for instilling healthy habits of minimal sedentary screen-based behaviors for optimal health (4).

According to the Indian (2020) (5) and American (2016) (6) Academy of Pediatrics guidelines, a ST of more than 1 h per day in children aged 2–5 years is considered excessive. However, approximately six in ten Indian children aged 2–5 years exceed the daily ST which is permitted (1 h per day) by the age-specific guidelines (7). There are early (delayed motor skills, cognitive and language development, reduced sleep, and disrupted nighttime sleep) and late (prevalence of overweight, obesity, and NCDs) health consequences of excessive ST among children (1, 8). Kaur et al. reported a 59.5% prevalence of exaggerated ST among children aged 2 to 5 years in Chandigarh, India. Excessive ST was found to be significantly associated with emotional problems (15%), sleep problems (8%), and physical inactivity (46.5%) (7).

Nevertheless, researchers acknowledge the benefits of high-quality preschool programs for improving learning outcomes, enhancing literacy skills, and developing vocabulary and comprehension with interactive media, especially during pandemic situations such as the COVID-19 pandemic that had significantly increased early childhood learning (9, 10). Preschoolers play digital games and attach meanings to them, and if used meaningfully, it could improve their learning abilities (11). Most learning apps positively affect the child's computational thinking skills and classroom learning (12). There are lacunae concerning learning-based interventions for children aged 2–5 years in India to effectively manage media exposure and its resultant ill effects (short- and long-term effects). Since most learning apps positively affect the child's computational thinking skills and learning (9), the current study used an experimental approach to provide a feasible delivery of offline and online training interventions.

A narrative review by Kaur et al. (1), where intervention studies were reviewed, reported a significant reduction in ST by effective intervention strategies such as increasing digital-media literacy of the parents, reducing sedentary time, controlling the duration of ST, restricting use of electronic devices to age-specific content, family-based counseling, and excessive eating (1, 13–15). They reported that almost all the intervention studies to reduce ST among children younger than years were conducted in developed countries, and seven out of seventeen of the studies concentrated primarily on ST reduction (1, 16–22). The reduction in ST among children of younger than 5 years varied from 0.3 (SE = 13.3) min to 47.16 (SE = 2.01) min in high-income countries. However, no such studies were from middle- and low-income countries (1).

Previous Asian studies on ST aimed to study Internet usage among older children. According to Pedersen et al., recreational intervention to reduce ST resulted in a sizable increase in children's involvement in physical activity (13, 23). Kaur et al. have reported a significant association of excessive ST with sleep and emotional behaviors (7, 8). Limited interventions were done to reduce ST in children in low- and middle-income countries (LMICs), especially in lowering ST at preschool age, which is a critical developmental stage of learning in school and at home (1). Recently, Poonia et al. reported an RCT in Delhi, India, where parental education starting in infancy in the clinic-based setting (immunization) had shown a decline in ST among children (24).

After reviewing the gap in the existing literature, a comprehensive Program to Lower Unwanted Media Screens (PLUMS) was developed based on the Socioecological model (25), Social Cognitive model (26, 27), and Self-determination theory with motivational interviewing of the parents (27). As digital-screen exposure usually occurs at home, PLUMS was designed to target the family to change the family's media literacy and home-media environment and develop parent and child-specific modules to intervene and eventually reduce the ST among children (1). Additionally, as there was evidence that children should be involved in decision-making and goal-setting so that parents could channel their children's energy and help them gain independence for sustained behavior change, social cognitive theory was used to design the intervention (1).

To the best of our knowledge, this is one of India's first intervention studies using an indigenously designed parents' and child's learning modules to reduce ST among 2–5-year-old children. This study substantially differs from the existing studies as it used an

Abbreviations: AAP, American Academy of Pediatrics; aOR, Adjusted odds ratio; CONSORT, Consolidated standards of reporting trials statement; CI, Confidence interval; DSEQ, Digital screen exposure questionnaire; IBM, International business machines; LMICs, Low- and middle-income countries; PLUMS, Program to lower unwanted media screens; Pre-CBCL, Preschool child behavior check list; Pre-PAQ, Preschool physical activity questionnaire; *p*-value, Probability; RCT, Randomized controlled trial; SD, Standard deviation; ST, Screen time; SPIRIT, Standard protocol items: recommendations for interventional trials; SPSS, Statistical packages for social sciences by IBM.

RCT-based approach for evaluating the effectiveness of the intervention in decreasing unwanted ST among this specific pediatric age group. In addition, we used a mixed (online and offline) approach to provide knowledge to the families. The primary objective of the study was to assess the effectiveness of PLUMS in reducing ST among children aged 2–5 years in Chandigarh, Union Territory, North India, and secondary objectives were to evaluate the status of emotional problems, sleep problems, and physical activity among children after the intervention.

Methodology

This trial was registered in the Clinical Trial Registry India: Clinical Trial Registry India CTRI/2017/09/009761: Available at: https://ctri.nic.in/Clinicaltrials/pmaindet2.php?trialid=20050&EncHid=&userName=CHILDREN.

The study protocol is given in detail elsewhere (28). In brief, the methodology is described here.

Study design and settings

An open-label randomized controlled parallel-group trial was conducted according to the CONSORT guidelines in Chandigarh, a north Indian Union Territory, from October 2020 to August 2021. The CONSORT checklist is shown in Supplementary Table S1. We used a randomized control trial to address the research questions, as these are one of the best study designs with randomly assigned controls to measure the effectiveness of the intervention and generate robust evidence in this regard (28). The study area was the field practice area of the Department of Community Medicine and School of Public Health, Postgraduate Institute of Medical Education and Research (PGIMER), i.e., zone three, Chandigarh, as demographic surveillance was set up in this area. The total population of this area was nearly 250,000, as per the annual health survey report for 2019–2020. There were 8,681 families with children aged 2–5 (±3 months) years in the study area.

Study participants

The unit of intervention was a family with a child of 2–5 years old. The intervention was delivered at the family level, and the primary caregiver was selected to provide the intervention. The primary caregiver was the person who spent the maximum time with the child and was involved in childcare decision-making. The eligibility criteria included a family who had consented in writing was a resident of the study area for the past 6 months and intended to stay in the study period till the follow-up period was completed. According to medical records, children previously diagnosed with long-term/chronic illnesses were excluded from the study.

Sample size

The sample size for individual-level randomization was estimated by using the formula (29); $N_I = (\sigma_1^2 + \sigma_2^2)\,(Z_{1-\alpha/2} + Z_{1-\beta})^2/\Delta^2$ (30), where, n = sample size, σ_1 = standard deviation of the control group and assumed it to be 2.09 (31), σ_2 = standard deviation of the intervention group and assumed to be 1.46 (31), Δ = difference in group means of average ST and is considered 0.54 (31), $Z_{1-\alpha/2}$ = two-sided Z value (Z = 1.96 for 95% confidence interval), and $Z_{1-\beta}$ = power (80%). Hence, N_I came out to be 161 per arm. After considering the attrition rate of 5%, the sample size was estimated at 170 participants per arm, i.e., 340 for the intervention study.

Sampling technique and randomization

A list of eligible families was obtained from the study area's auxiliary nurse-midwife's annual health survey register. These families were numbered, and a computer-generated randomized list of the sequences was generated to randomize the families into intervention and control arms to avoid selection bias. The participants were recruited until each arm's desired sample size was achieved. Each family in the study area had an equal chance of receiving or not receiving the intervention. The study flow diagram, according to the CONSORT guidelines, is shown in Figure 1.

Concealment of intervention

The intervention package consisted of information, education, and communication material. The participants were made to understand the intervention to change their media behaviors and reduce ST among children; hence, concealment of the intervention was impossible.

Blinding

Blinding of the investigator and participants was not possible in this study as the investigator had implemented the intervention herself (first author). The participants were also aware that they were being given the intervention to reduce the ST of their children. This was required as the intervention was targeted for changing the behaviors of the primary caregivers and family members by motivational interviewing methodology. However, data were entered by a blinded data entry operator.

PLUMS intervention

The intervention program was developed in four phases and was described elsewhere in detail (28). The intervention package is shown in Supplementary File S1. In phase one, an extensive literature review was done to identify the most successful strategies to reduce unwanted ST and understand the theories (such as Social Cognitive Theory for changing children's behavior and Self-determination theory for caregivers) (1).

The Social Cognitive Theory was used to modify preschoolers' cognitive development by developing targeted strategies to modify behaviors of the caregivers/children regarding ST or home media environment. When designing the intervention, we used this theory's framework for modeling (by the caregivers and healthcare worker),

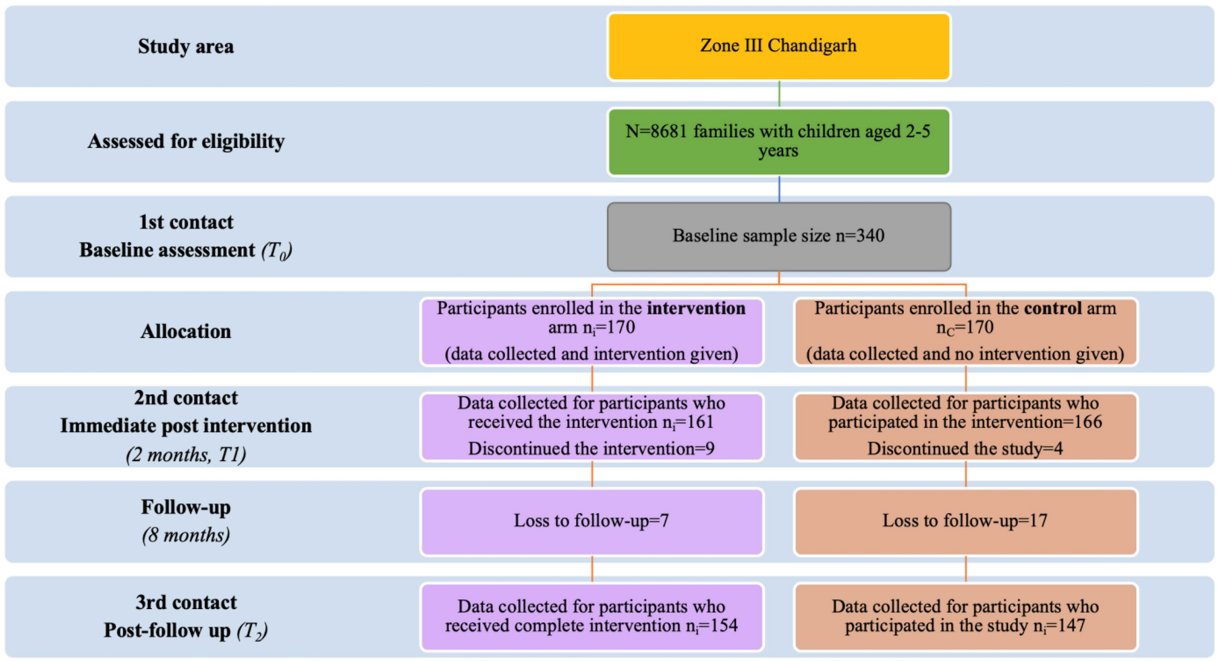

FIGURE 1
CONSORT flow chart of randomized controlled trial.

production (alternatives to ST, such as activities given to children or suggested by them), retention (repeated positive feedback provided by a healthcare worker), and reinforcement (rewards for encouraging positive behavioral outcomes offered by the healthcare worker) in observational learning, which is pivotal due to the limited cognitive development of preschoolers (26). In addition, self-determination theory was used to design the strategies to keep the caregivers motivated to limit the ST among the children and modify the home media environment. Self-determination theory targets three primary needs: competence, autonomy, and internalization of the learned concepts leading to desired outcomes (27).

According to a systematic review, the most effective treatments for reducing ST in children (0–5 years) were those that lasted for more than or equal to 6 months and were delivered in a community setting, which might have helped in bringing about a long-term positive behavior change among the parents and children (32). The intervention plan was adapted to the Indian setting, based on the content on ST reduction for 2–5-year-old children, as recommended by the Centers for Disease Control and the American Academy of Pediatrics' official websites. Hence, PLUMS was developed as a family-oriented, theme-based intervention based on Social Cognitive Theory and Self-determination theory (28).

The literature review helped us to identify the modifiable risk factors for each level, including a child (demographic, behavioral, and biological factors), caregiver (demographic, behavioral, and biological factors), and home-media environment level (access to electronic devices, digital-media rules, background TV, etc.); hence intervention was designed likewise (Supplementary Figure S1). We adapted the "Social–Ecological Model" so that the PLUMS modules could effectively target the child's entourage with specific strategies to reduce the unwanted excessive media exposure among children at the micro (child) level and caregiver along with the home-media environment at the meso level. The conceptual model based on the socio-ecological model is shown in Supplementary Figure S2.

In the second formative phase, in-depth interviews with caregivers ($n = 20$) and two focus group discussions with healthcare providers ($n = 11$), including clinicians (pediatricians), community physicians, and psychologists, were conducted to get their views and opinions on the effective intervention strategies to reduce the unwanted ST in the Indian context. In the third phase, we developed context-specific caregiver/parent and child modules in English and Hindi, with targeted interventions including media-free activities for children and videos for parents on how to engage children in these activities. The contents of these modules were discussed in a consultation meeting with the experts, including psychiatrists, psychologists, and public health experts, before finalizing. The details of the modules and intervention packages are described elsewhere (1).

In brief, the parents and child's module had eight weekly themes. The parent/caregiver had a choice of 10–12 activities per week for children to choose from every day for the specific theme of that week. Week one focused on excessive screen-time and development milestones of children, week two focused on screen-time rules at home, week three focused on sleep and digital media, week four focused on home media environment, week five focused on meal time and digital media gadgets, week six focused on effective communication within family regarding focusing on home media environment, week seven focused on education in positive experiences in a community setting, week eight focused on positive reinforcement and counseling as shown in the weekly calendar in Supplementary File S1. It was envisaged that child would need to spend 30–60 min per activity per day. There were information-based videos for the parents on the same themes to engage the children in activities which were free from media screens. The motivational counseling was given to parents weekly via phone/video calls, in

addition to the next week's theme-based goals. Specifically, those parents who were not actively participating in sharing the videos of activities were selected and counseled on the perceived barriers/inhibitions. These modules were pretested among 10 families in the fourth phase to determine the intervention strategies' acceptability, feasibility, and compliance. The final child and caregiver/parent modules are shown in Supplementary File S1.

Study instruments

The study instruments used to measure the study's outcomes, which were proxy-reported by the caregivers, are as follows:

- Digital-screen exposure questionnaire (DSEQ): This is a pretested and validated tool to assess the mean ST and physical activity (PA) (33). It has 86 items under five domains, including sociodemographic (age, sex, socioeconomic status, parents' education, occupation, and religion), screen-time exposure and home media environment, level of physical activity, media-related behaviors, and parental perceptions. For screen time estimation, the frequency, duration, and content of media watched by the child on a typical day were recorded using validated digital screen exposure questionnaire (DSEQ). The DSEQ had good internal consistency, reliability (Cronbach's alpha = 0.73–0.82), and good inter-rater agreement (Kappa = 0.75, 95% CI 0.72–0.78) (7, 28, 33). The physical activity questions were taken from PrePAQ and reported by parents via face-to-face interviews (7, 29, 34). The questionnaire was used to obtain information on ST in children, digital-screen exposure patterns, caregivers' perceptions of digital-screen exposure, and the child's physical activity in liaison with the existing literature (11). The time spent on online classes was recorded separately.
- Pre-school Child Behavior Check List: It assesses the child's emotional and behavioral problems. It has been shown to have high reliability and validity in the Indian setting (Cronbach's alpha = 0.95) (34). It is 100 items with a 3-step response scale: absent (score, 0), occasionally present (score, 1), and very often present (score, 2).
- Sleep Disturbance Scale for Children: It is a validated tool and was used for measuring the child's sleep patterns, which has a good consistency (Cronbach's alpha = 0.71–0.79, test–retest reliability of 0.71, and diagnostic accuracy of 0.91) (35). It is a 26-item Likert-type scale that measures specific sleep problems and overall sleep disturbances in children.

Data collection procedures

The intervention study was conducted in three phases: baseline, intervention, post-intervention assessment, and follow-up phase. The CONSORT flow chart depicting the enrolment and loss to follow-up at each assessment point in the intervention and control arm is shown in Figure 1. The DSEQ, PA, emotional and behavioral problems, and sleep disturbances were measured by visiting the homes of the eligible families and conducting face-to-face interviews with the primary caregivers at each assessment point.

We trained two post-graduate level (Masters in Social Work and MA Sociology) field investigators in assisting the first author (NK) in collecting the data in the community during baseline and endline assessments. Field investigators also helped in identifying the families in the community as per the sampling plan. NK herself delivered the intervention at household level weekly and also provided videos on WhatsApp to the primary care givers. She had created WhatsApp group with the participants in the intervention arm for monitoring the progress of the intervention weekly and ensuring positive reinforcement. NK actively participated in delivering the intervention as per the weekly plan and conducting motivational interviewing with the primary caregivers at the household level by personally visiting them and also telephonically. Similar WhatsApp group was also created for the control group, but no intervention material was shared with them, and none of the control families visited during intervention phase. MG, SG, and PM (authors) were involved in weekly supervision and validation of the data collection. Overall, 10% of the data collected was validated by them. The WhatsApp group was monitored by them weekly.

Baseline assessment phase (T_0)

All the families with 2–5-year-old children in the study area were assessed for eligibility. The baseline assessment was initially done from December to March 2020 (25) but had to be repeated from 29th October to 21st November 2020 due to the COVID-19 pandemic, which might have influenced the ST at the baseline due to the lockdown. Then, 340 parents were randomly enrolled in the intervention ($n = 170$) and control arm ($n = 170$).

Intervention phase (T1)

The intervention was implemented for 2 months (22nd November 2020 to 3rd January 2021) in the intervention arm at the household level, whereas the control arm received regular health services. There were 170 families in each arm at baseline. Due to the lack of follow-up at the post-intervention assessment, there were 161 in the intervention and 166 in the control arm in this phase. The PLUMS intervention continued for 2 months. Weekly videos (2 min) were shared with the parents on a WhatsApp group during the intervention. The first author performed motivational counseling sessions for the parents who were not participating actively or had inhibition about the intervention plan. The motivational counseling was provided via phone/video calls at a convenient time due to COVID-19 travel restrictions. The daily time spent by the families on the activities was 30–60 min per day. Parents were asked to change the home media environment as a part of the intervention (Supplementary File S1). The control group received the routine care by the health system and given the assessments by us.

Post-intervention assessment (T1) and follow-up assessment phase (T2)

A post-intervention immediate evaluation (T_1) was conducted from 11th January 2021 to 31st January 2021 using the same tools as used in baseline assessment at T_0. Follow-up of the families continued for another 6 months after intervention from 1st February to 13th August 2021. In this phase, 154 families remained in the intervention group and 147 in the control arm. This maintenance phase included sharing information, communication, and educational material fortnightly with the parents on the WhatsApp group, as shown in

Supplementary File S1. A follow-up assessment after 6 months of intervention was conducted using the same tools as the baseline assessment conducted in August 2021.

Outcomes

The primary outcome was the mean differences in ST (in minutes per day) separately on typical days [this was the average of 7 days in a week calculated by deriving the weighted average of weekdays and weekends in a manuscript published elsewhere (7, 8)], weekdays (Monday–Friday), and weekends (Saturday and Sunday) in the intervention versus the control arm. The secondary outcomes of the study were the difference in proportions of children with excessive ST, emotional behavior problems, sleep problems, change in media rules at home, and the duration of the physical activity (in minutes) per day in the intervention versus the control arm.

Adherence to the intervention

During the weekly counseling sessions, the compliance proforma was given to the caregivers to check their fidelity during the active intervention phase (2 months). The child's adherence and level of engagement were assessed with the help of activity videos and/or pictures shared by the parents on the WhatsApp group during the 8-week intervention period. The compliance proforma has been published elsewhere (28).

Data analysis

Data was entered into a Microsoft Excel sheet and analyzed using IBM SPSS for Macintosh version 25.0. and StataCorp. 2019. *Stata Statistical Software: Release 16*. College Station, TX: StataCorp LLC. The results are presented per the Intention to Treat (ITT) analysis. The ITT approach was preferred as it preserves the balance by maintaining the comparability between treatment and control arms, reducing the risk of bias, and maintaining the effect of randomization, thereby retaining the power of the research study. Missing values were excluded from the analysis.

The per-protocol analysis was also executed for exploratory assessments. A p-value <0.05 was considered statistically significant for all analyses at a 95% confidence interval (CI). According to Kolmogorov–Smirnov test results, ST data were non-normally distributed for children's ST (36). The medians, standard deviation (SD), standard error (SE), and interquartile ranges were estimated for continuous variables. The differences in means between the two groups regarding ST of the children on a typical day, weekday, and weekend were assessed by the Mann–Whitney U test (36).

For categorical variables, the proportions were calculated. The differences in proportions between the two groups were tested using the chi-square and Fisher exact tests (for less than five observations). The relative risk reduction (1-relative risk*100) was estimated to assess the effectiveness of the intervention. As this was longitudinal data, the Generalized Estimating Equation approach was used to adjust the effect of clustering on the effectiveness of the intervention. The models were developed for dependent variables, including ST as a continuous variable (average ST of the child in minutes on a typical day), ST as a categorical variable (proportion of children having ST of less than one versus more than 1 h per day), emotional problems (scores), sleep problems (scores), and duration of physical activity (minutes). Independent variables adjusted were the child's age, sex of the child, socioeconomic status of the family, average daily father's ST, father's education, average everyday mother's ST, mother's education, and digital media rules.

Ethical considerations

The Ethics Committee of the Postgraduate Institute of Medical Education and Research, Chandigarh, approved the study (INT/IEC/2019/000711), and all prior permissions were obtained to conduct research in the community setting (VO/FW/17/1894, Dated-30/08/17). Verbal and written informed consent was obtained from the parents before giving the PLUMS intervention.

Results

The randomization of families is illustrated using the Consolidated Standards of Reporting Trials (CONSORT) flow chart, as shown in Figure 1. This CONSORT flow chart depicts the enrollment and loss to follow-up at each assessment point in the intervention and control arm.

Among the parents in the intervention arm ($n = 170$) who had received the video intervention, approximately 94.7% completed the weekly activities, and 61% required motivational counseling. It can be observed that in 46% of parents, fathers changed their behavior. Most parents acknowledged that the intervention was simple and understandable with easy-to-perform activities. There was an increase in the participants' knowledge concerning ST (Supplementary Table S2).

There were more or less similar numbers of participants in both the intervention and control arms to the sex and age of the child. Predominantly, the study participants belonged to the Hindu religion and were urban residents. Most of the children belonged to the nuclear family setup, wherein the child's mother was the primary caregiver. Most of the parents were married, wherein for most participants, the mother's age was younger than 30 years old, and that of the fathers' was older than 30 years for both the control and intervention arms. Mothers were slightly more educated in the intervention arm than in the control arm. However, the majority of the mothers were unemployed for both arms. There were no significant differences between the background characteristics of the children in the intervention versus the control arm, and the children were equally distributed among both arms (Table 1). On a typical day, the mean ST of children aged 2–5 years in Chandigarh had a significantly non-normal distribution as represented by Whisker box plots (Supplementary Figure S3).

The mean ST (27.7 min, CI = 5.1, 50.3, $p = 0.011$) at the immediate post-intervention assessment significantly decreased in the intervention arm (102.6 ± 98.5 min) as compared with the control arm (130.3 ± 112.8 min) on a typical day. The mean ST of children on the weekend reduced significantly at the follow-up assessment (21.7 min, CI = −4, 47.3, $p = 0.041$) in the intervention arm (105.4 ± 124 min) versus the control arm (127.1 ± 116.5 min). However, there were no

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TABLE 1 Background characteristics of the parents of children aged 2–5 years in Chandigarh in the intervention and control groups in 2021.

Variable	Intervention arm *N* = 170 (%)	Control arm *N* = 170 (%)
Child's sex		
Boys	86 (50.6)	87 (51.2)
Girls	84 (49.4)	83 (48.8)
Age of the child		
2 to <3 years	47 (46.5)	54 (53.5)
3–4 years	17 (45.9)	20 (54.1)
>4 to 5 years	103 (52.6)	93 (47.4)
Religion		
Hindu	140 (82.4)	149 (87.6)
Sikh	15 (8.8)	12 (7.1)
Muslim	12 (7.1)	9 (5.3)
Others	3 (1.8)	0
Place of residence		
Urban	90 (52.9)	85 (50)
Resettlement colony/urbanized village	80 (47.1)	85 (50)
Family type		
Nuclear	104 (61.2)	115 (67.6)
Extended/joint	66 (38.8)	55 (32.4)
Parents' marital status		
Married	167 (98.2)	167 (98.2)
Divorced/separated/single	3 (1.8)	3 (1.8)
Mother's age		
Less than 30 years	103 (60.9)	93 (54.7)
More than 30 years	66 (39.1)	77 (45.3)
Father's age		
Less than 30 years	56 (32.9)	52 (30.6)
More than 30 years	114 (67.1)	118 (69.4)
Primary caregiver of the child		
Mother	160 (94.1)	159 (93.5)
Father	3 (1.8)	3 (1.8)
Grandfather	3 (1.8)	1 (0.6)
Grandmother	6 (3.5)	4 (2.4)
Others	0	1 (0.6)
Mother's education		
Illiterate/primary school	29 (17.1)	22 (12.9)
Middle school	25 (14.7)	25 (14.7)
High school intermediate diploma	59 (34.7)	47 (27.6)
Graduation/professional honors	57 (33.5)	75 (44.1)
Father's education		
Illiterate/primary school	19 (11.2)	18 (10.6)
Middle school	40 (23.5)	31 (18.2)
High school/Intermediate diploma	55 (32.4)	49 (28.8)
Graduation/professional honors	56 (32.9)	72 (42.4)
Per capita income of the family*		
Below Rs.11000 (USD 147)	102 (60)	118 (69.4)
Above Rs.11000	68 (40)	52 (30.6)
Mother's occupation		
Unemployed	151 (88.8)	140 (82.4)
Employed	19 (11.2)	30 (17.6)
Father's occupation		
Legislator/senior officer/ manager/professionals	34 (20)	42 (24.7)
Technician/associate professional/clerks	29 (17.1)	40 (24.4)
Skilled worker/craft related worker/plant operator	88 (39.4)	83 (48.8)
Unemployed	1 (0.6)	0

*1 USD = 75 INR.

significant changes on the weekdays. The duration of physical activity was significantly ($p < 0.0001$) different at the follow-up between the intervention and control arm (Table 2).

The proportion of families in the intervention arm changed the placement of the TV significantly ($p = 0.04$) and increased in the intervention arm at the immediately post-intervention assessment point ($N = 78$, 44.1%), as compared with the control arm ($N = 99$, 59.6) from the baseline assessment point (intervention 56.5%, control 58.8%). The proportion of families in the intervention arm who changed the placement of the smartphone significantly ($p = 0.01$) increased at the immediately post-intervention (intervention $N = 98$, 61.3%; control $N = 123$, 74.5%) and follow-up assessment (intervention $N = 123$, 83.7%, control $N = 109$, 71.2%) from the baseline assessment (intervention $N = 135$, 79.4%, control $N = 141$, 82.9%) points.

The relative risk of having excessive ST among children immediately post-intervention was 0.79. The PLUMS intervention had statistically significant moderate effectiveness in reducing the excessive ST at the immediately post-intervention assessment period [(1–0.79)*100 = 21%, $p = 0.0038$], but it was insignificant at the follow-up assessment point [(1–0.91)*100 = 9%, $p = 0.43$].

The results of the generalized estimating equation have shown that there was a significant ($p = 0.04$) reduction of ST ($\beta = -35.81$ min, CI = −70.6, −1.04) in the intervention arm as compared with the control arm from the baseline (T_0) to the follow-up (T_2) assessment point. When ST was dichotomized as a categorical variable (less than versus more than 1 h per day ST), there was a significant reduction (adjusted odds ratio = 0.48, CI = 0.15, 0.27) in the proportion of children with excessive ST from baseline (T_0) to post-intervention (T_1) assessment points in the intervention as compared with the control arm. The physical activity duration had increased considerably in the intervention arm versus the control arm at both the immediate post-intervention T_1 ($\beta = 48.4$ min, CI = +6.6, +90.3) and follow-up T_2

TABLE 2 Mean screen time (in minutes) of children aged 2–5 years in Chandigarh on a typical day, weekday, and weekend in the intervention and control arms in 2021.

Variables	Intervention arm ($N = 170$)	Control arm ($N = 170$)	The difference in ST (min)	95% CIs	*P*-value
A. Typical day					
	Mean ST ± SD (SE)	Mean ST ± SD (SE)			
Baseline (T_0)					
Mean screen time	123.1 ± 83.1 (6.3)	130.5 ± 114.8 (8.8)	7.4	−13.9, 28.8	0.36
Post-intervention (T_1)	$N = 170$	$N = 170$			
Mean screen time	102.6 ± 98.5 (7.5)	130.3 ± 112.8 (8.6)	27.7	5.1, 50.3	0.011
Follow-up (T_2)					
Mean screen time	116 ± 114.9 (8.8)	136.6 ± 118.1 (9)	20.7	−4.1, 45.6	0.09
B. Weekday					
Baseline (T_0)					
Mean screen time	125.9 ± 81 (6.2)	135.6 ± 121.6 (9.3)	9.7	−12.3, 31.7	0.4
Post-intervention (T_1)					
Mean screen time	113.7 ± 109.3 (8.3)	133.2 ± 120.4 (9.2)	19.5	−5, 44	0.12
Follow-up (T_2)					
Mean screen time	126.8 ± 130.3 (9.9)	146.1 ± 138.1 (10.6)	19.2	−9.4, 47.9	0.13
C. Weekend					
Baseline (T_0)					
Mean screen time	120.4 ± 95.5 (7.3)	125.4 ± 116.6 (8.9)	5	−17.8, 27.7	0.5
Post-intervention (T_1)					
Mean screen time	104 ± 115.2 (8.8)	117.7 ± 121.4 (9.3)	13.7	−11.5, 39	0.19
Follow-up (T_2)					
Mean screen time	105.4 ± 124 (9.5)	127.1 ± 116.5 (8.9)	21.7	−4, 47.3	**0.041**

*T_0 is the baseline assessment, T_1 is the post-intervention assessment, and T_2 is the follow-up assessment.

($\beta = 73.4$, CI = 36.2, 110.5) assessment points in the intervention arm as compared with the control arm (Table 3). No significant changes were observed in the children's sleep and emotional behaviors (Supplementary Table S3).

Discussion

The PLUMS intervention's focus on enhancing the parents' ST literacy home-media environment and customizing the counseling sessions seemed to have eventually brought a sustainable change in ST behaviors among Indian children aged 2–5 years. As parents act as an essential liaison between the young child and the health worker, family-based counseling (6) has been proven productive in bringing about behavior change; thus, we incorporated the parents in our intervention for role-modeling as per the socioecological model (25). Additionally, Bandura's "Social Learning Theory" (37) was incorporated to explain how learning occurs in a social context with a reciprocal and dynamic interaction between the person (here, child/caregiver), behavior, and environment. As the parents were role-modeling the appropriate behaviors, we used the self-determination theory (38). High-quality learning and favorable outcomes have been observed with the self-determination theory and motivational interviewing (27) when used together.

The PLUMS intervention significantly decreased the mean ST (27.7 min, CI = 5.1, 50.3) at the post-intervention assessment in the intervention arm compared with the control arm on a typical day. Additionally, it effectively reduced the ST ($\beta = -35.81$ min CI = −70.6, −1.04) among children in the intervention versus the control arm from the baseline to the follow-up assessment points. The duration of physical activity had increased significantly in the intervention arm versus the control arm at both the post-intervention ($\beta = 48.4$ min, CI = +6.6, +90.3) and follow-up ($\beta = 73.4$ min, CI = 36.2, 110.5) assessment points. However, sleep problems and emotional problems among children did not change.

Overall, the mean reduction in ST was well within the range [0.3 (SE = 13.3) to −47.16 (SE = 2.01) min], as reported in a review that included 16 intervention studies among children of younger than 5 years old in high-income countries (1). A greater and significant reduction in ST from baseline to follow-up was observed in this study compared with a European intervention study conducted by Yilmaz et al. among 2–6-year-old children (39). Our study followed the latest ST guidelines of less than 1 h per day to determine the ST as excessive. In contrast, previous studies followed older ST guidelines of less than 2 h per day as the permissible ST limit for 2–5-year-old children. The average ST was significantly reduced on a typical day and the weekends but not on the weekdays between the intervention and control groups in this study. Paradoxically, a Canadian study reported

TABLE 3 Generalized estimating equations for estimating the longitudinal effect of the PLUMS intervention.

Parameters in the intervention versus control arm	Measure	Standard error	95% CI		
			Lower	Upper	*p*-value
Screen time in minutes	Beta coefficient (β)				
Post intervention period (T1)	−13.8	14.8	−42.96	15.31	0.21
Post 6 months (T2)	−35.8	17.74	−70.59	−1.04	0.04
Physical activity in minutes					
Post intervention period (T1)	48.4	21	6.6	90.33	0.023
Post 6 months (T2)	73.37	18.97	36.19	110.55	<0.0001
Emotional problems scores					
Post intervention period (T1)	2.67	1.64	−0.55	5.9	0.1
Post 6 months (T2)	2.06	2.17	−2.18	6.31	0.34
Sleep problem scores					
Post intervention period (T1)	0.86	1.3	−1.84	3.57	0.53
Post 6 months (T2)	1.56	1.41	−1.21	4.33	0.27
Screen time as categorical variable	Adjusted odd's ratio		Lower CI	Upper CI	*p*-value
Post intervention period (T1)	0.48	0.15	0.27	0.87	0.016
Post 6 months (T2)	0.51	0.18	0.25	1.01	0.056

The model was adjusted for father's ST and education, mother's ST and education, digital media rules, area of residence socioeconomic status, and gender and age of the child. [$]ST, Screen time.

no significant change among preschoolers on weekdays and weekends (17). These differences might be due to differences in the study objectives and settings; additionally, we performed home visits (first visit) and gave motivational counseling via phone/video calls. There was a significant change in the placement of electronic devices in the room where the child slept, such as television ($p = 0.042$), smartphone ($p = 0.01$) post-intervention assessment, and only smartphone ($p = 0.01$) at follow-up assessment, as reported in other studies (40, 41).

Our study results observed an increase in the duration of physical activity in children with an improvement in ST literacy. It has been observed in the existing literature that multicomponent intervention studies combining physical activity with nutritional interventions have shown beneficial effects (42). Moreover, it is likely that health education-focused, customized family-based counseling (28) with persistently motivating the participants might bring about sustainable behavior change (1). A 14-week intervention among 18 American schools observed more rigorous physical activity than the children in the control schools (43). The COVID-19 pandemic restrictions might have affected the type of physical activity performed by the children in our study.

The effect of ST on psychological health and cognitive abilities in young children has been previously debated but not investigated in a randomized design, raising questions regarding its causal impact. To reduce ST among children of 4–6 years of age (23), a recent Taiwanese intervention study had observed a significant change in the psychosocial health of children, in contrast to this research. This change can be due to different study settings (classroom or home-based) where appropriate psychosocial behaviors were observed. The Taiwanese study selected children with more than 2 h of ST per day, while we randomly selected children from the community. The PLUMS intervention did not affect sleep duration, sleep patterns, and emotional problems. This could be because the primary focus of this study was reducing sedentary screen behaviors.

However, parents reported a change in their child's behavior (emotional, physical activity, and sleep patterns) during the COVID-19 pandemic. Another long-term study showed no effect on sleep duration and cognitive abilities among European preschoolers ($n = 652$) (42), which is similar to this study. In contrast, in an American trial among 2–5-year-old children, an increase in the sleep duration (0.56 h per day) in the intervention group and a decrease in the control group (0.19 h per day) were reported (42). In the former study, academicians and health educators gave motivational coaching during four home visits, mailed educational materials, and offered incentives to the study participants, in contrast to the present study. Pediatricians, child psychologists, and educators can devise similar educational modules to counsel families regarding ST, its regulation or alternatives, and its consequences in future studies. Thus, the educational material developed in the current study might also aid teachers, educators, and practitioners in reducing ST among children.

This research is valuable to academicians and researchers as it provides evidence of the effectiveness of PLUMS at the home level in reducing unwanted STs among young children. In the future, they can plan a study on its impact on emotional and sleep behaviors to assess health impacts. For the practitioners, the results of this study provided evidence that motivational coaching of the parents regarding reducing unwanted ST and modifying the home media environment during visits of the children in the clinics can reduce unwanted ST. The practitioners should be sensitized to exploring the digital ST of the young children during such visits.

The strengths of the study included a robust study design, i.e., a randomized control trial among the parents in the community settings conducted for the first time in India among preschoolers to reduce excessive ST. Another strength is the multiphasic development of the PLUMS, which helped identify the problems and related solutions before the implementation. To overcome

the recall bias in reporting ST, the first author recorded the names of TV/online programs and the approximate duration the child watched in the past week to calculate the ST accurately. TV diaries were also proposed to the primary caregivers to capture the children's actual ED use. However, the parents found it challenging to maintain them; instead, they shared a daily activity journal that verified the children's adherence to the intervention and activities at home. A meta-analysis concluded that interventions enabled the participants to change their behaviors by controlling the electronic devices at home, setting goals, and planning media use (where children participated in this decision-making); children were allowed to watch electronic devices for a specified time, rewards for good behavior, increasing ST literacy or parents. All these strategies were incorporated into the present study. We observed a small effect size (21%) in the post-intervention assessment, supported by the former meta-analysis that ST-focused interventions generate a small effect size due to wider CIs and ranges of participants' ST, small sample size, which does not affect the overall impact of the intervention (44). The study findings can be generalized to similar urban settings in North India and Southeast Asia.

The study has several limitations. First, the parents worked from home during the COVID-19 pandemic, making it difficult to focus on the child. Moreover, the PLUMS module suggested home-based feasible activities with adult supervision. There was a loss in follow-up in the intervention and control arms (post-intervention-T_1:4%; follow-up-T_2:12%), which might be due to the overlapping information of PLUMS with the ongoing online classes for the children. Second, the social desirability and recall bias might have affected some responses reported by the parents. The COVID-19 pandemic might have weakened the impact of the intervention on the emotional and sleep behaviors of the children. Third, fathers' involvement was low as observed previously that fathers' participation and retention in an intervention program is challenging in LMICs (45). The only solution to this problem is to customize an intervention plan to make the program feasible and accessible to the participants. Following up with the parents on the phone and sending them brochures on the adverse effects of excessive ST helped increase their participation. Finally, blinding could not be done as this project was a part of the first author's Ph.D. program, and she gave the intervention to the participants. In addition, the intervention group was performing the activities; hence, they knew they were a part of the intervention. Finally, the study protocol assumed the non-response rate/refusal rate to be 10% and loss to follow-up to be 15%, which estimated the sample size to be 214 per arm (28). However, the sample size estimation was revised after obtaining the Doctoral Committee's approval due to the loss of participants during the COVID-19 pandemic in the follow-up and the paucity of funds. Moreover, the attrition rate was reduced to 5% to reduce the final sample size (170 per arm). We acknowledge that the intervention aimed to reduce the ST, not necessarily modifying the choice of ST programs/content the children viewed. We also realize that as children's daily non-sleep time is limited, adding additional activity time exposure to media screen time might decrease naturally, but evidence needed to be generated in this regard.

The study findings have important public health implications. This study has provided evidence that carefully designed; evidence-based, culturally appropriate ST reduction programs can successfully modify the home-media environment and reduce the burden of excessive ST among young children. Hence, home-based intervention programs are potentially needed to decrease the burden of ST and its associates. This study might help implement ST reduction interventions in India and other countries in the Southeast Asian region.

Conclusion

Based on Social Cognitive and Self-determination theory, an evidence-based, culturally appropriate multicomponent home-based intervention, known as Program to Lower Unwanted Media Screen (PLUMS), was developed and implemented at the micro (child) and meso (family and home environment) level as per the socioecological model. It effectively reduced excessive ST at the child and the family levels. This is one of the first intervention studies from the Southeast Asia Region in this regard. The new knowledge added to the existing literature is that it is feasible to implement PLUMS intervention at the family level in urban Indian settings to effectively reduce unwanted ST among young children, with evidence of its sustainability for 6 months.

What is known about the subject

Excessive screen-time among children is a significant public health problem globally, with implications for their growth and development. Unwanted screen-time can be effectively reduced; however, almost all intervention studies were conducted in developed countries to mitigate screen-time among children of younger than 5 years old.

What this study adds

This is the first randomized controlled trial in Indian households to generate evidence on the program's effectiveness in lowering unwanted screens (PLUMS), significantly reducing it among children aged 2–5 years. PLUMS was especially designed to consider the context of low-middle income countries using social cognitive theory for children and self-determination theory for caregivers.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The study involve humans were approved by PGIMER Institutional Ethics Committee, Chandigarh India. (INT/IEC/2019/00711 dated 02/04/2019). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

NK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MG: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing. VC: Data curation, Formal analysis, Methodology, Software, Validation, Visualization, Writing – review & editing. FK: Data curation, Formal analysis, Software, Writing – review & editing, Validation, Visualization. PM: Writing – review & editing. TK: Supervision, Writing – review & editing, Data curation, Formal analysis, Software, Writing – original draft. SG: Conceptualization, Investigation, Software, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1304861/full#supplementary-material

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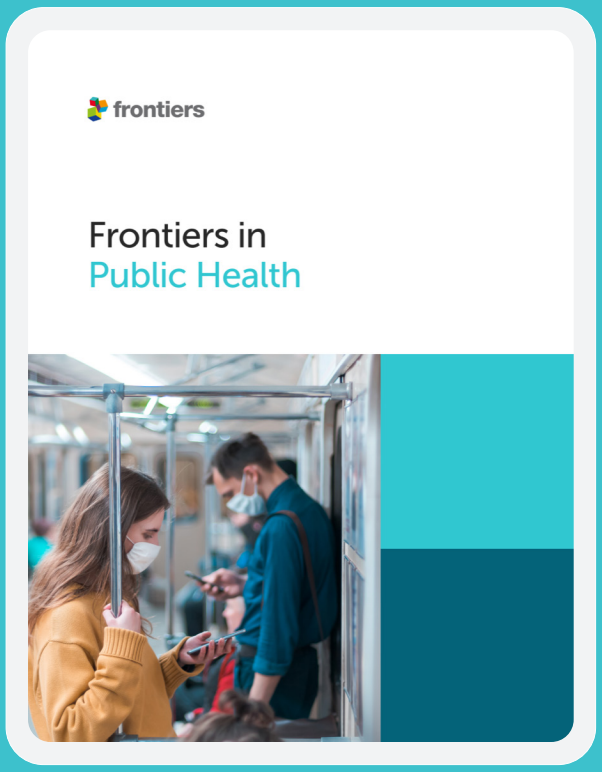

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