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Children and adolescent health-related behaviors

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Maha El Tantawi

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Children and adolescent health-related behaviors

Topic editor
Maha El Tantawi — Alexandria University, Egypt

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Christiane Stock,
Charité – Universitätsmedizin Berlin, Germany;
Humboldt-Universität zu Berlin, Germany

*CORRESPONDENCE
Maha El Tantawi
maha.tantawy@alexu.edu.eg

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Editorial: Children and adolescent health-related behaviors

Maha El Tantawi*

Faculty of Dentistry, Alexandria University, Alexandria, Egypt

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Editorial on the Research Topic
Children and adolescent health-related behaviors

The United Nations Convention on the Rights of the Child (1) recognizes the right of the child to the highest attainable standard of health. A life course approach to health acknowledges the importance of exposures and experiences in early life to the health and wellbeing of individuals in later stages of their life. The health of adolescents and children impacts their health in later life and the health habits they develop in early life affect their health in the long run (2). The Sustainable Development Goals (SDGs) also aim to ensure that every child survives and thrives (3) and acknowledges that children wellbeing is critical to the achievement of sustainable development. Greater focus is needed on the health of children and adolescents and associated determinants to establish healthcare programs tailored to their needs and characteristics and to allocate more resources to support them. This Research Topic provides this focus.

The Research Topic sheds light on risk factors that may impact young people's health like they impact the health of adults such as use of tobacco, obesity, inadequate sleep and limited physical activity in addition to risk factors that are more relevant to younger age groups such as longer screen use time and use of e-cigarettes. The quality of sleep and physical activity affect perceived and actual health. In this Research Topic, Ding et al. showed that short sleep periods and low sleep quality were associated with suboptimal self-reported health among medical students in China. Qin et al. reported an association between weight and physical fitness in Chinese high school students thus showing an association between physical activity and obesity in younger age groups. Physical activity has direct and indirect benefits for health. In this Research Topic, Zeng et al. showed that physical activity mitigated the negative impact of prolonged use of screens on visual acuity among Chinese children during the COVID-19 pandemic, thus, providing evidence to guide parenting practices. Despite this health promoting effect of physical activity, Deng and Fan presented data from a national US survey of adolescents showing that sports participation has declined in the last decade with differences among ethnic subgroups and subsequent negative health effects to be expected among this young population. Obesity (4) and sedentary lifestyles (5) are modern times pandemics in various age groups and if these problems currently observed in children and adolescents are not addressed, the burden of non-communicable diseases associated with this lifestyle can only be expected to increase.

Tobacco use is another global health problem with statistics showing that although cigarette smoking has decreased among adolescents, the use of other tobacco products has increased or remained the same over the last two decades (6). This Research Topic confirms the important effect of the social environment on young people's intended or actual tobacco use (7). Parents, siblings and friends who smoke facilitate smoking for youngsters.

The Theory of Planned Behavior (8) posits that perceived norms are among the factors affecting intention to engage in a health behavior. How people surrounding an individual behave sets the stage for expectations and accepted standards. In this Research Topic, Dai et al., showed that exposure to second-hand smoking and multiple sales sources, as well as having parents and friends who use e-cigarettes were all associated with greater likelihood of Chinese adolescents' expressing an intention to use e-cigarettes. Mai et al. also confirmed the association between friends' using e-cigarettes and Chinese adolescents' use of e-cigarettes although they showed that some personality traits, like agreeableness, may be associated with lower odds of e-cigarettes' use. Ribera-Osca et al. also confirmed the impact of having parents who are smokers on secondary school students' tobacco use in Spain.

The Research Topic offers an insight into health intervention opportunities that are of special importance to children and adolescents by describing several school-based health interventions. School health programs offer a good chance to integrate health promotion activities into school activities and to reduce workforce needs by utilizing schoolteachers to supervise program activities. Gasoyan et al. described a program to improve oral health and reduce caries among Armenian schoolchildren in rural areas where fluoridation is not possible. Nagy-Pénzes et al. reported on a school-based program that improved health-related knowledge, reduced unhealthy eating and alcohol consumption and improved physical activity among Hungarian secondary school students. Gross et al. used quality improvement and participatory approach to design a health education curriculum to improve American adolescents' health behaviors. These various interventions demonstrate the usefulness of school-based interventions to modify and instill positive health behaviors thus benefiting from the social environment in which children and adolescents live and turning perceived norms and role modeling into an opportunity rather than a threat.

The health of children and adolescents is at a critical stage. New challenges specific to this age group and risks that are characteristic of older age groups but apply to younger populations require innovative solutions that build on the specific attributes of young people and their vulnerability to the impact of peers and role models. Involving members of the target group in designing health behavior modification interventions is key to promoting the health of children and adolescents.

Author contributions

ME: Writing—original draft, Writing—review and editing.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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COMMUNITY CASE STUDY
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School-Based Preventive Dental Program in Rural Communities of the Republic of Armenia

Hamlet Gasoyan[1,2]*, *Armen Safaryan*[3], *Lusine Sahakyan*[4], *Nairuhi Gasoyan*[3], *William E. Aaronson*[1] and *Robert A. Bagramian*[5,6]

[1] Department of Health Services Administration and Policy, College of Public Health, Temple University, Philadelphia, PA, United States, [2] Visiting Scientist in Health Services Administration and Policy, Yerevan State Medical University, Yerevan, Armenia, [3] Faculty of Public Health, Yerevan State Medical University, Yerevan, Armenia, [4] Children of Armenia Fund, Yerevan, Armenia, [5] School of Dentistry, University of Michigan, Ann Arbor, MI, United States, [6] Dean Emeritus, School of Public Health, American University of Armenia, Yerevan, Armenia

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Edited by:
Maha El Tantawi,
Imam Abdulrahman Bin Faisal University, Saudi Arabia

Reviewed by:
Hams Hamed Abdelrahman, Alexandria University, Egypt
Asim Al-Ansari, Imam Abdulrahman Bin Faisal University, Saudi Arabia

***Correspondence:**
Hamlet Gasoyan
hamlet.gasoyan@temple.edu

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Objectives: This paper describes a school-based preventive dental program implemented in 14 rural schools within nine villages of Armenia. As part of the program, school-based toothbrushing stations (called Brushadromes) were installed in the participating schools. The intervention included school-based supervised toothbrushing with fluoride toothpaste and oral hygiene education.

Methods: The study evaluates the prevalence and levels of dental caries among rural schoolchildren in 2013 (before the implementation of the preventive program, referred to as a pre-intervention group) and 2017 (4 years after the start of the program, referred to as an intervention group) in two randomly selected villages where the program was implemented. A repeated cross-sectional study design was used. The prevalence of caries and the number of decayed, missing, and filled teeth in permanent dentition (DMFT) and primary dentition (dmft) were recorded among 6–7 and 10–11-year-old schoolchildren in 2013 ($n = 166$) and 2017 ($n = 148$). The pre-intervention and intervention groups include different children in the same age range, from the same villages, examined at different time points. In both instances, they represented over 95% of the 6–7 and 10–11-year-old student populations of the studied villages. Pearson Chi-square, Fisher's Exact test, independent t-test, and quasi-likelihood Poisson regression were utilized for data analysis.

Results: Schoolchildren involved in the intervention had significantly less decay levels compared to same-age pre-intervention groups. For 10–11-year-old schoolchildren involved in the program, the mean number of permanent teeth with caries was lower by a factor of 0.689 (lower by 31.1%), $p = 0.008$, 95% CI, 0.523; 0.902, compared to the 10–11-year-old pre-intervention group, after controlling for age, sex, child's socio-economic vulnerability status, the village of residence, and the number of permanent teeth with fillings.

Conclusions: The study indicates a significantly lower level of caries among schoolchildren in the studied two villages where the intervention was implemented. The described intervention is particularly suitable in rural settings where water fluoridation is not available and homes have limited availability of running water.

Keywords: caries prevention, primary schoolchildren, fluoride toothpaste, school-based intervention, Armenia

INTRODUCTION

Dental caries remains one of the most prevalent chronic conditions among children in many countries (1, 2). The reported outcomes of dental caries and poor oral health in children are well-documented and range from serious health problems, such as dental abscess, to negative effects on nutrition, growth, and development, as well as children's school performance (3, 4). In the post-Soviet Republics, including Armenia, there has been very little data collected on the prevalence and levels of dental caries. A 2005 study conducted by the American University of Armenia reported an 86% prevalence of dental caries in a sample of 12 year-old schoolchildren in one of the provinces of Armenia (5).

Armenia is classified by the World Bank in the upper-middle-income economies tier (6). After its independence in 1991, the Armenian healthcare system experienced decentralization and partial privatization, leading to increased out-of-pocket payments and limited access for the poorest households to essential health and dental services (7, 8). Armenia is subdivided into 11 administrative divisions (10 provinces and the capital—Yerevan). Poverty and underdeveloped infrastructures are typical for the country's remote villages (9, 10). The percentage of people in the country living below the state-defined poverty level was 25.7% in 2017 (9).

Like in many middle-income countries, water fluoridation, or other similar mass-preventive methods, is not provided in Armenia (11). Inadequate knowledge on dental hygiene among children and their parents, unhealthy nutritional habits, and limited availability of running water in many homes of remote villages prompted the Children of Armenia Fund (COAF) to implement a school-based supervised toothbrushing intervention with fluoride toothpaste and oral hygiene education project in three provinces of Armenia.

There have been previous studies documenting the efficacy of school-based supervised toothbrushing programs in England, Scotland, and Australia (12–14). The authors are not aware of any similar studies that were conducted in the context of post-Soviet countries.

This paper presents a school-based preventive dental program implemented in nine villages within three provinces of Armenia. In addition, the paper evaluates the prevalence and levels of dental caries among rural schoolchildren ages 6–7 and 10–11 in 2013 (before the implementation of the preventive program, referred as a pre-intervention group) and 2017 (4 years after the start of the program—intervention group) in program implementation areas.

METHODS

Intervention

Within the preventive dental program, in 2013, COAF installed school-based toothbrushing stations (called Brushadromes) in 14 rural schools of nine (Karakert, Arteni, Dalarik, Lernagog, Shenik, Miasnikian, Bagaran, Yervandashat, Argina) villages within three (Armavir, Aragatsotn and Lori) provinces of Armenia. The "Brushadrome" is a room, next to the cafeteria, equipped with multiple sinks and individual cabinets for dental hygiene supplies which allow schoolchildren to brush their teeth after lunch. The program began in 2013 and is currently running with an expansion to 22 more villages.

The intervention was 5 days per week (after lunch) of supervised toothbrushing, using fluoridated toothpaste and a medium soft brush (products by Colgate®) at school, coupled with oral hygiene education for children and parents. The school-based supervised toothbrushing was conducted for overall 135 school days per year (excluding cold months of the year, when the school cafeteria was closed, and out-of-school days). The toothbrush was replaced after ∼70 days of use, at the beginning of the Fall and Spring semesters, as well as whenever there was noticeable toothbrush wear. The fluoride concentration in the toothpaste was 1,000 p.p.m.; no other relevant ingredients were included in the toothpaste. Children also received oral hygiene products for home use.

Children were instructed on proper oral hygiene and brushing techniques, as well as supervised while brushing, either by the school nurse or primary school teachers; both received the same training as part of the intervention. The Vertical Sweeping Brushing Technique was followed. The brushing time was set to 2 min and timed via sand timers. Parents of the schoolchildren were also educated on oral hygiene topics and encouraged to monitor whether the child brushed the teeth twice a day at home.

The utilization of the "Brushadromes" by the schoolchildren was very high throughout the intervention.

Study Design

This study employed a repeated cross-sectional design. The prevalence of caries and the number of decayed, missing and filled teeth in permanent dentition (DMFT) and primary dentition (dmft) were recorded among 6–7 and 10–11-year-old schoolchildren at two time-points: in 2013 (before the initiation of the intervention) and in 2017 (four years after the start of the intervention).

Setting and Data Sources

In 2013, COAF examined 6–7 and 10–11-year-old schoolchildren residing in nine participating villages, as part of its community

needs assessment. The 2017 examination targeted 6–7 and 10–11-year-old schoolchildren residing in two of the randomly selected villages (Karakert and Lernagog) from the 2013 study. The latter was done due to time and resource limitations. Many of the homes in both villages do not have running water.

All examinations were by visual assessments only; only mouth mirrors were used with natural light. The children were in an upright position during the examinations. The tooth was considered decayed if there was an untreated or secondary caries at least into dentine. No primary incisor was recorded as missing to reduce error due to the physiological loss in the age group 6–7.

The 2013 examination was carried out by a medical doctor trained in oral health (LS). The 2017 examination was conducted by a general practice dentist (AS). To assure the reliability and validity of the data, the examiner who completed the 2013 screening participated in a calibration meeting with the examiner who conducted the 2017 round of the examinations before its initiation. The first examiner was also available for consultations to the second examiner throughout the second round of examinations.

According to statements from COAF, school officials, and parents, during 2013–2017 no other dental mass-preventive program or water fluoridation was available for the discussed population. Permission to conduct the study was obtained from the Research Ethics Committee at Yerevan State Medical University and the research has been conducted in full accordance with the World Medical Association Declaration of Helsinki. Each parent or guardian received a study information sheet and provided written consent for their child to participate. The consent procedure was approved by the Research Ethics Committee at Yerevan State Medical University and was carried out following the local law.

Study Size and Participants

The decay prevalence and levels were calculated for the primary teeth at the age group 6–7 and for the permanent teeth at the age group 10–11 among schoolchildren residing in the selected two villages at two-time points: pre-intervention ($n = 166$) and 4 years after the start of the intervention ($n = 148$). In both rounds of the examinations, over 95% of the targeted-aged schoolchildren of the selected two villages participated in the examinations. The selected age groups correspond to the lower and upper age bounds of the primary schoolchildren population in Armenia. Schoolchildren ages 8–9 were not included in this study due to the challenges introduced by their mixed dentition. We also present the 2013 caries prevalence data covering all nine villages that were included in the initial community needs assessment ($n = 422$).

To be included in the pre-intervention group, schoolchildren had to be 6–7 or 10–11 years old as well as be residing in the selected two villages and attending one of the three local schools. 2017 (intervention group) examination had the same eligibility criteria. In addition, it required that schoolchildren participate in the intervention for at least 1 year for the age group 6–7 and 3 years for the age group 10–11.

Variables

The key outcome variables within this study include caries prevalence and levels as well as DMFT/dmft indices. Caries levels were defined by the number of decayed teeth (components D and d in the respective indices). For the calculation of prevalence, at least one untreated decayed tooth was considered as a threshold.

The primary predictor variable in the multivariable regression model is participation in the intervention. Covariates include participant's age, sex, socio-economic vulnerability status, the village of residence, and the number of teeth with fillings. The socio-economic vulnerability status was assigned to either vulnerable or not-vulnerable categories, based on the records from COAF's database of vulnerable children. The latter is maintained by community social workers and is determined based on a 22-item checklist. The number of permanent teeth with fillings was included in the multivariable model as a proxy for access to dental services. The village of residence was included to account for village-level unobservable characteristics.

Statistical Analysis

The statistical significance of differences in decay prevalence was tested by using Pearson Chi-square and Fisher's Exact test (based on the count of decay-free cases) and 95% Confidence Intervals were calculated using the modified Wald method. Differences in mean decay levels, as well as DMFT and dmft scores, were tested using independent *t*-tests.

Poisson distributions are often used in modeling count data (15). A quasi-likelihood Poisson regression was performed to investigate the association of participation in the intervention, age, sex, socio-economic vulnerability status, the village of residence, the number of permanent teeth with fillings, and the levels of permanent caries among the 10–11-year-old children from the two villages. Significance level was determined using an alpha of 0.05. The analyses were performed with IBM SPSS Statistics for Windows, version 24.0., Armonk, NY: IBM Corp. and R (R statistics), version 3.5.1.

RESULTS

Sample Characteristics

The pre-intervention group in the selected two villages included 80 children in the 6–7-year-old age group (53% male, 47% female) and 86 in the 10–11-year-old age group (59% male, 41% female). Approximately 57% of the pre-intervention group was from Karakert and 43% from Lernagog village.

The intervention group in the selected two villages included 73 participants in the 6–7-year-old age group (57% male, 43% female) and 75 in the 10–11-year-old age group (51% male, 49% female). This group included 64% of its participants from Karakert and 36% from Lernagog village.

While the participation in the intervention was voluntary, our consultations with the program administrators, schoolteachers, and nurses as well as the self-reported data by schoolchildren

and their parents indicated almost no refusals to participate in the intervention.

Prevalence of Decay

The 2013 examination involving the selected two villages showed that 98.75% (95% CI, 92.59; 99.99) of the children aged 6–7 had decay in primary dentition and 82.56% (95% CI, 73.08; 89.25) of the children aged 10–11 in permanent dentition. The 2013 prevalence data pooled from all nine villages shows almost identical baseline numbers of decay prevalence (**Table 1**). The 2017 examination among the two villages revealed 91.27% (95% CI, 82.89, 96.49) prevalence in the age group 6–7 and 73.33% (95% CI, 62.31, 82.09) in the age group 10–11. There was a larger difference in the prevalence of caries in the age group 10–11 (9.23%) than in the 6–7 group (7.48%). This coincides with the exposure to the intervention. However, the difference in prevalence in the 2013 and 2017 examinations in the two villages was not statistically significant.

Levels of Decay

The mean number of decayed primary teeth among the intervention group aged 6–7 was significantly lower (−1.57, $p < 0.05$) compared to the same age pre-intervention group (**Table 2**). The mean number of decayed permanent teeth among the intervention group aged 10–11 was also significantly lower (–0.61, $p < 0.05$) compared to the same-aged pre-intervention group (**Table 3**).

Tables 2, **3** also present the mean values and differences in DMFT and dmft indices in the intervention vs. pre-intervention groups. The mean number of primary teeth with fillings among the intervention group aged 6–7 was slightly higher (0.23, $p < 0.05$) compared to the same-aged pre-intervention group. However, across the board, components D/d (decay) remained very high and constituted the largest portion of the DMFT and dmft indices. For example, in the pre-intervention group aged 6–7, the mean number of decayed primary teeth was 7.80 and in the ages 10–11, the mean number of decayed permanent teeth was 2.27. As opposed to that, the mean values of components F/f (fillings) were very low across the board (<0.50).

Results of the Multivariable Model

A slight overdispersion was detected in the data obtained from the 10–11-year-old pre-intervention and intervention groups (dispersion parameter = 1.22), indicating that there was somewhat greater variability in the data than would be expected based on the Poisson model. To control for this, a quasi-likelihood Poisson model was used.

According to the multivariable regression model results, the mean number of permanent teeth with caries in the 10–11-year-old intervention group was lower by a factor of 0.689 (lower by 31.1%), $p = 0.008$, 95% CI, [0.523; 0.902] compared to the 10–11-year-old pre-intervention group, after controlling for age, sex, child's socio-economic vulnerability status, the village of residence, and the number of permanent teeth with fillings (**Table 4**). The individual estimates of other covariates in the model should not be interpreted in the same way as the primary predictor (16).

DISCUSSION

This study indicates a high prevalence of dental caries among rural children, ages 6–7 and 10–11, in nine villages of Armenia. Results also showed that access to dental restorative services remains very low among the studied schoolchildren population in the two villages. These findings indicate the need for further dialogue on the implementation of oral health preventive measures in the remote rural communities.

TABLE 2 | Decay levels in primary teeth pre-intervention and four years after the start of the program among 6–7-year old schoolchildren in Karakert and Lernagog villages.

Assessment	Pre-intervention group Mean (*SD*)	Intervention group Mean (*SD*)	Mean difference pre-intervention group – intervention group, [95% CI]
d (decay in primary teeth)	7.80 (3.43)	6.23 (4.12)	−1.57* [−2.78; −0.35]
dmft	8.24 (3.50)	7.29 (4.30)	−0.95 [0.64;−2.21]
f (number of primary teeth with fillings)	0.08 (0.47)	0.30 (0.76)	0.23* [0.10; 0.02]

*$p < 0.05$; **$p < 0.005$.

TABLE 1 | Prevalence of caries pre-intervention and 4 years after the start of the program.

Group	Pre-intervention group prevalence of decay in % [95% CI] (*n*; mean age)		Intervention group prevalence of decay in % [95% CI] (*n*; mean age)
	All nine villages, 2013 data	Karakert and Lernagog villages only, 2013 data	Karakert and Lernagog villages only, 2017 data
6–7-year-old (primary teeth)	97.36% [94.22; 98.92] ($n = 227$; 6.67)	98.75% [92.59; 99.99] ($n = 80$; 6.59)	91.27% [82.89; 96.49] ($n = 73$; 6.95)
10–11-year-old (permanent teeth)	81.33% [74.30; 86.81] ($n = 195$; 10.12)	82.56% [73.08; 89.25] ($n = 86$; 10.07)	73.33% [62.31; 82.09] ($n = 75$; 10.40)

*$p<0.05$; **$p < 0.005$.

TABLE 3 | Decay levels in permanent teeth pre-intervention and four years after the start of the program among 10–11-year old schoolchildren in Karakert and Lernagog villages.

Assessment	Pre-intervention group Mean (*SD*)	Intervention group Mean (*SD*)	Mean difference pre-intervention group – intervention group, [95% CI]
D (decay in permanent teeth)	2.27 (1.59)	1.65 (1.48)	−0.61* [−1.09; −0.14]
DMFT	2.50 (1.73)	1.76 (1.53)	−0.74** [−1.25; −0.23]
F (number of permanent teeth with fillings)	0.09 (0.36)	0.08 (0.32)	−0.01 [−0.12; 0.09]

*$p < 0.05$; **$p < 0.005$.

TABLE 4 | Association of participation in the intervention, age, sex, socio-economic vulnerability status, village of residence, the number of permanent teeth with fillings, and the number of permanent teeth with caries, among the 10–11-year-old children from the two villages.

Parameter	Exponentiated poisson regression coefficient	95% CI (exponentiated)	*p*-value
Intervention group (reference category non-intervention group)	0.689	[0.523; 0.902]	0.008
Female (reference category male)¶	1.034	[0.806; 1.324]	0.790
Socio-economic status vulnerable (reference category non-vulnerable)¶	1.034	[0.637; 1.593]	0.886
Village Lernagog (reference category Karakert)¶	0.917	[0.703; 1.191]	0.519
Age (one-year increase)¶	1.132	[0.832; 1.512]	0.418
Number of permanent teeth with fillings (one-unit increase)¶	0.787	[0.498; 1.150]	0.261

Dependent variable: Number of permanent teeth with caries; ¶Covariates in the model, these estimates should not be interpreted in the same way as the primary predictor.

The study results indicate that those involved in the intervention had significantly less decay levels in their primary dentition after 1 year and in the permanent dentition after 3-year exposure, compared to same-age schoolchildren examined before the initiation of the program. The findings of this study can be placed into context with those conducted in other countries. For example, a similar intervention among 5–6-year-old schoolchildren in England, including once-a-day, at school, during term time, teacher-supervised toothbrushing with commercial toothpaste, showed that children in the intervention group had an overall 10.9% lower mean total caries increment (2.60 vs. 2.92, $p < 0.001$) compared to those in the non-intervention group (12). Another study including supervised toothbrushing with a fluoridated toothpaste in high-caries-risk children living in deprived areas of Tayside, Scotland, showed that children in the intervention group had a 32% lower D_1 level (all visible cavitated and non-cavitated lesions in enamel and dentine) 2-year mean caries increment on first permanent molars compared to the control group (13).

Toothbrushing with a fluoridated toothpaste is an effective means of reducing caries and periodontal disease and those who practice good oral hygiene at an early age are more likely to maintain it throughout their lives (17, 18). However, in many low-income families in the rural villages of Armenia twice-daily toothbrushing is not a usual practice (5).

Some study limitations should be highlighted. First, the intervention did not produce its results under ideal conditions, and the study was unable to account for all "real life" scenarios (e.g., possible changes in diet, etc.). Second, the study cross-sectional design and the absence of a concurrent control group introduces challenges regarding group comparability. Third, both rounds of the examinations were under natural lighting, limiting the ability to detect caries. Finally, data on the prevalence and levels of caries among rural schoolchildren in Armenia are limited, making it difficult to conduct comparisons.

School-based mass preventive programs using supervised toothbrushing with a fluoridated toothpaste could be an effective preventive measure in rural communities of Armenia. Leaders of the organization (COAF) have begun to add additional preventive methods to this program such as topical fluoride treatments. However, due to the timing of the introduction of these components, their impact did not apply to the studied sample.

The COAF has made the preventive dental program a part of its core operations and is utilizing various fundraising mechanisms to sustain it. The formed partnerships with local schools contribute to its low cost of operations.

Further studies could inform whether starting the intervention at earlier ages in kindergarten and adding other low-cost components, such as parental education on oral health, supervised flossing, topical fluoride, and fluoride varnish applications could result in more reduction of the prevalence and levels of caries among children in deprived rural communities of Armenia. It is anticipated that we will see greater reductions in dental caries in this population as children participate for a longer period. The value of this program will need to be evaluated as children are exposed and participate in all the years that they are in school.

DATA AVAILABILITY

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

Permission to conduct the study was obtained from the Research Ethics Committee at Yerevan State Medical University (Armenia) and the research has been conducted in full accordance with the World Medical Association Declaration of Helsinki.

AUTHOR CONTRIBUTIONS

HG, AS, LS, WA, and RB: concept and design. HG, AS, LS, and NG: acquisition, analysis, or interpretation of data. HG: drafting of the manuscript. All authors provided critical revisions of the manuscript for important intellectual content, reviewed the manuscript and approved the manuscript for submission, and attest they meet the ICMJE criteria for authorship.

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A School Intervention's Impact on Adolescents' Health-Related Knowledge and Behavior

Gabriella Nagy-Pénzes[1,2]*, *Ferenc Vincze*[1] and *Éva Bíró*[1]

[1] Department of Public Health and Epidemiology, Faculty of Medicine, University of Debrecen, Debrecen, Hungary, [2] Doctoral School of Health Sciences, University of Debrecen, Debrecen, Hungary

Background: Many factors can influence health behavior during adolescence, and the lifestyle of adolescents is associated with health behavior during adulthood. Therefore, their behavior can determine not only present, but also later health status.

Objective: We aimed to develop an intervention program to improve high school students' health behavior and to evaluate its effectiveness.

Methods: We performed our study at a secondary school in a rural town in East Hungary between 2016 and 2020. Sessions about healthy lifestyles were organized regularly for the intervention group to improve students' knowledge, to help them acquire the right skills and attitudes, and to shape their behavior accordingly. Data collection was carried out via self-administered, anonymous questionnaires (n = 192; boys = 49.5%; girls = 50.5%; age range: 14–16). To determine the intervention-specific effect, we took into account the differences between baseline and post-intervention status, and between the intervention and control groups using individual follow-up data. We used generalized estimating equations to assess the effectiveness of our health promotion program.

Results: Our health promotion program had a positive effect on the students' health-related knowledge and health behavior in the case of unhealthy eating, moderate to vigorous physical activity, and alcohol consumption.

Conclusion: Our findings suggest that school health promotion can be effective in knowledge transfer and lifestyle modification. To achieve a more positive impact on health behavior, preventive actions must use a complex approach during implementation.

Keywords: adolescent and youth, school health promotion programme, school health promotion and prevention, health education, intervention study, health-related knowledge, health behavior

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***Correspondence:**
Gabriella Nagy-Pénzes
penzes.gabriella@med.unideb.hu

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INTRODUCTION

Adolescents' health behavior changes with age; however, the vast majority of behaviors and habits acquired at this age persist into adulthood, so these behaviors determine not only present, but also later health status.

The health behavior of Hungarian school-age children is not very favorable in an international context. Hungarian children eat more unhealthily (less frequent breakfast, fruit and vegetables and more frequent sweets and sugared soft-drinks consumption) than their counterparts in other

countries, with a higher proportion of regular smokers, drinkers, and those who are sexually active. Hungarian adolescents consider their health to be more unfavorable, and it is more common for them to be overweight and obese (1, 2).

In addition to gender (e.g., girls exercise less, their mental health is less favorable) and age (e.g., older adolescents are more prone to risky behaviors) (1, 2), adolescents' health and health behavior may be affected by their socioeconomic status and social relationships. Teenagers with better family affluence—based on material assets in the household and traveling for a holiday—are more satisfied with their lives and less overweight (1). Healthy eating is more frequent (3), and extreme alcohol consumption is lower when parents are highly educated (4, 5). Students who experience greater social support are more likely to cope with their everyday problems, have better mental health, and are less affected by physical and mental symptoms (6–9).

Today, there is a strong emphasis on mass media, advertising and social media, which can influence an individual's behavior, attitude, and self-image (10–13). Internet orientation and mass media can be very useful for health (14–17), but they can also pose great dangers due to the lack of credibility and social media trends (18).

School also plays an important role in shaping lifestyle because children spend a significant part of their time in school, which is a crucial area for institutional socialization. Therefore, health promotion in school is of paramount importance in promoting adolescents' health behavior and health. School can also play a key role in helping the adolescents filter out misinformation by disseminating and using credible sources of information online and promoting critical thinking.

In 2000, the International Union for Health Promotion and Education (IUHPE) collected and evaluated evidence on the effectiveness of health promotion, including school health promotion, over the previous 20 years. The IUHPE found that interventions were most effective when, together with behavioral change, they: focused on academic and social outcomes; were comprehensive and holistic; linked school to health organizations and other sectors; were sufficiently deep; had been running several school years; and fundamentally influenced students' social and academic growth (19).

Several literature review studies have compared the methods of school interventions and their effectiveness. Evidence suggests that more intensive (20) interventions targeting multiple (risk) behaviors at the same time (21, 22) may be more successful. Relatively few studies have examined the long-term impact of school health promotion programs, but the ones that do exist found that the positive effects of interventions may disappear, so longer-term maintenance of programs or occasional "reminder" sessions may be warranted. Involving parents and the school's partners or local community enhances the effectiveness of interventions (20, 21), but more emphasis should be placed on involving these actors and examining their impact (22, 23). The abovementioned reviews concluded that more, better-designed, reliable intervention studies with long-term follow-up are needed, with the potential to determine effectiveness with greater certainty; hence, it is important to strive for program sustainability (21–24).

The world's largest health and disease prevention organizations—including the US Centre for Disease Prevention and Control, the World Health Organization, and the School for Health in Europe Network Foundation—strongly support the complex approach of school health promotion (25–27).

In Hungary, there are numerous laws (28–31); governmental (32, 33) and non-governmental (34–38) organizations alike have taken public health actions and launched programs to foster adolescents' health and health behavior in the past few years. However, whether these methodologically extremely heterogeneous initiatives have actually improved the health and health behavior of Hungarian adolescents is not clear due to a lack of documented evaluation of their effectiveness. Therefore, we wished to develop a replicable and sustainable health promotion program among high school students and to determine its effectiveness.

MATERIALS AND METHODS

Study Population

We carried out our study at a secondary school in a rural town in East Hungary between 2016 and 2019. We performed the recruitment, inclusion, and randomization of 9th-grade adolescents in two waves in autumn of 2016 and 2017 (in total 12 classes with 260 pupils). The school is a mixture of high, vocational high, and secondary school institution types. From all the attainable classes, we randomly allocated six classes by institution type to the control group, where participants received no intervention, and six classes to the intervention group. We invited all students of the classes to participate in the survey. We sent consent forms to the parents of all adolescents; only students who received parental consent and gave active consent themselves were eligible to be involved. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Hungary's Medical Research Council Scientific and Research Committee (49460–5/2016/EKU).

Theoretical Framework of the Study

To design effective interventions, a team of psychologists synthesized all the theories describing behavioral change and developed the COM-B model, which describes the conditions influencing behavior. In the COM-B model, capability (the physical and psychological ability to enact a behavior), opportunity (the physical and social environment that enables a behavior), and motivation (the reflective and automatic mechanism that activates/inhibits a behavior) all affect an individual's behavior, thereby also influencing the previously listed factors; capability and opportunity separately affect one's motivation (39). We used this model as the theoretical framework for our study: We assumed that by developing students' abilities, enhancing motivation, and changing environmental factors, we could facilitate a positive effect on the health behavior of adolescents and thus on their health status (**Table 1**).

The basis of our intervention was the development of capability (i.e., provide the necessary knowledge and improving skills) and the enhancement of motivation (through increasing knowledge and understanding, persuasion to elicit appropriate

TABLE 1 | Methods designed to promote positive student health behavior and to evaluate their effectiveness in light of the COM-B model.

Capability	
Methods for shaping abilities and skills	**Evaluation of effectiveness**
Physical capacity: The students' physical capacity was taken as given	–
Psychological capacity: Knowledge and skills development • Basic biological, anatomical, and physiological knowledge • Describing the advantages, disadvantages, and consequences of health behaviors to make responsible decisions • Authentic sources of information and the use of smartphone applications • Discussing experiences	Knowledge test on intervention topics
Motivation	
Methods used to foster motivation	**Evaluation of effectiveness**
Creating intention (reflective processes), attitude-forming: • Main message: Health is a value that needs to be protected and developed. • Group tasks • Arguments for healthy or risky behaviors and against; budgeting. • Situational practice, playful tasks, tasks using phone applications and websites • Presence of a public health professional or teacher • Encouragement **Habits (automatic processes):** • Strengthening and striving to learn good habits • Striving to stop unfavorable habits	Questionnaire on health behavior and attitudes
Opportunities	
The environment that supports the intervention as a resource	**Evaluation of the environment**
Social environment: • School management, classroom teachers, physical education and science teachers • Class community • Parents (who agreed to have their child participate in the study) • The work of the health promotion office	• Family support • Friends' support • Friends' health behavior • Classmates' support • Teacher's support • Attitudes toward school
Physical environment: School and home • Difficult to shape: infrastructural constraints; the control group is also in the school. • Classroom decorations for lessons	–
Behavior	
The intervention aims to positively influence the following behaviors	**Evaluating the intervention's effectiveness**
• Nutrition • Physical activity • Screen time • Smoking • Alcohol consumption • Substance abuse • Sexual behavior	Health behavior survey with questionnaire
Health status	
Physical: • Chronic illness • Body mass index (BMI) • Body fat percentage **Mental:** • Self-rated health • Life satisfaction • Self-esteem • Depression	**Aim of the intervention** Positively influence nutritional status and mental health **Evaluating the effectiveness:** Hungarian National Student Fitness Test (NETFIT®) data, questionnaire

Text in gray: We have planned these parts of the intervention study, but we do not discuss them in the manuscript; or we were not able to implement them.

feelings about the behavior and stimulate action) (39). Our intervention did not cover students' physical ability; it was taken as given. We have not measured students' motivation directly but decided to assess their attitudes because a positive attitude could increase motivation, and we thought that this interpretation is closer to the COM-B framework (39) (i.e., the possible ways of motivation enhancement during an intervention). Regarding the students' social environment, the cohesion among classmates was improved through games and group tasks. The management of the school and the teaching staff were supportive and inquiring, but were not involved directly in the intervention. The involvement of the parents was planned, but could not happen due to low parental activity. On the other hand, we were able to contact the staff of the local health promotion office as part of the health sector and to carry out some of our work with them. The shaping of the physical environment was limited by infrastructural constraints and the fact that the members of the control group were also students of the given educational institution, which is why we were able to change the classrooms only for the duration of the sessions with the help of posters and pictures on the blackboard. We also monitored changes in students' physical and mental health. Sessions related to mental health would have received more emphasis in the 2019–2020 school year; however, most of these classes were canceled due to the COVID-19 pandemic (**Table 1**).

The Intervention

First, we carried out a baseline survey to assess the students' health-related knowledge, attitudes toward a healthy lifestyle, health behavior, and health status. We planned the health promotion sessions based on the main results of the baseline survey, so the main problems determined the topics.

We organized regular healthy lifestyle sessions for the intervention group. These were embedded into the curriculum (built into lessons of different subjects) and usually required 2–3 lessons per academic year for each topic. Our goal was to expand students' knowledge, to help them acquire the right skills and attitudes, and to shape their behavior accordingly through classes led by a public health professional and a public health student.

We built the sessions around the following topics (in line with the knowledge test and the health behavior questionnaire): health as a value, nutrition, physical activity, sexuality, addiction, alcohol consumption, smoking, substance abuse, cancer in light of lifestyle factors, and mental health. We wanted to include the students in our research until they finished their studies, but some of the intervention sessions and the planned end-of-study surveys were canceled due to the COVID-19 pandemic.

To help the students gain diverse knowledge, skills, attitudes, and behaviors, we employed various interactive methods and tools such as mind maps; individual, pair and group work; presentations; posters; professional websites; and telephone applications.

Data Collection to Measure and Evaluate the Intervention's Effectiveness

In both the intervention and control groups, all students were assessed *via* an anonymous, self-administered questionnaire at baseline and immediately at the endpoint (post-intervention) of the intervention (2 and 3 school year follow-up) in a cross-sectional manner. All students had a unique code for anonymous individual follow-up and they also had to answer questions like the password reminders for the case if they would forget their code.

With the baseline survey, we wished to determine the participants' baseline characteristics, as well as the possible differences between the intervention and control groups. With the post-intervention survey, we assessed changes in student health-related knowledge (as a proxy of their capability), attitudes toward a healthy lifestyle (related to their motivation), health behavior, and health status that were attributable to the intervention. We also administered the post-intervention survey to the control group to describe the changes among the subjects that were independent of the intervention. All of the questionnaires used at each time point were identical and completed in a classroom setting, supervised by a research team member.

The first part of the questionnaire focused on demographic and socioeconomic data and questions were taken from the Hungarian version of the Health Behavior in School-Aged Children (HBSC) survey (40). We used the following demographic and socioeconomic data: gender, the parents' education level (maximum primary school, vocational certificate, secondary/high school, university, or college), and the participant's family affluence. We measured family affluence with the Family Affluence Scale (FAS III), which can be used to assess material assets in a family. A previous article describes the FAS III scale in detail (41).

Measurement of Health-Related Knowledge

The research team developed most of the health-related knowledge tests to gauge students' knowledge. The health-related knowledge test covered topics from the intervention sessions and from the health behavior questionnaire: nutrition, physical activity, risky behavior (alcohol consumption, smoking, and addiction), and sexuality. We calculated the students' average score for each topic. Overall, a higher score implied better knowledge. During the analysis, we examined the change in test scores overall and by topic. The highest score on the nutrition knowledge test was 31 (Cronbach's alpha = 0.59); in the physical activity section it was 34 (Cronbach's alpha = 0.79); in the risky behavior section it was 27 (Cronbach's alpha = 0.71); and in the sexuality section it was 52 (Cronbach's alpha = 0.78). For the total health-related knowledge test, the maximum score was 145 (Cronbach's alpha = 0.90).

Measurement of Health Behavior

To compile the health behavior questionnaire, we used questions from three previous nationwide studies in Hungary after preliminary consultation with the research leaders. Thus, we developed our questionnaire based on the self-administered, anonymous questionnaire employed in the Hungarian Health Behavior in School-Aged Children 2014 (HBSC 2014) survey (40), the School Health Communication Survey (42), and the

Hungarian European School Survey Project on Alcohol and Other Drugs 2015 (ESPAD 2015) (43).

We measured the frequency of breakfast consumption; students were asked how often they had breakfast on weekdays. For analysis, we dichotomized the variable: breakfast on 5 weekdays or less (40). We determined healthy and unhealthy eating through scales. We assessed how often students consumed vegetables, fruits, sweets, sugary soft drinks, energy drinks, salty snacks, and fast food (40, 44). We formed two scales from the variables: "healthy eating scale" and "unhealthy eating scale." To compile the scales, we first converted the answers into numerical values, as follows: never = 0, less than once a week = 0.25, once a week = 1, 2–4 days a week = 3, 5–6 days a week = 5.5, and at least once a day = 7. Subsequently, we summed the scores for fruit and vegetable consumption to obtain a "healthy eating" scale ranging from 0 to 14. For the "unhealthy eating scale," we added scores for sweets, sugary soft drinks, energy drinks, salty crisps, and fast food consumption. The scale ranged from 0 to 35. A higher score on the scales indicates more frequent consumption of healthy or unhealthy foods (45, 46).

We established the students' moderate-to-vigorous physical activity (MVPA) and vigorous physical activity (VPA) using the HBSC 2014 methodology (40, 47). For analysis, we dichotomized the MVPA variable based on the literature; the cutoff point was exercise performed for 5 days or longer (48). For the data analyses, we dichotomized the answer to the VPA question; the cutoff point was being active at least 2 times per week (40, 47).

We defined screen time as including watching TV, videos, or DVDs; playing games on a computer or game console; and using a computer for email, the internet, or homework (40, 47). For analysis, we dichotomized the variable; the cutoff point was 4 h or more on weekdays (49).

In connection with smoking habits, we examined the frequency of regular and electronic cigarette use (40, 43). For the analysis of our intervention's effectiveness, we dichotomized the variables of smoking, in which we considered non-smokers to be "never" smokers (40, 50).

We measured the monthly prevalence of alcohol consumption, drunkenness, and binge drinking before completing the questionnaire. A student engaged in binge drinking if he/she consumed 5 or more units of alcohol at one time (a unit of alcohol = 250 ml of beer, 100 ml of wine, 60 ml of vermouth/liqueur, or 30 ml of a short drink) (40, 43).

We also looked at the lifetime prevalence of sexual intercourse and the usage of condoms, contraceptive pills, and other contraceptive methods during the participant's last experience of intercourse (40).

We also examined the students' self-rated health (40) using a dichotomous variable of the self-rated health indicator to analyze our intervention's effectiveness; one category was rated by those who thought their health was excellent or good, while the other category was rated by those who viewed their health as fair, bad, or very bad.

We used 5-item questions to gauge students' attitudes toward a healthy lifestyle. Students were asked to answer:

"How important is it to you…"

- "what is healthy and what is not?"
- "to avoid unhealthy items like foods that are too fat or high in sugar?"
- "to drink sugar-free soft drinks rather than sugary drinks?"
- "to use a computer, play electronic games, watch TV?"
- "to move, play sports, exercise?"

They had to mark their answers to the questions on a 5-point scale: 1: "not important at all," 2: "not important," 3: "maybe important," 4: "important," and 5: "very important" (42). From the answers to the five questions, we created a new scale. To create the scale, first we reversed the value of the answers to the question "How important is it to you to use a computer, play electronic games, or watch TV?". So the answer "not important at all" was worth 5 points, and the answer "very important" was worth 1 point. With this modification, we added the value of the answers to the questions to form a healthy lifestyle attitudes scale of 5–25 points (Cronbach's alpha = 0.72). A higher value on the scale indicated a more favorable attitude toward a healthy lifestyle.

Measurement of Nutritional Status

Based on the Hungarian National Student Fitness Test (NETFIT®) (51), we collected data on students' body fat percentage, height, and weight to calculate their BMI (52).

Data Processing and Statistical Analyses

At baseline, we included 145 adolescents in the intervention group and 115 respondents in the control group. We excluded 68 students from the analysis because (1) these students had to repeat a year due to their unsatisfactory academic performance and that's why they interchanged between the intervention and control groups or have duplicated baseline data ($n = 17$), (2) they did not participate in the baseline or post-intervention surveys due to their persistent absence from school at the time of completing the questionnaire ($n = 51$). The restriction of this sample resulted in a database of 192 people with baseline and post-intervention data.

We used descriptive univariate analyses to describe the baseline characteristics of the adolescents. After taking random missing patterns into consideration, we imputed all variables that contained missing values with multiple imputation through fully conditional specification, which is an iterative Markov chain Monte Carlo (MCMC) method.

We quantified the intervention's effect on the imputed database using generalized estimating equations (GEE), which comprise a generalized linear modeling technique for modeling longitudinal correlated or clustered data. We assessed issues related to breakfast, exercise frequency, screen time, cigarette use, e-cigarette use, last month's alcohol consumption, drunkenness, binge drinking, sexual intercourse, contraception use during one's last experience of intercourse, and self-rated health via logistic models. We expressed the results using odds ratios (ORs) and their associated 95% confidence intervals (CIs). We normalized knowledge test scores, healthy and unhealthy eating and attitude scores, and BMI and body fat percentage scores through Cox-Box transformation, then tested them in linear models as continuous variables. We described the

relationships between dependent and independent variables using regression coefficients (β) and their associated 95% CIs. We employed the IBM SPSS 25.0 software package for the analyses.

To determine the intervention-specific effect, we took into account the differences between baseline and post-intervention status of the participants and differences between the intervention and control groups, where the question was whether the change in the outcome from pre-intervention to post-intervention differed between the members of two groups (intervention and control). We measured this directly *via* the interaction of the intervention and the time period they spent in the study in the GEE models.

We corrected all analyses for the respondents' gender and family affluence, their parents' education level, and the time period they spent in the study (2 or 3 years). To assess the intervention's effectiveness in all models, we also examined the differences between the baseline and post-intervention survey results and between the intervention and control groups using the individual follow-up data. The results of these analyses were summarized in tables, where the "specific effect of the intervention" means the main result after adjusting for the above mentioned factors. The conclusions about the effect of the intervention were drawn based on these values.

RESULTS

We scrutinized data from 192 students after we cleaned the data: 43.8% at the 3-year follow-up and 56.2% at the 2-year follow-up. More than half of the students belonged to the intervention group; 49.5% were boys, 44.3% were high school students, 24.5% were vocational high school students, and 34.2% were vocational school students (**Table 2**).

Most fathers had a lower level of education than mothers: a higher proportion of fathers had a vocational certificate or lower, while more mothers had a baccalaureate or diploma. Nearly half of the students had a low FAS, one-third had medium FAS, and only one-fifth had high family affluence.

TABLE 2 | Percentage of students who participated in both the baseline and end-of-study surveys according to their main characteristics ($n = 192$).

		n	%
Time spent in the study	3-year study period (involved in 2016)	84	43.8
	2-year study period (involved in 2017)	108	56.2
Study groups	Control group	84	43.8
	Intervention group	108	56.2
Students' gender	Boy	95	49.5
	Girl	97	50.5
Type of educational institution	High school	85	44.3
	Vocational high school	47	24.5
	Secondary school	60	31.2

We found a positive relationship between the intervention's specific effect and the risky behavior, sexuality, and total knowledge test scores (**Table 3**).

A further outcome of our intervention was that among the students in the intervention group, the consumption of unhealthy foods was significantly lower (**Table 4**), and the frequency of exercise significantly increased (**Table 5**). There was a significant decline in the number of students in the intervention group who spent <3 h playing on computers or consoles (**Table 5**). There was a significantly greater chance of alcohol abstinence by the end of the study. In addition, the chances of not smoking also increased, but this was not significant (**Table 6**).

Our intervention did not affect students' healthy lifestyle attitudes (**Table 3**), sexual behavior (**Table 7**), self-rated health, or nutritional status (**Table 8**).

DISCUSSION

Our high school intervention program, which focuses on the development of knowledge and skills and covers several segments of a healthy lifestyle, was embedded into the curriculum in the framework of the school system and school health promotion. As a result of the intervention study, it became possible to improve the students' knowledge about health, as well as some areas of their health behavior.

Students' overall knowledge in the intervention group showed a significant increase compared to the control group, except for the tests regarding diet and physical activity. Both the intervention and the control group included students—among others—from the food industry (bakers, confectioners, and chefs), trade, hospitality, and sports areas for which training contains more information about nutrition and physical activity. This might be the reason that the additional knowledge that could be gained from the intervention couldn't be detected regarding these topics. Appropriate knowledge is a necessary condition for behavior change but alone is not enough (e.g., the phenomenon of cognitive dissonance).

Our intervention was not able to change the students' attitudes toward a healthy lifestyle in a positive direction. According to the Theory of Planned Behavior attitude is one of the determinants of the person's intention, which represents his/her motivation. Within this theory, intention to engage in a certain behavior together with perceived behavior control will determine the person's behavior (53).

Our intervention had a positive impact on unhealthy diet; however, we did not achieve a positive shift in terms of breakfast regularity and healthy eating (fruit and vegetable consumption) compared to the control group. One reason may be that adolescents have much more control over the consumption of unhealthier foods than the consumption of breakfast or fruits and vegetables. The latter is perhaps more influenced by family eating habits and affluence (1, 54, 55). The students' frequency of MVPA increased compared to that of the control group. In the intervention group, the duration of playing games on a computer or game console rose significantly. The Hungarian HBSC 2018

TABLE 3 | Determinants of students' scores on the knowledge test and evaluation of the intervention's specific effect based on multivariate analysis.

		Total knowledge test score β [95% CI]	Nutrition knowledge test score β [95% CI]	Physical activity knowledge test score β [95% CI]	Risky behavior knowledge test score β [95% CI]	Sexuality knowledge test score β [95% CI]	Healthy lifestyle attitude scale β [95% CI]
Students' gender (ref.: boy)	Girl	**9.80 [5.50; 14.10]**	**1.98 [0.83; 3.13]**	1.07 [−0.17; 2.32]	**2.00 [1.04; 2.96]**	**4.03 [2.28; 5.77]**	−0.47 [−1.23; 0.29]
Father's education level (ref.: primary or less)	University or college degree	11.64 [−1.87; 25.15]	**4.09 [0.76; 7.43]**	1.64 [−2.16; 5.44]	1.84 [−0.58; 4.26]	3.59 [−2.72; 9.90]	−0.19 [−1.87; 1.49]
	Secondary school/high school	**10.04 [2.14; 17.94]**	**2.42 [0.14; 4.70]**	1.89 [−0.31; 4.09]	**2.83 [1.07; 4.58]**	**3.58 [0.47; 6.69]**	0.33 [−0.78; 1.44]
	Vocational school	**7.17 [1.04; 13.31]**	1.30 [−0.29; 2.88]	**1.78 [0.20; 3.36]**	**2.29 [0.88; 3.71]**	2.0 [−0.71; 4.72]	0.33 [−0.56; 1.23]
Mother's education level (ref.: primary or less)	University or college degree	7.76 [−1.76; 17.27]	−0.52 [−2.97; 1.92]	2.53 [−0.11; 5.17]	**2.60 [0.77; 4.42]**	2.07 [−1.94; 6.08]	0.75 [−0.53; 2.01]
	Secondary school/high school	1.65 [−5.48; 8.77]	−0.34 [−2.08; 1.40]	1.14 [−0.80; 3.09]	0.49 [−1.10; 2.07]	0.80 [−1.85; 3.45]	**1.27 [0.27; 2.26]**
	Vocational school	3.27 [−2.73; 9.28]	0.19 [−1.37; 1.75]	0.74 [−0.93; 2.41]	0.64 [−0.66; 1.95]	1.35 [−1.04; 3.74]	0.64 [−0.28; 1.55]
Family affluence (ref.: low)	High	−1.40 [−5.88; 3.09]	−0.61 [−1.78; 0.55]	−0.40 [−1.77; 0.97]	−0.41 [−1.67; 0.85]	−0.68 [−2.67; 1.30]	0.617 [−0.41; 1.64]
	Medium	−0.93 [−4.52; 2.66]	0.16 [−0.75; 1.07]	−0.32 [−1.34; 0.70]	−0.26 [−1.19; 0.67]	−0.54 [−2.17; 1.08]	0.45 [−0.32; 1.22]
Time spent in the study (ref.: 2 years)	3 years	−2.04 [−6.45; 2.37]	−0.59 [−1.72; 0.54]	−0.80 [−2.01; 0.41]	−0.82 [−1.81; 0.17]	0.117 [−1.74; 1.97]	−0.25 [−0.96; 0.47]
End-of-study survey (ref.: baseline survey)		0.17 [−2,82; 3,16]	**0.96 [0.15; 1.78]**	−1.15 [−2.37; 0.07]	**0.95 [0.14; 1.76]**	−0.328 [−1.79; 1.13]	−0.32 [−1.00; 0.36]
Intervention group (ref.: control group)		−1.48 [−5,26; 2,31]	−0.42 [−1.64; 0.80]	−0.16 [−1.48; 1.16]	−0.54 [−1.54; 0.47]	−0.19 [−1.823; 1.44]	0.19 [−0.67; 1.05]
The intervention's specific effect (interaction of the intervention and the time period they spent in the intervention)		**7.84 [3, 53; 12, 15]**	0.41 [−0.73; 1.55]	0.69 [−0.83; 2.19]	**1.74 [0.57; 2.91]**	**4.07 [2.02; 6.13]**	−0.74 [−1.70; 0.22]

β, *regression coefficient calculated from a generalized estimation equation; 95% CI, 95% confidence interval; in bold, significant associations.*

TABLE 4 | Determinants of students' eating habits and evaluation of the intervention's specific effect based on multivariate analysis.

		Scale of healthy eating β [95% CI]	Scale of unhealthy eating β [95% CI]	Breakfast on weekdays (5 times) OR [95% CI]
Students' gender (ref.: boy)	Girl	0.57 [−0.41; 1.55]	−0.12 [−2.16; 1.91]	0.71 [0.41; 1.24]
Father's education level (ref.: primary or less)	University or college degree	−1.50 [−4.38; 1.37]	1.09 [−4.20; 6.39]	0.32 [0.07; 1.42]
	Secondary school/high school	−0.04 [−1.67; 1.59]	−0.61 [−4.59; 3.37]	0.44 [0.17; 1.13]
	Vocational school	0.13 [−1.29; 1.55]	−0.21 [−3.57; 3.15]	**0.41 [0.19; 0.88]**
Mother's education level (ref.: primary or less)	University or college degree	0.09 [−2.00; 2.18]	**−6.75 [−11.35; −2.15]**	2.45 [0.78; 7.69]
	Secondary school/high school	0.35 [−1.13; 1.82]	**−6.20 [−9.07; −3.33]**	1.46 [0.66; 3.25]
	Vocational school	−0.41 [−1.74; 0.92]	**−6.28 [−9.15; −3.42]**	1.10 [0.51; 2.33]
Family affluence (ref.: low)	High	0.44 [−0.81; 1.70]	−1.37 [−3.75; 1.01]	0.72 [0.38; 1.34]
	Medium	0.31 [−0.53; 1.15]	−1.32 [−2.87; 0.23]	1.04 [0.65; 1.69]
Time spent in the study (ref.: 2 years)	3 years	0.50 [−0.40; 1.39]	−0.67 [−2.80; 1.47]	0.61 [0.36; 1.04]
End-of-study survey (ref.: baseline survey)		−0.55 [−1.46; 0.37]	1.50 [−0.27; 3.27]	0.78 [0.44; 1.39]
Intervention group (ref.: control group)		−0.03 [−1.05; 1.00]	1.29 [−0.98; 3.55]	1.26 [0.68; 2.34]
The intervention's specific effect (interaction of the intervention and the time period they spent in the intervention)		0.02 [−1.20; 1.24]	**−2.78 [−5.02; −0.54]**	0.79 [0.38; 1.61]

β, *regression coefficient calculated from a generalized estimation equation; 95% CI, 95% confidence interval; in bold, significant associations.*

survey examined the relationship between physical activity and screen time, and found that not only those who do not move in their free time spend more time playing computer games, but also those who exercise daily; the relationship between screen time and exercise turned out to be U-shaped (50). In this way, our findings are in line with the Hungarian national experience.

Regarding cigarette use, there was a more favorable trend in the intervention group than in the control group, but this trend was not statistically significant. This outcome is encouraging, as it is conceivable that there would have been a significant difference between the two groups if the intervention were to have been continued. Our intervention also had a positive effect on the frequency of alcohol consumption, and last month's abstinence was significantly more likely in the intervention group.

Our intervention failed to influence sexual behavior (sexual activity and contraception use), self-rated health, and nutritional status. The latter may be due to positive shift in health status where nutrition might be expected in the longer term following a change in health behavior. Improving these indicators could be facilitated by health promotion programs that focus more on students' physical activity (56) and eating habits (e.g., by transforming the school environment to encourage exercise and healthy eating, or by promoting healthier eating opportunities through peer helpers) (57).

Strengths and Limitations

Planning

One of the limitations of our intervention is that the intervention and control group studied in the same school, so we cannot rule out that the knowledge and skills acquired during the intervention may have also appeared among the members of the control group. But taking into account that it can lead to the underestimation of the impact of our intervention, this could not jeopardize our conclusions. Due to the design of the study, we could not change the wider school environment (e.g., using posters, courtyards, stair decorations), which could have had a further positive effect on students' health behavior. However, from a research point of view, the difference between the intervention and control groups was probably smaller in light of other background factors that could potentially influence the effect of the intervention (e.g., exercise opportunities in the broader environment, food supply) than in the case of another control group.

One of the study's strengths is that we took into account the aspects of IUHPE (19), namely, that our program has been operating at regular intervals for several years and addressing several segments of a healthy lifestyle.

Implementation

The goal of the program was hampered by the COVID-19 pandemic, which resulted in restrictions for the spring of 2020, when some sessions and the closing data collection had to be canceled. This may have had a negative effect on the results obtained, and we can assume that based on the data for the entire time period, changes in other areas could be made as well.

From the angle of IUHPE (19), we were able to involve the health sector in our program and to coordinate some parts of our work with the activities of the local health promotion office.

TABLE 5 | Determinants of students' physical activity and screen time, and evaluation of the intervention's specific effect based on multivariate analysis.

		Report at least 60 min of MVPA (5 or more days a week) OR [95% CI]	Report VPA at least twice a week OR [95% CI]	Watch television, videos, or DVDs for 3 or more hours on weekdays OR [95% CI]	Playing games on a computer or game console for 3 or more hours on weekdays OR [95% CI]	Using a computer for email, the internet, or homework for 3 or more hours on weekdays OR [95% CI]
Students' gender (ref.: boy)	Girl	**0.28 [0.16; 0.48]**	**0.25 [0.15; 0.43]**	0.95 [0.50; 1.80]	**2.33 [1.14; 4.77]**	1.00 [0.59; 1.69]
Father's education level (ref.: primary or less)	University or college degree	1.20 [0.31; 4.60]	3.43 [0.63; 18.61]	2.03 [0.39; 10.45]	6.01 [0.68; 52.96]	1.05 [0.20; 5.43]
	Secondary school/high school	1.25 [0.48; 3.26]	1.45 [0.55; 3.81]	1.42 [0.53; 3.79]	1.06 [0.33; 3.45]	0.45 [0.17; 1.22]
	Vocational school	1.42 [0.66; 3.04]	1.77 [0.82; 3.82]	0.99 [0.48; 2.06]	1.08 [0.39; 3.02]	0.58 [0.24; 1.42]
Mother's education level (ref.: primary or less)	University or college degree	2.73 [0.91; 8.25]	1.09 [0.33; 3.60]	1.91 [0.52; 7.09]	1.90 [0.59; 6.10]	**6.00 [2.02; 17.83]**
	Secondary school/high school	1.19 [0.53; 2.69]	0.89 [0.40; 1.95]	1.30 [0.65; 2.59]	1.84 [0.74; 4.59]	**3.00 [1.39; 6.48]**
	Vocational school	0.86 [0.37; 1.98]	0.85 [0.42; 1.75]	**2.46 [1.10; 5.48]**	**6.34 [2.01; 19.93]**	**3.07 [1.33; 7.09]**
Family affluence (ref.: low)	High	1.15 [0.59; 2.26]	1.91 [0.97; 3.77]	0.82 [0.38; 1.75]	1.09 [0.52; 2.31]	0.66 [0.34; 1.28]
	Medium	1.26 [0.74; 2.16]	**1.77 [1.08; 2.92]**	0.89 [0.49; 1.64]	1.55 [0.74; 3.22]	0.83 [0.47; 1.47]
Time spent in the study (ref.: 2 years)	3 years	0.95 [0.55; 1.66]	0.77 [0.44; 1.33]	0.91 [0.50; 1.66]	0.98 [0.50; 1.90]	1.05 [0.62; 1.77]
End-of-study survey (ref.: baseline survey)		**0.30 [0.16; 0.55]**	0.66 [0.41; 1.06]	1.26 [0.64; 2.47]	**2.51 [1.14; 5.54]**	0.95 [0.51; 1.79]
Intervention group (ref.: control group)		1.01 [0.54; 1.89]	1.07 [0.55; 2.08]	1.39 [0.65; 2.98]	2.41 [1.00; 5.82]	0.80 [0.40; 1.59]
The intervention's specific effect (interaction of the intervention and the time period they spent in the intervention)		**2.19 [1.01; 4.76]**	1.06 [0.52; 2.15]	0.59 [0.23; 1.47]	**0.27 [0.09; 0.79]**	0.93 [0.41; 2.14]

OR, odds ratio calculated from a generalized estimation equation; 95% CI, 95% confidence interval; MVPA, moderate-to-vigorous physical activity; VPA, vigorous physical activity; in bold, significant associations.

TABLE 6 | Determinants of students' smoking and alcohol consumption habits, and evaluation of the intervention's specific effect based on multivariate analysis.

		Do not use cigarettes OR [95% CI]	Do not use e-cigarettes OR [95% CI]	Have not drunk alcohol in the last 30 days OR [95% CI]	Have not been drunk in the last 30 days OR [95% CI]	Have not been a binge drinker in the last 30 days OR [95% CI]
Students' gender (ref.: boy)	Girl	1.64 [0.92; 2.93]	**2.49 [1.34; 4.62]**	1.57 [0.94; 2.62]	**2.08 [1.21; 3.60]**	**2.15 [1.28; 3.61]**
Father's education level (ref.: primary or less)	University or college degree	1.25 [0.24; 6.63]	0.25 [0.05; 1.45]	0.57 [0.14; 2.35]	0.88 [0.20; 3.91]	2.44 [0.68; 8.73]
	Secondary school/high school	0.87 [0.34; 2.29]	**0.31 [0.11; 0.89]**	0.86 [0.35; 2.13]	0.47 [0.20; 1.10]	1.11 [0.44; 2.79]
	Vocational school	0.90 [0.42; 1.96]	0.57 [0.24; 1.36]	0.71 [0.34; 1.50]	0.66 [0.32; 1.34]	1.33 [0.63; 2.77]
Mother's education level (ref.: primary or less)	University or college degree	1.80 [0.56; 5.83]	2.56 [0.60; 10.97]	1.78 [0.60; 5.27]	2.53 [0.84; 7.67]	1.73 [0.61; 4.92]
	Secondary school/high school	1.58 [0.74; 3.38]	1.76 [0.77; 4.02]	1.57 [0.74; 3.33]	2.08 [0.99; 4.34]	1.14 [0.55; 2.36]
	Vocational school	1.48 [0.73; 3.00]	1.41 [0.63; 3.13]	0.89 [0.43; 1.84]	1.47 [0.75; 2.88]	0.92 [0.46; 1.83]
Family affluence (ref.: low)	High	1.34 [0.76; 2.37]	1.63 [0.73; 3.64]	0.68 [0.36; 1.29]	0.62 [0.33; 1.20]	0.74 [0.42; 1.33]
	Medium	1.16 [0.71; 1.9]	1.16 [0.63; 2.13]	1.27 [0.78; 2.09]	0.82 [0.48; 1.40]	1.29 [0.76; 2.17]
Time spent in the study (ref.: 2 years)	3 years	0.80 [0.45; 1.41]	0.72 [0.39; 1.32]	**0.59 [0.36; 0.99]**	0.62 [0.36; 1.06]	0.62 [0.37; 1.06]
End-of-study survey (ref.: baseline survey)		**0.20 [0.12; 0.34]**	**0.23 [0.11; 0.48]**	**0.25 [0.14; 0.44]**	**0.44 [0.24; 0.81]**	**0.42 [0.24; 0.71]**
Intervention group (ref.: control group)		0.86 [0.42; 1.78]	1.26 [0.45; 3.49]	0.72 [0.40; 1.30]	1.52 [0.70; 3.30]	1.59 [0.80; 3.15]
The intervention's specific effect (interaction of the intervention and the time period they spent in the intervention)		1.77 [0.92; 3.39]	1.08 [0.37; 3.14]	**2.12 [1.01; 4.43]**	0.56 [0.25; 1.28]	0.59 [0.28; 1.22]

OR, odds ratio calculated from a generalized estimation equation; 95% CI, 95% confidence interval; in bold, significant associations.

TABLE 7 | Determinants of students' sexual behavior, and evaluation of the intervention's specific effect based on multivariate analysis.

		Have not had sexual intercourse OR [95% CI]	Used a condom, contraceptive pill, or other contraceptive method during the last experience of intercourse OR [95% CI]
Students' gender (ref.: boy)	Girl	1.66 [0.95; 2.91]	1.20 [0.49; 2.94]
Father's education level (ref.: primary or less)	University or college degree	0.51 [0.12; 2.21]	2.78 [0.29; 26.41]
	Secondary school/high school	0.84 [0.33; 2.13]	1.50 [0.36; 6.32]
	Vocational school	0.85 [0.40; 1.78]	1.97 [0.56; 6.89]
Mother's education level (ref.: primary or less)	University or college degree	2.28 [0.73; 7.18]	0.89 [0.12; 6.47]
	Secondary school/high school	1.67 [0.75; 3.69]	1.49 [0.35; 6.36]
	Vocational school	2.02 [0.95; 4.30]	0.61 [0.17; 2.14]
Family affluence (ref.: low)	High	0.70 [0.35; 1.40]	1.71 [0.54; 5.48]
	Medium	0.95 [0.56; 1.60]	1.20 [0.44; 3.31]
Time spent in the study (ref.: 2 years)	3 years	**0.33 [0.19; 0.59]**	1.54 [0.58; 4.06]
End-of-study survey (ref.: baseline survey)		**0.20 [0.11; 0.34]**	0.23 [0.02; 2.62]
Intervention group (ref.: control group)		1.49 [0.69; 3.24]	0.10 [0.01; 1.21]
The intervention's specific effect (interaction of the intervention and the time period they spent in the intervention)		0.582 [0.261; 1.30]	6.97 [0.43; 111.94]

OR, odds ratio calculated from a generalized estimation equation; 95% CI, 95% confidence interval; in bold, significant associations.

TABLE 8 | Determinants of students' self-rated health and nutritional status, and evaluation of the intervention's specific effect based on multivariate analysis.

		Self-rated health is good or excellent OR [95% CI]	BMI β [95% CI]	Body fat percentage β [95% CI]
Students' gender (ref.: boy)	Girl	**0.40 [0.24; 0.67]**	−0.67 [−1.97; 0.63]	**10.07 [7.92; 12.23]**
Father's education level (ref.: primary or less)	University or college degree	1.06 [0.34; 3.26]	−1.49 [−4.59; 1.60]	−4.19 [−11.00; 2.63]
	Secondary school/high school	1.16 [0.48; 2.82]	**−2.32 [−4.52; −0.13]**	**−4.65 [−8.13; −1.17]**
	Vocational school	0.86 [0.41; 1.80]	−1.25 [−2.97; 0.47]	−2.75 [−5.61; 0.11]
Mother's education level (ref.: primary or less)	University or college degree	1.04 [0.39; 2.76]	1.93 [−0.17; 4.04]	1.05 [−4.46; 6.55]
	Secondary school/high school	0.93 [0.46; 1.87]	1.37 [−0.20; 2.95]	2.42 [−0.62; 5.47]
	Vocational school	0.64 [0.32; 1.25]	1.56 [−0.08; 3.19]	1.98 [−0.62; 4.58]
Family affluenc e (ref.: low)	High	1.00 [0.56; 1.79]	**1.18 [0.14; 2.21]**	2.15 [−0.70; 5.00]
	Medium	0.91 [0.55; 1.52]	0.22 [−0.49; 0.92]	−0.80 [−2.42; 0.82]
Time spent in the study (ref.: 2 years)	3 years	0.80 [0.49; 1.31]	0.29 [−1.00; 1.57]	−0.42 [−2.58; 1.74]
End-of-study survey (ref.: baseline survey)		1.28 [0.74; 2.22]	**0.79 [0.06; 1.52]**	**2.09 [0.68; 3.49]**
Intervention group (ref.: control group)		1.56 [0.84; 2.91]	0.07 [−1.31; 1.45]	1.30 [−1.04; 3.65]
The intervention's specific effect (interaction of the intervention and the time period they spent in the intervention)		0.74 [0.37; 1.50]	−0.21 [−1.22; 0.80]	−0.88 [−3.03; 1.28]

β, *regression coefficient calculated from the generalized estimation equation; OR, odds ratio; calculated from the generalization estimation equation; 95% CI, 95% confidence interval; in bold, significant associations.*

A further strength of the program was that, as part of the intervention, a public health professional participated in the daily life of the school and regularly consulted with the school management and teachers regarding the planned intervention sessions and measurements. Thanks to this individual's presence, the teachers became more open to the program, and some teachers volunteered for a certain activity. Professional participation in school life also helped to facilitate the students' acceptance of the program and to build a solid relationship with them, which was essential for effective collaboration.

Another strength of the program is that, with cost-effectiveness in mind, we tried to develop it taking into account the school's capabilities, so we mostly used existing and easily accessible tools (e.g., blackboard, computer, projector, websites, and telephone applications) during the intervention. The intervention sessions were carried out taking into consideration the specifics of each class (e.g., prior knowledge, ability), which promoted equal opportunities to acquire knowledge, favorable attitudes, and health behavior. Further, students were able to access useful websites and telephone applications that provided reliable information learned and practiced during the sessions, regardless of space, people, or time outside of school, thus providing safe guidance for developing appropriate health behaviors. Given the elements of the program that have taken place, we can assume that, with the coordination of a public health professional or trained teachers, our program can be used in other schools based on the capabilities of each school and its students. However, when planning and implementing a school health education program, it is necessary to consider the prior knowledge, abilities, and skills of the target group together with their needs and shape the planned course accordingly. But it is also important to take into consideration the possibilities and the characteristics of the setting.

Evaluation

On the negative side, the necessary data cleaning process due to the nature of the individual follow-up reduced the size of the already relatively small sample, which limited the study's statistical power.

There was no systematic evaluation undertaken with the students to find out how they felt about the program, partly because of the length of the questionnaire. Still, they had the opportunity to share their thoughts during the sessions.

We were unable to control all potential influencing factors, especially the impact of advertising or social media on the adolescents' health behavior was not investigated during the study.

The data analysis and evaluation of the intervention were made by an independent statistician, who was not involved in the planning or delivery of the intervention.

Within the limits of our study, in some cases, we could not identify differences due to the absence of adequate statistical power. We could not perform stratified data analysis due to the nature of the sample and the relatively low sample size. The shortcomings resulting from the low statistical power are nuanced by the fact that we corrected the statistical metrics obtained during the analysis for sociodemographic factors; therefore, the indicators show the connection between the dependent and independent variables without the effect of sociodemographic confounders.

The system used for anonymous individual tracking of students in the study (individual code provided by the student and answers to questions similar to password reminders) not only worked well for follow-up but also facilitated the anonymous use of NETFIT data and the other datasheets (i.e., health behavior questionnaire, knowledge test).

Conclusions

Schools are cost-effective settings for health education programs and are critical areas for developing health-related knowledge of children and adolescents. Based on our experiences, the COM-B model can be used as a theoretical framework for designing complex school health promotion programs. These programs can be most successful if they not only cultivate the target group's knowledge regarding a healthy lifestyle but also its skills, thus motivating the group members (39), and—in line with the IUHPE findings—operate in a supportive social and physical environment over time (19). Therefore, in 2016, we tried to take all these factors into account when planning our school education program. For several years, our intervention study sought to shape students' knowledge, skills, attitudes, health behavior, and health in a positive direction using a variety of interactive methods and digital tools, and to monitor the effectiveness of our health promotion program at regular intervals.

Our intervention also achieved positive results in terms of knowledge transfer and, in some topics, changes in health behavior. These results are in line with the conclusion of the IUHPE (19) as school-based interventions can transmit knowledge, develop skills and support healthy choices. But we have to keep in mind that the health behavior and health status of the students are influenced by other, outside of the school factors, too.

Prior research has not identified a clear connection between nutritional knowledge and healthy eating or exercise-related knowledge and physical activity (58–60). Relatedly, in childhood and adolescence, the parent is mostly responsible for providing the food consumed and ways of spending one's free time (e.g., sports funding), so adolescents can control these behaviors the least, as opposed to smoking or alcohol consumption.

Previous studies (1, 3, 4, 6, 7, 61–63) have also shown that adolescents' demographic and socioeconomic background (gender, parents' education levels, family affluence), their social environment and the media can affect their health-related knowledge, attitudes, health behavior, and health status. Hence, we cannot ignore these factors when designing health promotion programs for school-age children. Greater involvement of parents and teachers in the health promotion program, and the creation of a supportive school environment, can greatly contribute to its success. In the spirit of a comprehensive school, health promotion programs should include all segments of a healthy lifestyle, affect all students and faculty members in the school, involve other organizations in addition to parents, and keep sustainability in mind. The Balassagyarmat Health Education Program and the Buda Region Health Program (2018–2030) are good examples from Hungary, but these programs were

started after our intervention, and their effectiveness has not yet been evaluated. The Balassagyarmat Health Education Program is a complex school-based health education program with peer helpers that places special emphasis on students' own knowledge, creating an environment that promotes positive health behavior and deepens motivation (34). The Buda Region Health Program (2018–2030) aims to support and strengthen health promotion and prevention activities at the local level with the involvement of local and regional authorities, health care providers, non-governmental organizations, academia, and government. The program's main objective is to promote children's health in a complex way by creating an environment that is conducive to healthy choices, the development of health services, the improvement of children's health behaviors and education, the involvement of schools and families, and the transfer of experience (35). Due to the limiting factors described earlier, as well as the goal of making the program sustainable without external funding, it was not possible in the present research to implement such a complex intervention.

In support of complex programs, there is also a need for well-designed health promotion programs to be given more space in schools' pedagogical programs, taking into account the infrastructure, community, the school's unique features, and possibilities provided by the settlement where the school is located.

Teachers can play a key role in knowledge transfer about healthy lifestyles and in shaping students' attitudes and lifestyles in a positive direction (64). In addition to imparting knowledge about healthy lifestyles, such skills may include integrating the topic of health into individual subjects, knowing and presenting about credible sources of information, planning, and organizing topic weeks and programs for healthy lifestyles, or involving peer helpers. It is also vital to shape educators' attitudes in a positive direction, as they also have a great responsibility, since the development of students' health includes having the teacher himself/herself be credible in his/her role as a health promoter.

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 Hungary's Medical Research Council Scientific and Research Committee. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

GN-P and ÉB: conceptualization and funding acquisition. GN-P, FV, and ÉB: methodology. FV: formal analysis. GN-P: investigation and project administration. GN-P and FV: writing—original draft preparation and visualization. ÉB: writing—review and editing and supervision. All authors have read and agreed to the published version of the manuscript.

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EDITED BY
Maha El Tantawi,
Alexandria University, Egypt

REVIEWED BY
Long Zhou,
Sichuan Academy of Medical Sciences and Sichuan Provincial People's Hospital, China
Xiao-Ping Wang,
Shanghai Jiao Tong University School of Medicine, China

*CORRESPONDENCE
Hongying Shi
shying918@163.com
Xiaoli Ye
yezipiaow@163.com

†These authors have contributed equally to this work and share last authorship

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Independent and joint effects of sleep duration and sleep quality on suboptimal self-rated health in medical students: A cross-sectional study

Pan Ding[1], Jinyong Li[2], Huajian Chen[1], Chongzhou Zhong[1], Xiaoli Ye[3*†] and Hongying Shi[1*†]

[1]Department of Preventive Medicine, School of Public Health and Management, Wenzhou Medical University, Wenzhou, China, [2]Renji College, Wenzhou Medical University, Wenzhou, China, [3]Propaganda Department, Wenzhou Medical University, Wenzhou, China

Objective: Studies on the association between sleep behavior and health often ignored the confounding effects of biorhythm-related factors. This study aims to explore the independent and joint effects of sleep duration and sleep quality on suboptimal self-rated health (SRH) in medical students.

Methods: Cross-sectional study. Proportional stratified cluster sampling was used to randomly recruit students from various medical specialties at a medical university in eastern China. Our questionnaire mainly included information on basic demographic characteristics, SRH, sleep behavior, and biorhythm-related factors. The independent and joint effects of sleep duration and sleep quality on suboptimal SRH were assessed by logistic regression after controlling for potential confounders.

Results: Of 1,524 medical students (mean age = 19.9 years, SD = 1.2 years; 59.1% female), 652 (42.8%) had suboptimal SRH. Most medical students (51.5%) slept for 7 h/night, followed by ≥8 (29.1%) and ≤6 h (19.4%). After adjusting for basic demographic characteristics and biorhythm-related factors, compared with students who slept for ≥8 h/night, the adjusted *ORs* (95%*CI*) for those who slept 7 and ≤6 h/night were 1.36 (1.03, 1.81) and 2.28 (1.60, 3.26), respectively ($P < 0.001$ for trend); compared with those who had good sleep quality, the adjusted *ORs* (95%CI) for those who had fair and poor sleep quality were 4.12 (3.11, 5.45) and 11.60 (6.57, 20.46), respectively ($P < 0.001$ for trend). Further, compared with those who slept for ≥8 h/night and good sleep quality, those who slept ≤6 h and poor sleep quality had the highest odds of suboptimal SRH (*OR* 24.25, 95%*CI* 8.73, 67.34).

Conclusions: Short sleep and poor sleep quality were independently and jointly associated with higher odds of suboptimal SRH among medical students.

KEYWORDS

sleep duration, sleep quality, joint effects, suboptimal self-rated health, medical students

Introduction

Self-rated health (SRH) comprehensively assesses mental and physical health, which is an easily securable and widely used global health indicator (1). It has been shown to be an important predictor for future morbidity and even mortality (2). Previous studies have shown the suboptimal SRH rates was 33.2–38.6% in the general population (1, 3, 4), 35.6–54.6% in college students (5, 6). And the SRH status of medical students was rarely reported. The health status of medical students was often less optimistic than that of the general population due to their heavy academic burden and employment pressure (7, 8). Therefore, it is crucial to explore the factors influencing SRH of medical students. Although the evidences for the association of SRH with lifestyle (e.g., physical activity, diet, sleep behavior) have been validated in the general population (9, 10), the evidence in the medical student was insufficient and required further study.

Sleep behavior is involved in the regulation of individual metabolism and energy balance, and is an important part of the biological rhythm mechanism. Previous studies have shown a strong association between sleep duration and SRH (11). However, most current studies were performed in the middle-aged and elderly population. Sleep behavior changes with age, and the health effects of the recommended sleep duration may be different for different age groups (12). There were few and inconsistent reports on how sleep duration affects health outcomes in young individuals who do not yet have chronic diseases. Some studies suggested a *U*-shaped association between sleep duration and suboptimal SRH (13), and others suggested that only short sleep is associated with suboptimal SRH (14). To the best of our knowledge, previous studies have not controlled for confounding effect of circadian rhythm-related factors such as chronotype, daytime napping, snacking after dinner. Previous studies have shown that poor sleep quality was another risk factor for SRH, and there was a linear association (15). But this also did not take into account the confounding factors of biological rhythms, so the results need further verification. In addition, the joint effects of sleep duration and sleep quality in young individuals have rarely been reported, especially in medical students.

In this study, from the perspective of circadian rhythm, we aimed to compare the differences in behavioral habits and SRH of medical students with different sleep duration; and explored the independent and joint effects of sleep duration and sleep quality on suboptimal SRH after controlling for confounding factors including circadian rhythm-related factors, to provide a scientific basis for the prevention of suboptimal SRH in medical students from sleep behavior perspectives.

Methods

Study design and participants

This cross-sectional study was performed in a medical university in eastern China, from April to September 2021. The questionnaire was designed by experts in the fields of epidemiology, medical statistics, and sociology according to other large-scale cohort studies (6, 16–19), including basic demographics, sleeping behaviors, other lifestyle factors, biorhythm variables, and health status. We used proportional stratified cluster random sampling method to recruit undergraduates of various majors. Firstly, we stratified students according to majors (clinical medicine, nursing and others), and then randomly selected several classes by grade in each major. The number of classes was determined according to the proportion of the number of students in the major to that of the whole university. All students in the selected classes were invited to participate in the survey. This study is part of a cross-sectional study, so the sample size is calculated by the following formula:

$$N = \frac{u_{\alpha/2}^2 \times P_0(1-P_0)}{\delta^2} \times deff \times stratification$$

According to previous relevant studies (5, 6), the proportion of suboptimal SRH (P_0) was 35.6–54.6%. Suppose $\delta = 10\% \times P_0$, $\alpha = 0.05$, $u_{\alpha/2} = 1.96$, design efficiency $deff = 1.5$, stratification $= 3$, non-response rate $= 10\%$, the total sample size should be 1,067–2,317. We actually recruited 1,635 medical students (1,524 valid response), which was within the target sample size.

Inclusion criteria: 18 years of age and above, medical-related majors, and able to cooperate with the investigator (submission of questionnaires was regarded as informed consent). Exclusion criteria: those who could not participate in the survey due to various reasons, those with missing self-rated health or missing sleep duration. We excluded those who had missing information on sleep behaviors ($n = 26$), and those who had missing SRH information ($n = 85$), leaving 1,524 participants (mean age $=$ 19.9 years, SD $= 1.2$ years; 59.1% female) in our main analysis.

In order to evaluate the test-retest reliability of measurement methods for sleep duration, sleep quality and self-rated health in the questionnaire, we randomly selected 163 medical students (95 were female) from the source population, and conducted a repeated survey in June 2022. To verify the calibration validity of sleep quality, we used the Pittsburgh Sleep Quality Index (PSQI) as the reference method. And to assess the validity of SRH, we collected 103 medical students in the source population and used the Self-Rated Health Measurement Scale (SRHMS) as the reference method, which includes 48 items and has a Cronbach's α coefficient of 0.93 (20). We also selected 60

medical students from the source population and asked them to record sleep diary for five consecutive days (including both weekdays and weekends, a total of 267 valid diaries were collected in 5 days) to evaluate the validity of sleep duration. The sample size needed for our validation study was shown in the Supplementary Figure 1.

This study was approved by the Ethics Committee of Wenzhou Medical University (ethics approval number: 2021-022). The online submission of the questionnaire by all participants was deemed informed consent. The entire investigation process was conducted in accordance with the principles of the Declaration of Helsinki.

Assessment of sleep behaviors

The sleep duration was measured by the item: "How many hours do you usually sleep per night?", and the options were divided into 7 groups: ≤5, 6, 7, 8, 9, 10, and ≥11 h (n = 28, 268, 784, 403, 34, 4, and 3). According to previous study (21), they were combined into 3 groups: ≤6 h of sleep duration (short sleep), 7 h of sleep duration, ≥8 h of sleep duration (long sleep). In secondary analyses, we divided sleep duration into 4 groups (≤6, 7, 8, ≥9 h). In our validation study, among 163 students, the mean ± SD of sleep duration at the first survey was 7.20 ± 0.87 h, and the mean sleep duration of the second survey was 7.49 ± 0.92 h, and there was no statistical difference between these two surveys (P > 0.05). The test-retest correlation of sleep duration between the first and the second surveys was 0.84. The mean ± SD of sleep duration in the sleep diary was 7.49 ± 0.86 h, and the correlation coefficient (r) between diary-reported and questionnaire-reported sleep duration was 0.78. We also evaluated the agreement between these two methods using Bland-Altman plot (Figure 1). This indicates that our questionnaire-reported sleep duration has good reliability and validity. Furthermore, the correlation between weekends and weekdays sleep duration in the questionnaire was 0.83, which was consistent with previous study (22), indicating that despite the observation of compensatory sleep on weekends, this sleep duration variability was negligible in this study. Previous studies also have found a good correlation between self-rated sleep duration and objective methods [e.g., wrist actigraphy, sleep diary; (23)], and can truly reflect the population's sleep duration.

The sleep quality was evaluated by the item: "How do you think your sleep quality is?", and the options were divided into 5 groups: very good, good, fair, poor, and very poor (n = 289, 602, 520, 90, and 23). Further, they were combined into 3 groups (good, fair, and poor) in analysis. In order to verify the validity of the item for evaluating sleep quality, we used the Pittsburgh Sleep Quality Index Questionnaire (PSQI) as the reference method, and found that the correlation (r_s) between the sleep quality obtained by the items in the questionnaire and the sleep quality obtained by the PSQI scale was 0.65. And 87.0% of the participants had consistent response on sleep quality in the first and second surveys, and the test-retest correlation of sleep quality between these two surveys was 0.47, indicating moderate reproducibility of questionnaire-reported sleep quality (24). Studies had shown that the single self-rated sleep quality item in the PSQI can distinguish between good and poor sleep quality (25).

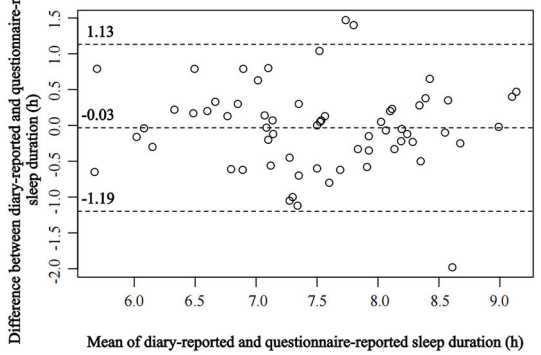

FIGURE 1
Bland-Altman plot of diary-reported and questionnaire-reported sleep durations.

Assessment of self-rated health

SRH is a subjective measure of health status that integrates a person's biological, psychological, social, and functional aspects; and has been widely used in epidemiological studies (1, 5, 26). In this study, SRH was assessed by five-point Likert scale of self-rated health corresponding: "How do you feel about your health in general?" (27, 28), and the options were divided into 5 groups (1 = very good, 2 = good, 3 = fair, 4 = poor, 5 = very poor) (6). Referring to the standards of other international cohort study (29), those with a score of 3–5 were defined as suboptimal SRH, and those with a score of 1 or 2 were defined as good SRH. Psychometric performance of this assessment has been demonstrated in previous studies (30, 31). Although self-rated health was assessed with only a single item, the expertise and competence of medical students facilitated the acquisition of relatively reliable information for this study. We found that the test-retest correlation of SRH between the first and the second survey was 0.50, and 70.4% of the respondents had consistent responses in the two measurements, and the weighted kappa coefficient was 0.41, indicating moderate reproducibility of self-rated health. We also used the Self-Rated Health Measurement Scale (SRHMS) to assess the health status, and the Spearman correlation coefficient (r_s) between SRH and SRHMS was 0.74.

TABLE 1 Basic characteristics and biorhythmic factors of medical students by sleep duration ($n = 1524$).

Characteristics	Sleep duration, h/night			χ^2/H	*P*-value
	≤6 ($n = 296$)	7 ($n = 784$)	≥8 ($n = 444$)		
Female, *n* (%)	186 (62.8)	464 (59.2)	250 (56.3)	3.14	0.208
Junior year and above, *n* (%)	172 (58.1)	343 (43.8)	159 (35.8)	35.9	**<0.001**
One-child family, *n* (%)	151 (51.0)	359 (45.8)	199 (44.8)	3.09	0.214
Clinical medicine major, *n* (%)	142 (48.0)	400 (51.0)	221 (49.8)	0.82	0.664
Parental education level, *n* (%)				2.26	0.323
Elementary school or below	35 (11.8)	65 (8.3)	28 (6.3)		
Junior middle school	105 (35.5)	299 (38.1)	159 (35.8)		
Senior high school	92 (31.1)	221 (28.2)	160 (36.0)		
University or above	64 (21.6)	199 (25.4)	97 (21.9)		
Residential district, *n* (%)				2.50	0.645
City	123 (41.6)	290 (37.1)	169 (38.1)		
Town	55 (18.6)	171 (21.9)	98 (22.0)		
Village	118 (39.8)	320 (41.0)	177 (39.9)		
Underweight/normal, *n* (%)	241 (85.2)	660 (88.1)	376 (88.5)	2.04	0.361
Chronotype, *n* (%)				9.90	**0.007**
Morning type	68 (23.0)	208 (26.5)	144 (32.4)		
Neutral type	87 (29.4)	226 (28.8)	129 (29.1)		
Evening type	141 (47.6)	350 (44.7)	171 (38.5)		
Bedtime ≥ 11:00 PM, *n* (%)	261 (88.2)	623 (79.5)	277 (62.4)	74.68	**<0.001**
Waketime ≥ 7:00 AM, *n* (%)	169 (57.3)	576 (73.5)	361 (81.3)	52.01	**<0.001**
Sleep quality, *n* (%)				82.03	**<0.001**
Good	120 (40.5)	451 (57.5)	320 (72.1)		
Fair	129 (43.6)	284 (36.2)	107 (24.1)		
Poor	47 (15.9)	49 (6.3)	17 (3.8)		
Sleep latency, min, *n* (%)				27.01	**<0.001**
≤15	125 (46.5)	391 (53.9)	259 (64.9)		
16–29	46 (17.1)	133 (18.3)	51 (12.8)		
≥30	98 (36.4)	202 (27.8)	89 (22.3)		
Daytime napping, min, *n* (%)				7.46	0.114
0	73 (25.2)	178 (23.5)	106 (24.5)		
1–30	116 (40.0)	325 (42.8)	153 (35.3)		
>30	101 (34.8)	256 (33.7)	174 (40.2)		
Screen time, h, Median (P_{25}, P_{75})	4.00 (2.50, 6.00)	4.00 (3.00, 6.00)	4.00 (2.50, 5.00)	4.49	0.201
Sedentary behavior ≥9 h, *n* (%)	114 (39.5)	281 (63.4)	133 (30.2)	7.51	**0.023**
Physical activity <2 h, *n* (%)	196 (68.8)	569 (75.5)	307 (71.7)	5.26	0.072
Breakfast time <8:00 AM, *n* (%)	226 (76.4)	550 (70.2)	248(55.9)	45.09	**<0.001**
Lunch time ≥12:00 AM, *n* (%)	67 (22.6)	151 (19.3)	105 (23.7)	3.73	0.155
Dinner time ≥6:00 PM, *n* (%)	78 (26.4)	151 (19.3)	69 (15.5)	13.46	**0.001**
Snacking after dinner, *n* (%)	57 (19.3)	124 (15.8)	71 (16.0)	1.98	0.372
Maximum meal = dinner, *n* (%)	77 (26.0)	174 (22.2)	78 (17.6)	7.83	**0.020**

The Chi-square test was used for unordered categorical data and the Kruskal-Wallis test was used for ordinal data, and bold values indicated statistical significance $P < 0.05$.

Moreover, we assessed the medical history during the past year by the question "Have you been to the hospital in the past year" in the original survey; and found that the proportion of suboptimal SRH with medical history in the past year was higher than that of medical students without medical history (50.2 vs. 36.1%). All these findings indicated that the method for evaluating SRH in this study had acceptable reliability and validity.

TABLE 2 Association of sleep duration and sleep quality with suboptimal SRH among medical students.

Sleep behaviors	Suboptimal SRH, *n* (%)	[a]*OR* (95%*CI*)		
		Crude model	Adjusted model I	Adjusted model II
Sleep duration, h				
≥8	141 (31.8)	1.00	1.00	1.00
7	339 (43.2)	1.65 (1.29, 2.10)	1.60 (1.25, 2.05)	1.37 (1.03, 1.81)
≤6	172 (58.1)	2.99 (2.20, 4.06)	2.70 (1.97, 3.69)	2.24 (1.57, 3.19)
P for trend		<0.001	<0.001	<0.001
Sleep quality				
Good	247 (27.7)	1.00	1.00	1.00
Fair	314 (60.4)	3.97 (3.16, 5.00)	4.04 (3.19, 5.11)	4.14 (3.13, 5.47)
Poor	91 (80.5)	10.79 (6.62, 17.57)	11.70 (7.10, 19.27)	11.50 (6.52, 20.29)
P for trend		<0.001	<0.001	<0.001

OR, odds ratio; *CI*, confidence interval.

[a]Model I was adjusted for sex, grade (sophomore and below, Junior year and above), major (clinical medicine, others), parental education level (elementary school or below, junior middle school, senior high school, university or above), residential district (city, town, village). Model II was additionally adjusted for chronotype (morning type, neutral type, evening type), daytime napping (0, 1–30, >30 min), sleep latency (≤15, 16–29, ≥30 min), dinner time (<6:00, ≥6:00 PM), snacking after dinner (yes, no), body type (underweight/normal, overweight/obese), sedentary behavior (<9 h, ≥9 h), and physical activity (<2 h, ≥2 h), maximum meal (dinner, other).

Assessment of covariates

The demographic characteristics included sex, grade [sophomore and below, Junior year and above; (32)], parental education (elementary school or below, junior middle school, senior high school, university or above), major (clinical medicine, others), residential district (city, town, village), one-child family (yes, no). Lifestyle and biorhythm variables included physical activity (continuous), sedentary behavior (continuous), smoking (yes, no), drinking (yes, no), sleep latency (≤15, 16–29, ≥30 min), daytime napping (0, 1–30, >30 min), chronotype (morning type, neutral type, evening type), snacking after dinner (yes, no), meal time (ordinal), and maximum meal (breakfast, lunch or dinner).

Social-economic status was evaluated by parental education. The parental education refers to the educational level of the father or mother with higher educational level, and divided into 4 groups (elementary school or below, junior middle school, senior high school, university or above). Physical activity and sedentary behavior were obtained from part of the International Physical Activity Questionnaire-Short Form (IPAQ-SF) scale (33). Studies have shown that more than 2 h of physical activity and <9 h of sedentary behavior will reduce the incidence of disease (34). So physical activity was divided into 2 groups (<2, ≥2 h) in studies. Similarly, sedentary behavior was divided into 2 groups (<9, ≥9 h). Sleep latency was divided into three groups according to PSQI classification criteria (≤15, 16–29, ≥30 min) (35). Daytime napping was divided into three groups (0, 1–30, >30 min) (36). Chronotype was an indicator for assessing an individual's circadian rhythm status (37). The question "People can be divided into early risers and late sleepers, which type do you think you belong to?" was asked, and the options were divided into 3 groups (morning type, neutral type, and evening type) (38, 39). Studies have shown that the self-rated chronotype had a good correlation with the total score of the Morning and Evening Questionnaire-5 (MEQ-5) ($r = 0.72$) (40), which can better reflect the individual's circadian rhythm state. The time of three meals was divided into breakfast (<8:00, ≥8:00 AM), lunch (<12:00, ≥12:00), and

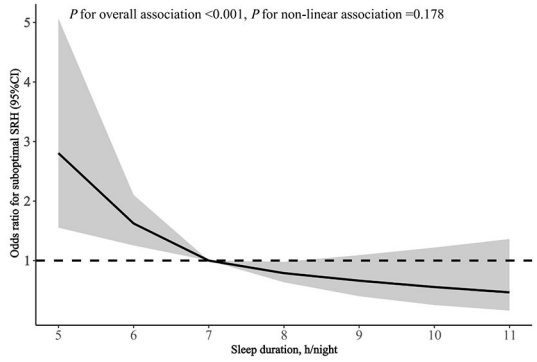

FIGURE 2
Spline curve for the association of sleep duration with suboptimal SRH among medical students. Adjusted for sex, grade (sophomore and below, Junior year and above), major (clinical medicine, others), parental education level (elementary school or below, junior middle school, senior high school, university or above), residential district (city, town, village), body type (underweight/normal, overweight/obese), sedentary behavior (<9, ≥9 h), physical activity (<2, ≥2 h), snacking after dinner (yes, no), chronotype (morning type, neutral type, evening type), daytime napping (0, 1–30, >30 min), sleep latency (≤15, 16–29, ≥30 min), dinner time (<6:00, ≥6:00 PM) and maximum meal (dinner, other).

TABLE 3 Association of suboptimal SRH with sleep duration and sleep quality, stratification analyses.

Subgroup	*n*	[a]*OR* (95%*CI*)							
		Sleep duration				Sleep quality			
		≤6 h	7 h	≥8 h	*P* for interaction	Poor	Fair	Good	*P* for interaction
Sex					0.749				0.141
Female	900	2.57 (1.60, 4.12)	1.40 (0.96, 2.03)	1.00		18.08 (7.15, 45.73)	3.61 (2.52, 5.18)	1.00	
Male	624	1.78 (1.00, 3.15)	1.33 (0.85, 2.07)	1.00		9.18 (4.18, 20.15)	5.07 (3.20, 8.03)	1.00	
Major					0.876				0.425
clinical medicine	763	1.98 (1.18, 3.32)	1.19 (0.79, 1.79)	1.00		8.15 (3.54, 18.74)	4.59 (3.06, 6.89)	1.00	
others	761	2.45 (1.48, 4.04)	1.48 (0.99, 2.20)	1.00		14.09 (6.34, 31.29)	3.89 (2.61, 5.79)	1.00	
Grade					0.487				0.337
Freshman/sophomore	850	2.90 (1.74, 4.81)	1.59 (1.09, 2.32)	1.00		15.59 (7.03, 34.59)	4.85 (3.32, 7.08)	1.00	
Junior year and above	674	1.68 (1.00, 2.85)	1.08 (0.69, 1.68)	1.00		8.35 (3.65, 19.12)	3.78 (2.45, 5.85)	1.00	
Daytime napping, min					0.927				0.882
0	357	2.12 (1.01, 4.44)	1.67 (0.90, 3.09)	1.00		11.01 (3.53, 34.33)	3.85 (2.12, 7.01)	1.00	
1–30	594	2.72 (1.50, 4.93)	1.53 (0.96, 2.43)	1.00		14.74 (5.41, 40.15)	3.95 (2.52, 6.21)	1.00	
>30	531	2.04 (1.12, 3.73)	1.17 (0.73, 1.87)	1.00		10.30 (4.01, 26.46)	5.23 (3.20, 8.55)	1.00	
Sleep latency, min					0.175				0.063
≤15	775	2.18 (1.34, 3.55)	1.27 (0.87, 1.83)	1.00		14.29 (4.92, 41.50)	5.66 (3.76, 8.51)	1.00	
16–29	230	0.75 (0.28, 2.00)	0.71 (0.33, 1.53)	1.00		22.37 (2.48, 201.46)	1.75 (0.93, 3.30)	1.00	
≥30	389	3.65 (1.81, 7.35)	2.12 (1.18, 3.81)	1.00		9.82 (4.47, 21.57)	4.71 (2.73, 8.15)	1.00	
Sedentary behavior, h					0.148				0.450
<9	974	1.63 (1.04, 2.56)	1.26 (0.90, 1.77)	1.00		14.28 (7.00, 29.13)	4.66 (3.28, 6.62)	1.00	
≥9	528	3.85 (2.04, 7.27)	1.71 (1.01, 2.91)	1.00		8.77 (3.28, 23.45)	3.67 (2.24, 6.02)	1.00	
Physical activity, h					0.333				0.052
<2	1072	2.36 (1.55, 3.59)	1.26 (0.91, 1.74)	1.00		7.90 (4.26, 14.68)	3.60 (2.62, 4.95)	1.00	
≥2	395	1.70 (0.83, 3.46)	1.73 (0.96, 3.13)	1.00		83.07 (15.16, 455.25)	7.45 (3.96, 14.02)	1.00	
Chronotype					0.611				0.067
Morning type	420	3.03 (1.41, 6.53)	1.73 (0.94, 3.18)	1.00		80.49 (8.94, 724.52)	6.61 (3.48, 12.53)	1.00	
Neutral type	442	2.11 (1.09, 4.07)	1.22 (0.72, 2.06)	1.00		11.95 (4.64, 30.76)	5.49 (3.18, 9.46)	1.00	
Evening type	662	2.07 (1.21, 3.54)	1.36 (0.89, 2.08)	1.00		7.23 (3.30, 15.86)	2.93 (1.96, 4.39)	1.00	
Maximum meal					0.256				0.520
Dinner	329	3.34 (1.50, 7.42)	2.08 (1.06, 4.09)	1.00		7.07 (2.15, 23.21)	3.54 (1.91, 6.55)	1.00	
Other	1195	2.02 (1.34, 3.03)	1.18 (0.86, 1.61)	1.00		13.38 (6.93, 25.84)	4.62 (3.34, 6.37)	1.00	

OR, odds ratio; *CI*, confidence interval.

[a]Adjusted for sex, grade (sophomore and below, Junior year and above), major (clinical medicine, others), parental education (elementary school or below, junior middle school, senior high school, university or above), residential district (city, town, village), snacking after dinner (yes, no), body type (underweight/normal, overweight/obese), sedentary behavior (<9, ≥9 h), physical activity (<2, ≥2 h), chronotype (morning types, neutral types, evening types), daytime napping (0, 1–30, >30 min), sleep latency (≤15, 16–29, ≥30 min), dinner time (<6:00, ≥6:00 PM), and maximum meal (dinner, other), except for the stratification factor itself.

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TABLE 4 Sensitivity analyses of the association of suboptimal SRH with sleep duration and sleep quality.

Limiting population to:	*n*	[a]*OR* (95%*CI*)					
		Sleep duration			Sleep quality		
		≤6 h	7 h	≥8 h	Poor	Fair	Good
Non-smokers	1497	2.26 (1.58, 3.24)	1.33 (1.00, 1.77)	1.00	12.09 (6.78, 21.58)	4.21 (3.18, 5.58)	1.00
Non-drinkers	1474	2.33 (1.62, 3.36)	1.45 (1.09, 1.93)	1.00	12.52 (6.91, 22.69)	4.24 (3.19, 5.63)	1.00
No snack after dinner	1272	2.30 (1.55, 3.40)	1.32 (0.97, 1.79)	1.00	11.01 (5.99, 20.23)	4.20 (3.09, 5.71)	1.00
Dinner time ≤6:00 PM	1224	2.26 (1.51, 3.37)	1.37 (1.00, 1.87)	1.00	12.51 (6.54, 23.91)	4.19 (3.06, 5.74)	1.00
Underweight/normal	1277	2.47 (1.68, 3.63)	1.50 (1.11, 2.03)	1.00	13.20 (6.96, 25.05)	4.05 (3.00, 5.45)	1.00
Bedtime ≥11:00 PM	1161	2.13 (1.42, 3.19)	1.26 (0.90, 1.76)	1.00	10.29 (5.54, 19.10)	4.16 (3.04, 5.68)	1.00
Waketime ≥7:00 AM	1106	2.30 (1.50, 3.54)	1.51 (1.11, 2.05)	1.00	10.15 (5.35, 19.25)	4.89 (3.55, 6.75)	1.00

OR, odds ratio; *CI*, confidence interval; BMI, body mass index.
[a]Adjusted for sex, grade (sophomore and below, Junior year and above), major (clinical medicine, others), parental education level (elementary school or below, junior middle school, senior high school, university or above), residential district (city, town, village), snacking after dinner (yes, no), body type (underweight/normal, overweight/obese), sedentary behavior (<9, ≥9 h), physical activity (<2, ≥2 h), chronotype (morning type, neutral type, evening type), daytime napping (0, 1–30, >30 min), sleep latency (≤15, 16–29, ≥30 min), dinner time (<6:00, ≥6:00 PM) and maximum meal (dinner, other).

TABLE 5 Joint effects of sleep duration and sleep quality on suboptimal self-rated health.

Sleep quality	Sleep duration, h/night	Suboptimal SRH, *n* (%)	[a]*OR* (95%*CI*)	*P* for interaction
Good	≥8	68 (21.3)	1.00	0.297
	7	138 (30.6)	1.43 (0.97, 2.09)	
	≤6	41 (34.2)	1.49 (0.87, 2.56)	
Fair	≥8	61 (57.0)	5.59 (3.29, 9.50)	
	7	162 (57.0)	4.52 (2.97, 6.89)	
	≤6	91 (70.5)	7.23 (4.23, 12.33)	
Poor	≥8	12 (70.6)	6.74 (1.98, 22.93)	
	7	39 (76.6)	14.28 (6.20, 32.85)	
	≤6	40 (85.1)	23.12 (8.33, 64.17)	

[a]Adjusted for sex, grade (sophomore and below, Junior year and above), major (clinical medicine, others), parental education level (elementary school or below, junior middle school, senior high school, university or above), residential district (city, town, village), body type (underweight/normal, overweight/obese), sedentary behavior (<9, ≥9 h), physical activity (<2, ≥2 h), snacking after dinner (yes, no), chronotype (morning type, neutral type, evening type), daytime napping (0, 1–30, >30 min), sleep latency (≤15, 16–29, ≥30 min), dinner time (<6:00, ≥6:00 PM) and maximum meal (dinner, other).

dinner (<6:00, ≥6:00 PM) according to the medical university teaching schedule to which the participant belongs. Evidence has shown that people who eat too much at dinner would get less sleep (41), so we divided maximum meals into 2 groups (dinner or not). Height and weight were the most recent measurements reported by the participants, and body mass index (BMI) was calculated as BMI = weight (kg)/height $(m)^2$. We used the WS/T 428-2013 (China) standard to divide BMI into 4 groups (36): underweight (BMI < 18.5 kg/m^2), normal (18.5 ≤ BMI < 24 kg/m^2), overweight (24 ≤ BMI < 28 kg/m^2) and obese (BMI ≥ 28 kg/m^2). Evidence has shown that overweight and obesity were more harmful to health than underweight (42), so we divided body types into 2 groups: underweight or normal (BMI < 24 kg/m^2), overweight or obese (BMI ≥ 24 kg/m^2).

Statistical analyses

Continuous data among students with different sleep durations were compared by ANOVA if normally distributed or the Kruskal–Wallis test otherwise. The Chi-square test was used for nominal data and the Kruskal–Wallis test was used for ordinal data. For the correlation between two quantitative variables, we used the Pearson correlation or Spearman correlation as appropriate; and the consistency between the two categorical variables was evaluated by the weighted kappa coefficient. We also evaluated the agreement of sleep duration obtained from sleep diary or from questionnaire using Bland-Altman analysis. We used a restricted cubic spline to explore the form of the relationship between sleep duration and suboptimal SRH. Logistic regression was used to analyze the

independent and joint effects of sleep duration and sleep quality on suboptimal SRH. Results were expressed as odds ratio (*OR*) and 95% confidence interval (*CI*). The model I adjusted for demographic and lifestyle characteristics including sex, grade, major, residential district, parental education, physical activity, and sedentary behavior. To further control the potential confounding of biorhythmic variables, we adjusted for dinner time, maximum meal, chronotype, and daytime napping in Model II.

To explore the consistency of the association of sleep duration, sleep quality with suboptimal SRH in medical students, we conducted stratified analyses according to sex, major, grade, sleep latency, daytime napping, sedentary behavior, physical activity, chronotype, and maximum meal. The *P* for trend was obtained by assigning the ordinal value to each sleep duration and sleep quality categories and modeling them as continuous variables. The interactions between sleep quality, sleep quality and stratification factors were assessed by likelihood ratio tests comparing the models with and without the multiplicative interaction terms. Then, we investigated the joint association of sleep duration and sleep quality on suboptimal SRH. In this multivariable-adjusted logistic model, we combined the 3 groups of sleep quality with the 3 groups of sleep duration to form 9 subgroups, with sleep duration ≥8 h/night and good sleep quality as reference.

In sensitivity analyses, we restricted participants within medical students who did not smoke, drink alcohol, snack after dinner, or those who had dinner ≤6:00 PM, bedtime ≥11:00 PM, waketime ≥7:00 AM, or those who were underweight/normal. In addition, we performed multiple imputations for covariates with missing values to test the robustness of our results. All statistical analyses were implemented using SAS software, version 9.4 and R (http://www.R-project.org). A 2-sided *P*-value < 0.05 was considered statistically significant.

Results

The mean age of the 1,524 participants was 19.6 years (SD = 1.2 years; 59.1% female). Of them, 652 participants (42.8%) had suboptimal SRH, with females reporting higher rates of suboptimal SRH than males (45.6% for females vs. 38.8% for males, $\chi^2 = 6.9$, $P = 0.009$). From the distribution of sleep duration per night, most medical students slept 7 h ($n = 84$, 51.5%), 19.4% of them ($n = 296$) had short sleep (≤6 h), and 29.1% of them ($n = 444$) had long slept (≥8 h).

Basic characteristics of medical students according to sleep duration

Compared with medical students who slept ≥8 h/night, those who slept ≤6 h/night had a higher proportion of junior year and above (159 [35.8%] for those with sleep ≥8 h vs. 172 [58.1%] for those with sleep ≤6 h), had a higher proportion of evening types (171 [38.5%] for those with sleep ≥8 h vs. 141 [47.6%] for those with sleep ≤6 h), had a higher proportion of sleeping after 11:00 PM (277 [62.4%] for those with sleep ≥8 h vs. 261 [88.2%] for those with sleep ≤6 h), a higher proportion of poor sleep quality (17 [3.8%] for those with sleep ≥8 h vs. 47 [15.9%] for those with sleep ≤6 h), a higher proportion of long sleep latency (89 [22.3%] for those with sleep ≥8 h vs. 98 [36.4%] for those with sleep ≤6 h), a higher proportion of dinner time ≥6:00 PM (69 [15.5%] for those with sleep ≥8 h vs. 78 [26.4%] for those with sleep ≤6 h) and a higher proportion of maximum meal was dinner (78 [17.6%] for those with sleep ≥8 h vs. 77 [26.0%] for those with sleep ≤6 h; Table 1).

Independent effects of sleep duration and sleep quality on suboptimal self-rated health

Our study showed that the proportion of suboptimal SRH reported with sleep duration ≥8 h/night was the lowest (31.8% for those who sleep ≥8 h vs. 43.2% for those who sleep 7 h vs. 58.1% for those who sleep ≤6 h; $\chi^2 = 50.5$, $P < 0.001$; Table 2). Similarly, the proportion of suboptimal SRH reported with good sleep quality was the lowest (27.7% for those who have good sleep quality vs. 60.4% for those who have fair sleep quality vs. 80.5% for those who have poor sleep quality; $\chi^2 = 214.2$, $P < 0.001$; Table 2). In addition, the restricted cubic spline also showed that short sleep duration was associated with suboptimal SRH (*P* for overall <0.001, *P* for non-linear = 0.178; Figure 2).

Compared with students sleeping for 8 h/night, the multivariable-adjusted *ORs* in the model I were 2.70 (95%*CI*: 1.97–3.69) for ≤6 h, 1.60 (95%*CI*: 1.25–2.05) for 7 h, respectively, $P < 0.001$ for trend. After further adjustment for biorhythmic factors such as chronotype, daytime napping, dinner time, and maximum meal (model II), the adjusted *ORs* were 2.24 (95%*CI*: 1.57–3.19) for those sleeping ≤6 h, 1.37 (95%*CI*: 1.03–1.81) for those sleeping 7 h, respectively (Table 2). For comparability with other studies, we used 7 h as the reference, and recalculated odds ratio (*ORs*) by multivariable-adjusted logistic regression. In model II, the *ORs* (95%*CI*) for short sleep (≤6 h), sleep 8 h, and long sleep (≥9 h) were 1.72 (1.26–2.35), 0.69 (0.51–0.92), and 1.00 (0.49–2.04), respectively, $P < 0.001$ for trend (Supplementary Table 1). We also explored the association between sleep quality and suboptimal SRH. Compared with medical students with good sleep quality, the students with fair or poor sleep quality had higher odds of suboptimal SRH, the multivariable-adjusted *ORs* in model I were 4.04 (95%*CI*: 3.19–5.11) for fair, 11.70 (95%*CI*: 7.10–19.27) for poor, respectively, $P < 0.001$ for trend. After further adjustment for the confounders in model II, the adjusted *ORs* were 4.14 (95%*CI*: 3.13–5.47) for those with fair sleep quality, 11.50 (95%*CI*: 6.52–20.29) for those with poor sleep

quality, respectively (Table 2). The stratified analysis according to selected variables found consistent trends in the association between short sleep duration, sleep quality, and suboptimal SRH (Table 3). To further exclude the confounding of lifestyle factors, we performed sensitivity analyses. When we restricted participants to non-smokers, non-drinkers, or participants who do not snack after dinner, had dinner ≤6:00 PM, bedtime ≥11:00 PM, waketime ≥7:00 AM or those with underweight or normal weight, the association between sleep duration and suboptimal SRH was consistent (Table 4). Then to evaluate the effect of missing values on our results, we performed multiple imputations. In our study, the *n* (%) of missing value for sleep latency, body type, physical activity, daytime napping, sedentary behavior, residential district, and dinner time were 130 (8.5), 67 (4.4), 57 (3.7), 42 (2.8), 22 (1.4), 3 (0.2), and 2 (0.1), respectively. In multiple imputation, we included the above variables and also SRH, sleep duration, sleep quality, sex, grade, chronotype, snacking after dinner, and found that the association of sleep duration and sleep quality with suboptimal SRH remained unchanged (Supplementary Table 2).

Joint effects of sleep duration and sleep quality on suboptimal self-rated health

In addition, we explored the joint effects of sleep quality and sleep duration on suboptimal SRH. Taking participants who reported sleeping ≥8 h/night and good sleep quality as a reference, the multivariable-adjusted *ORs* of other groups were all >1, of which the group with sleep ≤6 h and poor sleep quality had the highest odds of suboptimal SRH (*OR* 23.12, 95%*CI*: 8.33–64.17; Table 5).

Discussion

In this cross-sectional study of medical students, we observed that short sleep duration (≤6 h) was significantly associated with suboptimal SRH, but not long sleep. We also observed that sleep quality was highly correlated with suboptimal SRH in a dose-response relationship. In addition, we found that sleep duration and sleep quality had significant joint effects on suboptimal SRH. All these associations were independent of biorhythmic variables, such as chronotype, dinner time, and maximum meal, which most current studies have not considered.

This study found that 42.8% of medical students reported suboptimal SRH, which was higher than the level of suboptimal SRH reported in the general population (43, 44). Additionally, the difference in the reporting rate of suboptimal SRH among young adults between sex was controversial. The European Health Behavior Survey (6) showed no difference in the reporting rate of SRH between the sexes. But we found that female medical students reported a higher rate of suboptimal SRH than males, which is consistent with findings from the European Health Interview Survey (1). One of the reasons for the difference may be related to the heavy academic and learning pressure of medical students, and the other reason is related to the different definitions of suboptimal SRH in different studies. We found that 296 (accounting for 19.4%) of medical students suffered from short sleep, which was lower than other college students (21–46%) (6, 39, 45). This may be related to the rules and regulations of the university to which the interviewee belongs. As far as we know, the library of this university is closed at 10:30 PM, the study room is turned off at 11:00 PM at night, and the dormitory is set up with access control at 11:00 PM. Furthermore, our study found that average daily screen time of medical students was ∼4 h, which was lower than the level of previous studies (7 h) (46). This may be another reason that medical students have a lower rate of short sleep than other university students. Therefore, even though medical students face pressures such as clinical practice and further studies, their short sleep rate is lower than other studies.

Unlike the *U*-shaped association between sleep duration and suboptimal SRH in general adults (5, 16, 43), we found that short sleep duration was significantly associated with suboptimal SRH, but not long sleep. And this association remained robust after adjusting for demographic characteristics and biorhythms. The reason for the difference may be related to the large variability of sleep duration in different previous studies. In our study, most participants slept 7–8 h per night (77.9%). But in previous studies, the proportion of sleep 7–8 h was between 42.9 and 62.1% (16, 43, 47), and the proportion of participants with short or long sleep duration was very high. Few studies among undergraduates (6, 45) and adolescents (48) also proved that short sleep (≤6 h) was significantly associated with suboptimal SRH, while long sleep (≥9 h) was non-significant. It may be related to the confounding effects of biological rhythm factors such as maximum meal, and chronotype that were not controlled in previous studies. In this study, we found that after controlling for these factors, short sleep (≤6 h) was still associated with suboptimal SRH, while long sleep (≥9 h) was not statistically significant. The result was consistent with the joint statement of the American Academy of Sleep Medicine and the Sleep Research Society, indicating optimal sleep duration standard for young people might be different from that of middle-aged and elderly people and that regular long sleep duration is suitable for them (49).

The previous study had shown that sleep quality was an important predictor of SRH in adults (50). Our study also found that sleep quality had a dose-response association with suboptimal SRH, the better the sleep quality, the lower the proportion of suboptimal SRH. This was consistent with previous findings that sleep quality was linearly associated with SRH (15). These data indicated that the excellent sleep quality

of young medical students or young individuals played an important role in health.

Moreover, it is worth noting that joint effects of sleep duration and sleep quality were significantly associated with suboptimal SRH, which was consistent with another cohort study (36). However, an observational study showed poor sleep quality was associated with suboptimal SRH in long sleep duration but not short sleep duration (n = 1,304, 18–79 years) (15). In our study, this association might exist because we used a more homogeneous sample (18–26 years) while adjusting for biorhythm covariates in the analysis.

Existing evidence suggests that short sleep duration and poor sleep quality can lead to increased fatigue (51, 52), adverse effects on endocrine function, the immune system (53), blood sugar regulation (54), and cognitive function (55). Of course, suboptimal health might also lead to short or long sleep or poor sleep quality. But this was unlikely in this study because medical students are a younger adult population with a lower probability of having health problems. These data indicate that medical students or young adults should ensure adequate sleep duration and good sleep quality for optimal health.

There are several limitations to our study. Although we evaluated the relationship between sleep duration and suboptimal SRH under the condition of comprehensive control of various confounding factors, and we selected a relatively young adult population, medical students as the research participants, limiting the problems of reverse causality that may exist in the middle-aged and elderly population in previous studies due to changes in sleep behavior caused by chronic diseases. The association between sleep duration and suboptimal SRH could not be interpreted as a causal relationship because the data were cross-sectional and our results only suggest that poor sleep health is a marker or correlate of suboptimal SRH. In addition, sleep duration, sleep quality, and other variables were collected through questionnaires. Although we designed the SRH questionnaire with reference to many large cohort studies (6, 18, 36), and conducted detailed reliability and validity assessments on variables such as sleep duration, sleep quality, and self-rated health, the variable acquisition method was relatively subjective, and the information was not as accurate as the objective evaluation method. We also did not monitor other residual confounding such as sleep duration variability, social jetleg, the number of wake-ups from sleep, fatigue and stress. Therefore, further cohort study among medical students is needed to confirm the relationship between sleep behavior and health.

In conclusion, based on the perspective of circadian rhythm, this study further verified the association between sleep quantity, quality and health in medical students, and found the rate of suboptimal SRH in medical students was higher than that in the general population, short sleep and poor sleep quality were independently and jointly associated with higher odds of suboptimal SRH, which was consistent with previous studies among college students and young adults, but was different from those in middle-aged and older populations. Therefore, education on sleep hygiene among medical students should be strengthened, and adequate and high-quality sleep should be advocated to prevent adverse health events. Furthermore, governments and universities should pay close attention to the sleep behaviors of medical students and young adults, conduct better cohort studies on sleep behaviors, and formulate recommendations for healthy sleep behaviors to promote health.

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 Ethics Committee of Wenzhou Medical University, Wenzhou Medical University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

PD and HS designed the study and analyzed the data. JL, XY, and HS collected the data. PD drafted the manuscript. HC, XY, and CZ supervised the study. All authors contributed to revising the manuscript 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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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.957409/full#supplementary-material

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EDITED BY
Maha El Tantawi,
Alexandria University, Egypt

REVIEWED BY
Sitong Chen,
Victoria University, Australia
Jingyi Tan,
Lundquist Institute for Biomedical Innovation, United States

*CORRESPONDENCE
Anhui Fan
huifanan@126.com

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Trends in sports participation in adolescents: Data from a large-scale sample in the US adolescents

Yu Deng and Anhui Fan*

Department of Physical Education, Southwest University Chongqing, Chongqing, China

Background: Although changes in overall physical activity (PA) have been identified in adolescents, the trend in sports participation is still understudied. It is widely believed that monitoring the changes in sports participation is conducive to promote the development of sports activities. The purpose of this research was to identify the changes in sports participation in adolescents over the past years.

Methods: This research selected secondary data from 2011, 2013, 2015, 2017, and 2019 Youth Risk Behavior Surveillance (YRBS). Logistic regression models were applied to discuss and analyze the secular changes across the years of data. The change differences in sports participation by sex, grade, and race/ethnicity were also explored *via* separate logistic regression.

Results: A declined overall trend could be observed in sports participation in adolescents, the prevalence of sport participation was 58.4% in 2011 and 57.4% in 2019. The declining trend was also observed in grades 10 (62.3% in 2011 and 57.9% in 2019) and 12 (52.5% in 2011 and 49.8% in 2019) adolescents, and an increase could be observed in grade 11 (56.2% in 2011 and 59.1% in 2019) adolescents, but few changes were found in grade 9 (61.4% in 2011 and 61.9% in 2019) adolescents. Only white adolescents reported an increasing prevalence of sports participation, slight declines in sports participation were observed in black or African American, Hispanic/Latino, and other adolescents.

Conclusions: The declining trend in sports participation could be seen in adolescents between 2011 and 2019, but it should also note that large variations of trends in sport participation by subgroups were also found.

KEYWORDS

sport participation, adolescents, US, physical activity, trends

Introduction

Sports participation is the outcome of basic education reform and represents a new field of learning (1). Sports participation is not only a new overall goal of education for students but also an important way to realize children's socialization (2, 3). The word "participation" is bound up with management and organizational behavior, and it is the basis to measure whether an individual, as an entity, participates in activities (4).

However, with the emphasis on the development needs and inner psychology of students, the research began to highlight the involvement in cognitive and emotional aspects and gradually explored the external factors affecting sports participation of teenagers (5). Sports participation means mental and physical energy input of teenagers (6). The initiative degree of students' sports participation can be judged not only by external indicators that include heart rate, expression, and emotion but also by students' attitude and persistence (7).

Ren et al. (8) investigated over 7,000 students to model the relationship between family and community resources and the frequency of sports participation of students and found that only one-sixth of the students participated in sports clubs or planned sports by themselves, so they classified most of the students into the sub-health group and found that in the sub-health group, girls, senior students, and Han people accounted for a large proportion (8). It has been known that family culture has a strong promotion effect on sports participation (9). By conducting structured interviews with sports children, parents can set scientific goals and dietary collocation for them to better promote their children to get a pleasant experience of sports and persist in it (10). However, these studies on the relationship between sports participation and family communities were selected from a specific region or interviewed in small numbers, resulting in limiting other regions that represent different education policies.

At the same time, Chen et al. (3) focused on the factors affecting youth sports participation. Based on the data provided by Youth Risk Behavior Survey (YRBS), gender, grade, and academic achievements of American students in grades 9–12 were taken as variables, and it was concluded that academic achievements were positively associated with sports participation. By making a comparison between sports participation and other behaviors of adolescents, the study found that sports participation was associated with many positive health behaviors and the proportion of bad habits is small (11, 12). From the perspective of psychological influence, teenagers' sports participation plays a pro-social role (13). Teenagers enjoy healthy emotions brought by sports and entertainment, which to some extent refutes the connection between sports participation and social resources (8, 14), suggesting that schools should organize sports groups and competitions to intervene in academic achievements of students and different grades adopt diverse sports based on physical characteristics of adolescents. Using nationally representative data from the United States, these reports provide evidence of the relationship between diversified factors and sports participation. However, the specific causes of rank and gender should be further explored.

To our knowledge, only a limited number of studies surveyed changes in sports participation in children and adolescents, despite much evidence on changes in overall PA. Monitoring and forecasting the changes in sports participation enable researchers and practitioners to do effective action plans for encouraging engagement in sports activities by considering further health promotion.

This research targeted reporting changes in sports participation of children and adolescents over the past years. Beyond that, to detect secular changes, we also explored sociodemographic factors related to sports participation.

Methods

Study design and population

This study used data from five cycles of the YRBS (2011, 2013, 2015, 2017, and 2019). The YRBS is a biennial, cross-sectional school-based survey of health-related behaviors among a nationally representative sample of high school students living in the United States. The YRBS uses a three-stage cluster sample design to recruit students attending public and private schools in grades 9–12. Students in grades 9–12 in public and private schools in the United States were included in the sampling frame. In the first stage, the primary sampling units (PSUs) were included from counties and adjacent counties. In the second stage, the public and private schools with 9–12 grades were selected from PSUs. In the third stage, one or two entire classes in each grade were randomly selected from the chosen school. The survey was administered in person by trained data collectors and completed by students during class time. Overall response rates were above 60% during the administration of each cycle of the YRBS. Survey results were weighted to represent the populational and national health data. The data used in this secondary analysis were de-identified and publicly available, which have been approved by Centers for Disease Control and Prevention's (CDC) institutional review board. Additional details about the YRBS can be found at https://www.cdc.gov/healthyyouth/data/yrbs/index.htm.

Measures

Participants provided demographic information about their sex (female/male), grades (9, 10, 11, and 12), and race/ethnicity (white, black/African American, Hispanic/Latino, other). The term "sports participation" refers to playing on 1 or more sports teams during the past 12 months (15). Sports participation was assessed by one single question, which was "during the past 12 months, how many sports teams did you play? (Count any teams run by your school or community groups.)" Responses to the question included 0 teams, 1 team, 2 teams, and 3 or more teams. This single question has been reported to be

TABLE 1 Demographic characteristics of the participants.

		n	%	Weighted %	95%CI	
Total		13,677	100	/	/	/
Sex						
	Female	6,885	50.3	49.4	47.9	50.9
	Male	6,641	48.6	50.6	49.1	52.1
	Missing	151	1.1			
Grade						
	9th	3,637	26.6	26.6	25.4	28.0
	10th	3,717	27.2	25.5	24.7	26.3
	11th	3,322	24.3	24.3	23.2	25.4
	12th	2,850	20.8	23.6	22.4	24.8
	Missing	151.0	1.1			
Race						
	White	6,668	48.8	51.2	46.4	56.0
	African American	2,040	14.9	12.2	10.2	14.6
	Hispanic/Latino	3,038	22.2	26.1	21.8	30.9
	All other races	1493	10.9	10.5	7.9	13.9
	Missing	438	3.2			

CI, confidence interval.

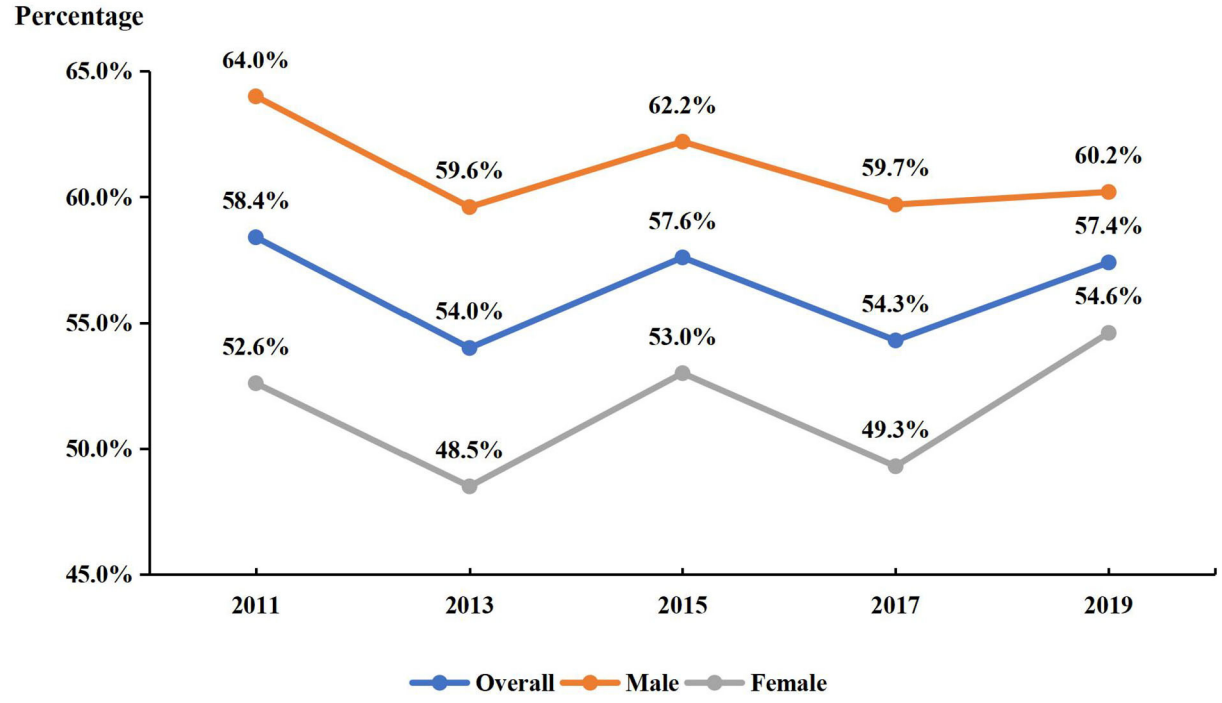

FIGURE 1
Prevalence of participating in at least one sports team over the past 12 months in the sample (overall and by sex) between 2011 and 2019. For the overall sample, models were controlled for sex, grade, and race/ethnicity. For sample by sex, models were controlled for grade and ethnicity.

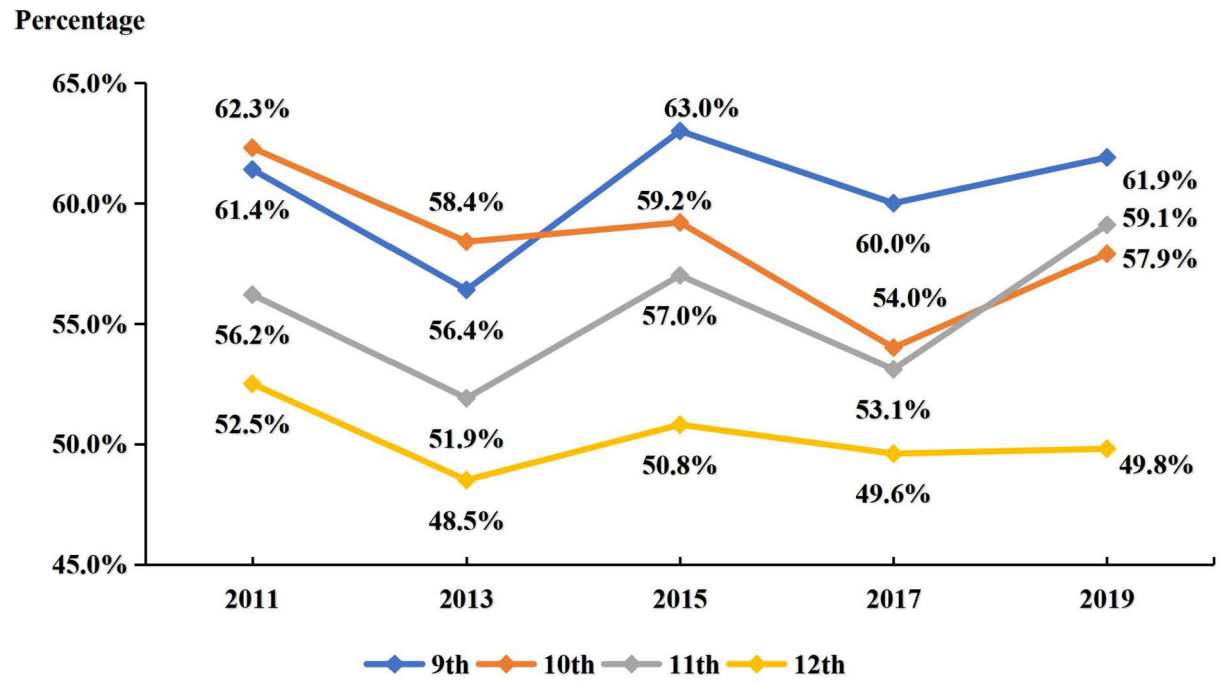

FIGURE 2
Prevalence of participating in at least one sports team over the past 12 months in the sample (by grade) between 2011 and 2019. All models were controlled for sex and race/ethnicity.

reliable for measuring sport participation in a previous study (15, 16).

Statistical analysis

All the variables included in this study were treated as categorical variables. For each variable, weighted prevalence estimates with 95% confidence intervals (CIs) were calculated while accounting for complex sampling surveys, using Taylor linearization to produce nationally representative prevalence estimates for each survey year. To examine trends in sport participation and across the 2011–2019 cycles of the YRBS, logistic regression models were conducted with time-trend variables that assess secular changes across the years of data. Separate logistic regression models were also performed to explore associations between sociodemographic variables (sex, grade, and race/ethnicity) and sport participation, which generated year-based and year-combined associations. Adjusted odds ratio (OR) with 95% CI after controlling for sex, grade, and race/ethnicity are presented for all logistic regression models. All analyses were performed using SVY procedures by taking sampling stratum, primary sampling unit, and weight based on the YRBS protocol in Stata/IC 16.1 (Stata Corp LLC). Statistical significance was considered at a 2-tailed $p < 0.05$.

Results

The demographic characteristics of participants are shown in Table 1. In total, 13,677 (50.3% girls) adolescents were recruited to participate in this survey. The weighted percentage of female participants was 49.4%, more than half of the participants were white, and 47.9% of students were over grade 11. The overall sex prevalence of participating in sports teams by each year is outlined in Figure 1. It can be seen from Figure 1 that the prevalence of participating in boys experienced a declining trend (from 64.0 to 60.2%), while the girls witnessed a slight rising trend between the years 2011 and 2019 (52.6–54.6%). In the overall sample, after trend analysis, there was statistically significant declining changes in sport participation (both linear and quadratic, $p < 0.005$). Similar significant changes were also observed in only boys (both linear and quadratic, $p < 0.001$) instead of girls ($p > 0.05$).

Secondly, by analyzing grade parameters (shown in Figure 2), compared grades 10 and 12 experienced a downward trend and grades 9 and 11 demonstrated a rising trend from the year 2011 to 2019. The trends of sport participation

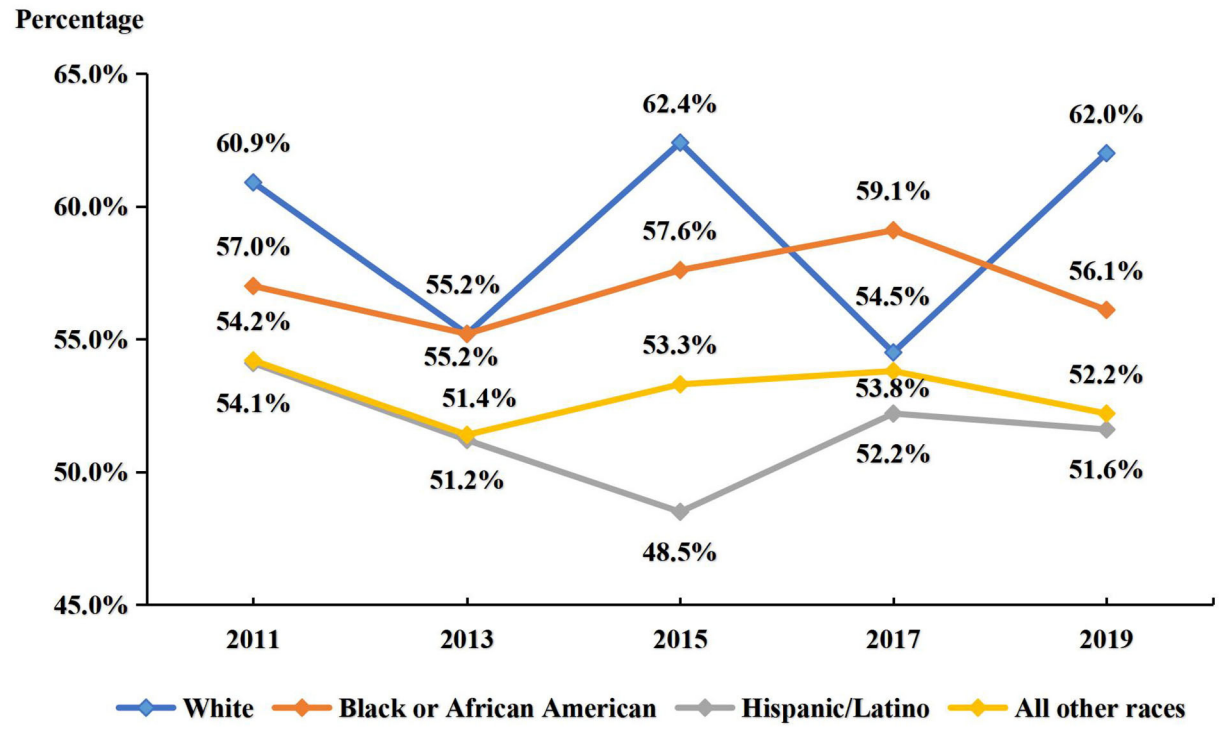

FIGURE 3
Prevalence of participating in at least one sports team over the past 12 months in the sample (by race/ethnicity) between 2011 and 2019. All models were controlled for sex and grade.

over the past 10 years are presented in Figure 2. In grade 9, no significant changes were observed ($p = 0.129$). Similar changes were observed in grade 11 students. Significant quadratic declining trend of sport participation was detected in grade 10 students ($p = 0.009$) and grade 12 students ($p = 0.038$).

The prevalence of participating in at least one sports team by race/ethnicity is shown in Figure 3. Analysis by race/ethnicity showed that white adolescents had the highest sports participation, only surpassed by black or African American adolescents by 4.6% in 2017 and about the same percentage as other races and Hispanics/Latinos. In 2019, however, sport participation outnumbered blacks by about 6% and Hispanic/Latino or other races by about 10%. The trend analysis revealed different trends of sport participation in adolescents of different races/ethnicities. In white adolescents, no significant changes were found ($p > 0.05$). In black or African American adolescents and those of all other races, no significant changes were also observed ($p > 0.05$). However, in Hispanic/Latino adolescents, a significant quadratic declining trend was found ($p < 0.05$).

Table 2 demonstrates results for the relationship between sociodemographic factors and sports participation. It can be seen from Table 2 that relative to girls, boys show greater odds of engaging in sports participation (OR = 1.50, 95% CI: 1.40–1.61). In addition, the odds for sports participation in 9th graders (OR = 1.53, 95% CI: 1.41–1.67) were significantly higher than those in 12th graders. When it comes to ethnicity, people from white were more likely to get involved in sports participation (OR = 1.10, 95% CI: 0.99–1.23) than black or African adolescents.

Discussion

The purpose of this research was to investigate the trend of sports participation in American adolescents from 2011 to 2019 and the sociodemographic factors of sport participation. Evident changes in overall sports participation were observed in adolescents, but with large variations of the trends in adolescents by subgroups (e.g., boys were different from that of girls). Regarding the factors influencing sport participation, boys are lower graders were two important and positive factors of sport participation. More analysis is presented below.

Our study confirmed that boys were more possible to participate in sports than girls, which can be supported by previous studies (3, 8, 17), For instance, there was a study by

the YRBS that found that girls were less likely to participate in physical activities than boys, which indicated that girls might encounter huge barriers to take part in sports activities (17). Previous studies indicated that ratio of sports participation of girls was inferior to that of boys (18). Within the restricted sports environment or resources, boys were able to control the space and facilities of sports activities while girls might be isolated or excluded (19). Furthermore, there is evidence indicating that support of parents might be an important explanation because fathers tend to participate in the sports activities of their sons more than their daughters'. In this way, it is essential to safeguard resources and chances of sports participation in the school environment. Beyond that, given sex stereotypes and different social roles (20), boys performed more possibilities to attend sports activities while girls preferred to attend more leisure activities and personal art activities (17). Another factor should be puberty and menarche, such as girls entering early into puberty than boys (21). As a result, it is of great significance to construct positive female images under the sports content in which existing stereotypes and inspired sports participation (especially for girls) will be disadvantaged to some extent.

This research suggested that an overall decline in overall sports participation was observed in adolescents between 2011 and 2019, which was inconsistent with two previous studies (22, 23). For example, a stable increasing trend of sports participation was seen in Icelandic adolescents (24). However, it also should be noted that more than half of adolescents did not consistently participate in organized club sports (25). In addition, another study also reported a similar finding that there was an increasing trend of sports participation in Sweden adolescents (26). These two studies are inconsistent with our research findings. Several explanations might contribute to the difference between the current research and the previous studies, such as the sports opportunities, facilities, and sports policies (22). As the current study merely reported secular trends of sport participation over the past years in adolescents, there was no other information on better understanding or further explaining the trends, future studies based on the contexts and backgrounds should be put forward for reversing this declining trend.

When looking at the trends of sports participation in adolescents by groups (i.e., sex, grade, and race/ethnicity), some notable and interesting research findings are worth mentioning. First, in boys, although there was an overall decrease in sport participation over the past years, its changes underwent an evident variation. For example, from 2011 to 2013, an apparent decrease in sport participation was observed, following an increase by 2015. After that, a general but slight decrease was observed. Unlike this, in girls, a general but non-significant increase in sport participation was found, but also with some fluctuations from 2013 to 2017. The sex discrepancy that resulted in different trends in sport participation in boys and girls might be owing to sex-specific perceptions toward and engagements in sports activities in different survey years. In the current study, owing to limited data collected (public data), we cannot provide further insight into the sex difference, which should be addressed in the future. In terms of grade difference, graders 9 and 11 have no significant changes in sports participation, probably because of great variations in different survey years. Conversely, in graders 10 and 12, decreases in sport participation over the past years were found. It is expected that higher grade students should have sharper decreases in sport participation, but this study did not find such research findings. Unfortunately, we cannot consider the contexts of different survey years, such as specific survey time, sample characteristics, and other factors. In the future, to explore the variations of trends in sport participation in adolescents by grade well, it is needed to know more relevant contextual information. Regarding adolescents by race/ethnicity, only adolescents of Hispanic/Latino had a significant decreasing trend in sport participation, but adolescents of other races/ethnicities were not found with decreasing trend. This research finding indicates that the decreasing trends of sport participation in Hispanic/Latino adolescents should be considered when designing interventions. The present study extends the literature by identifying more nuanced patterns of changes in sport participation. Of note, however, it should be extremely cautious to compare our research results with the previous studies because of diversely cultural differences and contextual factors. To our knowledge, there is no comparable sport participation research for the past decade on the possible differences in sex-stratified, grade-stratified, and race/ethnicity-stratified groups; so that such novel research findings may highlight adolescents from different subgroups are undergoing health behavior disparities. This would be an evidence base for tailoring-specific measures aimed at increasing participation in sports activities.

Although this research analyzed a large sample to identify the trends in sports participation by sex, grades, and race/ethnicity in adolescents, several limitations

TABLE 2 Odds ratio and 95% CI for socioeconomic factors concerning sports participation in this study.

	OR	95%CI	
Male	1.50	1.40	1.61
Female		REF	
9th	1.53	1.41	1.67
10th	1.41	1.32	1.51
11th	1.23	1.15	1.32
12th		REF	
White	1.10	0.99	1.23
Hispanic/Latino	0.80	0.73	0.87
All other races	0.86	0.79	0.95
Black or African		REF	

OR, odds ratio; CI, confidence interval; REF, reference group.

should be addressed. First of all, this research made use of cross-sectional data from YRBS. In addition, adolescents were required to self-report their sports participation over the past 12 months, and the self-administrated questionnaire might contribute to recall bias and lead to underestimates or overestimates of the level of sports participation.

Conclusion

To sum up, data from YRBS reported an overall declining trend in sports participation in United States adolescents, but the trends varied greatly by different subgroups (e.g., sex and grade). Future studies should further explore the trends of sport participation in adolescents and design effective strategies to promote this population to engage in more sports activities in terms of health promotion. To promote sports participation in adolescents, girls and older adolescents (higher graders) are the target priority.

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/s.

Ethics statement

The studies involving human participants were reviewed and approved by all data were anonymized and publicly available; therefore no ethical approval was required. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

YD: writing—original draft. YD and AF: formal analysis and writing—review and editing. Both 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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Iffat Elbarazi,
United Arab Emirates University,
United Arab Emirates

REVIEWED BY
Lemeng Zhang,
Central South University, China
Jia Pu,
Mathematica Policy Research,
United States

*CORRESPONDENCE
Jingfen Zhu
zhujingfenjt@shsmu.edu.cn

†These authors share first authorship

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Social environment exposure to electronic cigarettes and its association with e-cigarette use among adolescents in Shanghai, China

Luojia Dai†, Weiyi Lu†, Juanjuan Wang, Lulu Zhang and Jingfen Zhu*

School of Public Health, Shanghai Jiao Tong University, Shanghai, China

Objective: This study investigated adolescents' social-environmental exposure to e-cigarettes in association with e-cigarette use in Shanghai, China. We also explored these differences by gender and school type.

Methods: Sixteen thousand one hundred twenty-three students were included by a stratified random cluster sampling, and the number was weighted according to selection probability. Association between social environment exposure and e-cigarette use was examined by multivariate logistic regressions.

Results: There were 35.07, 63.49, 75.19, 9.44, and 18.99% students exposed to secondhand e-cigarette aerosol (SHA), e-cigarette sales, e-cigarette information, parents' and friends' e-cigarette use. Students exposed to SHA (aOR = 1.73, 95% CI 1.40–2.14), e-cigarette sales from ≥2 sources (aOR = 1.55, 95% CI 1.18–2.03), e-cigarette information exposure from ≥2 sources (aOR = 1.39, 95% CI 1.05–1.83), and having a social e-smoking environment (friends' e-cigarette use: aOR = 2.56, 95% CI 2.07–3.16; parents' e-cigarette use: aOR = 1.54, 95% CI 1.17–2.02) were significantly associated with their intention to use e-cigarettes. More girls were exposed to e-cigarette sales in the malls, e-cigarette information at points of sale and on social media ($P < 0.01$), and exposure to sales from ≥2 sources were associated with girls' intention to use e-cigarettes (aOR = 1.84, 95% CI 1.22–2.78). However, boys were more likely to be exposed to friends' e-cigarette use ($P < 0.001$), and having friends using e-cigarettes was associated with greater intention to use them in boys (aOR = 2.64, 95% CI 1.97–3.55). Less vocational high school students were exposed to parents' e-cigarette use ($P < 0.001$), but they were more likely to use e-cigarettes in the future after being exposed (aOR = 2.27, 95% CI 1.50–3.43). A similar phenomenon was observed between junior high students and their exposure to SHA.

Conclusions: This study reported adolescents' high exposure rates to the social environment of e-cigarettes. Exposure to SHA, e-cigarette sales from ≥2 sources, e-cigarette information from ≥2 sources and having a social e-smoking environment were related to adolescents' intention to use e-cigarettes. Differences in gender and school type were observed.

More attention should be paid to girls, and different interventions should be designed for different types of school students. Additionally, comprehensive tobacco control policies are needed.

KEYWORDS

e-cigarettes, social environment, exposure, adolescents, tobacco control

Introduction

E-cigarettes have rapidly swept the world over recent years. By featuring various characteristics such as being suitable for use in no-smoking areas, being fashionable, and coming in diverse tastes, they have attracted many adolescents (1). Among current e-cigarette users, adolescents account for ≥20% in countries with a high prevalence of e-cigarettes, such as the United States, the United Kingdom, and Canada (1–3), while the rate of current e-cigarette users in China has also rapidly increased from 1.2% in 2014 to 2.7% in 2019 (4). E-cigarettes might harm adolescents' health, especially when they start using them at such an early stage in life. In the long term, the use of e-cigarettes may lead to a higher risk of cancer, cardiovascular disease, respiratory injury, and osteoporosis (5, 6).

Previous studies have indicated that e-cigarette-related exposure may be the risk factor predisposing adolescents to become current e-cigarette users and try e-cigarettes in the future (7–9). However, more and more adolescents are being exposed to e-cigarettes in their social environment globally *via* secondhand e-cigarette aerosol (SHA), e-cigarette sales, e-cigarette information, and social e-smoking environment. Although some countries, such as Canada, have issued bans prohibiting the advertising of e-cigarettes in mass media, there were still 74% of adolescents who reported being exposed to e-cigarette advertising in 2017. Also, the rate of adolescents was higher (>80%) in the United States and the United Kingdom, where no such ban was implemented (10). Additionally, 29.2 and 27.7% of adolescents in the UK recalled seeing e-cigarettes in supermarkets and retail stores in the past 30 days, respectively, in 2016 (8), while 28.8% of Chinese adolescents reported being exposed to e-cigarette advertising in the past 30 days (11). As for e-cigarette information exposure, previous research in Shanghai, China, also revealed that 73.9% of adolescents knew about e-cigarettes, and the primary sources of information were the internet (42.4%), movies/TV (36.4%), bulletin boards in retail stores or supermarkets (34.9%), advertising flyers (33.9%) (12). In addition, compared to non-e-cigarette users, current users among Chinese teens reported higher rates of friends' smoking (7.2 vs. 0.8%) and parents' smoking (4.9 vs. 1.9%) (13), which is consistent with the situation in the United States (friends' smoking: 32.6 vs. 23.1%; parents' smoking: 38.6 vs. 37.1%) (14). With regard to SHA, 25.6% of US adolescents reported being exposed to it in 2017 (15), vs. 29% of youth from Florida in 2019 (16). However, few studies have addressed SHA exposure among Chinese adolescents.

The sales of e-cigarettes have been increasing for quite some time now (17). For example, the total retail sales of e-cigarettes in the United States increased by 16% from 2015 to 2016 and 47% from 2016 to 2017 (18), thus increasing the likelihood among teens to see related products in vaping stores, convenience stores, supermarkets, and on the internet (19). Though tobacco control compliance is actively promoted in China, the tobacco industry constantly seeks countermeasures. One research reported that 106,485 pieces of online tobacco information were published on 11 different Chinese platforms (20), while another study comparing the web-based e-cigarette information from Google (in English) and Baidu (in Chinese) search engines revealed that more websites on Baidu were owned by manufacturers and were more likely to contain e-cigarette advertising (21). Moreover, in recent years, e-cigarette marketing has shifted from traditional media to social media (8), such as Facebook, Instagram, and YouTube in the United States and Weibo, WeChat, and TikTok in China, all of which are frequently used by adolescents. An earlier study showed that the proportion of adolescents using Facebook, Snapchat, Instagram, and YouTube was 51, 69, 72, and 85%, respectively (22), and 100% of high school students had at least one social account (23). Studies have shown that 30.4% of American junior and senior high school students reported seeing e-cigarette advertisements on social media in the past 30 days (24), while 18.0% reported exposure to e-cigarette information on social media among adolescents in Shanghai, China (12). Social media promote participation, openness, communalization, and connectivity, thus providing a convenient and informal channel for e-cigarette marketing, thus resulting in an unsatisfactory effect of regulations on e-cigarette marketing on social media (10).

Moreover, some specific groups may be especially targeted by e-cigarette marketing. For example, the gender differences in e-cigarette use are much more insignificant than that in traditional smoking (25), and the environmental exposure of girls to e-cigarettes is becoming more and more severe (10, 26). However, since there has been a paucity of related research, in the present study, we described adolescents' exposure to SHA, e-cigarettes information, e-cigarettes sales, and social e-smoking environment, examining the association between

social-environmental exposure of e-cigarettes and e-cigarette use among junior, senior, and vocational high school students in Shanghai, China. We also explored the differences in relation to gender and school type.

Methods

Research procedure

From June to October 2021, a stratified random cluster sampling was used to select a representative study sample of adolescents aged 13–18 years old in Shanghai. In the first stage, 3 districts in Shanghai were randomly selected, and in the second stage, schools in these districts were selected based on the proportion of junior, senior, and vocational high schools. A total of 21 schools, including 12 junior high schools, 6 senior high schools, and 3 vocational high schools, were randomly selected, and all students in the schools were invited to participate in the study. A total of 16,694 surveys were received, and 16,123 (96.58%) valid questionnaires were included in the analysis. Those with too short answer time and logical contradiction were excluded.

The self-administered questionnaire was adapted from the WHO Global Youth Tobacco Survey. Data were collected by trained investigators. Students were asked to fill out the questionnaires anonymously and independently. All research procedures were approved by the Shanghai Municipal Education Commission and the participating schools. Written informed consent, which was provided before enrollment, was obtained from respondents. The consent included the objectives, procedures, potential risks, and the benefits of the study. This study was approved by the Ethics Committee of the School of Public Health, Shanghai Jiao Tong University (SJUPN-202015; approved on February 20, 2021).

Measures

Socio-demographic factors

The assessed characteristics included gender, school type, boarding situation, school performance, and monthly allowance. School performance was divided into the top 25%, average, and the bottom 25% of the class; monthly allowance was divided into low, medium, and high, where <200 RMB (30 USD) was low, and ≥600 RMB (90 USD) was high.

Secondhand e-cigarette aerosol exposure

Exposure to SHA was determined by asking: "During the past 30 days, were you exposed to vapor from an e-cigarette smoked by someone else?" (15), with possible answers: "never," "sometimes/often." Respondents who chose a response other than "never" were considered as exposed to secondhand e-cigarette aerosol, and the variable was then recorded as "no" and "yes."

E-cigarette information exposure

Exposure to e-cigarette information was measured by asking: "Have you seen or heard of e-cigarettes from the following sources?." The sub-items were: "Social media (e.g., QQ, WeChat, Weibo, TikTok etc.)," "Traditional media (e.g., TV/movies/broadcasting, billboards, magazines etc.), "Points of sale (e.g., convenience stores, newsstands, tobacco stores etc.)" (11). Total e-cigarette information exposure was coded as: "no," "one source," and "two and more sources."

E-cigarette sales exposure

Exposure to e-cigarette sales was assessed by the following items: "Have you seen e-cigarettes sold in retail stores around your school?," "Have you seen e-cigarette sold in the malls?," "Have you seen anyone selling e-cigarettes on social media (e.g., QQ, WeChat, Weibo, TikTok etc.)?" (11). Total e-cigarette sales exposure was coded as: "no," "one source," and "two and more sources."

Social e-smoking environment

Adolescents were asked: "Have your parents used e-cigarettes in the past 30 days?" with a "yes "or "no" response; and "How many of your best friends use e-cigarettes?" with responses "none," "some," "most," or "all," which were then dichotomously re-coded as "no" or "yes"(27).

Cigarette and e-cigarette use

Use of cigarettes was measured by asking: "Have you ever tried cigarette smoking?" and "Have you ever smoked in the past 30 days?." Never smokers were defined as those who reported "I never smoked even just 1 or 2 puffs" to both items. Current smokers were identified as respondents who reported using cigarettes in the past 30 days, and ever smokers were classified as those who reported lifetime using cigarettes while having used it in the past 30 days (28). For e-cigarettes, respondents were asked whether they had tried e-cigarettes and whether they had used e-cigarettes in the past 30 days. "Never e-cigarette users," "current e-cigarette users," and "ever e-cigarette users" were identified based on the same approach as smokers above (28). Intention to use e-cigarettes was measured by the following questions: "Would you try e-cigarettes, even just one puff if given the chance?" and "If one of your best friends were to give you one, would you try it?." Response options were "Definitely yes," "Probably yes," "Probably not," and "Definitely not" (29). Those who reported "Definitely not" on both items were regarded as

having no intention to use e-cigarettes, and others were classified as having the intention to use e-cigarettes.

Statistical analysis

Considering the complexity of survey sample design, a weighing factor was calculated according to the selection probability of districts, the number of schools in each district, and the number of students in each school, and was then adjusted for the non-response. A Chi-square test was used to analyze whether the rates of SHA exposure, e-cigarette sales exposure, e-cigarette information exposure, parents' and friends' e-cigarette use differed by gender and school type. A series of multivariate logistic regressions were conducted to examine whether current e-cigarette use was associated with the social environment of e-cigarette exposure after controlling for gender, school type, boarding situation, school performance, monthly allowance, and traditional smoking status in model 1, while all variates were controlled in model 2. The association between intention to use e-cigarettes and the social environment of e-cigarette exposure was analyzed by multivariate logistic analysis among non-e-cigarette users and was also conducted after stratification by gender and school type in model 2. Adjusted odds ratios (aOR) with 95% confidence intervals (CIs) were calculated. A $p < 0.05$ was considered statistically significant. Data analysis was performed by SPSS 26.0 software (IBM, NY, USA) and R 4.1.2 software.

Results

Descriptive statistics

As shown in Table 1, 16,123 respondents were valid, and the weighted number of students in Shanghai in 2021 was 727,524. The overall weighted sample of students from junior high school, senior high school, and vocational high school accounted for 64.66% (95% CI 63.90–65.41%), 22.99% (95% CI 22.35–23.64%), and 12.36% (95% CI 12.00–12.72%), respectively. Their mean age was 14.22 (95% CI 14.18–14.25) years old. There were slightly more male students (53.11%, 95% CI 52.21–54.01%) than female (46.89%, 95% CI 45.99–47.79%), while boarding and local students accounted for 13.86% (95% CI 13.38–14.35%) and 62.92% (95% CI 62.03–63.81%), respectively. A small proportion of students (5.10%, 95% CI 4.73–5.50%) had ever smoked, and a few (1.47%, 95% CI 1.29–1.68%) were current smokers. As for e-cigarette-related behaviors, ever and current e-cigarette users accounted for 3.03% (95% CI 2.75–3.33%) and 0.97% (95% CI 0.83–1.13%), respectively. Moreover, there were more ever, and current male users (4.22%, 95% CI 3.79–4.69%; 1.48%, 95% CI 1.24–1.75%) than female users (1.68%, 95% CI 1.38–2.05%; 0.40%, 95% CI 0.29–0.57%). Meanwhile, the rates of ever, and current e-cigarette users increased in the order of junior (2.31%, 95% CI 1.96–2.73%; 0.46%, 95% CI 0.31–0.67%), senior (3.20%, 95% CI 2.72–3.75%; 1.64%, 95% CI 1.31–2.06%) and high school students (6.47%, 95% CI 5.86–7.14%; 2.42%, 95% CI 2.05–2.85%). Among all students, 6.46% (95% CI 6.06–6.89%) reported having intention to use e-cigarettes.

TABLE 1 Baseline characteristics.

	Weighted Proportion %(95% CI)	Number	Unweighted
Age (mean, 95% CI)			
	14.22 (14.18–14.25)	727524	16123
Gender			
Male	53.11 (52.21–54.01)	382773	8817
Female	46.89 (45.99–47.79)	337940	7306
School type			
Junior high school	64.66 (63.90–65.41)	466001	5888
Senior high school	22.99 (22.35–23.64)	165666	4566
Vocational high school	12.36 (12.00–12.72)	89046	5669
Boarding situation			
Yes	13.86 (13.38–14.35)	99893	4190
No	86.14 (85.65–86.62)	620820	11933
Residence			
Local	62.92 (62.03–63.81)	453482	10610
Non-local	37.08 (36.19–37.97)	267231	5513
School performance			
Top 25%	34.37 (33.51–35.23)	247689	5402
Average	47.23 (46.33–48.14)	340428	7733
Bottom 25%	18.40(17.71–19.11)	132597	2988
Monthly allowance			
Low	60.82 (59.97–61.68)	438373	7749
Medium	27.17 (26.41–27.94)	195828	5407
High	12.00 (11.50–12.53)	86512	2967
Traditional smoking status			
Never	93.43 (92.99–93.84)	673347	14821
Ever	5.10 (4.73–5.50)	36751	953
Current	1.47 (1.29–1.68)	10615	349
E-cigarette use			
Never	96.00 (95.67–96.31)	691878	15235
Ever	3.03 (2.75–3.33)	21826	649
Current	0.97 (0.83–1.13)	7010	239
Intention to use e-cigarettes			
No	93.54 (93.11–93.94)	674130	14824
Yes	6.46 (6.06–6.89)	46583	1299

Social environmental exposure

Table 2 shows students' social-environmental exposure to e-cigarettes and their stratification by gender and school type.

TABLE 2 Social environment exposure to e-cigarettes among adolescents.

	Gender					School type				
	Total %(95% CI)	Male %(95% CI)	Female %(95% CI)	χ2	*P*	Junior high school %(95% CI)	Senior high school %(95% CI)	Vocational high school %(95% CI)	χ2	*P*
SHA exposure				2.91	0.144				48.69	<0.001
No	64.93 (64.06–65.78)	64.32 (63.14–65.49)	65.61 (64.34–66.86)			66.49 (65.27–67.69)	63.97 (62.57–65.35)	58.51 (57.22–59.79)		
Yes	35.07 (34.22–35.94)	35.68 (34.51–36.86)	34.39 (33.14–35.66)			33.51 (32.31–34.73)	36.03 (34.65–37.43)	40.21–42.78		
Total e-cigarette sales exposure				19.71	0.001				83.82	<0.001
No	36.51 (35.64–37.39)	37.55 (36.36–38.75)	35.34 (34.07–36.62)			37.19 (35.97–38.44)	34.65 (33.28–36.04)	36.41 (35.17–37.67)		
One source	42.06 (41.17–42.96)	40.44 (39.23–41.67)	43.90 (42.58–45.22)			43.51 (42.25–44.78)	40.17 (38.75–41.60)	38.00 (36.74–39.27)		
Two and more sources	21.43 (20.71–22.16)	22.01 (21.03–23.03)	20.76 (19.72–21.84)			19.29 (18.31–20.32)	25.19 (23.95–26.47)	25.60 (24.48–26.75)		
Sales exposure in the malls				16.83	<0.001				6.91	0.016
No	40.15 (39.27–41.04)	41.64 (40.43–42.86)	38.47 (37.18–39.77)			40.54 (39.29–41.80)	38.37 (36.97–39.79)	41.44 (40.16–42.72)		
Yes	59.85 (58.96–60.73)	58.36 (57.14–59.57)	61.53 (60.23–62.82)			59.46 (58.20–60.71)	61.63 (60.21–63.03)	58.56 (57.28–59.84)		
Sales exposure in retail stores around school				9.71	0.010				55.93	<0.001
No	85.85 (85.19–86.49)	85.05 (84.13–85.93)	86.76 (85.81–87.66)			84.41 (83.46–85.31)	87.71 (86.73–88.63)	89.95 (89.13–90.70)		
Yes	14.15 (13.51–14.81)	14.95 (14.07–15.87)	13.24 (12.34–14.19)			15.59 (14.69–16.54)	12.29 (11.37–13.27)	10.05 (9.30–10.87)		
Sales exposure on social media				4.28	0.057				470.06	<0.001
No	85.90 (85.31–86.48)	85.37 (84.54–86.16)	86.51 (85.64–87.33)			90.25 (89.47–90.98)	78.98 (77.77–80.13)	76.03 (74.90–77.12)		
Yes	14.10 (13.52–14.69)	14.63 (13.84–15.46)	13.49 (12.67–14.36)			9.75 (9.02–10.53)	21.02 (19.87–22.23)	23.97 (22.88–25.10)		
Total e-cigarette information exposure				33.87	<0.001				153.49	<0.001
No	24.81 (24.03–25.61)	26.60 (25.52–27.72)	22.78 (21.67–23.93)			26.36 (25.25–27.50)	21.81 (20.64–23.04)	22.30 (21.23–23.40)		
One source	41.71 (40.82–42.61)	41.22 (40.00–42.45)	42.27 (40.97–43.59)			43.46 (42.20–44.73)	37.45 (36.06–38.86)	40.50 (39.23–41.79)		
Two and more sources	33.47 (32.64–34.32)	32.18 (31.05–33.33)	34.94 (33.70–36.20)			30.18 (29.02–31.37)	40.74 (39.32–42.17)	37.20 (35.95–38.47)		
Information exposure in points of sale				18.71	<0.001				10.71	0.002
No	51.64 (50.74–52.54)	53.24 (52.00–54.47)	49.83 (48.50–51.16)			50.99 (49.71–52.26)	51.69 (50.24–53.13)	54.98 (53.68–56.27)		
Yes	48.36 (47.46–49.26)	46.76 (45.53–48.00)	50.17 (48.84–51.50)			49.01 (47.74–50.29)	48.31 (46.87–49.76)	45.02 (43.73–46.32)		
Information exposure on social media				10.43	0.005				550.73	<0.001
No	62.09 (61.22–62.94)	63.24 (62.07–64.4)	60.77 (59.49–62.04)			68.65 (67.45–69.82)	51.64 (50.19–53.09)	47.17 (45.87–48.47)		
Yes	37.91 (37.06–38.78)	36.76 (35.60–37.93)	39.23 (37.96–40.51)			31.35 (30.18–32.55)	48.36 (46.91–49.81)	52.83 (51.53–54.13)		
Information exposure on traditional media				0.15	0.744				33.64	<0.001
No	62.92 (62.04–63.79)	63.06 (61.86–64.24)	62.77 (61.48–64.04)			64.05 (62.81–65.26)	58.89 (57.46–60.31)	64.53 (63.27–65.76)		
Yes	37.08 (36.21–37.96)	36.94 (35.76–38.14)	37.23 (35.96–38.52)			35.95 (34.74–37.19)	41.11 (39.69–42.54)	35.47 (34.24–36.73)		
Parents' e-cigarette use				3.69	0.109				31.16	<0.001
No	90.56 (90.00–91.08)	90.97 (90.21–91.67)	90.08 (89.25–90.86)			89.72 (88.92–90.47)	91.31 (90.45–92.09)	93.51 (92.84–94.12)		
Yes	9.44 (8.92–10.00)	9.03 (8.33–9.79)	9.92 (9.14–10.75)			10.28 (9.53–11.08)	8.69 (7.91–9.55)	6.49 (5.88–7.16)		
Friends' e-cigarette use				48.29	<0.001				1316.51	<0.001
No	81.01 (80.35–81.64)	78.99 (78.07–79.88)	83.29 (82.36–84.18)			89.22 (88.40–89.98)	67.87 (66.50–69.21)	62.48 (61.21–63.73)		
Yes	18.99 (18.36–19.65)	21.01 (20.12–21.93)	16.71 (15.82–17.64)			10.78 (10.02–11.60)	32.13 (30.79–33.50)	37.52 (36.27–38.79)		

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TABLE 3 Association between social-environmental e-cigarette exposure and adolescents' e- cigarette use and intention.

	Current e-cigarette use[a]				E-cigarette use intention[b]			
	Model 1[c] aOR(95% CI)	*P*	Model 2[d] aOR(95% CI)	*P*	Model 1[c] aOR(95% CI)	*P*	Model 2[d] aOR(95% CI)	*P*
SHA exposure								
No	Ref = 1		Ref = 1		Ref = 1		Ref = 1	
Yes	6.35 (3.95–10.20)	<0.001	2.18 (1.28–3.69)	0.004	2.68 (2.23–3.21)	<0.001	1.73 (1.40–2.14)	<0.001
Total e-cigarette sales exposure								
No	Ref = 1		Ref = 1		Ref = 1		Ref = 1	
One source	2.87 (1.52–5.43)	0.001	1.57 (0.76–3.22)	0.220	1.62 (1.28–2.04)	<0.001	1.15 (0.89–1.47)	0.284
Two and more sources	11.73 (6.68–20.61)	<0.001	5.68 (2.91–11.09)	<0.001	2.73 (2.15–3.46)	<0.001	1.55 (1.18–2.03)	0.002
Total e-cigarette information exposure								
No	Ref = 1		Ref = 1		Ref = 1		Ref = 1	
One source	1.22 (0.76–1.96)	0.403	0.97 (0.54–1.74)	0.918	1.29 (0.99–1.68)	0.062	1.16 (0.88–1.53)	0.290
Two and more sources	1.21 (0.75–1.94)	0.439	0.60 (0.33–1.07)	0.083	1.98 (1.53–2.55)	<0.001	1.39 (1.05–1.83)	0.020
Parents' e-cigarette use								
No	Ref = 1		Ref = 1		Ref = 1		Ref = 1	
Yes	9.91 (6.72–14.61)	<0.001	7.28 (4.75–11.14)	<0.001	1.99 (1.53–2.59)	<0.001	1.54 (1.17–2.02)	0.002
Friends' e-cigarette use								
No	Ref = 1		Ref = 1		Ref = 1		Ref = 1	
Yes	11.26 (6.40–19.81)	<0.001	5.44 (3.06–9.66)	<0.001	3.55 (2.92–4.32)	<0.001	2.56 (2.07–3.16)	<0.001

[a]Among all participants (N =727,524).
[b]Among non-e-cigarette users (N = 691,878).
[c]Model adjusted for gender, school type, boarding situation, residence, monthly allowance, school performance and traditional smoking status.
[d]Model adjusted for gender, school type, boarding situation, residence, monthly allowance, school performance, traditional smoking status, SHA exposure, e-cigarette sales exposure, e-cigarette information exposure, parents' e-cigarette use and friends' e-cigarette use.

Approximately 20% of students (18.99%, 95% CI 18.36–19.65%) reported having friends using e-cigarettes, and nearly 10% (9.44%, 95% CI 8.92–10.00%) had at least one parent using e-cigarettes. In addition, 35.07% (95% CI 34.22–35.94%) reported being exposed to the vapor of someone else's e-cigarette. As for e-cigarette sales exposure, most students (63.49%, 95% CI 62.61–64.36%) were exposed to e-cigarette marketing, where the rates from one source and two and more sources were 42.06% (95% CI 41.17–42.96%) and 21.43% (95% CI 20.71–22.16%), respectively. Additionally, 59.85% (95% CI 58.96–60.73%) of all students were exposed to e-cigarette sales in the malls, 14.15% (95% CI 13.51–14.81%) reported being exposed in the retail stores around school, and 14.10% (95% CI 13.52–14.69%) reported seeing people selling e-cigarettes on their social media. In terms of exposure to e-cigarette-related information, more than 70% of students were exposed, where the rates from one source and from two and more sources were 41.71% (95% CI 40.82–42.61%) and 33.47% (95% CI 32.64–34.32%), respectively. Also, there were 48.36% (95% CI 47.46–49.26%), 37.08% (95% CI 36.21–37.96%), and 37.91% (95% CI 37.06–38.78%) students who were exposed through points of sale, traditional media and social media, respectively.

When stratified by sex, results showed that female students were more likely to be exposed to sales in the malls (χ^2 = 16.828, $P < 0.001$), e-cigarette information at points of sale (χ^2 = 18.714, $P < 0.001$), and on social media (χ^2 = 10.428, $P < 0.01$). Also, males were more likely to be exposed to sales in retail stores around the school (χ^2 = 9.712, $P < 0.05$) and friends' e-cigarette use (χ^2 = 48.290, $P < 0.001$).

All kinds of social-environmental exposure to e-cigarettes differed by school type ($P < 0.05$). Additionally, the rates of exposure to SHA (χ^2 = 48.69, $P < 0.001$), e-cigarette sales exposure through social media (χ^2 = 470.06, $P < 0.001$), information exposure through social media (χ^2 = 550.73, $P < 0.001$) and friends' e-cigarette use (χ^2 = 1316.51, $P < 0.001$) increased in the order of junior, senior, and vocational high school, while the rates of exposure to e-cigarette sales in retail stores around the school (χ^2 = 55.93, $P < 0.001$), information in points of sale (χ^2 = 10.71, $P < 0.01$), and parents' e-cigarette use (χ^2 = 31.16, $P < 0.001$) decreased in the same order.

Associations between social-environmental exposure and e-cigarette use

As shown in Table 3, after adjusting for socio-demographic factors and traditional smoking status in model 1, results showed that students who were exposed to SHA, parents' and

friends' e-cigarette use, and e-cigarette sales were more likely to currently use and to express intention to use them in the future ($P < 0.01$). Moreover, greater sales exposure was related to higher odds of adolescents' intention to use. However, after adjusting for all variates in model 2, only students exposed to e-cigarette sales from two and more sources were significantly associated with current use and intention to use it ($aOR_{current} = 5.68$, 95% CI 2.91–11.09, $aOR_{intention} = 1.55$, 95% CI 1.18–2.03). Students who were exposed to SHA were significantly associated with current e-cigarette use (aOR = 2.18, 95% CI 1.28–3.69) and greater intention of using (aOR = 1.73, 95% CI 1.40–2.14). Moreover, friends' e-cigarette use was mostly associated with these e-cigarette-related behaviors ($aOR_{current} = 5.44$, 95% CI 3.06–9.66, $aOR_{intention} = 2.56$, 95% CI 2.07–3.16). Positive associations were also found between parent's e-cigarette use and students' current use and intention to use e-cigarettes ($aOR_{current} = 7.28$, 95% CI 4.75–11.14, $aOR_{intention} = 1.54$, 95% CI 1.17–2.02). With respect to e-cigarette information exposure, a positive association was only found between exposure from two and more sources and students' intention to use (aOR = 1.39, 95% CI 1.05–1.83).

Stratification of association between social-environmental exposure and e-cigarette use intention by gender and school type

When stratified by gender, female non-e-cigarette users were more likely to use e-cigarettes in the future when exposed to SHA (aOR = 2.43, 95% CI 1.78–3.32) and e-cigarette sales from two and more sources (aOR = 1.84, 95% CI 1.22–2.78). However, having friends using e-cigarettes (aOR = 2.64, 95% CI 1.97–3.55) was associated with greater intention to use e-cigarettes in boys compared to girls (aOR = 2.49, 95% CI 1.83–3.37). Also, only boys were significantly associated with intention to use e-cigarettes when exposed to e-cigarette information from two and more sources (aOR = 1.83, 95% CI 1.27–2.63) and parents' e-cigarette use (aOR = 2.64, 95% CI 1.97–3.55) (Figure 1).

As shown in Figure 2, junior high school students were more likely to use e-cigarettes when exposed to SHA (aOR = 2.02, 95% CI 1.41–2.87), e-cigarette sales from two and more sources (aOR = 1.73, 95% CI 1.07–2.79) and friends' e-cigarette use (aOR = 2.97, 95% CI 2.09–4.21). A positive association was only found between e-cigarette information exposure from two and more sources and intention to use among senior high school students (aOR = 1.67, 95% CI 1.14–2.46). Parents' e-cigarette use was only significantly associated with intention to use among vocational high school students (aOR = 2.27, 95% CI 1.50–3.43). Moreover, having friends using e-cigarettes was associated with the greatest intention to use among all students.

Discussion

This study reported social-environmental exposure and its association with e-cigarette use in adolescents from China. It was found that the social-environmental exposure to e-cigarettes among adolescents in Shanghai was not optimistic, with the rate of e-cigarette sales exposure (63.49%, 95% CI 62.61–64.36%) and the rate of information exposure (75.19%, 95% CI 74.39–75.97%) being especially high. Exposure to SHA, e-cigarette sales, and social e-smoking environment was positively associated with adolescents' current e-cigarette use. Moreover, exposure to SHA, e-cigarette sales from ≥2 sources, e-cigarette information from ≥2 sources and having a social e-smoking environment were significantly related to teenagers' intention to use e-cigarettes, while these associations differed by gender and school type.

In recent years, the Chinese government has highlighted the importance of protecting minors from e-cigarettes, and setting up relevant laws and regulations. According to "*Circular on further protection of minors from e-cigarettes*" issued by the State Administration for Market Regulation and the State Tobacco Monopoly Administration, all e-cigarette sales websites were to be shut down and e-cigarette advertisements posted on the internet withdrawn (30). However, the present study found that the rates of e-cigarette information and sales exposure *via* social media were 37.91% (95% CI 37.06–38.78%) and 14.10% (95% CI 13.52–14.69%), respectively. One study that analyzed the data from the Texas Adolescent Tobacco and Marketing Surveillance System revealed that 52.5% of students were exposed to e-cigarette-related social media in the past month (31). What's unique about e-cigarette information on social media was that they were mostly posted by individual users in various forms, such as push articles, videos, posts forwarded by friends, advertisements etc. (31), and were mostly viewed by their followers. E-cigarette users' positive comments on products on social media, the sharing of interesting e-smoking tricks, and the display of e-cigarettes as fashionable items may lower adolescents' perception of e-cigarettes as something harmful (11) and may arouse their curiosity (29), thus increasing the chances of future e-cigarette use (32). Moreover, it was found that viewing peers' posts on social media were associated with susceptibility to use e-cigarettes (33). On the other hand, the unofficial ways of selling e-cigarettes online may lead to more adverse outcomes, such as purchasing e-cigarettes of unknown origin, as well as issues with e-cigarette product control, which may cause traumatic injury due to self-exploded batteries or self-combusted assembled devices (34).

Accordingly, due to the ban on official online sales, China is now at the stage where offline e-cigarette stores are seizing the market and rapidly expanding, which leads to a high exposure rate of store sales and information. However,

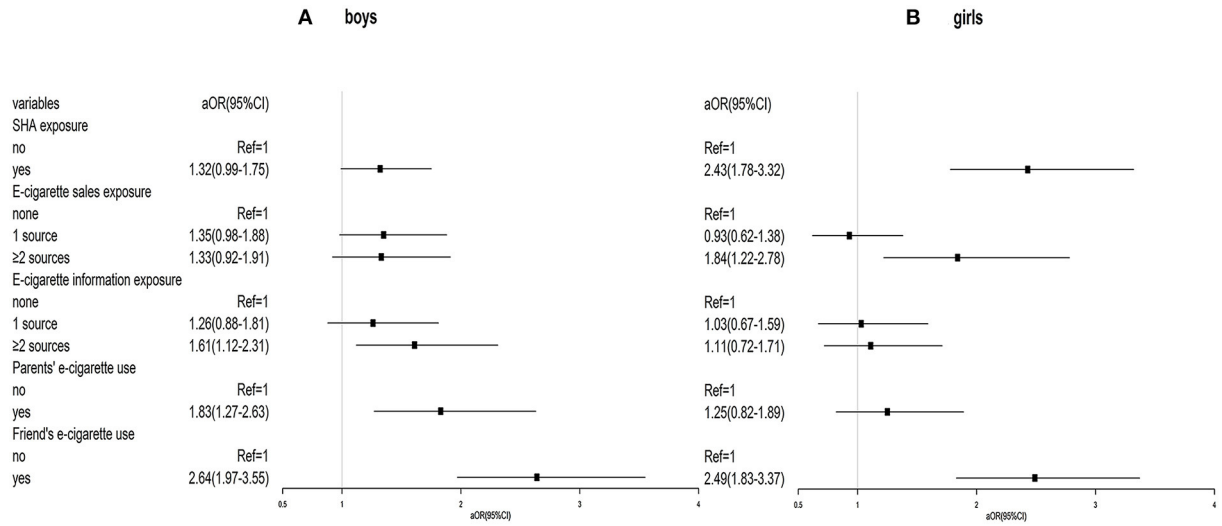

FIGURE 1
(A,B) Stratification of association between social-environmental exposure and e-cigarette use by gender.

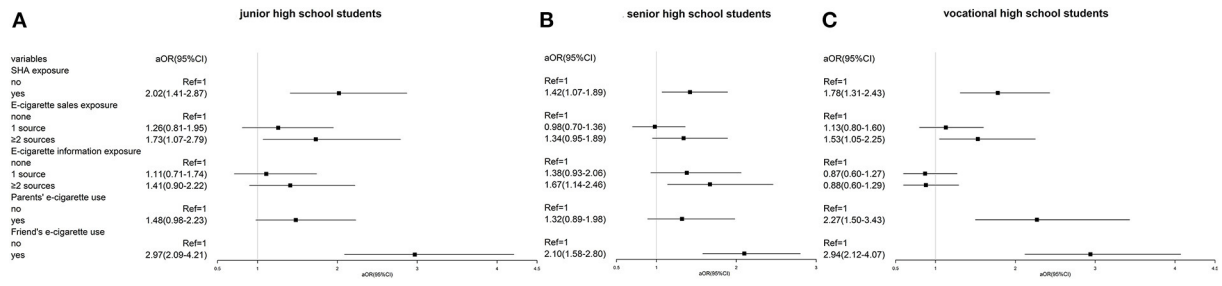

FIGURE 2
(A–C) Stratification of association between social-environmental exposure and e-cigarette use by school type.

previous research indicated that recalled exposure to point-of-sale cigarette displays and advertisements was associated with more frequent cravings to smoke (35). It is necessary to strengthen the implementation of the sign "*Minors are not allowed to buy e-cigarettes*" posted in prominent locations in stores, implement measures such as controlling age and identity cards, and strictly enforce the law, i.e., once minors are found to have purchased e-cigarettes, no matter what the reason, businesses should be punished. In addition, store location and density may also have a role in the prevention of minors from using e-cigarettes (36), as previous studies reported that frequent convenience store access and e-cigarette marketing were risk factors for e-cigarette susceptibility and initiation (37). Restricting e-cigarette shops from prominent positions in major shopping malls and reducing the number of e-cigarette vendors should also be considered. The placement of e-cigarettes at stores has been rarely discussed in China. However, a few states in America have issued legislation prohibiting the self-service of e-cigarettes (38). Regulatory efforts to control the placement of e-cigarettes, thus limiting youth exposure, such as requiring products to be placed in clerk-assisted locations, should be examined (39). As for exposure to e-cigarette sales around the school, the newly revised "*Law of the People's Republic of China on the Protection of Minors*" has established that there should be no e-cigarette retail stores around schools (40). This measure may have a certain effect; however, it does not specify the specific distance and store density, e.g., "Shops selling e-cigarettes are not allowed within 100 meters of the primary and secondary schools" in Beijing's tobacco control regulations can be a reference for consideration (41). The establishment of tobacco control regulations nationwide and the improvement of minors' protection laws are also needed. Moreover, our results showed that the risk of having the intention to use e-cigarettes was relatively higher in students exposed to e-cigarette sales and

information from two and more sources, suggesting that more comprehensive e-cigarette management policies are needed to minimize youth exposure to e-cigarette sales and information.

In the present study, we also identified adolescents' social e-smoking environment, showing that the rates of adolescents having parents' and friends' using e-cigarettes were 9.44% (95% CI 8.92–10.00%) and 18.99% (95% CI 18.36–19.65%), respectively. However, previous studies found that 42.4% (42) and 19.2% (43) of American youth reported having friends and parents who were using e-cigarettes. Consistent with earlier research, parents' and friends' e-smoking was significantly associated with adolescents' current e-cigarette use and may elevate the risk of intention to use among never users (43). It is possible that parents' and friends' use and positive attitude may be interpreted as social approval and permissive norms on e-cigarettes, leading to their use without fear of repercussions (42). As for SHA, the exposure rate in this study was 35.07% (95% CI 34.22–35.94%), which was higher than in American youth in 2019 (16). Additionally, SHA, which can lead to death by asthma, lower respiratory infections, and ischemic heart disease (44), is not only harmful to the overall health but may also elevate adolescents' susceptibility to use e-cigarettes (16). Given that regulations on e-cigarettes are relatively loose in China, potential increase for e-cigarette use among Chinese adolescents should be considered.

Similar with what was like among adults (45), the rates of ever and current e-cigarette users among boys were higher than those among girls in our study. Moreover, they were more likely to have friends using e-cigarettes and have intention to use it after being exposed. Therefore, tobacco control education and peer intervention for male students are of great importance. However, unlike traditional cigarette enterprises, females are the main target of e-cigarette marketing. The current e-cigarette use rate (0.4%) among the girls in this study was much higher compared to females aged 15–24 (0.1%) (45), while that rate among boys (1.5%) who were current e-cigarette users was lower than in males aged 15–24 (2.7%) (45), which suggests that preventing e-cigarette use among teenage girls is of crucial importance. Our results revealed that the rates of e-cigarette sales in the malls and information exposure were significantly higher among girls than boys, which is consistent with the findings in other countries. For example, Canadian females were more likely to be exposed to e-cigarette tricks on social media (46) and a significant higher prevalence of exposure to any e-cigarette advertisement was found among American girls than boys (47). Moreover, girls expressed greater intention to use e-cigarettes when exposed to sales from two and more sources. Thus, specific efforts should be made to lower their exposure to e-cigarette sales and information. For example, in addition to banning stores from selling e-cigarettes to female minors, it should also be considered not allowing e-cigarette stores to be set up on the girls' clothing floor of the shopping malls. E-cigarette advertising should not be allowed to use colorful and fashionable images, to set girls-targeted themes (e.g., "girls' night"), and to feature slim, sexy and attractive female models. Meanwhile, though no difference was found in exposure to SHA between genders, girls exposed to SHA were much more likely to use e-cigarettes. Previous research also found that among non-e-cigarette users, girls were more likely to be susceptible (46). Thus, there might be more female e-cigarette users in the future without proper intervention, which also calls for more attention on lowering girls' social environment exposure to e-cigarettes to prevent their use.

Social-environmental exposure to e-cigarettes also differed among adolescents of different school types. Students from vocational high schools were more likely to be exposed to friends' e-cigarette use, SHA, e-cigarette sales, and information exposure through social media. This may be related to the lower academic pressure and less strict school management. Special attention should be paid to the establishment of smoke-free schools in vocational high schools. Additionally, parents' and friends' e-cigarette use were the most relevant to vocational high students' intention to use e-cigarettes. Offline exposure, such as sales and information exposure in retail stores around the school, was found to be higher among junior high school students, which might be because younger adolescents are less likely to be allowed to use electronic devices, thus becoming the target of offline marketing. Moreover, students from junior high school were more likely to use e-cigarettes in the future when exposed to SHA, e-cigarette sales from two and more sources, and friends' e-cigarette use, which might be because younger teenagers are more likely to use to be influenced by their surroundings. E-cigarette exposure interventions should have different priorities for different types of school students. For example, intervention on vocational high school students should focus on their social e-smoking environment, and measures on lowering junior high school students' offline e-cigarette exposure should be promoted.

There are several limitations in the present study. First, data were self-reported and are subject to recall bias; thus, the rates of adolescents' social environment exposure to e-cigarettes may be under- or over-estimated. Second, since this was a cross-sectional study, a causal relationship could not be inferred. However, the odds ratios presented in this study remained significant after controlling for all variates, which strongly predicts adolescents' intention to use e-cigarettes when being exposed to such a social environment. Longitudinal data are critically needed. Third, as e-cigarette information exposure was assessed by a single item, unmeasured confounders or mediators might be neglected (e.g., level of social media use, pro or con of e-cigarettes conveyed by the information). Finally, the data from this study are representative of social environment exposure to e-cigarettes in Chinese urban cities, but not the overall situation in China. Nevertheless, Shanghai is the most economically developed mega-city in

China, where adolescents are more likely to be exposed to new and fashionable products; therefore, prevention and control in Shanghai can provide a reference for other cities and regions.

Conclusions

Overall, this study found that social-environmental exposure to e-cigarettes was high among adolescents in Shanghai, China. Exposure to SHA, e-cigarette sales from ≥2 sources, e-cigarette information from ≥2 sources and having a social e-smoking environment were related to their intention to use e-cigarettes. Moreover, more attention should be paid to girls, and relevant intervention measures should be tailored based on different priorities for different types of school students. Since e-cigarette is unsafe to adolescents and may lead to traditional smoking, comprehensive tobacco control policies, including efforts to prevent youth exposure to SHA, e-cigarette sales, information, and social e-smoking environment, should be made to prevent e-cigarette use among youth.

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 Ethics Committee of the School of Public Health, Shanghai Jiao Tong University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JZ and WL conceived and designed the study. LD and JZ analyzed the data. LD, JW, and WL drafted the manuscript. WL, LZ, and JZ collected the data. All authors contributed to revise the paper and approved the final 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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Margaret Anne Defeyter,
Northumbria University,
United Kingdom

REVIEWED BY
Stephanie DeBoor,
University of Nevada, Reno,
United States
Daryl VanderWilt,
Iowa Center, United States

*CORRESPONDENCE
Brad Richardson
brad-richardson@uiowa.edu

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Improving curriculum delivery: Using a results informed quality improvement model for teen behavioral health education

Gregory Gross[1,2], Rui Ling[1] and Brad Richardson[1]*

[1]National Resource Center for Family Centered Practice, University of Iowa School of Social Work, Des Moines, IA, United States, [2]Brown School, Washington University, St. Louis, MO, United States

Adolescence is a critical developmental stage to establish healthy decision-making processes and behavior patterns. Many interventions such as evidence-based curricula have been implemented to guide adolescents to avoid risk-taking behaviors and improve health and medical knowledge and outcomes. This study presents a participatory approach informed by the three-stage (3S) quality improvement process model to improve the quality of curriculum delivery, based on the results indicating outcomes achieved, needs for improvement, and quality assurance for maintaining the expected outcomes of an evidence-based curricula. Tests were conducted before and after the intervention. Using threshold levels and measures of change in the tests, instructors participated in guided discussion and analysis of the data to identify where and how instructional improvements should be made and where outcomes were being achieved as expected. This method was used to diagnose variation in the results and delivery and identify root causes informing actions to improve curriculum delivery and outcomes. After the facilitated discussions, pre- and post-tests from subsequent classes were analyzed. The results showed improved test item scores ranging from 2 to 69.5% and seven of 18 items obtained statistical significance following the implementation of the model described. Overall, an increase in the mean percent correct of 17.1% was found.

KEYWORDS

continuous quality improvement, behavioral health education, three-stage (3S) quality improvement process model, participatory approach to improving instruction, curriculum delivery, improving outcomes of instruction

Introduction

Adolescence is an important developmental stage to establish healthy decision-making processes and healthy behavior patterns (1). However, according to the 2017 Youth Risk Behavior Surveillance (YRBS) Report (2), many high school students are engaged in risk-taking behaviors, such as unsafe driving, substance use, unprotected sex, and unhealthy diet, which are associated with premature mortality, morbidity, and social problems among persons aged 10–24 years in the United States (2). Adolescent use of tobacco in the United States, including nicotine-containing electronic vapor products,

continues to increase in 2019 (3, 4). Sexual risk-taking behavior like unprotected sex or multiple partners relates to unexpected pregnancy, sexually transmitted infections (STIs), mental health, academic attainments (5, 6). From the YRBS report, only 53.8% of the respondents who are sexually active reported using a condom during their last sexual intercourse (2). Youth account for about 50% of the STIs cases in the United States (7, 8).

To help adolescents be aware and avoid risk-taking behaviors, numerous methods have been applied or discussed (6, 9). Some focused on school-based or group-based activities to promote risk avoidance (9–13), while others focused on relationships with parents or other trusted adults to affect decisions about risk-taking behavior (14–16). We also found digital intervention that aimed to target individual decision-making skills to promote healthy behaviors (17–19). Moreover, a variety of curriculum evaluation models were developed and used in the past few decades to look into the outcomes of the school-based education. A mini-systematic review in 2020 presents seven different models and frameworks for curriculum evaluation, including the CIPP Model, the Four-Level Model of Learning Evaluation, and Philips' Model of Learning Evaluation (20–23). The CIPP Model first developed by Stufflebeam has been used by researchers in a wide range of contexts worldwide, looking at the overall education process and outcomes (21, 24–26).

While extensive effort is involved with developing interventions and evaluation of the outcomes of curricula from a macro point of view, relatively little attention is given to the means of improving delivery process quality based on outcomes and assessment data (27). Quality improvement of intervention could be another trajectory to achieve the goal of improving adolescent health.

Quality improvement has been utilized in other fields for a long time, and the use of it in health instruction can be traced to at least the 1990s (28, 29). In healthcare, quality improvement was defined as a continuous process to improve the efficiency, effectiveness, outcomes, or other indicators of quality in a program, leading to achieving the aims of health equity and community health improvement (29, 30). Three essential features of continuous quality improvement (CQI) were identified in a systematic review, including "systematic data-guided activities," "designing with local conditions in mind," and "iterative development and testing process" (31). The benefits of CQI on improving the health outcomes remain unclear (28), but we do see positive outcomes from some of the CQI studies. Doherty et al. studied a participatory quality improvement intervention to improve the coverage of a mother-to-child transmission prevention program in South Africa which resulted in great improvements in the program indicators (32). Iyengar et al. reported substantial improvement in adherence to childbirth practices after implementing a quality improvement intervention in India (33).

This present study is a natural experiment with an iterative participatory quality improvement model designed to aid delivery of an adolescent behavioral health curriculum using pre- and post-tests. The purpose of the study is to demonstrate a CQI model using the results to inform curriculum delivery based on a multi-site implementation of a teen behavioral health education curriculum. The study was also designed to meet one of the goals for the Office of Population Affairs which was to increase the quality of program delivery intended to improve gains in student knowledge.

Powerful Choices (34) is a curriculum designed for school-based delivery to promote decision-making for healthy choices, avoid risky behaviors, and promote positive attitudes, protective factors, and behavioral intentions. The curriculum includes 10 sessions: wisdom, awareness, friendship, control, courage, knowledge, boundaries, excellence, ambition, and success. All curriculum instructors received training from the curriculum developer. The primary focus of the curriculum is to teach good decision-making and avoid risk behavior that could lead to negative consequences, including unintended pregnancy. For evaluation purposes, a survey was administered to students who participated in the classes before and after the curriculum. Knowledge of key content was gathered using an 18-item instrument, authored with the developer, piloted, revised, and tested for validity prior to implementation.

Models and methods

Three-stage quality improvement process model: Results, diagnosis, and focus for improving the results

The 3S quality improvement process model (Figure 1) was designed and used to improve the delivery quality of the Powerful Choices curriculum. It is a participatory CQI model that values the dissemination of the results to inform delivery improvement. The model includes three stages: preparing and presenting the results, diagnosis, and improving the results. The core element of the model is the qualitative facilitated discussion of the results and their interpretation held in the second stage, which provides the opportunity for skilled evaluators to facilitate reflective discussions of the results with instructors focusing on how the results "fit" with the classroom experience. The first stage starts before the discussion when the evaluation team prepares the results in a format that is understandable and easy to follow and performs preliminary analysis summarized in a brief written statement to guide the discussion (see, e.g., Tables 1, 2). This discussion should happen soon after the team has evaluation results available (e.g., in the week following the completion of instruction). During the discussion, the facilitator first describes the results

and the summary of each item to make sure the instructors have a good understanding of what the data show. In the second stage, evaluators facilitate discussion to help diagnosis what might account for scores that are lower than desired guided by the three basic results scenarios which guide the identification of planned action. The three scenarios are described below:

- Scenario one: In a situation in which there is a high percentage correct at pre-test. Although the purpose of validating the instrument through the piloting process should lead to relatively low correct percentages at baseline (pre-test), a high percentage of correct pre-test answers may indicate that the content is generally known and a detectable difference at post-test would be difficult to obtain. It could also indicate that choices in the response set require revision because the correct answer is easily identified prior to participation in the delivery of the curriculum.
- Scenario two: The second commonly encountered result is higher than the desired number of incorrect responses due to static, or no change in responses (e.g., students "stick with" their original answer). This can be seen when the percentages at pre-test and post-test for each response are nearly the same. The discussion focuses on what may be happening in the delivery that is not clearly providing information consistent with the correct answer or maybe meeting resistance.
- Scenario three: The third scenario is where an incorrect response is chosen on the pre-test, and on post-test a different but incorrect choice is selected. This can be seen in a table where, for example, if 20% choose one incorrect response on the pre-test and on the post-test, a substantial number from the 20% consistently chose another incorrect response.

After diagnosis, a more in-depth discussion is facilitated to discover the root cause based on the information at hand including the guidance offered by the scenarios from the diagnosis, identifying the source of the problems (35, 36). It starts from the problems diagnosed at the last step and continues with asking why it happened until the group reaches agreement about the root cause. Lastly, the discussion focuses on action planning[1] to improve the results based on the information already discussed crucial for identifying underlying reasons including curriculum content, delivery process, and the instrument used for assessment.

Procedures

During the 2018–2019 and 2019–2020 school years, the Powerful Choices curriculum was delivered in eight school districts. Students participating in the Spring lessons completed a knowledge pre-test in the beginning session of the Powerful Choices lessons and completed a knowledge post-test at the end of the last session (Group 1). Data were analyzed by the evaluation team, and a summary of the results was written for each set of pre- and post-test comparisons for the discussion with instructors and the curriculum developer. Evaluators guided the discussion using the three-stage (3S) quality improvement model (Appendix 1). A table for each of the 18 questions on the pre-test and post-test was produced to show the number and percentage for each response category on each test item in a pre-test by post-test table. Highlighted rows (pre-test) and columns (post-test) provide data visualization of correct answers for easier interpretation. Each table included a brief narrative describing the distribution of responses including meaningful changes observed among response items for each question.

Following the completed delivery of instruction in Spring 2019, the facilitated discussion was held with five instructors and the curriculum developer to review the results and identify strengths, and areas for improvement based on the data. The discussions were facilitated by the evaluation team guided by the 3S quality improvement model:

- Results: review tables and narratives, facilitated discussion, and consensus on the results.
- Diagnosis: using three results scenarios to guide decision-making about the results.
- Focus to improve results: root cause analysis and consensus (curriculum content, curriculum delivery, and instrument) determining actions for improvement (see footnote 1).

The facilitated discussion takes about 1 h. During the discussion, the facilitator started with a brief introduction about the purpose and the agenda of the meeting, followed by the discussion of each of the 18 sets of questions. For each question, the facilitator first reviewed with instructors the tables and brief narratives describing the comparative results in the table showing the pre- and post-test results by response selected and percent correct at pre- and post-test. Next, the facilitator allowed for some reflection on the results and used the three scenarios in the diagnosis portion

1 The action planning step in the model is similar to process improvement methods such as before and after action reviews, AARs and BARs: the Plan-Do-Study-Act model, Implementation Science, Six Sigma, or any of several other process improvement methods that involve group decisions for next steps; however, unlike this model, those do not begin with systematically gathered longitudinal data.

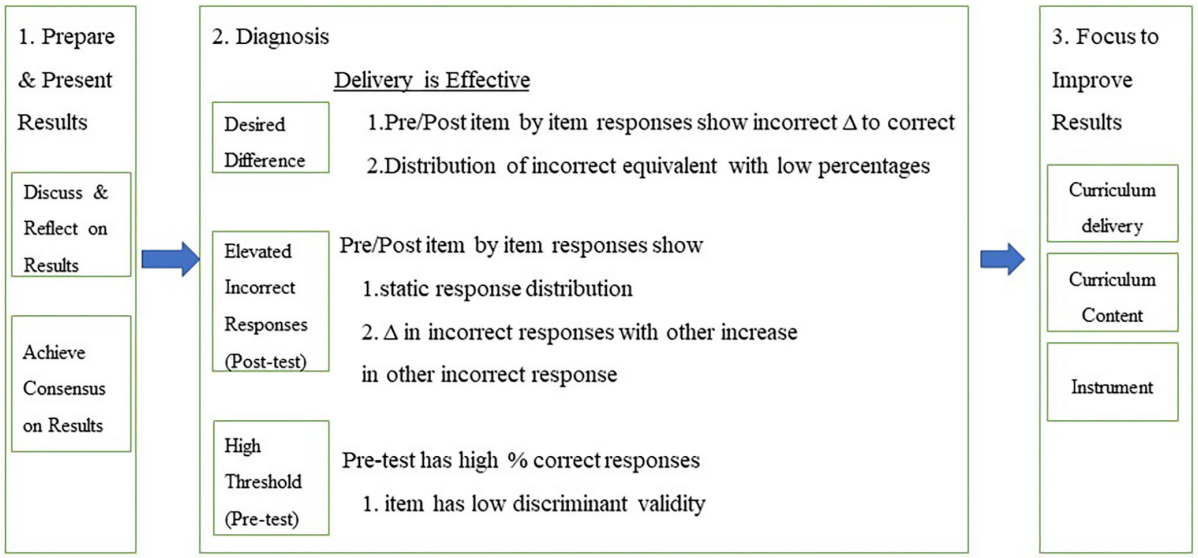

FIGURE 1
Three-stage quality improvement process.

of the model to guide the discussion of reasons for changes on each item. For those items with the post-test results of <70% correct, the discussion focused on the root cause and corrective action that could improve the delivery process so that students could better understand the curriculum content. The instructors started classes in the 2019–2020 school year with the planned actions. Another group of students participated in the Powerful Choices Fall classes during the 2020–2021 school year as referred as Group 2. The same pre- and post-tests were administrated before and after the classes. The comparison analysis of the two groups was done after the classes.

Data

Data were collected using student input into an electronic survey application at the conclusion classroom delivery of Powerful Choices in eight midwestern school districts. The eight school districts were similar in size, location in the state, and general characteristics of students attending. Students were asked to take the 18-item knowledge test prior to the beginning of the first instructional session (pre-test) and at the conclusion of the final instructional session (post-test). Parental permission was obtained by the program for student participation in the program and study. Tests were de-identified by the use of a respondent code known only to the student and school district teacher (not the curriculum instructor). The current analysis used a de-identified dataset and given the nature of identity protection and data security, The University of Iowa Institutional Review Board determined that the project did not meet the federal definition of human subjects' research and issued a Human Subjects Research Determination letter to that effect.

Measures

Demographics

Demographic information included sex, grade level, school, race, and ethnicity.

Curriculum knowledge

An 18-item (Appendix 2) knowledge test was designed with the curriculum developer based on key curriculum content. Students could answer the 18 questions by selecting one of four response options for each question. The validity and reliability of the instrument were tested with the developer as the trainer. Testing was conducted based on a pilot set of four classes. The instrument was revised with the curriculum developer and tested a second time with a different set of classes. Refinement of the instrument was based on internal consistency reliability and percent correct for each knowledge content item. The post-test instrument included satisfaction items and was otherwise identical to the pre-test.

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TABLE 1 Initial (pre-test) by follow-up (post-test) knowledge test item (Group 1).

Initial		To have the most successful life a person should? Follow-up A.	B.	C.	D.	Initial Totals
A. Finish high school, get a good job, not have children before marriage.	Count	67	5	7	4	83
	% of Total	38.7%	2.9%	4.1%	2.3%	48.0%
B. Remain single, go to college, get a good job.	Count	7	9	1	1	18
	% of Total	4.1%	5.2%	0.6%	0.6%	10.4%
C. Get a good job, pay all bills on time.	Count	21	2	4	6	33
	% of Total	12.1%	1.2%	2.3%	3.5%	19.1%
D. Get a job that I like and that pays well.	Count	23	3	7	6	39
	% of Total	13.3%	1.7%	4.1%	3.5%	22.5%
Follow-up totals	Count	118	19	19	17	173
	% of Total	68.2%	11.0%	11.0%	9.8%	100.0%

The follow-up assessment obtained 68.2% correct compared to the initial 48% correct for choice "A," the correct response. The greatest improvement from initial assessment to follow-up was the choice "D" with less than half of the students who had selected this response initially choosing the incorrect response at follow-up. Choice "B" is the area of opportunity as 18 students chose the response incorrectly initially and 19 students (11.0%) chose the response at follow-up. In addition, while there was a decrease in the number of students selecting "C," 19 students still chose the response incorrectly at follow-up.

Analysis

Data were analyzed using SPSS 27. Crosstabulation tables were created to compare pre-test to post-test responses for each item for each of the two groups. Tables were post-processed to highlight the row (pre-test) and column (post-test) with the correct answer. Missing data were excluded by test item ("pairwise deletion"). To determine whether significant differences were obtained, correct responses were coded 1 and incorrect responses were coded 0 resulting in the mean score and the percent correct being virtually the same number. *T*-tests were calculated to determine the statistical significance of differences. Of interest to the program was the achievement of 70–80% correct at post-test; therefore, we also examine the percentage of correct responses on the post-test.

Results

Three-stage quality improvement process

To prepare for the facilitated discussion, pre-test by post-test tables of responses for each of the 18 items of the instrument were created for review. A typical example of information provided to instructional staff for the facilitated discussion is presented in Table 1 below. The column labeled Initial Totals (far right column) shows the number and percentage of participants choosing each answer at pre-test. The row labeled Follow-up Totals (bottom row) shows the number and percent choosing each answer at post-test. The correct response is highlighted (e.g., Answer A in Table 1) for each test question. Overall, 118 (68.2%) chose A on the post-test compared to 83 (48.0%) who chose A on the pre-test; this is an increase of 20.2%.

With the presentation of the results to the instructors, the evaluation team facilitated discussion of each question comparing pre-test and post-test responses. Following the discussion of the results and achieving a consensus or common understanding of those results, instructors were asked what they thought could account for the change in responses, and what could be improved to achieve a higher percentage of correct responses (i.e., change of delivery, curriculum content, or test question and response items). The discussion of each test question and responses followed this general procedure. The discussion of all 18 items took about 1 h.

To provide an example of the discussions that take place, we provide a typical discussion that took place leading to the identification and adoption of strategies for improvement.

> *Example from one facilitated discussion:*
> *Evaluator: For this question there was a 20 percent increase in correct responses at post-test. However, 32% still chose one*

TABLE 2 Initial (pre-test) by follow-up (post-test) knowledge test item (Group 2).

Initial		To have the most successful life a person should? Follow-up A.	B.	C.	D.	Initial totals
A. Finish high school, get a good job, not have children before marriage.	Count	80	4	1	0	85
	% of Total	44.9%	2.2%	0.6%	0.0%	47.8%
B. Remain single, go to college, get a good job.	Count	11	6	2	1	20
	% of Total	6.2%	3.4%	1.1%	0.6%	11.2%
C. Get a good job, pay all bills on time.	Count	21	0	3	3	27
	% of Total	11.8%	0.0%	1.7%	1.7%	15.2%
D. Get a job that I like and that pays well.	Count	34	1	0	11	46
	% of Total	19.1%	0.6%	0.0%	6.2%	25.8%
Follow-up totals	Count	146	11	6	15	178
	% of Total	82.0%	6.2%	3.4%	8.4%	100.0%

The follow-up assessment obtained 82% correct compared to the initial 47.8% correct for choice "A," the correct response. The dramatic improvement in the correct responses at follow-up accompanies consistently low frequencies of incorrect responses across all incorrect response options at follow-up demonstrating an example of the desired improvement and suggests effective curriculum delivery.

of the incorrect answers. While the results show improvement in number and percent of correct responses between pretest and posttest, the overall percent correct at post-test is still lower than the conventional target of 70–80% target correct. What might account for difference and how could it be further improved?

Instructor 1: Well, that's one of the lessons that I struggle with, students don't seem to grasp that part as well as other lessons.

Instructor 2: I agree. They seem to come in with a lot of preconceived ideas that are hard to change with our instruction.

Instructor 3: Exactly! The incorrect answers they chose are not necessarily wrong, it's just that they are not all are relying on what was taught but their attitudes about things that they held before attending the class. That isn't the best way to build a strong foundation for your life.

Evaluator: That's a good point. Looking at the results, there are about 11% who stayed with the same answer even though it was not the correct answer: 9 (5.2%) stayed with B, 4 (2.3%) stayed with C, and 6 (3.5%) stayed with D. Thinking about the possible reasons, sources or causes of these results, would you say it is more due to the curriculum, or more due to how it is being delivered?

Instructor 1: Oh, this one definitely fits in curriculum delivery. I know there's got to be a better way to present this material, so the students understand that not having children before marriage is a key to finishing school and getting a good job.

Evaluator: Is there a similar challenge where you have discovered students not completely getting what you're telling them, and it shows up later? What have you done and how might that apply here?

Instructor 2: Similar to one of the one we talked about earlier questions we talked about being sure to say it a second time and ask a question so that students say the words together so that is "sticks."

As shown from the example conversation above, the evaluator facilitated discussion helping guide the instructors in exploring the reasons why any specific item may have been challenging for students based on the test results. The table of the results made it easy for instructors to see the responses and offer their perspectives from their experience teaching the students. In the example, two specific reasons were identified: (1) students come into the class with preconceived ideas that are hard to change; and (2) difficulty choosing the one correct answer according to the curriculum when the other options are not necessarily wrong, but less relevant. To address the problem, instructors proposed to enhance students' understanding and memories related to the questions by repeating the curriculum content. Also, having more interaction with students during the lectures to help students grasp the main idea the question was capturing that "not having children before marriage is a key to finishing school and getting a good job."

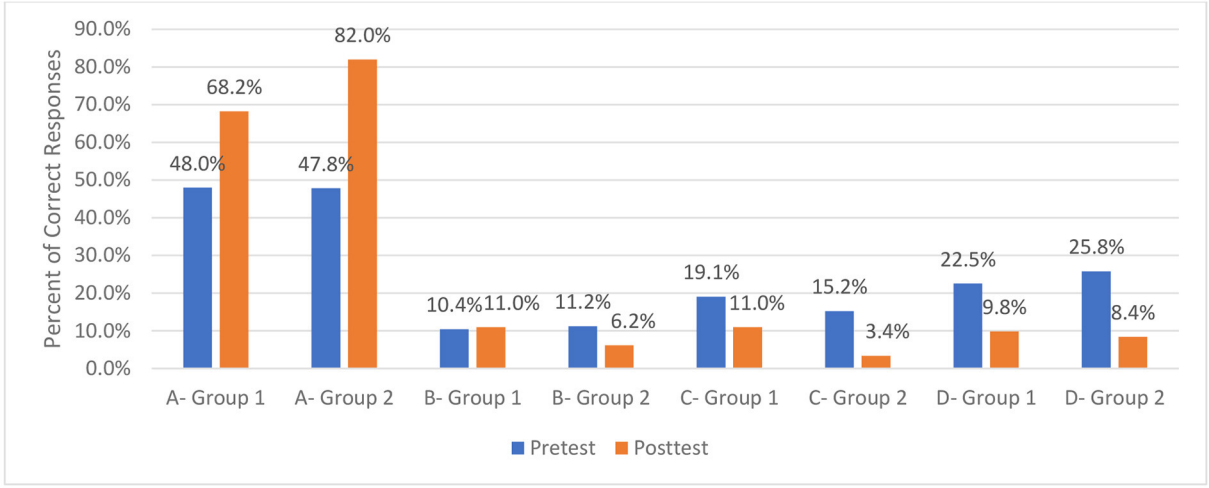

FIGURE 2
Percent corrected by response category (Group 1 compared to Group 2). Response categories for two groups (Group 1 Response A, Group 2 Response A, Group 1 Response B, Group 2 Response B). Response A is the correct answer.

Comparison of two groups

A total of 351 7th- and 8th-grade students participated in Powerful Choices and completed the instruments. Of the 173 students in Group 1, 55.5% were boys, 52% were in 7th grade, and 91% were white/Caucasian. Of the 178 students in Group 2 who participated in Powerful Choices classes in Fall, 2019 (after the facilitated discussion and improvement strategies were implemented), 53.9% were boys, 47.8% were in 7th grade, and 94%, were white/Caucasian.

Table 2 presents the results from the same question presented in Table 1 (To have the most successful life a person should?), but the results in Table 2 reflect the adjustments to instruction made in delivering the curriculum to Group 2 based on the facilitated discussion from Group 1. The percent correct at pre-test for Group 2 in Table 2 (47.8%) is nearly identical to the percent correct for Group 1 in Table 1 (47.9%) indicating similar knowledge levels at pre-test; however, the percent correct at post-test increased to 82% for Group 2 compared to 68.2% in Group 1.

Figure 2 illustrates the distribution differences for each of the response categories (Table 1 compared to Table 2; Group 1 is labeled Cohort 1, and Group 2 is labeled Cohort 2). Comparison of percentages for Response A, the correct answer, is typical of what many programs use as the only measure of assessing effectiveness (percent correct); however, such comparisons do not provide the level of detail needed to assess specific response by response "movement" from pre-test answer to post-test answer that the tables we use provide.

The analysis of the results shows changes for each response (pre-test and post-test) on the instrument for those participating in classes before adjustments were made based on the facilitated discussion, and after adjustments were made before delivery of the curriculum to Group 2. The results of the improvement across all 18 items of the instrument are presented in Table 3. Table 3 presents the percent correct at post-test by question for the two groups. Overall, increases in the percent of correct responses at post-test were found on 16 of the 18 items. Statistically significant improvement in the percent correct was found for seven items ($p. \leq 0.05$). Perhaps more importantly, at post-test for Group 2, 10 items reached a 70% correct threshold, and seven items reached an 80% correct threshold.

Discussion

In this study, we introduce a three-stage process using tables of responses to questions before (pre-test) and after (post-test) participating in a course of instruction using a curriculum titled Powerful Choices. The results demonstrated improvement on the post-test results among participants following the facilitated discussion of the results with instructors. Taken together, the results from this study demonstrate an effective approach for improving curriculum delivery and using the results to engage instructors in examining how they may contribute to achieving improved effectiveness for learning content by students in their classes. The analysis of root cause discussions leads to one of

TABLE 3 Percent correct at post-test by group and *t*-test of significance between groups.

Instrument questions	Percent correct, Group 1 ($N = 173$)	Percent correct, Group 2 ($N = 178$)
K1. When I need to make an important decision I would?	61.9	72.7
K2. Gaining positive relationships is experienced best by?	13.1	82.6*
K3. The best way to develop a close friendship is?	68.0	70.2
K4. How do I avoid behavior that could have a negative consequence for me?	74.9	80.9
K5. What makes people successful in life?	73.0	86.5
K6. How can you avoid bad habits?	53.4	94.9*
K7. What would you do if a person from your class spread a rumor about your close friend on social media?	28.7	64.6*
K8. Wisdom is best gained by which of the following?	59.1	91.6*
K9. According to Powerful Choices lessons, when is the best time for a person to become sexually active?	30.7	46.3
K10. Accepting the challenge of thinking before acting helps a person to?	35.3	52.0*
K11. How can you build a strong foundation for your life?	63.0	67.6
K12. The use of drugs and alcohol have the strongest effect on?	57.7	63.1
K13. What does a person need to do to make good decisions for the future?	56.8	65.7
K14. Making a good decision is a result of?	74.3	77.3
K15. Taking Powerful Choices lessons results in?	13.4	80.9*
K16. To have the most successful life a person should?	68.2	82.0*
K17. How do you show your friend that you care when they make mistakes?	69.1	48.3
K18. How can you be a positive role model?	60.6	42.1

*p. < 0.05.

three categories for revision: curriculum delivery, curriculum content, or the instrument measuring knowledge (attribution to the instrument tends to fade as an explanation after the instrument is piloted and used in practice a time or two). The model was designed to be an iterative process because of the reality of drift in curriculum delivery fidelity and effectiveness. The model is a reset strategy that is engaging and improves fidelity and effectiveness. Using the three-stage quality improvement process, program evaluators and instructional staff working together are well-positioned to track the results and use the model to facilitate the discussion for ongoing assessment of effectiveness and improvement in curriculum delivery. Programs early in their development will identify more revisions. As programs develop and mature, the curriculum and testing become more "standardized" as part of the organizational culture. Delivery may stand out as the primary mechanism for improvement as programs mature; however, the discussion of causes and strategies for improvement remains key for highly effective instruction.

The results suggest that the use of full information from responses and using pre-tests and post-tests, not post-tests alone, is important for identifying factors to consider in the discussions of root causes and is an effective approach to improve curriculum delivery. Deming emphasized that it was important to study, reflect on the data, and from that take actions to improve the program (27). The process is one of a continuous feedback spiral toward continuous improvement. The process described here is participatory involving instructional staff. It is also highly efficient in terms of time and engages all involved in data-guided discussion to focus instructors on their accounts of what may underlie the results and how instruction could be adjusted to improve the results. In fidelity monitoring, observations are typically only conducted on a subset of lessons, and the focus is on the process, not the results. The model described in the present study helps instructors see across all of their lessons, helps illuminate blind spots that may exist, and engages and assists instructors in identifying what modifications could best improve curriculum delivery.

Limitations

The positive results support the benefit of using the three-stage quality improvement model. The results were derived

from a natural experiment without the benefit of a comparison or control group which is necessary for more robust findings. Without the benefit of a control group, the effect of other factors that could account for improvements in knowledge scores is not known. Also, given the nature of the natural experiment, notes rather than verbatim documentation of the discussions providing qualitative data were identified as a limitation. An example of the discussion was presented to demonstrate an example of the way in which the discussion was guided. Further investigation using a more rigorous study design and documentation, and preferably a randomly controlled trial to replicate the process, is needed to further support the model by comparing the results under the two conditions.

Conclusion

The results of the present study suggest the three-stage quality improvement process model used to improve the quality of the Powerful Choices curriculum is feasible and effective. It is a practical, data-driven approach that enables program evaluators to engage instructors in a participatory approach to improving practice, based on item-by-item comparisons, and to improve and maintain the quality of curriculum delivery. The approach is not limited to any specific curriculum and may be broadly applied to curriculum delivery programs in which the instructors and researchers combine to achieve quality improvement.

Data availability statement

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

Ethics statement

Ethical review and approval was received through an IRB human subjects research determination finding IRB was not required for the study on human participants in accordance with the local legislation and institutional requirements. The legal guardian/next of kin provided their informed consent for participation in this study.

Author contributions

Study conception, design, analysis and interpretation of results, and draft manuscript preparation: GG, RL, and BR. Instrument validation and data collection: GG and BR. All authors wrote, reviewed the results and approved the final 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.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.965534/full#supplementary-material

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EDITED BY
Gyulli Kazakbaeva,
Ufa Eye Research Institute, Russia

REVIEWED BY
Zheng Kang,
Harbin Medical University, China
Miaomiao Zhao,
Nantong University, China
Xuejing Bi,
Harbin Medical University, China
Hanping Shi,
Beijing Shijitan Hospital, Capital Medical University, China

*CORRESPONDENCE
Chichen Zhang
zhangchichen@sina.com
Zuguo Qin
153350362@qq.com

†These authors have contributed equally to this work

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Effects of physical activity and use of digital devices on visual acuity in children and adolescents during the COVID-19 pandemic: A cross-sectional study

Xiao Zheng[1,2†], Lei Shi[2†], Weiyan Ou[2], Yaqing Xue[2], Ying Xu[3], Benli Xue[2], Jiachi Zhang[2], Pengyan Liang[4], Wei Huang[4], Zuguo Qin[4*] and Chichen Zhang[1,2*]

[1]Department of Health Management, Shunde Hospital, Southern Medical University (The First People's Hospital of Shunde, Foshan), Foshan, China, [2]School of Health Management, Southern Medical University, Guangzhou, China, [3]Division of Physical Education, Hygiene and Arts Education Department of Education of Guangdong Province, Guangzhou, China, [4]Health Publicity and Education Center of Guangdong Province, Guangzhou, China

Purpose: To determine the association between poor visual acuity, the use of digital devices and physical activity (PA) during the COVID-19 pandemic.

Methods: A total of 327,646 Chinese children and adolescents were included in the analysis using a cluster random sampling method; this is a case-control study, of those 144,708 children and adolescents with poor visual acuity were included in the case group, while 182,938 who did not have poor visual acuity were included in the control group. A logistic regression model was used to assess the contribution of PA and the use of digital devices to poor visual acuity.

Results: A total of 144,708 children and adolescents experienced poor visual acuity during the COVID-19 pandemic; 54.8% were male, and 55.2% live in rural areas. Compared to controls, children and adolescents with poor visual acuity exhibited more time for the use of digital devices (4.51 ± 2.44 vs. 3.79 ± 2.34 for cases and controls, respectively; $P < 0.001$) and PA (3.07 ± 0.92 vs. 2.85 ± 1.00 for cases and controls, respectively; $P < 0.001$). During the COVID-19 pandemic, risk factors related to poor visual acuity among children and adolescents included the use of digital devices (OR 1.135; 95% CI 1.132–1.139), and PA (OR 1.269; 95%CI 1.259–1.278). The results of interaction analysis show that for children and adolescents aged 12 to 17, the positive association between the use of digital devices and poor visual acuity decreased. The interaction effect between PA and digital devices is 0.987.

Conclusions: Children and adolescents were at risk of poor visual acuity during the COVID-19 pandemic. Extended use of the digital devices increased the

risk of poor visual acuity, especially for children aged 6–11 years. But the risk of poor visual acuity among children and adolescents decreases as the time spent on PA increases.

KEYWORDS

poor visual acuity, children and adolescents, COVID-19, physical activity, digital devices, health management

Background

Myopia has emerged as a major health concern worldwide, particularly in East Asia (1). In June 2020, China Ministry of Education conducted a survey on the visual acuity of 14,532 students from primary, middle, and high schools. The results showed that compared with the data at the end of 2019, the myopia rate of students increased by 11.7% after the COVID-19 outbreak (2). In response to the COVID-19 outbreak, many countries adopted a series of control strategies (3). These measures significantly reduced the number of cases, including the closure of schools, home quarantine, and social distancing (4). According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), more than 160 countries implemented nationwide closures, affecting over 87% of students worldwide (5). A nationwide school closure was implemented as an emergency measure to prevent the spread of COVID-19 among children and adolescents in China (6). China Ministry of Education estimated that more than 220 million children and adolescents are confined to their homes. Therefore, online courses were offered in a well-organized manner to ensure continuity of school learning and improve students' educational attainment (7). Online courses for primary and secondary schools are being offered from February 2020, lasting 3–4 months (8).

Recent research has mainly focused on unhealthy behaviors caused by the closure of schools, such as fewer outdoor activities, longer use of digital devices, irregular sleep patterns, and unhealthy diets among children and adolescents during the COVID-19 pandemic, as well as the negative effects of such behaviors on physical and mental health (9–11). The impact of reduced physical activity (PA), decreased outdoor time, and increased use of digital devices on visual acuity caused by quarantine measures worldwide has been largely ignored. Liu et al. (9) suggested that with the implementation of control measures, such as school closure, children and adolescents were physically less active and used digital devices for longer, periods, exhibited irregular sleep patterns, and adopted unhealthy diets, resulting in weight gain and loss of cardiorespiratory fitness. Pellegrini et al. (12) identified an increased risk of myopia after home quarantine. Wong et al. (4) reviewed studies on the associations between the use of digital devices, near work, outdoor time, and myopia, presenting the risk impact of increased use of digital devices on myopia during the COVID-19 pandemic. Although the etiology of myopia remains unclarified, education as one of the environmental factors has been correlated with them (13, 14).

The high prevalence of myopia among children and adolescents was found to be attributable to several factors, including the level of education, time spent outdoors, PA, and use of digital devices (15–18). According to some research, myopia was shown to be more common in students who studied for more than 5 h each day, and they think myopia is substantially more common in Singapore, Korea, and China than in other nations, presumably due to the high-pressure education systems (19). Rose et al. (20) found that "higher levels of total time spent outdoors, rather than sports *per se*, were associated with less myopia." He et al. (21) pointed out that increased outdoor activities at school contributed to a reduced incidence of myopia among school children. Children and adolescents were not allowed to go outdoors, and could only exercise indoors due to COVID-19 containment measures. Some scholars have proposed the potential impact of home quarantine and online courses on myopia among children and adolescents (22). However, few large-scale empirical study has yet been conducted to validate this proposition. This study aimed to assess the impact of PA and the use of digital devices on the visual acuity of children and adolescents during the COVID-19 pandemic.

Methods

Sample

A stratified cluster random sampling method was used to collect data between May 8 and June 30, 2020. To build our sample, 5% of primary and secondary schools from each city in Guangdong province (21 cities) were randomly selected using equal probability method. Each city's education department has a list containing all schools in the region. The schools included in this study were selected by the education department based on this list, using the random number table method. A cluster sampling method was used to extract students from these

schools, and the probability of each student being selected was the same. In this study, children and adolescents reported visual acuity in 2019 and 2020, respectively. We screened the sample based on the visual acuity of children and adolescents in 2019. Inclusion criteria: Children and adolescents aged 6–17 years; Without poor visual acuity in 2019. Visual acuity of children and adolescents in 2020 was analyzed as an outcome variable.

Respondents in the target population completed the Chinese version of the electronic questionnaire through an online survey platform (SurveyStar; Changsha Ranxing Science and Technology). The survey link was sent to the cell phone of the child's guardian, and guardians were asked to provide consent before the child could participate.

This is a case-control study. The questionnaires were anonymized to ensure data confidentiality and reliability. There were 356,552 children and adolescents were included in this study. Questionnaires in which the visual acuity status was left unfilled were excluded. Finally, 327,646 valid questionnaires were returned, with a response rate of 91.9%. Visual acuity of children and adolescents in 2020 was analyzed as an outcome variable. In this study, we defined children and adolescents with poor visual acuity were case group, and people without poor visual acuity were control group.

Measurements

Dependent variables

The dependent variables included daily time spent on digital devices and PA during the COVID-19 pandemic. Demographic variables included sex (male, female), age (6–17), and residence (rural, urban).

Outcome variable: Poor visual acuity

In China, the Ministry of Education introduced "Administrative Measures for the Health Examination of Primary and Secondary School Students" in 2008 as part of a health surveillance program (23). Students of all grades were asked to perform a visual acuity test. The logarithm of the minimum angle of resolution (LogMAR) chart by ophthalmologists was used (24). LogMAR (using the Standard for Logarithmic Visual Acuity Charts, GB/T 11533-2011 of the Standardization Administration of the People's Republic of China) is the "gold standard" used by majority of clinical trials or interventions (25, 26). Poor visual acuity was defined as a UCDVA (LogMAR) < 5.0.

Analyses

The differences between cases and controls were compared using the two-sample student's *t*-test and chi-squared test. First, a logistic regression model was used to assess the contribution of PA (h/day) and the use of digital devices (h/day) to poor visual acuity. The outcome measure was poor visual acuity. The model was adjusted for age, sex, and residence. Second, we tested the two-way interaction of digital devices and age or PA (age $\times$ use time of digital devices; PA $\times$ use time of digital devices) on poor visual acuity among children and adolescents. Finally, we analyzed the effects of digital devices on poor visual acuity of children and adolescents at different ages using marginal effects. All analyses were performed using Stata software (version 15.0). All reported *P*-values were 2-sided.

Results

Difference between cases and controls

In 2020, A total of 144,708 children and adolescents experienced poor visual acuity were included in case control. Of which, 79,343 (54.8%) were male, most respondents were aged 8–12 years (96,143, 66.4%), and average age was 10.56, and 79,886 (55.2%) lived in urban areas. A total of 182,938 children and adolescents were included in the control group, the average age of respondents was 10.29, 95,095 (52.0%) were male, and 107,038 (58.5%) lived in urban areas. There were differences between cases and controls according to sex, age, and residence ($P < 0.001$). There were differences between cases and controls in the time of PA, but the difference was small (3.07 ± 0.92 vs. 2.85 ± 1.00 for cases and controls, $P < 0.001$). Children and adolescents with poor visual acuity spent more time on digital devices than controls (4.51 ± 2.44 vs. 3.79 ± 2.34 for cases and controls; Table 1).

Risk factors related to poor visual acuity among children and adolescents

A logistic regression model was used to analyze the effects of digital device usage and PA on poor visual acuity among children and adolescents during the COVID-19 pandemic. The results showed that the risk factors related to poor visual acuity among children and adolescents included the use of digital devices (OR 1.135; 95% CI 1.132–1.139), and PA (OR 1.269; 95%CI 1.259–1.278). Females had a lower risk of poor visual acuity than males, and rural people had a higher risk than urban ones (Table 2). Age was positively associated with poor visual acuity, and its effect showed an inverted *U*-shape with increasing age (Figure 1).

The interaction effect of digital devices and age or PA on poor visual acuity

To better understand the effect of digital device usage on poor visual acuity among children and adolescents during

TABLE 1 The poor visual acuity of children and adolescents during the COVID-19 pandemic.

Variables	Case group	Control group	X^2/t	*P*
Sex			263.176	<0.001
Male	79,343 (54.8)	95,095 (52.0)		
Female	65,365 (45.2)	87,843 (48.0)		
Age (year)			1,540.673	<0.001
6	1,100 (0.7)	1,991 (1.1)		
7	15,360 (10.6)	24,845 (13.6)		
8	21,744 (15.0)	31,232 (17.1)		
9	18,267 (12.6)	23,912 (13.1)		
10	19,208 (13.3)	23,537 (12.9)		
11	18,399 (12.7)	20,713 (11.3)		
12	18,525 (12.8)	20,252 (11.1)		
13	11,698 (8.1)	12,550 (6.9)		
14	8,279 (5.7)	8,992 (4.9)		
15	5,385 (3.7)	6,227 (3.4)		
16	3,836 (2.7)	4,682 (2.6)		
17	2,907 (2.1)	4,005 (2.2)		
Residence			360.302	<0.001
Urban	79,886 (55.2)	107,038 (58.5)		
Rural	64,822 (44.8)	75,900 (41.5)		
Digital devices (h/day)	4.51 ± 2.44	3.79 ± 2.34	85.538	<0.001
Physical activity (h/day)	3.07 ± 0.92	2.85 ± 1.00	65.480	<0.001

This table reports the N (%) or Mean (SD) of the items.

TABLE 2 Logistic regression model of poor visual acuity among children and adolescents.

Variables	*OR*	*SE*	*P*	*95%CI*
Sex				
Female	0.913	0.007	<0.001	0.901–0.926
Age (year)				
7	1.102	0.044	0.014	1.020–1.190
8	1.218	0.048	<0.001	1.128–1.315
9	1.313	0.052	<0.001	1.216–1.419
10	1.401	0.055	<0.001	1.297–1.513
11	1.511	0.059	<0.001	1.398–1.632
12	1.531	0.061	<0.001	1.417–1.654
13	1.477	0.060	<0.001	1.365–1.598
14	1.384	0.057	<0.001	1.276–1.500
15	1.256	0.054	<0.001	1.155–1.365
16	1.140	0.051	<0.001	1.045–1.244
17	0.990	0.045	0.828	0.905–1.083
Residence				
Rural	1.157	0.008	<0.001	1.141–1.174
Physical activity (h/day)	1.269	0.005	<0.001	1.259–1.278
Digital devices (h/day)	1.135	0.002	<0.001	1.132–1.139

The time of physical activity and digital devices were calculated as continuous variables.

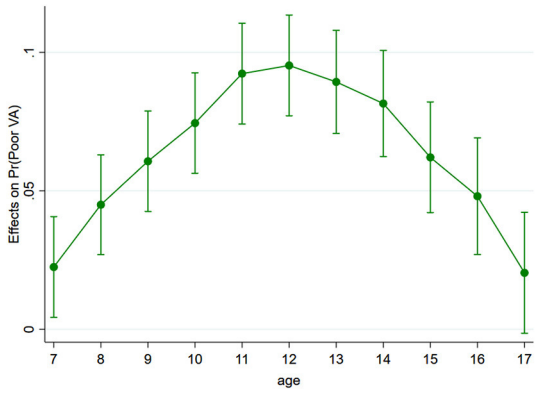

FIGURE 1
The effects of age on poor visual acuity among children and adolescents.

the COVID-19 pandemic, we tested whether there was an interaction between age and time spent on digital devices (Table 3). The results showed there are no significant association between the time spent on digital devices and poor visual acuity among children aged 6–11 years ($P > 0.05$). Among adolescents aged 12–17 years, the effects of time spent on digital devices decreased with age (Figure 2). The interaction effects of time spent on PA and digital devices is 0.987. It means that time spent on digital devices is positively associated with poor visual acuity, but the risk of poor visual acuity decreases as the time spent on exercise is increased among children and adolescents.

Discussion

The implementation of home quarantine effectively curbed the spread of COVID-19, but it also harmed the mental and physical health of young people. We conducted a study on the poor visual acuity of children and adolescents during the COVID-19 pandemic. The proportion of children and adolescents with poor visual acuity decreased with age. He et al. also found that the proportion of mildly reduced UCDVA among school-aged children and adolescents was relatively higher in primary grades one and two. The proportion of moderately poor visual acuity remained similar among the 12 grades (6–18 years) (27).

We investigated the risk factors of poor visual acuity and found that increased time spent on digital devices due to online courses was the main risk factor for poor visual acuity among children and adolescents. Some studies have indicated that the use of screen devices plays a key role in visual impairment, increasing the possibility of poor visual acuity and myopia (18, 28–30). For instance, a prospective clinical study showed

TABLE 3 The interaction effects of digital devices and age or PA on poor visual acuity.

Age (years)	Digital devices	*OR* (*95%CI*)	*P*
Age × digital devices			
6 (reference)	3.60 ± 2.01	/	/
7	3.70 ± 1.97	1.011 (0.972–1.052)	0.581
8	3.78 ± 2.08	1.010 (0.972–1.051)	0.603
9	3.95 ± 2.23	1.000 (0.962–1.041)	0.972
10	4.01 ± 2.31	0.973 (0.935–1.011)	0.161
11	4.10 ± 2.39	0.968 (0.931–1.006)	0.097
12	4.34 ± 2.53	0.954 (0.917–0.992)	0.017
13	4.98 ± 2.85	0.938 (0.902–0.976)	0.001
14	5.54 ± 2.99	0.918 (0.882–0.954)	<0.001
15	5.77 ± 3.04	0.913 (0.877–0.950)	<0.001
16	6.31 ± 3.10	0.904 (0.868–0.941)	<0.001
17	6.54 ± 3.17	0.898 (0.862–0.936)	<0.001
Digital devices × PA	/	0.987 (0.985–0.991)	<0.001

This table reports the OR and 95%CI of the interaction terms. All models were adjusted by the characteristics listed in Table 2.

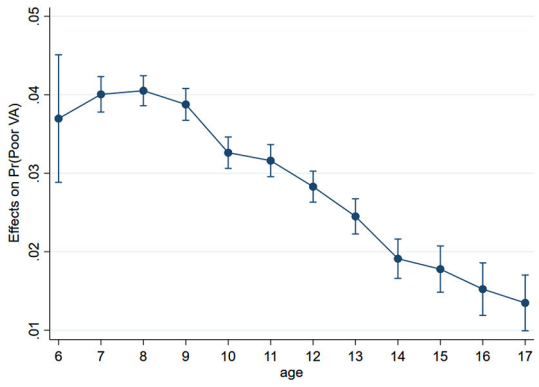

FIGURE 2
The marginal effects of age and the use time of digital devices on the poor visual acuity among children and adolescents. The results adjusted by sex, residence.

that smartphone use for 4 h resulted in a higher eye disease index than that measured at baseline (31). Liu et al. (32) found that a more myopic spherical equivalent refraction and longer axial length were both associated with more time spent using smartphones and computers but not with time spent using tablets and watching television. In our study, there was a positive association between the use of digital devices and poor visual acuity during the COVID-19 pandemic. We also found that the marginal effect of digital device use on poor visual acuity decreased with age. Similar findings were found by Wang et al. (29) in that the overuse of smartphones was significantly associated with visual impairments, and these visual impairments were more apparent in children than in young adults. This means that the use of digital devices more harmful to younger children than adolescents.

The results of our study suggest that PA is positively correlated with poor visual acuity in children and adolescents. It is contrary to the results of existing studies. Many researchers have found that PA is mildly or not positively associated with myopia and poor visual acuity (33, 34). Some unconventional results must be interpreted carefully. In our study, there was a small difference in the PA time of children and adolescents between cases and controls, ranging from 2.85 to 3.07 h. Some statisticians believe there is a large sample size problem, implying that almost all parameters are significantly different from zero if the sample size is large enough (35–37). Therefore, although we wanted a large sample size to generate more accurate data, an excessively large sample size might cause difficulties interpreting the usual tests of significance (38). This may be the reason for our unusual research results. Meanwhile, we also found the interactions between age and PA are insignificant, but PA can reduce the influence of digital devices on poor visual acuity. Our study is a cross-sectional study rather than a longitudinal cohort study. Therefore, we did not have sufficient evidence to conclude that PA was positively correlated with poor visual acuity, especially this result is contrary to the existing research results.

Some studies have found that time spent outdoors is predictive of the incidence of myopia independent of PA level (15). A systematic review of the correlation between PA and myopia did not find that PA was an independent risk factor for myopia. Instead, the time spent outdoors was identified as the most important factor (34). Dirani et al. (39) suggested that total sports, but not indoor sports, were also significantly negatively associated with myopia. The time spent outdoors had a protective effect on the visual acuity of children and adolescents. However, during the COVID-19 pandemic, children and adolescents were not allowed to play outside. Additionally, the increased use of digital devices was associated with more time at work and less time spent outdoors, resulting in a substitution effect (18, 29, 40). For example, Dirani et al. (40) reported that the lack of adequate outdoor activity might be related to increased time spent on digital devices. However, the substitution effect of the time spent on digital devices and outdoor time is warranted (18, 41, 42). During the COVID-19 pandemic, educational screen time has substituted reading or writing, because of online courses. Thus, poor visual acuity in children and adolescents is associated with home isolation and increased use of digital devices during the COVID-19 pandemic.

Increased use of digital devices was positively associated with poor visual acuity in children and adolescents, and this association decreased with age, but the risk of poor visual acuity decreases as the time spent on PA increases. Parents should strictly control the amount of time students spend on electronics and increase their exercise time, especially outdoor activities.

When online courses are necessary, educational institutions should pay more attention to students' eyes use, set reasonable lesson times, and allow students to relax their eyes. Students should ensure that they spend at least 1 h outdoors every day. Parents should focus on the vision of children aged 6 to 11 and help them to develop healthy eye behaviors.

This study has several limitations. Only the duration of PA was measured, and the content and intensity of PA were not included. Therefore, the effect of PA on poor visual acuity could not be accurately determined. We did not collect the frequency and duration of children's daily use of digital devices. However, this was a case-control study with a large sample size of 327,646 children and adolescents. This study partially revealed the negative effects of online courses and the use of digital devices on visual acuity among children and adolescents during the COVID-19 pandemic.

Conclusion

Our study suggests that children and adolescents were at risk of poor visual acuity during the COVID-19 pandemic. The time spent on digital devices is positively associated with poor visual acuity among children and adolescents during the COVID-19 pandemic, and the association decreased with age. But the risk of poor visual acuity among children and adolescents decreases as the time spent on PA increases. It is essential to pay attention to the negative effect of online courses and home quarantine on visual acuity among children and adolescents.

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/s.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee of Southern Medical University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

CCZ and ZGQ conceived the study. XZ and LS were major contributors in analyzing data and writing the manuscript. WYO, PYL, WH, and YQX mainly collected data. YX, JCZ, and BLX edited and contributed content to the final draft. All authors read and approved the final 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.

Publisher's note

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EDITED BY
Morteza Taheri,
Imam Khomeini International University, Iran

REVIEWED BY
Elahe Arab Ameri,
University of Tehran, Iran
Leila Youzbashi,
University of Zanjan, Iran

*CORRESPONDENCE
Guoyang Qin
2021020265@stu.sdnu.edu.cn;
email@uni.edu

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Association between BMI and health-related physical fitness: A cross-sectional study in Chinese high school students

Guoyang Qin[1]*, Yong Qin[2] and Bin Liu[3]

[1]College of Physical Education, Shandong Normal University, Jinan, Shandong, China, [2]Physical Education Teaching and Research Office, Lixia District Bureau of Education and Sports of Jinan City, Jinan, Shandong, China, [3]Physical Education Teaching and Research Group, Jinan Licheng No. 2 High School, Jinan, Shandong, China

Background: Existing studies reporting on the levels of physical fitness among high school students use relatively few fitness tests for indicators of physical fitness, thus, incomprehensively evaluating the levels of physical fitness. Therefore, this study investigated the relationship between body mass index (BMI) and physical fitness index (PFI) by investigating five physical fitness indicators and calculating PHI.

Method: Anthropometric measurements and indicators from five measures of physical fitness (50-m sprint, sit and reach, standing long jump, 800/1,000-m run, pull-up/bent-leg sit-up) were assessed. BMI was calculated to classify individuals into underweight, normal weight, overweight, and obese categories. *Z*-scores based on sex-specific mean and standard deviation were calculated, and the sum of *Z*-scores from the six fitness tests indicated the PFI. The findings were fitted to a linear regression model to elucidate the potential relationship between BMI and PFI.

Results: In total, 176,655 high school students (male: 88,243, female: 88,412, age: 17.1 ± 1.05 years, height: 168.87 ± 11.1 cm, weight: 62.54 ± 15.15 kg) in Jinan, China, completed the physical fitness tests between 2020 and 2021. The one-way ANOVA models showed that PFI in the normal category was significantly higher as compared to all the other BMI categories within both male and female groups ($p < 0.001$), and PFI in the obese category was significantly lower as compared to all the other BMI categories for both male and female groups ($p < 0.001$). The association between PFI and BMI showed an inverted U-shape relationship.

Conclusions: This study demonstrated that BMI affects the PFI in both males and females. As compared to the obese and overweight categories based on BMI, significantly higher scores of PFI were observed for males and females.

KEYWORDS

high school students, body mass index, physical fitness, cross-sectional study, China

Introduction

The prevalence of obesity among adolescents has been rising globally due to the accelerated rate of unhealthy eating, and reduced or lack of adequate physical activity, and has become a public health problem (1). The high school comprises the transitional period from adolescence to adulthood and is crucial for developing healthy lifestyles and forming healthy behaviors (2, 3). In recent years, there has been a significant decline in physical activity among high school students (1, 4, 5). A study have shown that reduced physical activity can lead to weight gain and increased prevalence in adolescents (6). Being overweight is becoming increasingly common in high school students, while the physical fitness of adolescents is on a decline. Moreover, the desire to be thin is common among young people in Asia (7, 8). These regions and countries face the dual burden of both underweight and overweight adolescents (9, 10). Therefore, weight monitoring to maintain good health is crucial for high school students.

Body mass index (BMI) is universally considered a marker of health and is widely used to measure malnutrition, overweight, and obesity (11–13). Studies have shown that an increase in BMI increases the risk of cardiovascular disease (hypertension, myocardial infarction, lung disease, sleep apnea syndrome) (14). Also, study have shown that BMI can effectively reflect the physical fitness of ordinary college students (15). Moreover, physical fitness correlates positively with physical activity (16). Some studies have discussed the association between BMI and several components of physical fitness in children (17) and adolescents (18). Also study suggested that there was a significant difference between the (BMI) of normal females compared to the scoliotic female high school student (19). Therefore, monitoring the BMI of high school students is of great significance to understanding their physical development (20). Studies have shown that BMI may be affected by various factors (i.e., ethnic groups) (20), so it is unclear whether using the BMI index reflects their physical fitness and health.

This study aimed to analyze the levels of different physical fitness components among high school students and evaluate the association between BMI and health-related physical fitness. We hypothesized that BMI could effectively reflect the physical fitness levels of Chinese high school students.

Materials and methods

Subjects

The data were collected from a national survey on physical fitness conducted among high schools between 2020 and 2021 in Jinan of Shandong province, China. Students aged 15–18 years completed the physical fitness tests (n = 176,655, male: 88,243, female: 88,412, age: 17.1 ± 1.05years, height: 168.87 ± 11.1 cm, weight: 62.54 ± 15.15 kg; see Supplementary Figure S1 for the recruitment process). Due to the pandemic, high school students were in relatively closed state, in which students were just in school and at home regularly. For all participants, both participants and their parents (or guardians) gave their informed consent. The study protocol complied with the Declaration of Helsinki and was approved by the Ethics Committee of Shandong Normal University (2021036).

Procedures

According to the technical specifications including the "National Student Physical Health Standard," we first conducted anthropometric measurements, followed by tests for various physical fitness indexes (PFIs), and finally the cardiorespiratory endurance test. In the standing long jump test, the "best of three jumps" was considered the result; "the best of two" results were considered for the 50-m running test, while other tests were performed once. We adopted intelligent physical health monitoring equipment, through non-contact measurement using the infrared multi-point sensor array, which automatically recorded the students' scores and uploaded these values to the system for storage.

BMI calculation

The BMI was calculated using the following formula: BMI = weight (kg)/height $(m)^2$. Students were divided into four categories based on their BMI values according to the criteria recommended by the World Health Organization (WHO) as follows: $<$18.5 kg/m^2, 18.5–23.9 kg/m^2, 24–27.9 kg/m^2, and $\geq$28 kg/m^2, representing underweight, average weight, overweight, and obese individuals, respectively (21).

Physical fitness test

The tests for physical fitness included 50 m sprints, sit and reach, standing long jump, 800/1,000 m runs, pull-ups, and bent-leg sit-ups.

50 m sprint

To evaluate students' speed and explosive strength a 50 m sprint was conducted. Students were tested in groups of four. When the investigator indicated, "go," the subjects began the 50 m sprint. They finished the run as fast as they could. The time in minutes and seconds was recorded (15).

Sit and reach

To assess lower hamstring flexibility, a sit and reach test was conducted. Each subject was barefoot and sat on the test instrument. They gradually reached forward as far as possible with their knees extended. The test was conducted twice, and the best of the two scores was retained (15).

Standing long jump

Standing long jump was conducted to assess lower-limb strength. Each subject stood at the starting line and was asked to jump forward as far as they could. The distance was measured in meters from the starting line to the heel of the closest foot. The test was conducted twice, and the best of the two scores was retained (15).

800/1,000 m run

Each student stood at the starting line and was asked to complete the 800- or 1,000 m run as fast as they could. The time in minutes and seconds was recorded. Female students ran 800 m run, while male students ran 1,000 m (15).

Pull-ups

Pull-up was used to evaluate the upper body's muscular strength. The test was scored as the number of pull-ups. The subject jumped up and pulled the bars with both hands. After standing still, subjects pulled with both arms simultaneously. Only the male students performed this test (15).

Bent-leg sit-ups

Each subject was instructed to lay on a mat with knees bent at 90 degrees, raise their upper body, and touch their knees with their elbows. The number of bent-leg sit-ups completed in 1 min was recorded. Only the female students performed this test (15).

Physical fitness index

The specific calculation of the Z-score for each physical fitness test was (test value-national average)/national standard deviation; the shorter the time for the 50 m run, 1,000 m run for boys, and the 800 m run for girls, the better the performance. Therefore, the PFI was—Z pull-ups or 1-min sit-ups + Z standing long jump + Z seated forward bend-Z 50 m running-Z 1,000/800 m running (11, 22).

Statistical analysis

Experimental data were processed using the IBM SPSS statistical software (version 26.0, Chicago, IL, USA). All data were presented as "mean ± standard deviation" ($M \pm SD$). An independent sample t-test or one-way analysis of variance (ANOVA) was conducted to compare the mean differences among groups. When a significant interaction was observed, the LSD *post hoc* correction was performed to confirm the significance. The linear regression model in the Stata package was used to determine the trends in PFI throughout the study duration. The level of significance was set at $p < 0.05$ for all tests.

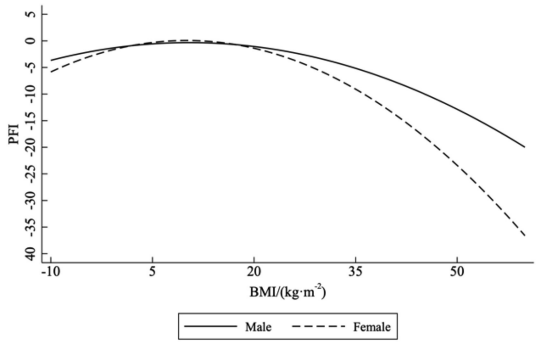

FIGURE 1
The relationship between PFI and BMI.

Results

The one-way ANOVA models showed that PFI in the normal category was significantly higher as compared to all the other BMI categories in both male and female groups ($p < 0.001$), and PFI in the obese category was significantly lower as compared to all the other BMI category for males and females ($p < 0.001$). No significant effect on PFI for all the BMI categories was observed within the male and female groups ($p > 0.150$).

The logistic regression analysis showed that PFI in both males and females was related to BMI ($p < 0.001$). Figure 1 and Table 1 displays the relationship between PFI and BMI. The equations for gender-specific characteristics are as follows:

$$PFI_{male} = -0.160BMI^2 + 0.135BMI - 6.549$$
$$PFI_{female} = -0.294BMI^2 + 0.026BMI + 1.405$$

Additionally, the logistic regression analysis showed that PFI in both males and females of different ages was related to BMI ($p < 0.001$). Figure 2 and Table 2 display the relationship between PFI and BMI in both males and females of different ages. The equations for age-specific characteristics are as follows:

TABLE 1 The percentage of BMI level grouped by gender and age.

Gender	Age	Low	Normal	Overweight	Obesity	*F*	p
Male high school students	16	0.64%	11.4%	3.25%	2.95%	37,789.3	<0.001
	17	0.59%	10.99%	2.8%	2.43%	35,115.3	<0.001
	18	0.65%	9.65%	1.99%	2.61%	33,032.9	<0.001
Female high school students	16	0.55%	12.39%	2.26%	2.6%	320,707.9	<0.001
	17	0.63%	12.49%	1.97%	1.93%	28,262.7	<0.001
	18	0.69%	11.4%	1.45%	1.69%	24,097.4	<0.001

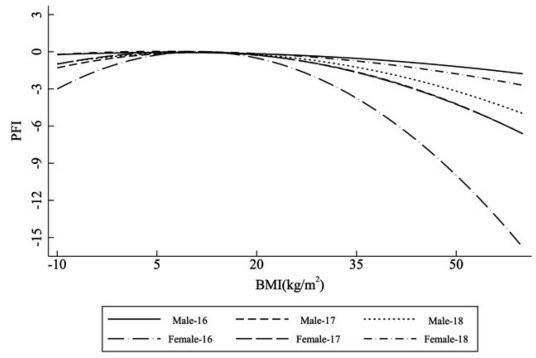

FIGURE 2
The relationship between PFI and BMI is grouped by gender and age.

$$PFI_{male-16} = -0.016BMI^2 - 0.376BMI - 6.249 \quad (F = 798.80, p < 0.001).$$

$$PFI_{male-17} = -0.275BMI^2 + 0.642BMI - 7.000 \quad (F = 885.10, p < 0.001).$$

$$PFI_{male-18} = -0.205BMI^2 - 0.165BMI + 1.722 \quad (F = 536.77, p < 0.001).$$

$$PFI_{female-16} = -0.665BMI^2 + 1.673BMI - 0.786 \quad (F = 959.38, p < 0.001).$$

$$PFI_{female-17} = 0.262BMI^2 - 0.165BMI + 1.722 \quad (F = 793.40, p < 0.001).$$

$$PFI_{female-18} = 0.095BMI^2 - 0.708BMI + 2.467 \quad (F = 464.08, p < 0.001).$$

Discussion

This study demonstrated that BMI significantly affected PFI in both males and females. As compared to the obese and overweight categories according to the BMI, significantly higher scores of PFI were observed for males and females in the normal-weight group. Our results suggested that the relationship between PFI and BMI was non-linear, characterized by an inverted U-shape association. The results of this study suggested that the BMI of high school students in the normal category indicated greater physical fitness and good physical health; physical fitness became better and then worse with increased BMI.

Sports in schools are important to maintain physical fitness among high school students and the quality of school physical education must be improved. During childhood and adolescence, sports participation in childhood is linked to Health-Related Quality of Life (HRQoL) in young adulthood, whether it is in the form of individual or team sports, or an unstructured physical activity like backyard games (6). School physical education aims to encourage students to actively participate in physical exercise, develop the habit of exercising regularly, and improve their self-care ability and physical health (15). Physical health is also essential from a public health perspective (23). Physical fitness levels are strongly associated with health-related outcomes, including obesity, cardiovascular disease, bone health, mental health, and social psychology, which have good potential for physical fitness (24). Students in high school are under great learning pressure, leading to a significantly rising trend of obesity and an increased number of overweight individuals. Although genetic factors play an important role in obesity, environmental and lifestyle factors such as physical activity and nutrition patterns are also crucial (25). Previous studies show that this increasing trend may be attributed to rapid changes in dietary and physical activity patterns (26).

The results of this study suggested that both low weight and obese categories according to BMI would induce a negative effect on physical fitness and physical health levels, consistent with the findings of previous studies (10, 27–29). Ding and Jiang (30) found that overweight and obese students showed poorer performance in physical fitness tests as compared to their normal-weight counterparts irrespective of their sex. They also showed that in overweight and obese students additional load and restriction of movement caused by excess body mass further impeded their performance; energy requirements increase to perform physical activities with heavy loads as compared to

TABLE 2 The PFI of participants grouped by gender, BMI, and age.

	Low weight (numbers)	Normal (numbers)	Overweight (numbers)	Obesity (numbers)	*F*	p
Male-16	−7.76 ± 1.40 (1,136)	−7.15 ± 1.45 (20,140)	−7.47 ± 1.48 (5,203)	−8.19 ± 1.53 (5,748)	782.50	<0.001
Male-17	−7.33 ± 1.43 (1,036)	−6.76 ± 1.47 (19,414)	−7.15 ± 1.46 (4,284)	−7.76 ± 1.52 (4,945)	642.65	<0.001
Male-18	−7.00 ± 1.53 (1,152)	−6.59 ± 1.39 (17,055)	−6.90 ± 1.40 (4,608)	−7.48 ± 1.51 (3,522)	412.40	<0.001
Female-16	−0.85 ± 2.74 (972)	0.002 ± 2.35 (21,886)	−0.66 ± 2.30 (4,593)	−1.73 ± 2.38 (3,997)	661.26	<0.001
Female-17	−0.37 ± 2.74 (1,121)	0.44 ± 2.25 (22,073)	−0.27 ± 2.15 (3,402)	−1.24 ± 2.19 (3,482)	621.60	<0.001
Female-18	0.17 ± 2.73 (1,216)	0.76 ± 2.23 (20,136)	0.02 ± 2.10 (2,964)	−0.71 ± 2.22 (2,570)	393.41	<0.001

those of normal-weight individuals, which can cause these students to avoid physical activity (30). According to our results, the relationship between BMI and PFI was characterized by an inverted U-shape association, similar to that described in a previous study. Normal weight students generally show better physical fitness than underweight, overweight, and obese students, especially among males (15).

Several limitations of the pilot study should be noted. First, this cross-sectional study cannot establish a causal relationship between physical fitness, body size, and fitness level, but it does identify an association between BMI and PFI. Second, the sample does not truly represent the number of high school students in China, as more than 95% of the study participants were from Jinan, Shandong Province. Additionally, though many of the observed results in physical fitness can be observed in these outcomes, body composition, and daily nutritional intake are more exact factors related to the level of physical fitness. Future studies consisting of body composition, food habits, and eating behaviors are thus demanded to confirm the findings of our study. Studies with larger sample sizes and comprising participants from different provinces, as well as other cohorts (e.g., age), are warranted to examine and confirm the observations in this study in the future.

Conclusion

In conclusion, BMI affects the PFI in both males and females. Compared to the obese and overweight categories based on BMI, significantly higher scores of PFI were observed for males and females. Nevertheless, this study provided preliminary evidence that BMI affects the PFI in both males and females. Compared to the obese and overweight categories based on BMI, significantly higher scores of PFI were observed for males and females. Thus, PFI should be highly demanded to predict the physical fitness of high school students. Future prospective and longitudinal cohort studies must accurately identify the causal relations and potential mechanisms.

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 studies involving human participants were reviewed and approved by the Ethics Committee of Shandong Normal University (2021036). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

GQ, BL, and YQ: design and/or conceptualization of the study. GQ and YQ: analysis and/or interpretation of the data. GQ drafting and/or revising the 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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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.1047501/full#supplementary-material

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EDITED BY
Risa Robinson,
Rochester Institute of Technology,
United States

REVIEWED BY
Tengyan Wu,
Guangxi Medical University, China
Ying Liu,
Tangshan Gongren Hospital, China

*CORRESPONDENCE
Jianrong Mai
✉ jmai7naz@163.com

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Will personality traits affect the use of e-cigar among college students? A cross-sectional study in Guangdong Province, China

Jianrong Mai*, Lina Lin, Ling Zhou, Qinyi Guan, Wenhui Zhu and Wenzan Zhou

School of Nursing, Guangzhou Xinhua University, Guangzhou, China

Background: The prevalence of e-cigar among adolescents and young adults around the world is increasing rapidly, which has a serious impact on the health of young people. This study assessed the prevalence of e-cigar among college students and to explore the relationship between e-cigar use and personality traits.

Methods: This study conducted an electronic questionnaire survey on college students who were from three undergraduate universities and three junior colleges in Guangdong Province from January 2022 to March 2022. The survey was conducted by stratified cluster sampling, and the respondents were 1362. Statistical descriptions are used to describe the demographic characteristics and personality traits of participants. Mann-Whitney U tests, and Chi-square tests were used to compare the differences between current e-cigar users and non e-cigar users. Two-step hierarchical Logistic regression was used to predict the associated factors with e-cigar use.

Results: The prevalence of current e-cigar users was 5.1%. Agreeableness showed statistically significant higher in non-users ($Z = 2.585$, $P < 0.01$). Moreover, gender (*AOR* = 0.312, *95%CI*: 0.174–0.562), the relationship with mother (*AOR* = 5.887, *95%CI*: 1.460–23.748), friends who use e-cigar (*AOR* = 3.808, *95%CI*: 2.159–6.719), allowance per month (*AOR* = 2.482, *95%CI*: 1.371–4.490), and agreeableness (*AOR* = 0.957, *95%CI*: 0.918–0.997) were related to the use of e-cigar.

Conclusion: The level of agreeableness is associated with the use of e-cigar among college students. All these provided an important theoretical basis for future intervention.

KEYWORDS

electronic cigarette, personality traits, college students, health education, health policy

1. Introduction

China has the largest number of traditional smokers in the world. With the vigorous promotion of electronic cigarette (e-cigar) manufacturers, the production and consumption of e-cigar has shown a trend of rapid growth in the past few years (1). The number of employees of e-cigar in China exceeded 2 million, with annual sales exceeding 33.7 billion yuan and exports approaching 30 billion yuan in 2018 (2).

Electronic cigarette is an electronic nicotine delivery system, and its impact on health varies. Studies have shown that the use of e-cigar may lead to short-term or long-term health risks (3). The liquid of e-cigar contains glycerol, propylene glycol, natural oil, extract and spices, nicotine and benzoic acid (4). As we know, nicotine can enter the blood circulation through the lungs, stimulating the brain to release dopamine and produce euphoria, which is also the main cause of nicotine addiction (5). Moreover, in order to attract teenagers and young adults to accept e-cigar, manufacturers adopt fashionable designs, good user experiences (for example, reducing irritation to the throat), different tastes (for example, fruit, mint and traditional cigarettes, etc.) and can be used in places where smoking is prohibited (1, 6, 7). These "advantages" that lead to the increasing popularity of e-cigar among college students year by year.

Some studies in China have found that the prevalence rate of e-cigar among college students in Shandong Province was 4.0% in 2015, 7.7% in Shanghai in 2017 and 8.2% in Hangzhou in 2019 (8–10). A study in Pakistan showed that 6.2% of college students had used e-cigar in 2016 (11). 74.9% of Malaysian college students used e-cigarettes in 2016 (12). A cross-sectional survey in New Zealand in 2018 found that 6.1% of college students were current smokers and 40.5% of respondents had used e-cigar (13). The prevalence of e-cigar was 4.0% in the United Arab Emirates in 2020 (14). These studies suggest that the prevalence of e-cigar among college students is getting higher and higher.

Previous studies report that the individual factors, such as age, gender, educational level, allowance per month (Yuan), the relationship with parents, and friends who use e-cigar, may be important factors affecting the use of e-cigar among adolescents. Compared with the elderly, the youth are more likely to accept and use e-cigarettes out of curiosity. The use of e-cigarettes may thought to be cooler and more fashionable, which is one of the important reasons why they use e-cigar (1, 15). Similar to those who use conventional cigarettes, most of the e-cigar users are male (16). A previous study showed that the use of e-cigar was related to educational level (9). The prevalence rate of e-cigar is lower in individuals with higher educational level, which may be related to the awareness of the health impact. Parental rearing style has a direct impact on parent-child relationship and children's stress coping style. Some studies have shown that parental rearing style may affect children's use of tobacco products (17, 18). Peer relationship has been proved to be closely related to healthy behavior. Deviant peer affiliation have been linked to unhealthy behaviors such as smoking, drinking and cyber bullying, which may be a window for college students to be exposed to e-cigar (19).

As early as the 1970s, people began to study the personality traits of smokers. Personality traits are specific and relatively stable characteristics and the main indicators of behavior (20). The Big Five Personality Traits, including neuroticism, conscientiousness, agreeableness, openness and extraversion, are widely used to study the health-related behaviors (21, 22). Neuroticism is thought to be associated with low self-esteem, pessimism and fear. Conscientiousness is related to organized social support. Agreeableness is related to obedience and belief in cooperation. Openness means rich imagination and curiosity about things. Extraversion refers to being good at socializing and having a wide range of interests. Some studies have shown that smoking is associated with high neuroticism, high extraversion, low agreeableness, low conscientiousness and low openness (23, 24).

However, few studies have reported the relationship between e-cigarette smoking status and the Big Five Personality Traits. A previous study on the relationship between three polymorphisms in the dopamine receptor 2 gene and personality traits and anxiety (25). Nevertheless, the relationship between the use of e-cigar and personality traits has not been analyzed from a group point of view. As far as we know, the use of e-cigar is a kind of behavior, which can be intervened by using a variety of theories of health education. Therefore, the purpose of this study is to assess the prevalence of e-cigar among college students, and to address the relationship between the use of e-cigar and personality traits among college students, and to further explore the factors affecting the use of e-cigar.

2. Participants and methods

2.1. Participants

The purpose of this study is to explore the use of e-cigar and its relationship with personality traits among college students in Guangdong Province, China. Through the questionnaire Star platform (www.wjx.cn), questionnaires were distributed to college students in Guangdong Province. The electronic questionnaires were distributed from January 2022 to March 2022.

According to the calculation, the sample size is 939, based on the fact that the prevalence rate of e-cigar smoker among college students in Shanghai was 4.6%, the margin of error was 3%, the probability of type I error was 5%, the power was 80%, and the rejection rate was 20%. Based on the principle of stratified cluster sampling, a survey was conducted among students from three undergraduate universities and three junior colleges in Guangdong Province. First of all, according to the level of economic development, one undergraduate university

and one college from Guangzhou, Foshan and Jieyang are selected respectively. Secondly, a stratified cluster sampling is used and all the students of each grade in each university or college are randomly selected as objects. The inclusion criteria for participants are age ≥16, studying in Guangdong Province, volunteering to participate in the research and completing the consent form. The exclusion criteria are participants with severe mental illness and unwillingness to cooperate. All participants will sign an electronic informed consent form and agree to start the investigation before the investigation. A total of 1,403 questionnaires are collected, and after data cleaning, the valid questionnaires are 1,362. The study is approved by the Biological and Medical Ethics Committee of Guangzhou Xinhua University (2022K002).

2.2. Current e-cigar user or non e-cigar user

Participants are required to complete a questionnaire on the use of e-cigar. The e-cigar smoking status is answered by the participants, and they are asked, "Have you used e-cigar in the past 30 days, even 1 or 2 puffs?" Response choices are "Yes" and "No." If the answer "Yes" is defined as the current e-cigar user, otherwise it is defined as non e-cigar user. The prevalence of e-cigar refers to the percentage of current e-cigar users in the population. The environmental factors of e-cigar smoking include two questions: "Whether you come from a smoke-free family." and the options are "Yes" and "No." "Whether any friends use e-cigar." The option is "0" to ">5." The answers are changed into dichotomies that is, "0" is "None" and "1" is "Yes."

2.3. Personality traits assessment

The personality traits of participants are measured by Chinese Big Five Personality Inventory Brief Version (CBF-PI-B) (26). In the past few decades, the Big Five Personality Structure model (neuroticism, conscientiousness, agreeableness, openness and extraversion) had been widely studied and proved to have cross-linguistic, cross-calming and cross-cultural stability. And it has been widely accepted by personality psychologists at the dimensional level. CBF-PI-B includes 40 items and 5 dimensions, and each dimension has eight items to measure. Participants respond according to the Likert 6 scale, ranging from 1 (very disagree) to 6 (very agree). In the present study, the Cronbach α coefficient is 0.889, and the Cronbach α coefficients of the five dimensions are between 0.752 and 0.922, indicating a high internal consistency.

2.4. Demographic characteristics

The demographic characteristics of the participants include age, gender, educational level (junior college, undergraduate or higher), allowance per month (<900 yuan, ≥900 yuan), the relationship with father (good or bad), and the relationship with mother (good or bad).

2.5. Statistical analysis

All statistics analyses are performed using IBM SPSS Statistics (IBM Corp., Armonk, NY, USA) for Windows Version 25.0. The quantitative data in accordance with the normal distribution are represented by mean ± SD, otherwise are expressed by median (Q_1, Q_3). Qualitative data are expressed by frequency or percentage (%). χ^2 tests are used to compare the demographic variables of current users and non-users. Mann-Whitney U tests are used to compared personality traits between current users and non-users. Two-step hierarchical Logistic regression is used to explore the influencing factors of the use of e-cigar. In the first step, hierarchical regression analysis mainly discusses the influence of demographic characteristics on the use of e-cigar. The second step hierarchical regression analysis adds personality variables on the basis of the first step and to explore the influence of personality traits on the use of e-cigar. All reported P value (two-sided) are considered statistically significant if $P < 0.05$, with a confidence interval at 95%.

2.6. Quality control

Before the formal survey, two rounds of pre-surveys are conducted and the opinions of the feedback are collected and sorted out in time. The questionnaire is revised again after the discussion by the research group. Investigators, who complete the training course and successfully pass the test in December 2021, can participate in the formal investigation. The whole process is guided by the investigator to ensure the quality of the investigation. After the questionnaire is collected, two people will carry out logical check and data screening, and eliminated the questionnaires that are invalid and inconsistent in logical examination.

3. Results

3.1. Demographic characteristics of the participants

As shown in Table 1, the average age of the participants is (20.0 ± 1.5) years. Of the participants, 51.8% are female and 51.2% are undergraduate or higher. There are 60.5% respondents

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TABLE 1 Demographic characteristics of 1,362 participants.

Characteristics	Mean ± SD/*n* (%)
Age (year)	20.0 ± 1.5
Gender	
Male	657 (48.2)
Female	705 (51.8)
Educational level	
Junior college	664 (48.8)
Undergraduate or higher	698 (51.2)
Allowance per month (Yuan)	
<900	538 (39.5)
≥900	824 (60.5)
The relationship with father	
Good	1,324 (97.2)
Not good	38 (2.8)
The relationship with mother	
Good	1,347 (98.9)
Not good	15 (1.1)
e-Cigar smoking status	
Non-users	1,293 (94.9)
Current users	69 (5.1)
Friends' e-cigar users	
No	790 (58.0)
Yes	572 (42.0)
Non-smoking family	
No	874 (64.2)
Yes	488 (35.8)

reporting that their allowance per month ≥900 yuan. 2.8% and 1.1% of the participants report that they have a bad relationship with their parents, respectively. 5.1% of the respondents report that they are using e-cigar, and 42.0% participants have friends who used e-cigar.

3.2. Differences between non-users and current users by demographic variables

5.1% of the participants reported that they are current e-cigar users. As shown in Table 2, the current e-cigar users have significantly higher proportion of male relative to female (χ^2= 15.101, $P < 0.001$). Students whose allowance per month larger than 900 Yuan are more likely to use e-cigar (χ^2= 5.472, P = 0.019). There is a statistically significant difference in current users who report that they have a bad relationship with their father (χ^2= 14.497, P = 0.001). Similar to the results of self-report relationship with father, this phenomenon also occurs to students who have a bad relationship with their mother (χ^2= 25.198, $P < 0.001$). Students who have friends using e-cigar are more likely to become current users (χ^2= 30.393, P<0.001). However, there are no statistical difference between non-users and current users in terms of age, educational level and whether they come from non-smoking family.

3.3. Personality traits between non-users and current users

As shown in Table 3, respondents who do not use e-cigar, have higher level of conscientiousness and agreeableness, lower level of neuroticism and extraversion. Among the current users, the score of openness is the highest, and follow by conscientiousness, agreeableness, and extraversion, while neuroticism scored the lowest. According to the results of Mann-Whitney U tests, agreeableness shows statistically significant higher in non-users (Z = 2.585, $P < 0.01$). There are no significant differences in total score of personality traits and other dimensions between non-users and current users.

3.4. Determinants of the use of e-cigar among college students

As shown in Table 4, two-step hierarchical Logistic regression analysis are used to determine the predictors that associated with the use of e-cigar. The purpose of using two-step hierarchical regression analysis is to study the unique influence of personality traits on the use of e-cigar after controlling demographic variables. Therefore, demographic variables such as gender, the relationship with father or mother (good or not good), and friends' e-cigar users (no or yes), allowance per month (<900 or ≥900 Yuan) enter the first step of hierarchical Logistic regression analysis (Model 1). The result shows that the use of e-cigar is influenced by gender, the relationship with mother, friends' e-cigar users, and allowance per month ($P < 0.01$).

Model 2, the second step of hierarchical Logistic regression analysis, includes demographic variables and personality traits such as neuroticism, conscientiousness, agreeableness, openness and extraversion. The result shows that the aforementioned variables in Model 1 retains a significant effect ($P < 0.05$), and agreeableness is related to the use of e-cigar (AOR = 0.957, $P < 0.05$). Adjusted odds ratio (AOR) for each predictor at two steps of the analysis are presented in Table 4.

TABLE 2 Comparing the demographic characteristics between non-users and current users.

Variables	Non-users (%)	Current users (%)	χ^2/Z	*P*
Age	20.0 (19.0, 21.00)	20.0 (19.0, 22.00)	0.245	0.807
Gender			15.101	<0.001
Male	608 (92.5)	49 (7.5)		
Female	685 (97.2)	20 (2.8)		
Educational level			0.690	0.406
Junior college	627 (94.4)	37 (5.6)		
Undergraduate or higher	666 (95.4)	32 (4.6)		
Allowance per month (Yuan)			5.472	0.019
<900	520 (96.7)	18 (3.3)		
≥900	773 (93.8)	51 (6.2)		
The relationship with father			14.497	<0.001
Good	1,262 (95.3)	62 (4.7)		
Not good	31 (81.6)	7 (18.4)		
The relationship with mother			25.198	<0.001
Good	1,283 (95.2)	64 (4.8)		
Not good	10 (66.7)	5 (33.3)		
Friends' e-cigar users			30.393	<0.001
No	772 (97.7)	18 (2.3)		
Yes	521 (91.1)	51 (8.9)		
Non-smoking family			0.197	0.657
No	828 (94.7)	46 (5.3)		
Yes	465 (95.3)	23 (4.7)		

TABLE 3 Comparison of the personality traits between non-users and current users.

Dimension	Non-users [M, (Q_1, Q_3)]	Current users [M, (Q_1, Q_3)]	*Z*
Neuroticism	20.0 (13.0, 28.0)	25.0 (13.0, 31.0)	1.597
Conscientiousness	32.0 (26.0, 38.0)	31.0 (25.0, 40.0)	0.100
Agreeableness	32.0 (28.0, 38.0)	31.0 (27.0, 33.5)	2.585*
Openness	31.0 (25.0, 38.0)	34.0 (24.5, 40.5)	1.744
Extraversion	28.0 (24.0, 33.0)	30.0 (24.08, 34.5)	1.482
Total score	146.0 (131.0, 162.0)	153.0 (136.0, 169.5)	1.428

*$P < 0.01$.

4. Discussion

To our best knowledge, this study is the first in China to explore the relationship between the use of e-cigar and personality traits among college students. Based on the theoretical study of Big Five Personality Traits, our study shows that there is significant difference between current users and non-users in the dimension of agreeableness, but there are no significant differences in neuroticism, conscientiousness, openness and extraversion. The results of two-step hierarchical Logistic regression analysis show that age, gender, the relationship with mother, friends e-cigar users and agreeableness are associated with the use e-cigar.

The present study shows that the prevalence of current e-cigar users is 5.1%, which is closed to other studies in China, but still at a low level comparing with the United States and New Zealand (10, 27). However, people in China know less about e-cigar. With the popularity of electronic products and

TABLE 4 Factors associated with the use of e-cigar among college students.

Variables	Model 1		Model 2	
Age	1.032	0.869–1.227	1.032	0.864–1.231
Gender (Ref. = Male)	0.271**	0.154–0.477	0.312**	0.174–0.562
The relationship with father (Ref. = Good)	1.646	0.552–4.911	1.256	0.403–3.916
The relationship with mother (Ref. = Good)	6.824**	1.740–26.764	5.887*	1.460–23.748
Friends' e-cigar users (Ref. = No)	3.895**	2.219–6.839	3.808**	2.159–6.719
Allowance per month (Ref. <900 Yuan)	2.312**	1.289–4.148	2.482**	1.371–4.490
Neuroticism			1.021	0.995–1.048
Conscientiousness			1.013	0.975–1.052
Agreeableness			0.957*	0.918–0.997
Openness			1.004	0.967–1.041
Extraversion			1.013	0.971–1.057
Constant	0.003**	–	0.003**	–

#AOR, adjusted odds ratio. ** $P < 0.01$; * $P < 0.05$.

the rapid development of domestic e-commerce platform, online shopping has become one of the main shopping channels for college students in China. Chen et al. (1) conducted a survey on Tmall, the largest e-commerce platform in China, and found that there was misleading information in online sales of e-cigar, such as low cost, healthier than traditional cigarettes, no addictive.

This study also shows that the level of agreeableness is higher in non-users than that of current users, which is consistent with Buczkowski et al. (28). This may be related to the fact that individuals with high level of agreeableness are more submissive and altruistic. According to the definition of agreeableness, it is a tendency to sympathize and cooperate, including altruism, trust and other prosocial behaviors (25). People with high level of agreeableness adopt problem-focused coping strategies, including seeking social support, passive endurance, and avoiding conflicts (29).

Although the four dimensions of personality traits, such as neuroticism, conscientiousness, openness and extraversion are not statistically significant in this study, they are proved to be different in other studies on tobacco products and personality. A previous study had shown that current e-cigarette users had higher level of neuroticism than non-users (25). Neuroticism is mainly related to negative emotions such as fear and anxiety. Studies have shown that individuals with high neuroticism are more likely to have an unhealthy lifestyle and have been linked to starting smoking (28, 30, 31). However, Gareth et al. (32) mentions the concept of "healthy neuroticism," which mean that higher neuroticism and more socioeconomic resources could lead to healthy behavior, such as seeking advice, requiring testing of screening programs and closer monitoring of life style.

In the Big Five Personality Traits model, conscientiousness is considered to be the most closely related to substance use (33). A meta-analysis of 194 studies confirmed that conscientiousness was negatively correlated with smoking, alcohol and drug abuse (34). Kubicka et al. (35) reported that low levels of conscientiousness in childhood could predict smoking in adulthood in a prospective study involving 24-year follow-up. Additionally, individual with low level of conscientiousness is also closely related to smoking relapse in former smokers. Individuals with high level of conscientiousness have better self-control and long-term planning ability, so their lower smoking behavior may be related to the compliance of healthy lifestyle and the adoption of public health advice (31).

Extraverts are considered to be more sociable. Chen et al. (1) found that e-cigarette sales advertisements in China mentioned that e-cigarette had social benefits such as promoting family harmony and establishing interpersonal relationships. Some studies have shown that smokers had higher extraversion scores than non-smokers (30, 31). On the one hand, high extraversion is related to social ability. Since smoking is usually a social activity, individuals with higher extraversion may start smoking and continue to smoke (31). On the other hand, high extraversion is also associated with sensation of seeking stimulation. Similar to openness, nicotine in e-cigarette solution can promote the release of dopamine and satisfy the sensation of seeking stimulation, which is also an important reason why it is difficult for extraverted people to quit smoking (28, 30).

Openness is a personality trait related to divergent thinking and intelligence (36). Previous study found that the degree of openness mainly depends on the function of dopamine in the prefrontal cortex (36). Nicotine in electronic cigarette solution

can stimulate dopamine in prefrontal cortex to increase its activity and make users feel happy, so it is considered to be the reason for individuals to start smoking and continue to smoke (37). Similar results have been found in traditional cigarette and personality studies, where individuals with high levels of openness are significantly associated with an increased risk of trying to use cigarettes and lifetime smoking. Previous studies have found that 20.7% of advertisements mention nicotine salt and vaguely claim that the product has a low nicotine content and misled consumers (1). In addition, Coleman et al. (38) believes that openness is similar to susceptibility, suggesting a lack of clear commitment to the use of tobacco products. Margolis et al. (39) found that teenagers had a low perception of the harm of e-cigar, which made them have a strong curiosity and openness to use of e-cigarettes. Therefore, public health educators need to provide college students with adequate and accurate health education about the effects of e-cigar on health, so as to reduce their curiosity and open attempts to e-cigar. In addition, government need to regulate e-cigarette advertisements to prevent misinformation about e-cigarettes to adolescents and young adults.

Moreover, age is thought to be one of the risk factors for the use of e-cigar. A previous study showed that e-cigar was more easily accepted by adolescents and young adults because it looked fashionable (15). Compared with traditional cigarettes, e-cigar have more flavors, such as fruit, candy, mint, etc. and are more popular with adolescents and young adults. In addition, e-cigar in China is mainly sold to adolescents and young adults, so the online publicity platform has become the main point of sale. However, many e-cigar advertisements gave the wrong message, such as no nicotine, no addiction, can effectively help quit smoking, and arouse strong curiosity among college students (1).

There are also gender differences in e-cigarette users. Overall, the prevalence rate of e-cigar in female are lower than that in male. A study in Japan showed that female smokers had higher extraversion and lower agreeableness than female non-smokers, while male smokers showed higher extraversion and lower openness than male non-smokers (30). Zhao et al. (40) found that female e-cigar users generally used e-cigar for social purpose, which is consistent with the higher extraversion mentioned above. Compared with male e-cigar users, female users will pay more attention to the appearance and design of e-cigar. However, the motivations for male to use e-cigar included use convenient, can help quit smoking, have a similar taste to traditional cigarettes, less harm to health, safety, fashion, can be used in non-smoking places, etc. (40).

In present study, the relationship with mother is considered to be another risk factor for e-cigar use. Students who have a bad relationship with mother are more likely to use e-cigar than those who have a good relationship with their mother. Studies have shown that there is a relationship between parental rearing styles and children's stress coping styles (17, 18). In traditional Chinese families, mother plays a major role in family care and upbringing of children. Mother can teach their children how to cope with stress in their daily life. Children who have a good relationship with their mother may get more attention and care, and their neuroticism (related to negative emotions such as anxiety and fear) have a lower score. Tobacco products have been shown to be associated with stress coping. People with high levels of neuroticism are more likely to use tobacco products to cope with stress (30).

Friends who use e-cigarettes are also closely related to the use of e-cigar, which is consistent with the results of other studies (10, 27). Deviant peer affiliation may be linked to unhealthy behaviors such as smoking, drinking and cyber bullying, which may be a window for college students to be exposed to e-cigarettes (19). When college students face with stressful life events, the cigarette delivery behavior of deviant peers is more likely to lead to the use of e-cigarettes. In addition, college students, who are exposing to the e-cigarette environment, are likely to use by the smoke of e-cigar, curiosity and taste. Therefore, friends who use e-cigar are closely related to the use of e-cigar.

Government should issue corresponding laws to restrict the sales approach of e-cigarettes, especially through the Internet. In addition, relevant laws and regulations should be formulated to prohibit the use of e-cigarettes in public places, so as to provide a good smoke-free support environment for teenagers and college students. Educational institutions should pay attention to tobacco health education activities and carry out courses related to the hazards of e-cigarettes to help teenagers realize the health hazards of e-cigarettes and reduce the possibility of using e-cigarettes. Teachers and staff should also avoid the use of e-cigarettes in schools and set an example for the establishment of a smoke-free campus (41). Family support is also an effective way to reduce the use of e-cigarettes. Parents can reduce the use of e-cigarettes among teenagers through education and supervision. The establishment of smoke-free families helps to protect teenagers from the effects of secondhand smoke, thereby reducing the possibility of using e-cigarettes (42).

The present study has several strengths. To our knowledge, this is the first study to explore the relationship between the use of e-cigar and personality traits among college students in Guangdong Province, China. We find evidence that personality trait, especially agreeableness, is associated with the use of e-cigar. As a protective factor, individuals with higher agreeableness are less likely to use e-cigar. In addition, other personality traits such as neuroticism, conscientiousness, openness, and extraversion should not be ignored, although they are not statistically significant in this study.

There are also some limitations in this study. First of all, the subjects of our study are selected only from

three undergraduate universities and three junior colleges in Guangdong Province, and the representativeness may be limited. In the future, our conclusion will be verified by increasing the sample size. Secondly, this is a cross-sectional study, and it is difficult to draw causal conclusions, but it can still provide clues for future longitudinal research. Finally, our study is a self-reported questionnaire, which may have recall bias or information bias. For example, some college students may not want to report the actual status of e-cigar use, so the actual prevalence rate of e-cigar use may be higher. Despite these limitations, our research confirms that there is a relationship between e-cigarette use and personality traits. All these provide an important theoretical basis for future intervention.

5. Conclusions

Overall, this study found that the prevalence rate of e-cigar among college students in Guangdong Province, China was 5.1%. In addition, it is confirmed that personality trait, especially agreeableness, is related to the use of e-cigar, but the effects of other personality traits such as neuroticism, conscientiousness, openness and extraversion on e-cigar use can't be ignored. In addition, notable predictors included gender, the relationship with mother and friends who used e-cigar, allowance per month are the factors associated with the use of e-cigar. These phenomena also sound the alarm for Chinese tobacco control departments and government departments. On the one hand, college students' awareness of the harm of e-cigarettes should be raised, on the other hand, relevant policies should be put forward to control the sales and use restrictions of e-cigar.

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 studies involving human participants were reviewed and approved by Biological and Medical Ethics Committee Guangzhou Xinhua University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JM contributed to conceiving and designing the study, wrote the manuscript, and edited the final version. LL and LZ contributed to discussing and analyzing the data. QG, WZhu, and WZhou contributed to data collecting and coding. 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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EDITED BY
Iffat Elbarazi,
United Arab Emirates University,
United Arab Emirates

REVIEWED BY
Rui Medeiros,
Portuguese Oncology Institute, Portugal
Esteve Fernandez,
Catalan Institute of Oncology, Spain
Omotayo Francis Fagbule,
University College Hospital Ibadan, Nigeria

*CORRESPONDENCE
Jose M. Martin-Moreno
jose.martin-moreno@uv.es

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Characteristics of tobacco use among secondary school students: a cross-sectional study in a school in Valencia, Spain

Joan Antoni Ribera-Osca[1], Francisco Carrion-Valero[2,3,4], Victor Martin-Gorgojo[4,5], Yolanda Rando-Matos[6], Carlos Martin-Cantera[7] and Jose M. Martin-Moreno[3,8]*

[1]Department of Health Valencia-La Fe, Health Care Center Alcàsser, Valencia, Spain, [2]Pneumology Department, Hospital Clínico Universitario, Valencia, Spain, [3]Medicine Department, Universitat de València, Valencia, Spain, [4]Biomedical Research Institute INCLIVA, Hospital Clínico Universitario, Valencia, Spain, [5]Orthopaedic Surgery and Traumatology Department, Hospital Clínico Universitario, Valencia, Spain, [6]Primary Health Center Florida Nord, Direcció d'Atenció Primària Costa de Ponent, Catalan Health Institute, L'Hospitalet de Llobregat, Barcelona, Spain, [7]Research Support Unit, Institut Universitari d'Investigació en Atenció Primària Jordi Gol (IDIAPJGol), Barcelona, Spain, [8]Department of Preventive Medicine and Public Health, Universitat de València, Valencia, Spain

Introduction: Cigarette smoking is a significant public health problem, and it is essential to work actively with young people to limit the incorporation of this addiction. This study aimed to identify characteristics associated with tobacco use in adolescents in a real setting.

Methods: Epidemiologic, cross-sectional study including secondary school students aged 12–17 years in the 1st, 2nd, and 3rd grades of "Joan Fuster High School" in the city of Sueca, Valencia (Spain). An anonymous, self-administered questionnaire was used to collect data on demographics, cigarette smoking history, alcohol consumption, nicotine dependence, and exposure to parental cigarette smoking.

Results: The final sample of individuals surveyed included 306 students (50.6% females) with a median age of 13 years. The prevalence of cigarette smoking was 11.8% (13.5% in females and 9.9% in males). The mean age of cigarette smoking onset was 12.7 $\pm$ 1.6 years. Ninety-three students (30.4%) were repeaters, and 114 (37.3%) reported alcohol consumption. Significant factors associated with tobacco use were being a repeater (odds ratio [OR] 4.19, 95% confidence interval [CI] 1.75–10.55, p = 0.002), alcohol consumption (OR 4.06, 95% CI 1.75–10.15, p = 0.002) and parental cigarette smoking (OR 3.76, 95% CI 1.52–10.74, p = 0.007).

Discussion: An operational profile of features associated with tobacco consumption was identified in the presence of parental cigarette smoking, alcohol consumption, and poor academic performance. Consideration of these factors could be useful in the operational design of cigarette smoking cessation interventions for young people in a context where there is a great need for better prevention and control of cigarette smoking.

KEYWORDS

smoking, tobacco, cigarette, adolescents, cross-sectional study, survey

1. Introduction

Smoking is considered one of the most relevant public health threats worldwide, and tobacco use is initiated primarily during adolescence (1, 2). The 2021 statistics of the US Centers for Disease Control and Prevention (CDC) on tobacco use among youth were striking: 4.0% of middle school students and 13.4% of high school students reported current use of a tobacco product (3). If cigarette smoking continues to increase at the current rate among this group of age, 5.6 million people bellow the age of 18 could die in the US of smoking-related illnesses (that is about 1 of every 13 Americans aged 17 years or younger who are alive today) (4). The 2019 report of the European School Survey Project on Alcohol and Other Drugs (ESPAD), based on 99,647 students (15- to 16-year-old) from 35 European countries, indicates that 9% of Spain's students consume tobacco daily, with a prevalence of lifetime cigarette use of 41%, similar to the rest of 35 participating countries (5). These data are consistent with the 2021 report of the Spanish Observatory on Drugs and Addictions (6), in which 41.3% of secondary school students smoked tobacco once in their lifetime and 26.7% in the previous 30 days, with a mean age at smoking onset of 14.1 years. Surveys from other countries and regions have warned of the high prevalence of tobacco use among adolescent populations (7).

Cigarette smoking is considered to be initially triggered by personal experimentation and is often mistakenly conceived among adolescents as the transition to adulthood (8, 9). This could be explained by the Attitude Self-Efficacy (ASE) model (10), a behavioral change framework aimed at preventing risky behaviors, such as smoking. It comprises three determinants, including attitudes towards the behavior that are shaped by beliefs and the associated outcomes, subjective norms that are the expectations perceived from the immediate environment regarding the behavior, and self-efficacy, which relates to an individual's expectations about their ability to engage in the health behavior.

In this respect, alcohol and tobacco are considered to be the most accessible drugs (5). In addition to the susceptibility to persistent addiction in adulthood, tobacco use during adolescence is associated with parallel alcohol consumption and cannabis use (8), with an increased hazard of depression and vascular damage (2). Moreover, social and environmental aspects can relate to smoking uptake. Thus, the probability of adolescents becoming smokers doubles if their peers smoke and triples if there is a favorable context towards smoking (11, 12). Kovacs et al. (13) identified low economic income, maternal alcohol consumption, parental smoking, and school dropout as determinants for smoking. Complementarily, higher tobacco consumption has been related to higher rates of school failure (14, 15). A link between tobacco use and parental smoking and/or perceived parental involvement (16), older age (17), alcohol intake, weak interest in school/poor academic performance, and being a smoker's best friend (18) has also been described. Nevertheless, the level of dependence is usually low, which justifies early intervention in this age group (19, 20).

Considering the magnitude and seriousness of the problem, it is dissapointing the paucity of research and programs carried out in this field. Furthermore, results of interventions in adulthood once smoking has become firmly established are limited. With this in mind, the main aim of the study was to characterize the prevalence of tobacco use and the level of dependence among adolescents in a population of secondary school students aged 12 to 17 years, as well as to jointly assess the possible associations between tobacco use and sex, poor academic performance, alcohol consumption or parental smoking. The practical, underlying motivation of this study was the need to identify the features of adolescent smokers so that their characterization could help us to design more effective smoking prevention programs adapted to the defining traits of the target population of adolescent schoolchildren.

2. Materials and methods

2.1. Design and study sample

This was an observational, cross-sectional survey study of secondary school students aged 12 to 17 years enrolled at the "Joan Fuster High School" of the city of Sueca (with 26,617 inhabitants according to the 2021 census) located in the autonomous community of Valencia (Spain). The starting age for 1st ESO students was 12 years old, for 2nd ESO students it was 13 years old and for 3rd ESO students 14 years old. As the school course takes two calendar years, the ages have a range of one more year (i.e., 1st ESO 12–13 years old, 2nd ESO 14–15 years old and 3rd ESO 15–16 and up to a maximum of 17 years old). The socio-economic level of the areas covered by the institute corresponds to the working population, mainly in the industrial and agricultural spheres, and to a lesser extent in the economic area corresponding to services. This center was chosen for its accessibility and also for its size, since we could reach all enrolled students, and the total study sample was large enough to meet the needs set by the predetermined statistical power and the expected precision of the study.

Students who attended scheduled talks on tobacco use between October and November 2017, who agreed to participate, and completed the study questionnaire were eligible. These scheduled talks on tobacco were part of a parallel objective to the one that is the subject of this manuscript. In summary, the intervention consisted of a talk given by the medical professional who conducted the study to the participating students about the consequences of tobacco use, as well as specific training in social skills and social influence management in the face of tobacco use. This survey was framed as the initial baseline action of a quasi-experimental doctoral thesis research study of one of the authors (J.A. R-O.) (21), which aimed to assess the effect of a preventive intervention program against tobacco use compared to the current established interventions promoted by the local government administration.

The study was approved by the Ethics Committee of the Health Research Institute of Hospital Universitari i Politècnic La Fe of Valencia (code 2016/0599, approval date January 17, 2017). Written informed consent was obtained from parents/legal guardians, after which assent was obtained from the under-aged students.

2.2. Study procedures

An *ad hoc* questionnaire was designed. This was adapted from different sources, including a previous study from Zaragoza (Spain) on nicotine dependence among school students who were active smokers (22) and surveys from the annual activities (2010 to 2016) of the "smoke-free week" promoted by the Spanish Society of Family and Community Medicine (23, 24). The final questionnaire included a section with general aspects on age, sex, school year, being a repeater or not of any academic year, the student's cigarette smoking history, attitudes towards cigarette smoking, and alcohol consumption, and a second section with

questions related to passive cigarette smoking. The questionnaire was anonymous, self-administered, and had to be completed by participants in their classrooms without the presence of teachers. All students were invited to participate. The actual questionnaire (in Spanish) is available from the first author (J.A. R-O.) upon request.

Each student was classified according to tobacco use into daily cigarette smoker (smokes at least one cigarette every day), occasional cigarrete smoker (smokes at least one cigarette, but not every day, including the so-called "experimenters"), ex-cigarette smoker, and never a cigarette smoker. A current cigarette smoker was defined as the one who in the last month has smoked any number of cigarettes. On the other hand, an ex-smoker was defined as a person who been a cigarette smoker in the past, has not consumed tobacco cigarettes in the last 6–12 months. Alcohol use was also classified into current alcohol consumption (daily or almost daily), occasionally or only when going out to parties, and non-drinker. All categories of alcohol consumption were categorized into the group of alcohol consumption. In order to examine the level of passive cigarette smoking in the family environment, we inquired about the cigarette smoking habit of the parents, asking the students if their parents smoked around them, and they could answer: always or almost always, occasionally or never.

The level of nicotine dependence was evaluated according to the adaptations made by Clemente Jimenez et al. (22) to the Fagerström Test of Nicotine Dependence. Please refer to Supplementary material section for more details about it. In this adaptation, the language of the test is adapted to suit adolescents, and the items are recoded as so to ensure comparability with other tests. A score < 4 is considered low, 4–6 moderate, and 7–10 high dependence on nicotine.

2.3. Statistical analysis

Categorical data were expressed as frequencies and percentages, and continuous data as mean and standard deviation (SD) or median and interquartile range (IQR). We examined the subset of missing replies trying to verify any noticeable trend in the way data was missing and then removed the values only after verifying that they could be deleted without significantly distorting readings. Differences in studied variables between smokers and non-smokers were compared with the Chi-square test for categorical data and the Student's t-test for continuous data. To assess factors associated with adolescent cigarette smoking, multivariate logistic regression model was fitted with covariates including sex, age, whether or not the patient was a repeater, alcohol consumption (categorized as yes/no), and parental cigarette smoking (categorized as yes/no). Odds ratio (OR) and 95% confidence intervals (CIs) were estimated. Statistical significance was set at $p < 0.05$. All statistical analyses were performed with the R statistical program (version 3.6.1) and the ordinal (2019.4–25) and clickR (0.4.32) packages.

3. Results

The total number of students from the 1st, 2nd, and 3rd grades at the "Joan Fuster High School" was 328. However, during the days in which the survey took place, 11 students were absent. Of the remaining 317 students who participated in the study, 11 provided incomplete questionnaires and were excluded from the analysis. Therefore, the final studied sample included 306 students, with a complete response rate to the questionnaire of 93.3%.

There were 151 boys and 155 girls, with a mean age of 13.4 ± 1.0 years. Almost 40% were in the 1st grade, and 30.4% were repeaters. Current smokers accounted for 11.8% of our sample, and 61.1% of smokers reported tobacco consumption on a weekly basis. The mean age at the onset of cigarette smoking was 12.7 ± 1.6 years. The level of nicotine dependence was low in 97.2% of the current cigarette smokers. Alcohol consumption was reported by 37.3% of participants, with 60.5% being occasional drinkers. More than 50% of students were exposed to passive cigarette smoking, with a rate of parental tobacco consumption of 54.1%. Salient characteristics of the study sample are shown in Table 1. Statistically significant differences between males and females in the distribution of study variables were not found.

In the bivariate analysis, there were statistically significant differences between current smokers and non-smokers in terms of mean age (smokers were younger, 13.3 vs. 13.6 years respectively), percentages of repeaters (66.7% vs. 44.5%), alcohol consumption (75.0% vs. 56.1%), and parental tobacco use (83.4% vs. 53.1%), all of which were higher among cigarette smokers (Table 2).

In the logistic regression model, significant factors associated to tobacco consumption were being a repeater, alcohol consumption, and parental cigarette smoking (Table 3). Being a repeater (OR 4.19, 95% CI 1.75–10.55, $p = 0.002$), alcohol consumption (OR 4.06, 95% CI 1.75–10.15, $p = 0.002$) and parental cigarette smoking (OR 3.76, 95% CI 1.52–10.74, $p = 0.007$) were associated with an increased risk of tobacco consumption.

4. Discussion

Adolescents are particularly vulnerable to nicotine addiction and the adverse effects associated with tobacco smoking (25). Among adolescent cigarette smoking' adverse effects is lung cancer, which has been firmly established. However, evidence is less cleared for other cancers, such as colorectal and breast cancer (26). Nonetheless, the prevalence of cigarette smoking of 11.8% among secondary school students in our study is high and consistent with data provided by the ESPAD project (5) and other studies (7, 27, 28). For this reason, it is essential to aim for a reduction in their initiation. The mean age of tobacco consumption onset in current cigarette smokers was 12.7 years, 19 months younger than that described in the ESPAD survey (14.1 years) (5). This may be due to a higher percentage of students in the first two grades of secondary school, which could have influenced the mean age of cigarette smoking onset. In fact, we are aware that we do not have age-specific surveys identical to those in our study, although those previously cited do include at least part of the consumption age range of our sample, so in this discussion we compare our estimates against those available from the reference surveys. However, there is no clear answer to explain these differences.

In the present study, there were a higher proportion of females who smoked (13.6%) compared with males (9.9%). However, this difference was not statistically significant. By contrast, other studies on adolescents have found that women smoke less than men (29, 30). Nevertheless, in a sample of 6,020 15- to 16-year-old pupils from 41 schools in England who completed an anonymous self-report survey, more females reported smoking, but males were more likely to be heavy smokers (31). Differences in smoking behaviors between male and female adolescent populations have been associated with numerous factors, including socioeconomic level and culture, the pressure of tobacco marketing, cigarette advertising and promotion,

TABLE 1 Demographic characteristics and data related to cigarette smoking, alcohol consumption, nicotine dependence, and parental cigarette smoking by sex.

Variables	Total students (*n* =306)	Males (*n* =151)	Females (*n* =155)
Median age, years (IQR)	13 (13–14)	14 (13–14)	13 (13–14)
Academic grade, *n* (%)			
1st	113 (36.9)	60 (39.7)	53 (34.2)
2nd	112 (36.6)	48 (31.8)	64 (41.3)
3rd	81 (26.5)	43 (28.5)	38 (24.5)
Repeaters, *n* (%)	93 (30.4)	56 (37.1)	37 (23.9)
Tobacco consumption, *n* (%)			
Never smoker	214 (69.9)	109 (72.2)	105 (67.7)
Ex-smoker	38 (12.4)	27 (17.9)	29 (18.7)
Current smoker	36 (11.8)	15 (9.9)	21 (13.5)
Occasional (< 1 cigarette/week)	6 (16.7)	2 (13.3)	4 (19.0)
Weekly (≥ 1 cigarette/week)	22 (61.1)	11 (73.3)	11 (52.4)
1–10 cigarettes/day	7 (19.4)	3 (20)	4 (19.0)
11–20 cigarettes/day	1 (2.8)	0	1 (4.8)
> 20 cigarettes/day	1 (2.8)	0	1 (4.8)
Median age at cigarette smoking onset, years (IQR)	13 (12–14)	13 (12–13)	13 (12–14)
Nicotine dependence, *n* (%)			
Low	35 (97.2)	15 (100)	20 (95.2)
Moderate	0	0	0
High	1 (2.8)	0	1 (4.8)
Alcohol consumption, *n* (%)			
No	192 (62.7)	99 (65.6)	93 (60.0)
Yes	114 (37.2)	52 (34.4)	62 (40.0)
Daily/almost daily	2 (1.8)	1 (1.9)	1 (1.6)
Occasionally	69 (60.5)	29 (55.8)	40 (64.5)
Only when going out to parties	43 (37.7)	22 (42.3)	21 (33.9)
Parental tobacco use (*n* = 303)			
No	139 (45.9)	60 (40.3)	75 (48.7)
Yes (in the presence of adolescents)	164 (54.1)	89 (59.7)	79 (51.3)
In the presence of adolescents	72 (43.9)	30 (33.7)	42 (53.2)
Always/almost always	36 (22.0)	25 (28.1)	11 (13.9)
Occasionally	56 (34.1)	34 (38.2)	22 (27.9)

IQR: interquartile range (25th–75th percentile).

male masculinity, and feminine roles, perception of harm, expectations and self-control, body weight concerns, environmental pressure, and vulnerability to smoking after trying a single cigarette (30, 32–36). In addition, several studies indicate that women's equality, misunderstood as the assumption of some traditional male roles, is often associated with poorer lifestyle habits, including tobacco con-sumption (25, 37).

Parental cigarette smoking is a strong and significant determinant for cigarette smoking by young people. In a meta-analysis of 58 studies, the relative odds of tobacco consumption in youth increased significantly if at least one parent smoked, especially if it was the mother or if both parents smoked (38). In a longitudinal analysis of data from 3,171 12- to 14-year-old students in 7 European countries allocated to the control arm of the European Drug Addiction Prevention trial, permissive parental norms toward cigarette smoking and alcohol use predicted adolescents' use of illicit drugs, especially among boys (39). In the present study, the majority of students whose parents smoked (83.3% vs. 16.7% of non-smoker parents) consumed tobacco. Thus, it seems essential to recall the importance of the parental role model, which can greatly influence their children's risky health behaviors. Moreover, alcohol consumption, parental tobacco consumption, and being a repeater of academic years were significantly associated with an increased likelihood of cigarette smoking in the regression model. Other studies have also shown that poor academic performance is associated with a greater probability of cigarette smoking initiation, more frequent

TABLE 2 Bivariate analysis on the baseline characteristics of the secondary school students studied comparing the group of cigarette smokers with non-smokers.

Variables	Total students (*n* =306)	Smokers (*n* =36)	Non-smokers (*n* =155)	*p*-value
Mean age, years ± SD	13.4 ± 1.0	13.3 ± 0.9	13.6 ± 1.1	<0.001
Gender, *n* (%)				
Male	151 (49.3)	15 (41.6)	136 (87.7)	0.422
Female	151 (50.6)	21 (45.6)	133 (85.8)	
Repeaters, *n* (%)	93 (30.4)	24 (66.7)	69 (44.5)	<0.001
Alcohol consumption, *n* (%)	114 (37.3)	27 (75.0)	87 (56.1)	<0.001
Parental tobacco use, *n* (%)	164 (54.1)	30 (83.3)	134 (53.1)	<0.001

TABLE 3 Logistic regression analysis of the factors associated to tobacco consumption in the studied group of secondary school students.

Variables	Odds ratio (95% confidence interval)	*p*-value
Gender		
Females (reference)	1	
Males	0.55 (0.24–1.23)	0.149
Age, years	1.10 (0.70–1.72)	0.675
Repeater		
No (reference)	1	
Yes	4.19 (1.75–10.55)	0.002
Alcohol consumption		
Never (reference)	1	
Yes (daily/almost daily)	4.06 (1.75–10.15)	0.002
Parental cigarette smoking in the presence of adolescents		
No (reference)	1	
Yes	3.76 (1.52–10.74)	0.007

cigarette smoking, a higher number of cigarettes smoked, and fewer attempts to quit smoking (40–42).

Given that adolescents who smoked were in the early stages of dependence, most of our participants under study (97.2%) had a low level of nicotine dependence. In the study by Clemente (22), whose population consisted of students in the age range of 10- to 17-years-old, low-to-moderate dependence rates were reported in a similar percentage of participants (86.6%). However, it has been shown that the first symptom of nicotine dependence can appear in some youths within days to weeks of the initiation of occasional tobacco use, often before the onset of daily smoking (43). The fact that symptoms of nicotine dependence may develop soon after initiation and/or at low levels of smoking suggests that novice adolescent smokers should not be neglected in smoking cessation interventions for early emerging symptoms (44).

Limitations of the study include the potentially limited external validity (generalizability to other schools in this district or other regions) due to the convenient sample, tobacco use defined by cigarettes only, and limited causality due to cross-sectional design. Other interesting variables, such as the use of electronic cigarettes or the assessment of biomarkers of tobacco exposure were not investigated. Moreover, self-report questionnaires may not always be reliable; although students were told in advance that the questionnaire was anonymous, it had to be completed without the presence of teachers in the classroom and truthfully because of the use of data for research purposes exclusively. This is probably the reason why participation among students was almost complete, being this fact noteworthy. However, we believe that the present results shed some practical facts to the current knowledge of adolescent cigarette smoking behavior and may help decision-making by authorities to develop preventive interventions for this population segment.

In conclusion, the present findings add evidence of the utmost importance of tobacco use in adolescence as a very relevant public health problem, especially because of an early age of onset. An operational profile of features associated with tobacco consumption was identified in the presence of parental cigarette smoking, alcohol consumption, and poor academic performance. Knowledge of this profile and the operational factors identified may be useful in designing cigarette smoking cessation in youth.

Data availability statement

The datasets presented in this study can be found in online repositories, and can also be provided by the first author upon request. The names of the repository/repositories and accession number(s) can be found at: https://roderic.uv.es/handle/10550/76772.

Ethics statement

This study was reviewed and approved by Ethics Committee of the Health Research Institute of Hospital Universitari i Politècnic La Fe of Valencia. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JR-O, FC-V, and JM-M: conceptualization and methodology. JR-O and VM-G: formal analysis. JR-O, FC-V, VM-G, YR-M, and CM-C: investigation. JR-O: resources. FC-V and JM-M: writing. JM-M: supervision. 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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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1069294/full#supplementary-material

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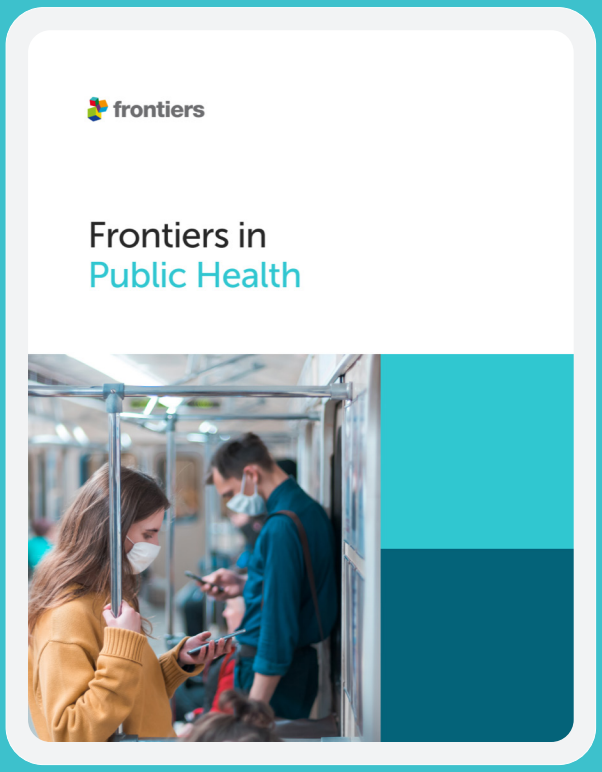

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Avenue du Tribunal-Fédéral 34
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