THE IMPORTANCE OF ASSESSING HEALTH STATUS AND HEALTH BEHAVIORAL CHARACTERISTICS IN CHILDREN

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THE IMPORTANCE OF ASSESSING HEALTH STATUS AND HEALTH BEHAVIORAL CHARACTERISTICS IN CHILDREN

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Psychometric Properties of the Korean Version of the Smoking Media Literacy Scale for Adolescents

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Smoking media literacy has proven to be an effective competency for reducing adolescents' smoking. This study aimed to cross-culturally modify the smoking media literacy scale and evaluate the validity and reliability of the Korean version of the revised Smoking Media Literacy Scale for Adolescents (K-SMLS). The translation of the K-SMLS was conducted according to the World Health Organization's guidelines. After the translation process, an online survey was conducted with convenience samples of 215 total adolescents from five high schools in the capital city of Korea. Construct validity was examined by exploratory factor analysis and confirmatory factor analysis. Internal consistency reliability was examined with Cronbach's alpha. The final version of the K-SMLS consisted of 15 items. The goodness of fit, determined through a confirmatory factor analysis of the three domains, was acceptable [$\chi^2 = 237.85$ ($p < 0.001$), CFI = 0.93, TLI = 0.92, RMSEA = 0.09, SRMR = 0.09]. The reliability of the K-SMLS was satisfactory (Cronbach's alpha = 0.78). The findings provide evidence for a valid and reliable tool that can be used to assess smoking media literacy in Korean adolescents. Further studies with a probability sampling design are suggested as the use of convenience samples limits the generalizability of the results to other populations.

Keywords: smoking, media literacy, adolescent, validation, adaptation

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INTRODUCTION

Adolescent smoking is a global health concern (1). Although the prevalence of tobacco use has declined in most countries with a high human development index (2), the continued diversification of tobacco products, such as electronic cigarettes (hereinafter e-cigs), and tobacco industry's novel marketing strategies through social media have significantly contributed to adolescents' imitation of tobacco smoking (3, 4). In South Korea (hereinafter Korea), adolescent smoking is on the decline, as cigarette use was reported to be only 6.7% in 2019 (5), which is significantly lower than in other developed countries (OCED average: 11.7%) (6). However, there is a growing interest in emerging tobacco products, such as e-cigs and heat-not-burn products, while the influence of smoking-related media has increased in recent years (7–9).

The considerable impact of the media on adolescents has been widely reported. Researchers have demonstrated that adolescents develop permissive attitudes toward dangerous behaviors after seeing depictions of smoking in the media (10). Similarly, adolescents develop positive attitudes toward smoking after seeing their peers post smoking-related content on social media (11). Since depictions of smoking in the media induce curiosity about smoking among adolescents, the tobacco industry has aimed for their products to gain exposure in the media including on television, in movies, and on social media, often by targeting young people with attractive images (12). Recently, social media has become an important marketing platform for the tobacco industry (13, 14), while the sharing and viewing of user-generated content (i.e., *selfies*) that depict smoking have contributed to its normalization (15). In Korea, smoking scenes appear in more than 50% of web-based cartoons, movies, and dramas that Korean adolescents enjoy (16). Further, after an analysis of popular YouTube channels, researchers found that 72.7% of videos displayed tobacco products or smoking, while 86% of channels showed prominent *YouTubers* smoking (16).

Smoking media literacy (SML), defined as the understanding, analysis, appraisal, and interpretation of media messages about smoking (17), has been accepted as an important concept in addressing adolescent smoking. According to a systematic review by Vahedi et al. (18), interventions for enhancing media literacy were found to be effective in mitigating risky health behaviors, such as smoking, among adolescents. Additionally, a large cluster-randomized trial showed that high school students (14–15 years old) who received SML education for 5 weeks had a significantly higher tendency to perceive a reduction of the smoking rate compared to those without SML education (19). In Korea, a partial amendment to the National Health Promotion Act, which regulates the promotion of cigarettes, tobacco-like products, and e-cigs, was established at the State Council in 2020 (20). Although regulations for adolescent smoking are being reinforced, reducing adolescents' exposure to depictions of smoking in the media has been a difficult process because of the emergence of new tobacco products and tobacco companies' changing marketing strategies (21, 22). E-cigs are now marketed indirectly by social media influencers rather than via traditional marketing means (21). Therefore, SML, which has proven to be an effective strategy to reduce adolescent smoking, should be the focus of future efforts to prevent smoking and lower smoking rates.

To assess SML and general media literacy among adolescents in the United States, the Smoking Media Literacy Scale for Adolescents (SMLS) was developed by Primack et al. (17) and was later revised in 2014 (19). The scale has been used in Hungary (23) and Vietnam (24). However, due to recent changes in information and communication technologies, it is necessary to modify the scale to reflect the current state of social media. This study aimed to (i) cross-culturally modify the SMLS and (ii) evaluate the validity and reliability of the Korean version of the Smoking Media Literacy Scale for Adolescents (K-SMLS).

MATERIALS AND METHODS

Translation of SMLS

SMLS

The SMLS is a one-factor scale with 18 items. The scale's items are classified into three core domains: (i) Authors and audiences (items 1, 2, 3, and 4); (ii) Messages and meanings (items 5, 6, 7, 8, 9, 10, 11, 12, and 13); and (iii) Representation and reality (items 14, 15, 16, 17, and 18). The 18 items are scored on a 4-point Likert-type scale (0 = *strongly disagree*, 1 = *disagree*, 2 = *agree*, and 3 = *strongly agree*). Total raw scores range from 0 to 54. The total scores were converted to a 10-point scale by dividing the raw score for the 54-point scale by 5.4. Following the SMLS' authors, we also converted K-SMLS scores to a 10-point scale by dividing the raw score for the 45-point scale by 4.5. The SMLS exhibited a Cronbach's alpha of 0.87. This study was conducted after obtaining approval from the original scale's corresponding author to develop the K-SMLS.

Translation and Adaptation

The translation and adaptation process of the SMLS was performed in five steps (25) (**Figure 1**). In the initial step, a bilingual translator, fluent in both Korean and English, translated the English version of the SMLS into Korean. In the second step, the translated scale was reviewed and revised for accuracy and cultural relevance with help from a virtual panel of five experts (including one translator, two health care professors, the corresponding author, and the first author of this study). According to Article 10 of the enforcement decree of the Tobacco Business Act in Korea, the acts of providing bounty for tobacco sales, premiums, merchandise coupons, and other money or goods are prohibited (26). Thus, considering the current regulations on the promotion of tobacco sales in South Korea, three items were deleted (items 1, 5, and 16) based on an expert meeting with four professors who had experience in instrument development and translation. The removed items were as follows: Item 1—"Buy-one-get-one-free" deals on cigarettes are designed to get people addicted; Item 5—Wearing a shirt with a cigarette logo on it makes you into a walking advertisement.; Item 16—When you see a "buy-one-get-one-free" cigarette deal, it's usually not actually a good deal in the long run. The term "ads" was changed to "social media (*YouTube*, *Instagram*, etc.) promotion," as social media posts promoting smoking are not regulated yet in South Korea. Subsequently, another bilingual translator who had not seen the SMLS translated the Korean version back into English (i.e., back-translation). Finally, the corresponding and first author of this study reviewed the original scale and the back-translation, discussed sections that appeared unclear, and corrected the translation. The final version of the K-SMLS was pre-tested with six adolescents aged 15–18 years old *via* an online survey to ensure that all items were understandable, appropriate, and culturally sensitive. Most participants responded without any difficulty. They understood that the term "social media (*YouTube, Instagram*, etc.) cigarette promotion" included videos,

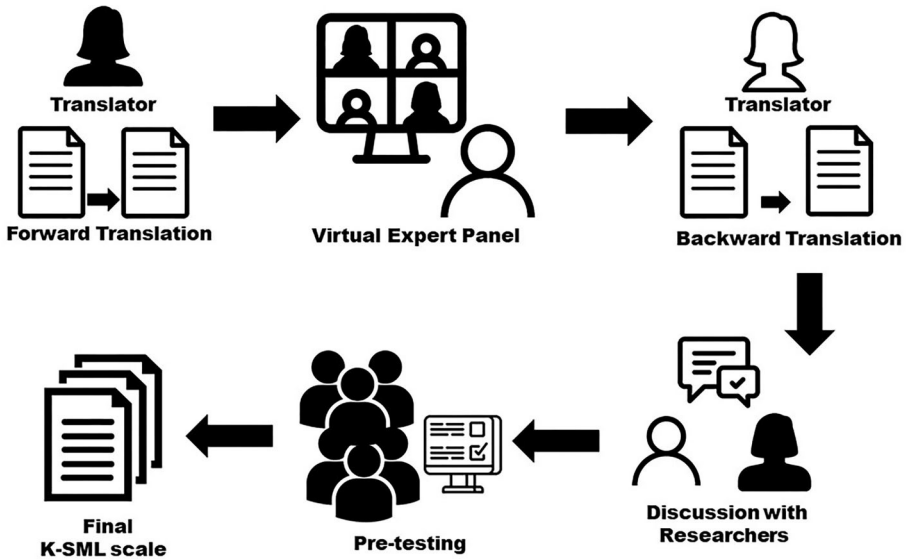

FIGURE 1 | Translation and adaptation process.

images, and posts reviewing tobacco products (e.g., cigarettes and e-cigs).

Content Validation

We used the item-level content validity index (I-CVI) (27) to evaluate whether the K-SMLS reflected the meaning of the SMLS' items appropriately, which allowed us to validate our version of the scale. A panel of nine experts was formed, comprising three professors in the health care field, three high school health teachers, and three master's or PhD candidates studying adolescent smoking. These experts were asked to rate the relevance of the scale's 15 items on a 4-point Likert scale (where 1 = *not relevant*, 2 = *somewhat relevant*, 3 = *quite relevant*, and 4 = *very relevant*). Each item's I-CVI was calculated as the proportion of experts who answered that the item was either *quite relevant* or *very relevant*. If the I-CVI value of an item was >0.8 (27), the item was deemed valid. Afterward, the experts were asked open-ended questions on the items' comprehensiveness.

Psychometric Properties

A psychometric evaluation of the K-SMLS was conducted to assess its construct validity and its internal consistency.

Sample and Data Collection

For this study, participants were conveniently sampled from five high schools in the capital city of South Korea. Potential participants were provided with information regarding the study's purpose; they were informed that their participation was voluntary, as they had the right to withdraw from the study at any time. It was also explained that their decisions whether or not to participate would not affect any school activities. Subsequently, informed consent forms were distributed to potential participants and their parents by teachers who were trained data collection process. Students who voluntarily wanted to participate brought research information and informed consents to their parents at home, and both adolescents and parents signed informed consents and submitted them to the teacher. The informed consents included a cell phone number to receive an online survey link. A total of 298 adolescents who submitted informed consents were invited to an online survey by giving the survey link. Two hundred fifty-four participants completed the online survey between August 4 and 21, 2020. A total of 39 surveys were excluded because they were outliers ($n = 5$) or duplicate submissions ($n = 34$). Ultimately, 215 valid surveys were identified, and response rate was 72.1%. The anticipated sample size was over 150 based on the criteria for the factor analysis, with a ratio of at least 5–10 cases per item (28).

Statistical Analysis

Data were analyzed using SPSS software for Windows (version 25, IBM Corp., Armonk, NY, USA) and RStudio (version 4.0.3., R Core Team, Vienna, Austria). A descriptive statistical analysis was conducted to parse participants' demographic characteristics, SML, and susceptibility to smoking. To assess the construct validity, an exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA) were performed. We used a parallel analysis (PA), the eigenvalues-greater-than-one rule, and a screen test for factor extraction at first. PA requires carrying out a comparison of the eigenvalues from actual study data with randomly generated eigenvalues. The number of factors to retain is equal to the number of actual study eigenvalues that exceed randomly produced eigenvalues. We carried out a PA with 1,000 random datasets and the 95th percentile of eigenvalues in this study. EFA

was conducted to support construct validity by identifying the characteristics of the factors. Subsequently, CFA was performed to assess the model's fit. CFA included root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis Index (TLI), and a chi-squared test. The RMSEA is a measure of average residual variance and covariance; average models have RMSEA values of $\leq$0.09. The criteria for accepted RMSEA value ranges are as follows: 0.05–0.08 (fair), 0.08–0.10 (mediocre), and >0.10 (poor) (29). The CFI is an index ranging from 0 to 1, with a value of >0.90 considered to be an indicator of good model fit (29, 30). To identify the internal consistency of the Korean version, we assessed Cronbach's alpha for total items as a whole and confirmed the item-total correlation coefficients.

Ethical Considerations

The study was approved by the Institutional Review Board of Yonsei University prior to conducting the study (IRB No. Y-2020-0066). All participants were provided with information about the study, signed an informed consent form, and received remuneration for participating in the study.

RESULTS

Demographic Characteristics of Participants

Table 1 summarizes participants' demographic characteristics. Participants' mean age was 16.73 ± 0.79 years. Male participants comprised 64.7% of the sample, while 14% of the participants reported having smoking experience. Further, 3.3% of the participants were current smokers, while 25.6% were classified as susceptible to smoking. About 71.2% of the participants' parents were current or past smokers, while 53.5% of the participants' friends were current or past smokers. Moreover, 16.3% of the participants perceived their friends to be heavy smokers, while 37.2% perceived them to be moderate smokers. Additionally, 30.2% of the participants spent over 4 h using their smartphone and/or computer daily. More than 70% of the participants' fathers and 67% of their mothers had higher education.

TABLE 1 | Demographic characteristics of the participants (n = 215).

Variables	Categories	Total
		Mean ± SD or *n* (%)
Age (year)		16.73 ± 0.79
Gender	Male	139 (64.7)
	Female	76 (35.3)
Smoking experience	Yes	30 (14.0)
	No	185 (86.0)
Current smoker	Yes	7 (3.3)
	No	208 (96.7)
Susceptibility to smoking	Yes	55 (25.6)
	No	160 (74.4)
Parents' smoking	Yes	153 (71.2)
	No	62 (28.8)
Friends' smoking	Yes	115 (53.5)
	No	100 (46.5)
Perceived level of best friends' smoking	Heavy smoking	35 (16.3)
	Moderate smoking	80 (37.2)
	No smoking	100 (46.5)
Daily usage of smartphone and computer (hours)	1–3	102 (47.4)
	3–4	48 (22.3)
	Over 4	65 (30.3)
Father's education	Middle school and below	3 (1.4)
	High school	37 (17.2)
	University and above	155 (72.1)
	Do not know	20 (9.3)
Mother's education	Middle school and below	2 (0.9)
	High school	40 (18.6)
	University and above	144 (67.0)
	Do not know	29 (13.5)

Content Validity

The 14 items exhibited an I-CVI value of $\geq$0.78 among 15 items. Item 4, which asserted that cigarette ads link smoking to things that people want (such as love, good looks, and power) exhibited an I-CVI value of 0.56. However, we judged it appropriate to include the respective item in the K-SMLS because it fit the SMLS from a conceptual standpoint.

Construct Validity

According to the EFA of the 15 items, the result of the Kaiser-Meyer-Olkin test was 0.79, and Bartlett's chi-squared test of sphericity with statistical significance was <0.001, which indicates that the factor analysis of these data was appropriate. The EFA was performed using a generalized least-squares technique due to a ceiling effect. Oblique rotation was conducted by considering the characteristics of K-SMLS that tend to be correlated with each item. Although the original scale had a one-factor model, the three sub-concepts of the scale showed the validity of results. In this study, the PA revealed that the eigenvalues of the three factors were bigger than the 95th percentile in the distribution of eigenvalues derived from the random data. Although 10 of the 15 items had factor loadings >0.30, five items were retained as they were conceptually linked to the scale (**Table 2**).

The R-lavaan package was used to perform CFA by incorporating Diagonally Weighted Least Squares (DWLS) as an estimator to examine our model's fit because the K-SMLS has ordinal variables and our data were positively skewed. The findings showed that the model's fit was good: $\chi^2 = 237.85$ ($p < 0.001$), CFI = 0.93, TLI = 0.92, RMSEA = 0.09, SRMR = 0.09 (**Table 2**). The average variance extracted (AVE) and composite reliability (CR) were calculated for every domain; however, one domain did not meet the minimum cutoff of the CR of 0.6 should the AVE be less than 0.5 (31). The value of CR was slightly lower than expected, but it was still acceptable because the model was fit.

Reliability

The Cronbach's alpha of the SMLS was 0.87 (17). In our study, the Cronbach's alpha of the K-SMLS was 0.78. Additionally, the

TABLE 2 | Results of the exploratory and confirmatory factor analyses ($n = 215$).

Domain	Item	EFA			CFA		
		Factor 1	Factor 2	Factor 3	Factor loading	AVE	CR
Authors and audiences	1. Tobacco companies are very powerful, even outside of the cigarette business (e.g., ginseng, sports club management) (2).	0.223			0.413	0.26	0.51
	2. Tobacco companies only care about making money (3).	0.257			0.449		
	3. Certain cigarette brands are designed to appeal to younger people (4).	0.376			0.649		
Messages and meanings	4. Social media (*YouTube, Instagram*, etc.) cigarette promotion link smoking to natural things that humans want like love, good looks, and power (6).		0.255		0.414	0.40	0.83
	5. Two people may see the same movie or TV and get very different ideas about it (7).		0.546		0.726		
	6. Two people may see the same social media (*YouTube, Instagram*, etc.) cigarette promotion and get very different ideas about it (8).		0.782		0.691		
	7. Cigarette signs/advertisements in convenience stores may catch one person's attention but not even be noticed by another person (9).		0.283		0.446		
	8. People are influenced by TV or movies, whether they realize it or not (10).		0.978		0.865		
	9. People are influenced by social media (*YouTube, Instagram*, etc.) cigarette promotion whether they realize it or not (11).		0.508		0.802		
	10. When people make TV or movie, every camera shot is very carefully planned (12).		0.285		0.331		
	11. There are often hidden messages in social media (*YouTube*, *Instagram*, etc.) cigarette promotions (13).		0.507		0.576		
	12. Most movies or TV that show people smoking make it look more attractive than it really is (14).		0.362		0.565	0.36	0.69
Representation and reality	13. Social media (*YouTube, Instagram,* etc.) cigarette promotion show green, natural, healthy scenes to make people forget about the health risks (15).			0.378	0.549		
	14. When you see a social media (*YouTube, Instagram,* etc.) cigarette promotion, it is very important to think about what was left out of the promotion (17).			0.508	0.640		
	15. Social media (*YouTube, Instagram,* etc.) promotion usually leave out a lot of important information (18).			0.346	0.659		
	Eigenvalue	4.07	1.51	1.44			
	Explained variance (%)	27.1	10.0	9.60			
	Cumulative (%)	27.1	38.2	46.8			
	Kaiser-Meyer-Olkin (KMO) = 0.79 Bartlett's test of sphericity = 725.32 ($p < 0.001$)				Model fitness χ^2 (87) = 237.85, $p < 0.001$, RMSEA = 0.09, SRMR = 0.09, CFI = 0.93, TLI = 0.92		
	Total Cronbach's α = 0.78						

The parentheses indicate the item number of the original scale. EFA, Exploratory factor analysis; CFA, Confirmatory factor analysis; AVE, Average variance extracted; CR, Composite reliability; RMSEA, Root mean square error of approximation; SRMR, Standardized root mean square residual; CFI, Comparative fit index; TLI, Tucker-Lewis index.

reliability was 0.78 as per McDonald's Omega values. The item-total correlation coefficients were > 0.30 except for item 10 (ranging from 0.303 to 0.537) (**Table 2**).

DISCUSSION

As the impact of media literacy on the health behavior of adolescents is increasing, a scale to measure SML that reflects the current situation in smoking behavior research is needed. This study described the cross-cultural translation process of the revised SMLS into Korean and examined the K-SMLS' psychometric properties in accordance with Korea's tobacco policy and environment of increased tobacco promotion on social media. The findings indicate that the K-SMLS is a valid and reliable instrument to assess SML among Korean adolescents. To maintain cross-cultural and conceptual accuracy, we performed a rigorous translation process that included contributions

from an expert panel, back-translation, and a trial with high school students.

The findings confirmed that the K-SMLS has acceptable internal consistency (Cronbach's alpha = 0.78). The item-total correlation coefficients were higher than 0.30, indicating that the revised version is acceptable and item discrimination is appropriate (30).

We tested the construct's validity using EFA and CFA and found that the K-SMLS could adequately measure adolescents' SML. Although several items showed low factor loading, there was no need to exclude any items because our study's goal was to confirm the translated version of the SMLS, not to reduce the number of items to develop a new scale. During CFA, the RMSEA achieved desirable values, while the CFI and TLI values were also satisfactory.

Although a factor loading of 0.32 is acceptable in socio-behavioral studies (32), the relatively low factor loading of the K-SMLS compared to the SMLS could be due to the translation process. Although efforts were made to increase validity of the SMLS in the translation process, it was necessary to change the term *advertisement* for the term *promotion*, as cigarette advertisements are illegal in Korea but social media posts promoting smoking or certain new tobacco products are not. However, adolescents would see these social media posts as an advertisement of tobacco products, as they present depictions of smoking. Additionally, the lower factor loading of the K-SMLS could be owed to slight semantic differences among the items (33). Semantic equivalence means "the meaning of each item in each culture is the same after being translated into the language and idiom of each culture" (34), and in a study by Squires et al. (35), it was stated that the criteria for equivalence were not mentioned or were not met, so the semantic equivalence was difficult to determine in translation studies. It is possible that the concepts of smoking media literacy are not fully captured in the items of the K-SMLS because of semantic differences. Furthermore, participants' characteristics could have also made a difference in factor loading. In the study of original SMLS development (17), smokers accounted for 19% of the sample, whereas, in our study, they accounted for only 3.3% of all participants. The smoking rate of participants in this study was lower than the average smoking rate of 6.7% of adolescents in Korea (5), so this could be a biased sample. Bauhoff et al. (36) showed that people who had ever smoked knew more about cigarettes because of advertising compared to never smokers; this could explain the lower factor loading of the K-SMLS, as our sample included only a small proportion of smokers. Therefore, further studies are required to re-validate the scale by including different populations, including current smokers and adolescents with susceptibility to smoking.

Although this study confirmed that the K-SMLS is a valid and reliable instrument to assess SML among Korean adolescents, its limitations should be mentioned. First, this study used a convenient sample from only five schools in a South Korean city. Due to COVID-19, the survey in this study was conducted online, and although frequent reminders were provided to reduce the non-response phenomenon, the response rate in this study was 72.1%. It should be noted that generalization of the results as representative of all Korean adolescents may be limited due to the possibility of sampling bias and non-response bias. Further large-scaled research that conducts a probability sample design such as stratification may compensate to generalize the results to address both possibilities of bias. And further studies need to include participants from diverse socio-demographic backgrounds, including participants living in rural areas and multicultural adolescents. Second, our scale exhibited a relatively low factor loading compared to the original scale, as detailed above. Therefore, in future studies, instruments should supplement words with symbols to convey their meaning more accurately after an instrument is developed through cognitive interviews with adolescents. Third, the number of data points is not sufficient to be divided into two to perform EFA and CFA, so cross-validation has not been performed. In a future study, it will be more helpful to test the factor model identified in this study for different groups.

CONCLUSIONS

SML is a contributor to adolescent smoking. This study translated the SMLS into Korean and tested the validity and reliability of the Korean version. To our knowledge, this is the first study to validate the SMLS with Korean adolescents. It might be possible to perform comparative studies with other countries based on our findings. Further studies should include diverse populations in order to expand the applicability of the K-SMLS.

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 Institutional Review Board of Yonsei University. Written informed consent to participate in this study was provided by the participants and the participants' guardian/next of kin.

AUTHOR CONTRIBUTIONS

SK and HL developed the conceptualization of this research and were responsible for the data analysis. HL supervised the research. SK was responsible for data collection and wrote the initial draft of the manuscript. SK, HL, JL, HH, and JK contributed to the interpretation of the results. All authors contributed to the article and approved the submitted version.

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Corrigendum: Psychometric Properties of the Korean Version of the Smoking Media Literacy Scale for Adolescents

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Keywords: smoking, media literacy, adolescent, validation, adaptation

A Corrigendum on

Psychometric Properties of the Korean Version of the Smoking Media Literacy Scale for Adolescents

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In the published article, there was a mistake in the Abstract and Results sections. Instead of Cronbach's alpha = 0.79 in the Abstract, and the Results section, it should be 0.78 to meet the same as Cronbach's alpha in Table 2 and the Discussion section.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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Developing and Testing the Validity and Reliability of the Brief Adolescent Respiratory System Health Assessment Scale-Student Version in a Chinese Sample

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Objectives: To develop a Brief Adolescent Respiratory System Health Assessment Scale-Student Version (BARSHAS-SV) and test the validity and reliability of the scale.

Methods: Considering common respiratory system diseases and respiratory system symptoms as a theoretical basis, researchers developed a Brief Adolescent Respiratory System Health Assessment Scale-Student Version-I (BARSHAS-SV-I). After six medical experts reviewed the BARSHAS-SV-I, and six adolescents tested the BARSHAS-SV-I, researchers developed an updated BARSHAS-SV-II. Researchers randomly selected two middle schools in Baoding, China. Thousand twenty nine valid questionnaires were recovered. Researchers evaluated the validity and reliability of the scale and obtained the final version of the scale (BARSHAS-SV). The exploratory factor analysis (EFA) and the confirmatory factor analysis (CFA) were used to evaluate the construct validity of the scale. The content validity index (CVI) was used to evaluate the content validity of the scale. The Cronbach's α coefficient and the mean inter-item correlation coefficient (MIIC) were used to assess the reliability of the scale.

Results: BARSHAS-SV Cronbach's α = 0.910, content validity = 0.941, and factor cumulative variance contribution rate = 64.047% conducting EFA. Conducting CFA, Chi square value ($\chi 2$) = 233.806, degrees of freedom (df) = 106, Chi square value/degree of freedom ($\chi 2/df$) = 2.206, root-mean-square error of approximation (RMSEA) = 0.063, normed fit index (NFI) = 0.922, goodness of fit index (GFI) = 0.917, Tueker-Lewis index (TLI) = 0.942, comparative fit index (CFI) = 0.955, incremental fit index (IFI) = 0.956. BARSHAS-SV consisted of 4 dimensions and 17 items. Four factors were as follows: Factor 1, mild respiratory system diseases (Cronbach's α coefficient = 0.781); Factor 2, severe respiratory system diseases (Cronbach's α coefficient = 0.829); Factor 3, respiratory system symptoms (Cronbach's α coefficient = 0.835); Factor 4, treatment and recovery of respiratory system diseases (Cronbach's α coefficient = 0.845).

Conclusions: BARSHAS-SV is a valid and reliable method that can be applied to assess adolescent respiratory system health status. BARSHAS-SV may help teachers and medical staff in schools to quickly and conveniently evaluate the adolescent respiratory system health status and identify respiratory issues.

Keywords: adolescent, respiratory system, health status, validity, reliability

INTRODUCTION

The prevalence of respiratory system diseases in adolescents is increasing worldwide (1). Acute infectious diseases, which are the most common issue, are a threat to adolescent health (2). For example, coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is a global pandemic of respiratory system (3). As schools begin to reopen, it becomes clear that SARS-CoV-2 infection may cause serious health consequences among adolescents (4). In addition, chronic diseases are also a concern. One of the most prevalent respiratory health conditions in adolescents is chronic respiratory disease (5). In adolescents, chronic respiratory disease can lead to a reduced pubertal growth spurt and delayed onset of puberty (6). Overall, respiratory diseases have a negative impact on pulmonary function, potentially resulting in its early deterioration (1). With the increase of atmospheric concentrations of nitrogen oxides, sulfur dioxide, carbon monoxide, and suspended particles, the variation of pathogenic microorganisms, and the increase of drug-resistant bacteria, more and more adolescents suffer from respiratory system diseases (2, 7, 8). Adolescent respiratory system diseases remain a major challenge for global health (9, 10). This is a serious public health problem that affects the adolescent group, and full understanding of the adolescent respiratory system health status is especially important.

By carrying out intervention programs for respiratory system diseases as well as creating an effective method that evaluates adolescent respiratory system health status, we can reduce disease symptoms, increase aerobic fitness and physical strength, improve pulmonary function, and enhance the quality of life among adolescents (11). Measurement of respiratory system health status is very important for the evaluation of physical development in the adolescents. However, there is currently a lack of a scale specifically designed to assess the health status of the respiratory system of adolescents in schools. Therefore, the research team developed a Brief Adolescent Respiratory System Health Assessment Scale-Student Version (BARSHAS-SV) and tested its validity and reliability.

Abbreviations: BARSHAS-SV, brief adolescent respiratory system health assessment scale-student version; EFA, exploratory factor analysis; CFA, confirmatory factor analysis; CVI, content validity index; MIIC, mean inter-item correlation coefficient; PCA, principal component analysis; KMO, Kaiser–Meyer-Olkin; RMSEA, root-mean-square error of approximation; $\chi 2$, chi square value; df, degrees of freedom; $\chi 2/df$, chi square value/degrees of freedom; NFI, normed fit index; GFI, goodness of fit index; TLI, Tueker-Lewis index; CFI, comparative fit index; IFI, incremental fit index.

METHODS

Development of BARSHAS-SV-I

Considering common respiratory system diseases and respiratory system symptoms as a theoretical basis (2), in addition to investigating extensive literature references, the research team developed an initial scale (Brief Adolescent Respiratory System Health Assessment Scale-Student Version-I, BARSHAS-SV-I). This initial scale included a total of 20 items and 3 dimensions. The research team then named the three dimensions as follows: Dimension 1, common respiratory system diseases; Dimension 2, respiratory system symptoms; Dimension 3, treatment and recovery of respiratory system diseases. The items of BARSHAS-SV-I were presented in a way that made them easy to understand for the adolescent population (12, 13).

Development of BARSHAS-SV-II

Six medical experts (two clinical doctors, two health care experts, and two clinical nurses) were invited to evaluate the scale content validity. The evaluation standard, which was used to evaluate the scale content validity ranged from 3 (strongly related) to 1 (not related). According to expert feedback, 3 items in the BARSHAS-SV-I were removed from the initial scale, which resulted in an updated scale (BARSHAS-SV-II). The updated scale (BARSHAS-SV-II) included a total of 17 items and 3 dimensions. The names of the dimensions in the BARSHAS-SV-II remained unchanged. BARSHAS-SV-IIused the Likert 5-point method (disagree = 1; agree a small part = 2; moderately agree = 3; agree most = 4; completely agree = 5). In reverse scoring, the scores were 5 points, 4 points, 3 points, 2 points, and 1 point, respectively. The total score of the BARSHAS-SV-II was determined by the sum of all items' scores. The higher the total score of the scale, the better the adolescent respiratory system health status. Subsequently, researchers invited 6 adolescents to complete BARSHAS-SV-II in order to make the research team be able to test the comprehension of statement expressions and possibly improve the wording of the scale. All items in the BARSHAS-SV-II were presented in simple and reader-friendly language so that the adolescent subjects could easily understand the meaning of each item in the BARSHAS-SV-II (12, 13).

Development of the Final BARSHAS-SV and Large Sample Test

Researchers randomly selected two districts from the twenty districts of Baoding, China, from June 2015 to April 2016. Subsequently, two middle schools from these two districts of Baoding were randomly selected by the research team. A class was considered as a unit. By adopting a stratified cluster sampling

method, researchers randomly selected five third-grade classes, five second-grade classes, and five first-grade classes from one middle school. The research team selected a total of 15 classes (50 students per class) and 750 students from the first middle school. In addition, two third-grade classes, two second-grade classes, and three first-grade classes were selected from the second middle school (a total of 350 students and 50 students per class). In this study, first grade, second grade and third grade referred to first grade, second grade and third grade only in the middle schools. A stratified cluster sampling method was the consideration of selecting five classes/grade in one middle school and 2–3 classes/grade in the other middle school. In the first middle school, there were fifteen classes for each grade. Therefore, researchers randomly selected five classes in each grade. In the second middle school, there were six classes in the third grade, six classes in the second grade, and nine classes in the first grade. Therefore, researchers randomly selected two classes in the third grade, two classes in the second grade, and three classes in the first grade. The first middle school was in the urban area, and the second middle school was in the suburbs. In total, the research team selected 1,100 adolescents. Inclusion criteria: (1) Subjects with a satisfactory capacity to comprehend questionnaires as well as answer them; (2) Subjects with no reading disabilities or no intellectual disabilities; (3) Subjects who do not suffer from any mental condition or brain diseases; and (4) Subjects who volunteered for the research. The investigators distributed 1,100

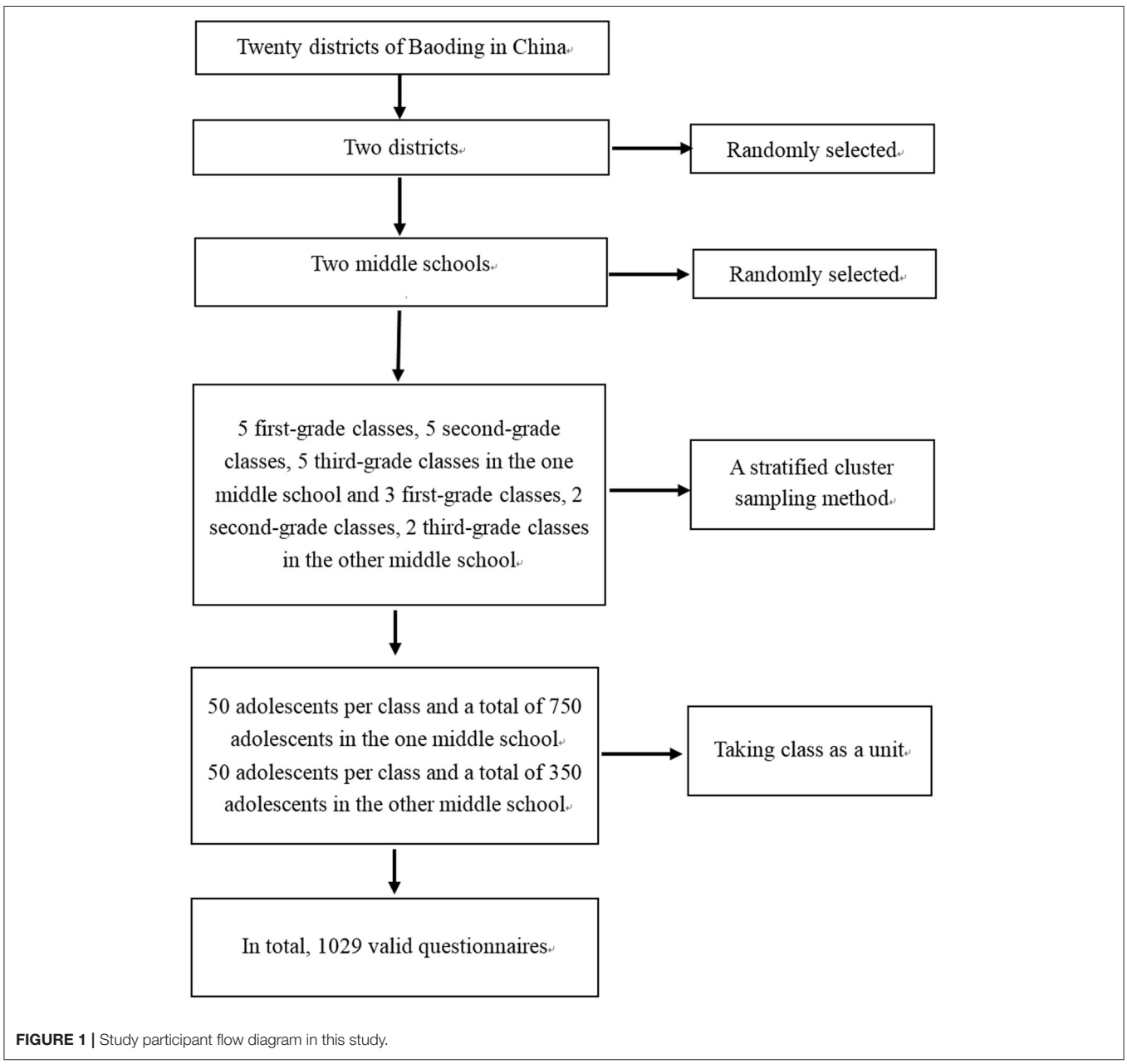

FIGURE 1 | Study participant flow diagram in this study.

questionnaires to the adolescents. Twenty three participants did not complete demographic characteristic questionnaires or scales, and 48 participants did not complete the scale. Thus, the 71 subjects were excluded from this study. Ultimately, in this study, 1,029 valid questionnaires were returned from the subjects. After analyzing the data of 1,029 valid questionnaires from the adolescents, the research team evaluated the validity and reliability of the scale and obtained the final version of the scale (BARSHAS-SV). The flow diagram of this study is shown in **Figure 1**.

Survey Method and Ethical Consideration

The investigators explained the purpose of this investigation to two middle school teaching management departments, guardians/parents of the minors, and the students themselves. After receiving consent from two middle school coordinators, guardians/parents of the minors, and the students, the investigators demonstrated to the subjects in detail how to answer these questionnaires. Standardized language and unified instruction were used in the questionnaires. The investigators conducted the study according to the Declaration of Helsinki. This study was approved by the Medical Ethics Committee of Hebei University. This study was also approved by the Health and Family Planning Commission of Hebei (NO.20150072).

Statistical Analysis

Researchers adopted the Epidata 3.1 software to input all of the data into our computer twice, as well as to conduct a data consistency check. The data were analyzed by using the IBM SPSS Statistics 24.0 software and the AMOS 22.0 software. In this study, researchers applied descriptive statistics (medians/interquartile ranges or frequency/percentages) to explore the demographic characteristics of the adolescents. The following list shows the statistical analysis methods that the research team used for testing the validity and reliability of scale: (1) Researchers used the exploratory factor analysis (EFA) and the confirmatory factor analysis (CFA) to evaluate the construct validity of the scale. The following detailed criteria were applied for the retention of factors (14): ① Eigenvalues > 1; ② EFA scree plot; ③ Items equal to, or >2 being retained; and ④ The factor loadings > 0.5. (2) Researchers applied the content validity index (CVI) to evaluate the content validity of the scale. (3) Researchers used the Cronbach's α coefficient and the mean inter-item correlation coefficient (MIIC) to assess the reliability of the scale. The cutoff point adopted for the Cronbach's alpha coefficient was 0.70, and the cutoff point adopted for the mean inter-item correlation coefficient (MIIC) was 0.30 (12, 15). The level of significance in this study was $p < 0.05$. The model fit criteria of the scale structure are as follows (16): ① Root-mean-square error of approximation (RMSEA) < 0.08; ② Chi square value/degrees of freedom ($\chi 2$ /df) < 3; ③ Normed fit index (NFI) > 0.9; ④ Goodness of fit index (GFI) > 0.9; ⑤ Tueker-Lewis index (TLI) > 0.9; ⑥ Comparative fit index (CFI) > 0.9; ⑦ Incremental fit index (IFI) > 0.9.

TABLE 1 | The characteristics of the adolescents in the large sample.

Characteristics	Frequency/ medians	Percentage (%)/ interquartile ranges, (IQR)
Gender		
Male	517	50.24%
Female	512	49.76%
Age	14.00	13.00, 16.00
Race		
Han	994	96.60%
Minority	35	3.40%
Monthly expenses (yuan)		
<300	344	33.43%
300∼	541	52.58%
600∼	144	13.99%
Do you have a religious faith		
No	955	92.81%
Yes	74	7.19%
Place of residence		
Urban area	685	66.57%
Rural area	344	33.43%
Medical insurance		
Urban medical insurance	597	58.02%
New rural cooperative medical system	307	29.83%
Self-paying	125	12.15%
Do you live with your family		
Yes	962	93.49%
No	67	6.51%

The characteristics data of the large sample were presented as medians (interquartile ranges, IQR) and frequency (percentage, %).

RESULTS

Characteristics of the Adolescents in the Large Sample

The research team distributed a total of 1,100 questionnaires to the adolescents in two middle schools and recovered 1,029 valid questionnaires (valid recovery rate of 93.55%). The participants included 517 males (50.24%) and 512 females (49.76%) from urban (66.57%) and rural areas (33.43%). The age of participants in this study was 14.00 (13.00, 16.00) years old (medians and interquartile ranges, IQR). Demographic characteristics of the adolescents included Han race (96.60%) and minority race (3.40%). According to monthly expenses (monthly expenses $<$ 300 yuan, 300 yuan $\leq$ monthly expenses $<$ 600 yuan, and monthly expenses $\geq$600 yuan), the adolescents were categorized into three groups, accounting for 33.43, 52.58, and 13.99%, respectively. According to the method of medical insurance, the participants were classified into three groups (urban medical insurance, new rural cooperative medical system, and self-paying), accounting for 58.02, 29.83, and 12.15%, respectively. The characteristics of the adolescents in the large sample from two middle schools are shown in **Table 1**.

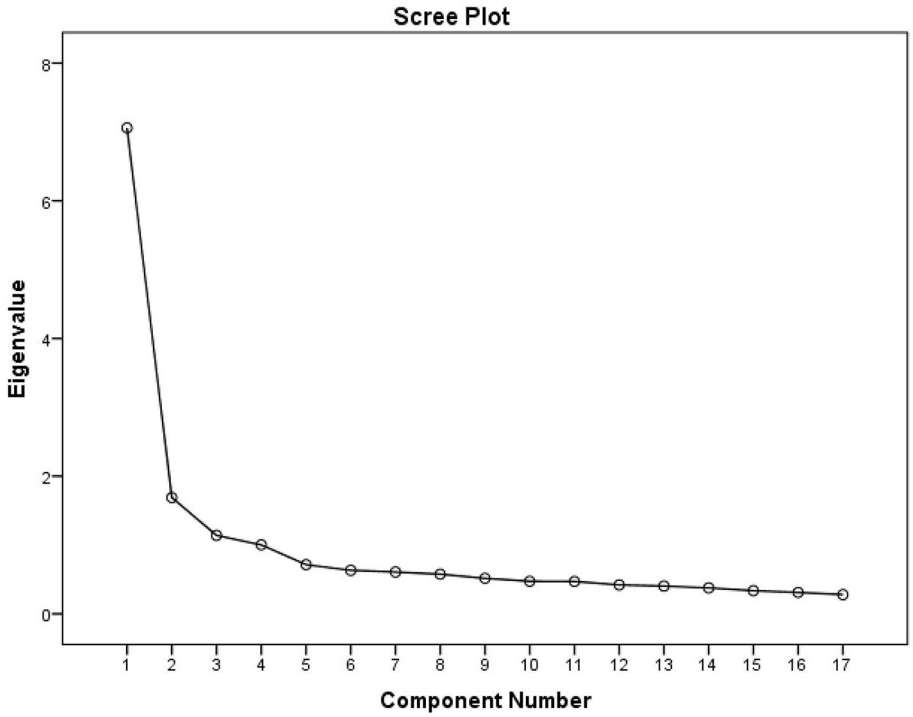

FIGURE 2 | Scree plot of exploratory factor analysis.

TABLE 2 | Rotated component matrix, eigenvalue, variance contribution rate and cumulative variance contribution rate.

	Items	Factor 3	Factor 2	Factor 4	Factor 1
	Item-1	-	-	-	0.789
	Item-2	-	-	-	0.840
	Item-3	-	-	-	0.707
	Item-4	-	0.659	-	-
	Item-5	-	0.768	-	-
	Item-6	-	0.721	-	-
	Item-7	-	0.604	-	-
	Item-8	-	0.739	-	-
	Item-9	0.644	-	-	-
	Item-10	0.712	-	-	-
	Item-11	0.685	-	-	-
	Item-12	0.738	-	-	-
	Item-13	0.630	-	-	-
	Item-14	-	-	0.723	-
	Item-15	-	-	0.750	-
	Item-16	-	-	0.744	-
	Item-17	-	-	0.678	-
Eigenvalue		3.008	2.921	2.695	2.264
Variance contribution rate (%)		17.693	17.182	15.852	13.320
Cumulative variance contribution rate (%)		17.693	34.875	50.727	64.047
Factor naming		Respiratory system symptoms	Severe respiratory system diseases	Treatment and recovery of respiratory system diseases	Mild respiratory system diseases

Suppress absolute values <0.500. The symbol "-" showed that these values were <0.500.

TABLE 3 | Detailed items of the brief adolescent respiratory system health assessment scale-student version (BARSHAS-SV).

Dimensions	Items	Completely agree 5	Agree most 4	Moderately agree 3	Agree a small part 2	Disagree 1
Mild respiratory system diseases	Item-1. I often catch a cold.					
	Item-2. I often cough.					
	Item-3. I often feel phlegm in my throat.					
Severe respiratory system diseases	Item-4. I often suffer from bronchitis.					
	Item-5. I often suffer from pneumonia.					
	Item-6. I often suffer from respiratory system injuries.					
	Item-7. I often feel weak due to respiratory system diseases.					
	Item-8. I often suffer from allergic diseases of respiratory system.					
Respiratory system symptoms	Item-9. I often have shortness of breath.					
	Item-10. I often have whistling or whooping sounds when I breathe.					
	Item-11. I often have trouble breathing when I sleep.					
	Item-12. I often walk slowly due to trouble breathing.					
	Item-13. I often have trouble breathing after I do some simple daily physical activities.					
Treatment and recovery of respiratory system diseases	Item-14. I often go to the hospital for treatments or examinations because of respiratory system diseases.					
	Item-15. I often take some medicines for respiratory system diseases.					
	Item-16. It often takes a long time for me to recover from a respiratory system disease.					
	Item-17. I often cannot study in class due to the treatment and recovery of respiratory system diseases.					

TABLE 4 | The model fit results of confirmatory factor analysis.

Factor model	χ^2	df	χ^2/df	RMSEA	NFI	GFI	TLI	CFI	IFI
4-factor model	233.806	106	2.206	0.063	0.922	0.917	0.942	0.955	0.956
3-factor model	558.837	109	5.127	0.116	0.813	0.812	0.803	0.842	0.844

χ2, Chi square value; df, degrees of freedom; χ2/df, Chi square value/degrees of freedom; RMSEA, root-mean-square error of approximation; NFI, normed fit index; GFI, goodness of fit index; TLI, Tueker-Lewis index; CFI, comparative fit index; IFI, incremental fit index.

Analyses of Validity and Reliability

Construct Validity

(1) EFA. A subsample of 720 participants, randomly selected from total sample, was used in EFA. Maximum variance orthogonal rotation and principal component analysis were applied. The Bartlett sphericity test value was 5,482.205 (df = 136, $p < 0.001$), and the Kaiser-Meyer-Olkin (KMO) value was 0.924. These results revealed that the data in this study were suitable for factor analysis. Researchers conducted the factor extraction under a condition of undefined factor number. Four factors (eigenvalue greater than 1) were extracted. The cumulative variance contribution rate (%) of four factors was 64.047%. The result of the EFA scree plot also indicated that the 4-factor structure was suitable for the scale (**Figure 2**). Based on the aforementioned analyses, the final version of the scale consisted of 4 factors and 17 items. The research team renamed the final four factors: Factor 1, mild respiratory system diseases (three items); Factor 2, severe respiratory system diseases (five items); Factor 3, respiratory system symptoms (five items); Factor 4, treatment and recovery of respiratory system diseases (four items) (**Table 2**). These detailed items of the Brief Adolescent Respiratory System Health Assessment Scale-Student Version (BARSHAS-SV) are shown in **Table 3**, at the end of this paper.

(2) CFA. To confirm the dimensional structure found in the EFA, the researchers used the remaining 30% of sample (309 participants) and adopted the Maximum Likelihood (ML) method to perform the CFA. The results are shown in **Table 4**. The 4-factor structure showed a good fit to the subsample after

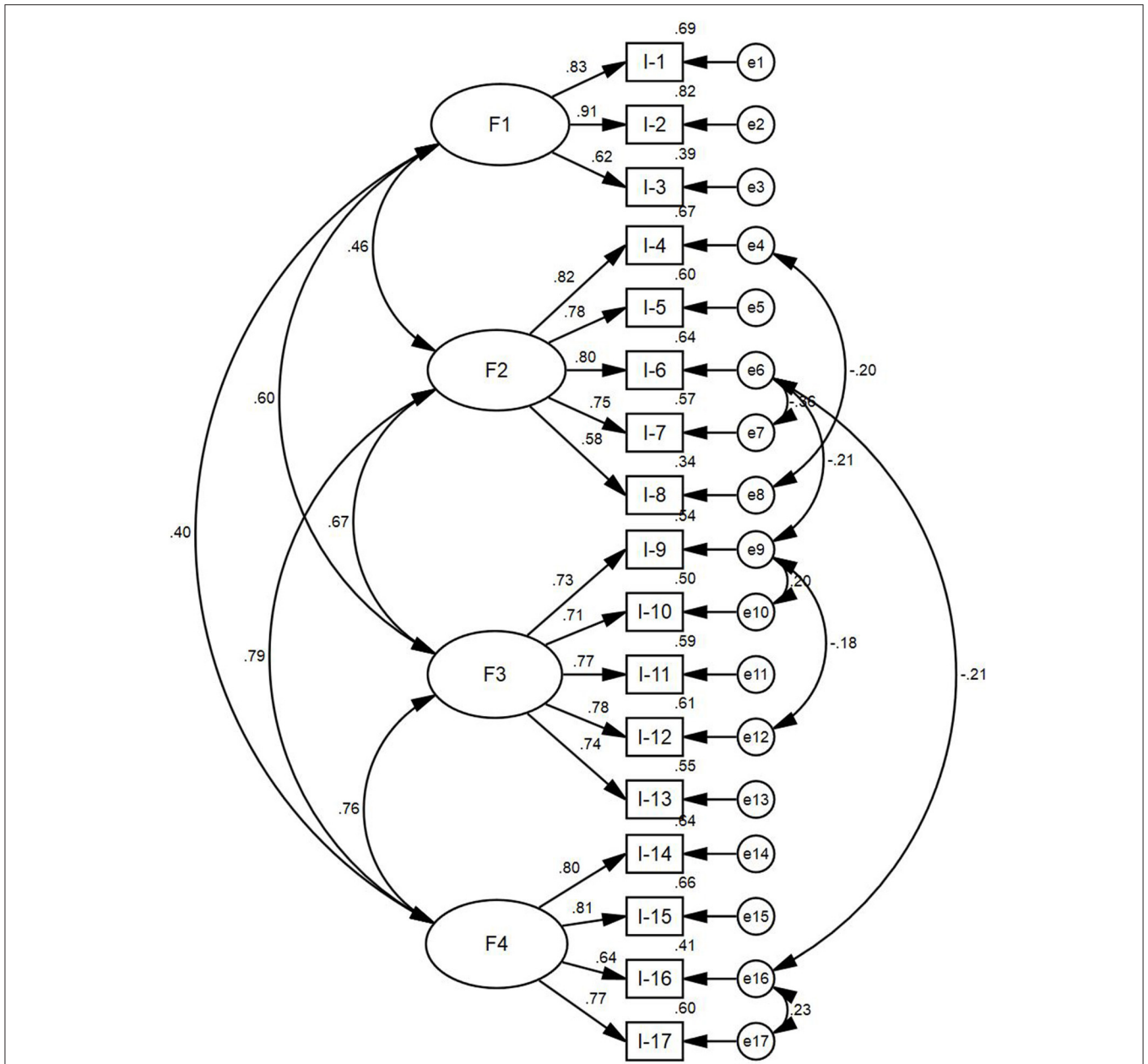

FIGURE 3 | Standard path and parameter estimation of confirmatory factor analysis. F1, Factor 1, mild respiratory system diseases; F2, Factor 2, severe respiratory system diseases; F3, Factor 3, respiratory system symptoms; F4, Factor 4, treatment and recovery of respiratory system diseases.

allowing covariances between the residuals. **Figure 3** shows the fitted structure. Additionally, the researchers also verified the fit of the 3-factor structure for the subsample (see **Table 4**). This structure showed a poor fit for the data.

Internal Correlation Test

Among four factors of BARSHAS-SV, the correlation coefficients of four factors ranged from 0.363 to 0.640 ($p < 0.01$). The correlation coefficients between different factors and the whole BARSHAS-SV were from 0.699 to 0.864 ($p < 0.01$), as shown in **Table 5**.

Content Validity

Based on the results obtained from six expert reviews, the content validity index (CVI) of the scale was 0.941. The CVI values of all items were from 0.667 to 1.00. The CVI values of item-1, item-2, item-3, item-4, item-5, item-7, item-8, item-9, item-10, item-11, item-13, item-14, item-15 and item-17 were 1.00. The CVI values of item-6, item-12 and item-16 were 0.667. After the research team improved the item statement expression and the item wording, six subjects reported that they could clearly comprehend the meaning of every item without any difficulty.

TABLE 5 | Correlation coefficients among four factors of the BARSHAS-SV and between different factors and the whole BARSHAS-SV.

Factor	Factor 2	Factor 3	Factor 4	BARSHAS-SV
Factor 1	0.363**	0.507**	0.425**	0.699**
Factor 2	-	0.582**	0.640**	0.808**
Factor 3	-	-	0.633**	0.864**
Factor 4	-	-	-	0.836**

*Factor 1, mild respiratory system diseases; Factor 2, severe respiratory system diseases; Factor 3, respiratory system symptoms; Factor 4, treatment and recovery of respiratory system diseases; BARSHAS-SV, Brief Adolescent Respiratory System Health Assessment Scale-Student Version. Pearson correlation coefficient was used. The symbol "-" showed no such correlation coefficient. The symbol "**" indicated $p < 0.01$.*

TABLE 6 | The Cronbach's α coefficients and the MIIC values and of four factors and the whole BARSHAS-SV.

Factor	Number of Items	MIIC	Cronbach's α
Factor 1	3	0.546	0.781
Factor 2	5	0.501	0.829
Factor 3	5	0.504	0.835
Factor 4	4	0.581	0.845
BARSHAS-SV	17	0.384	0.910

Factor 1, mild respiratory system diseases; Factor 2, severe respiratory system diseases; Factor 3, respiratory system symptoms; Factor 4, treatment and recovery of respiratory system diseases; BARSHAS-SV, Brief Adolescent Respiratory System Health Assessment Scale-Student Version. MIIC, mean inter-item correlation coefficient.

Reliability

The Cronbach's α coefficient of the BARSHAS-SV was 0.910. The Cronbach's α coefficient of factor 1 (mild respiratory system diseases) was 0.781. The Cronbach's α coefficient of factor 2 (severe respiratory system diseases) was 0.829. The Cronbach's α coefficient of factor 3 (respiratory system symptoms) was 0.835. The Cronbach's α coefficient of factor 4 (treatment and recovery of respiratory system diseases) was 0.845. The mean inter-item correlation coefficient (MIIC) value of the BARSHAS-SV was 0.384. The MIIC value of factor 1 was 0.546. The MIIC value of factor 2 was 0.501. The MIIC value of factor 3 was 0.504. The MIIC value of factor 4 was 0.581 (**Table 6**).

DISCUSSION

This study provides a practical and valid measurement instrument (BARSHAS-SV). In other studies on the development of scales for the respiratory system, some scholars have also conducted some studies and explorations. For example, Campbell et al. developed a Respiratory Distress Observation Scale (RDOS) for inpatients with an average age of 72 years and unable to self-report dyspnea. The RDOS included eight observer-rated items: respiratory rate, heart rate, paradoxical breathing pattern, accessory muscle use, grunting at end-expiration, restlessness, a fearful facial display, and nasal flaring. Each item score of the RDOS ranged from 0 to 2 points, and the total score of the RDOS was the sum of the scores of all items. The RDOS had a clinical value to measure the respiratory distress and response to clinical treatment among the inpatients (17). Haimovich et al. developed the quick COVID-19 Severity Index (qCSI) tool, a 12-point scale that used three items available at the bedside: respiratory rate, nasal cannula flow rate, and minimum documented pulse oximetry. The patients were assigned to four risk strata according to the following scores: ≥10 high risk, 7–9 high-intermediate risk, 4–6 low-intermediate risk, and 0–3 low risk (18). These scales developed mainly focused on hospitalized patients with specific respiratory diseases. These scales are more suitable for assessing respiratory diseases in adults. Therefore, the BARSHAS-SV in this study specially developed for adolescents in schools is a helpful and useful tool for assessing adolescents' overall respiratory system health. In our previous study, the research team developed a Brief Adult Respiratory System Health Status Scale-Community Version (BARSHSS-CV) (19). The BARSHSS-CV was primarily used to evaluate the respiratory system health status of adults in the community, while the BARSHAS-SV developed in this study is intended for adolescents in schools. In order to make the scale better applicable to different groups of people, the research team adjusted and improved some items. For example, adults have jobs, and their work environment may be full of dust or harmful gases, which is not a concern for adolescents. Adolescents are studying at school, and they have no jobs. Therefore, researchers deleted some items about the work environment. In order to better apply the scale to students, the researchers also modified the expression of some items. For example, researchers modified the expression of item "I often cannot work, learn, or carry out outdoor activities due to respiratory system diseases" to the expression of item "I often cannot study in class due to the treatment and recovery of respiratory system diseases." In addition, in our previous study, the results of factor analysis of BARSHSS-CV showed that the 3-dimension structure of BARSHSS-CV was more suitable among the adults in the community. However, in this study, the results of factor analysis of BARSHAS-SV showed that the 4-dimension structure of BARSHAS-SV was more suitable among the adolescents in schools. The dimensional structures of the two scales were different. The reason for the change in the dimensional structures of the two scales may be due to the differences in the growth and development status of the respiratory system, age, living habits, and health care knowledge between adolescents and adults. The BARSHAS-SV can be used as a good and brief assessment tool for evaluating the respiratory system health status of adolescents in schools. The BARSHAS-SV may help teachers in schools and medical staff in schools conveniently and quickly assess the adolescent respiratory system health status and find the main problems of the respiratory system to provide better health education and health care services. This will eventually reduce the medical burden placed on government bodies, schools, and families (20, 21).

In the research, to evaluate a hypothesized measurement model, both exploratory factor analysis and confirmatory factor analysis were conducted (22). The sample size in the research should contain at least 10 subjects to 15 subjects per variable for the factor analysis of the scale (22). The sample size of our study was large enough for the factor analysis of the BARSHAS-SV. In the exploratory factor analysis, the researchers carried out

the Bartlett sphericity test and calculated the KMO value to evaluate factor analysis's suitability. The Bartlett sphericity test was significant, and the KMO value in this research was >0.6 (23). These results revealed that the data of the scale in this research were suitable for the factor analysis. The results of exploratory factor analysis indicated that 17 items loaded substantially onto four conceptually clear factors. Dimension 1 (common respiratory system diseases) in the BARSHAS-SV-II was divided into dimension 1 (mild respiratory system diseases) and dimension 2 (severe respiratory system diseases) in the final BARSHAS-SV version. The reason for the change of the dimensions was most likely because the respiratory system diseases included the mild respiratory system diseases and severe respiratory system diseases. Hence the research team measured the respiratory system diseases from two separate dimensions (mild respiratory system diseases and severe respiratory system diseases). The 4-factor model produced a more appropriate and clearer measurement of the structure of BARSHAS-SV. In the confirmatory factor analysis, the model goodness of fit was assessed by RMSEA (<0.08 acceptable), $\chi 2/df$ (<3 acceptable), NFI (> 0.9 acceptable), GFI (> 0.9 acceptable), TLI (> 0.9 acceptable), CFI (> 0.9 acceptable), and IFI (> 0.9 acceptable) (16). The results of confirmatory factor analysis of BARSHAS-SV met the above evaluation criteria. The results of confirmatory factor analysis revealed that the stability and fit of 4-factor model structure of BARSHAS-SV are both satisfactory.

The content validity reveals whether items of a scale can identify the topic and content that the research team wants to measure (12). The CVI of every item of the BARSHAS-SV indicates the number of expert choices of two and three divided by the total number of experts. The total CVI value of the BARSHAS-SV is the average value of all of items' CVI values (24). The CVI values revealed that the BARSHAS-SV was able to reflect the variables that researchers intended to measure. Each item of the BARSHAS-SV was able to measure the correct content, and the BARSHAS-SV revealed a good content validity. The internal correlation test results of the BARSHAS-SV indicated that there was a certain degree of correlation between four factors of the BARSHAS-SV; moreover, there were also some differences between the four factors of the BARSHAS-SV. Therefore, the four factors of the BARSHAS-SV were able to reflect different aspects of adolescent respiratory system health status. The four factors of the BARSHAS-SV were able to comprehensively and effectively evaluate the health status of respiratory system of adolescents.

By applying the Cronbach's alpha coefficient and mean inter-item correlation coefficient, the research team could evaluate the reliability of the BARSHAS-SV (15, 25). A usual criterion for satisfactory reliability of a scale is the Cronbach's alpha coefficient of $\geq$ 0.70 (12). In our study, the Cronbach's alpha coefficient of the entire BARSHAS-SV was > 0.90, and the four factors of the BARSHAS-SV were all > 0.70. If the MIIC value of a scale is > 0.30, the reliability of a scale is acceptable in the study (15). In this research, the MIIC value of the whole BARSHAS-SV was > 0.30, and the MIIC values of four factors in the BARSHAS-SV were all > 0.50. Accordingly, based on the aforementioned comprehensive analysis, the BARSHAS-SV developed in this research has a satisfactory reliability.

LIMITATIONS AND FUTURE DIRECTION

Adolescents who participated in this study were recruited in two districts of the Baoding City in China. Therefore, the reliability and validity of the BARSHAS-SV are limited to this population. In the future, the research team should widen the scope of sampling in more cities. The BARSHAS-SV will be more widely applied and verified in more areas of the country, so that the BARSHAS-SV can be better improved and revised in the future. In addition, in the process of using the BARSHAS-SV in other different nations, further cross-cultural BARSHAS-SV improvement and cross-cultural BARSHAS-SV validation are also needed in the future. In the future, in the process of applying and validating the BARSHAS-SV among a wider range of adolescents in more other cities, researchers will recruit more new participants to further evaluate and improve the BARSHAS-SV. Researchers also hope that those scholars from other cities or countries who see this study and are interested in this scale can use the BARSHAS-SV in their cities or countries to further validate and improve the BARSHAS-SV in the future.

CONCLUSION

To sum up, the research team has rigorously developed and validated the BARSHAS-SV with proven validity and reliability. A 4-factor model of BARSHAS-SV showed good psychometric indicators for the sample of Chinese adolescents. This tool may be useful for quickly evaluating the health status of the respiratory system of adolescents in schools; however, the factorial model found must be confirmed in samples with different contexts from the present study (e.g., other countries). The BARSHAS-SV can help teachers and medical staff in schools conduct targeted health interventions and provide health guidance for adolescents in schools, making them establish a long-term healthy lifestyle, which will allow for their healthy growth.

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 study involving human participants was reviewed and approved by Health and Family Planning Commission of Hebei (No. 20150072). The study was also approved by Medical Ethics Committee of Hebei University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

LT, YG, PW, and YZhan conceived and designed the study and wrote and revised the manuscript. HD, XW, LY, DL, YZhao, and QZ collected data and analyzed data. All authors approved the final manuscript.

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Physical Activity, Screen-Based Sedentary Behavior and Physical Fitness in Chinese Adolescents: A Cross-Sectional Study

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Purpose: The aim of this study is to explore the relationship between screen-based sedentary behavior, physical activity and physical fitness among Chinese adolescents.

Methods: This study randomly selected adolescents from 10 administrative districts in Shandong, China. The data gathering tools for demographic and other characteristics (gender, age, body mass index and socioeconomic status), PA (PAQ-A) and screen-based sedentary behavior (YRBSS) and physical fitness (NSPFH 2014) were utilized in this study. Statistical analysis was performed by *T*-test, chi-square test and multiple linear regression.

Results: 10,002 adolescents (14.39 years ± 1.79) participated in the study. The results demonstrated that BMI and high TV viewing time had a significant negative correlation with physical fitness, but there was no association between the amount of time spent playing computer/video games and physical fitness among adolescents. High SES and physical activity in leisure time five or more times per week were significantly associated with most dimensions of physical fitness.

Conclusions: the results suggest that we not only need to focus on adolescent risk behavior associated with low socioeconomic status and obesity, but also enforce physical activity and reduce sedentary television-watching behavior, which will be crucial pathways and strategies to improve the physical fitness of Chinese adolescents.

Keywords: physical activity, screen-based sedentary behavior, physical fitness, adolescents, China

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INTRODUCTION

Physical fitness has become a crucial prognosticator of adolescent health (1) and significantly associated with gauges of health such as cardiovascular health (2), cognitive capability and psychological well-being (3). Relevant studies indicate that physical inactivity is not only an independent risk factor for chronic diseases such as hypertension (4), heart disease (5) and 2 diabetes mellitus (6), but also has a serious negative impact on physical fitness, which leads to massive social issues (7). Globally, 80% of adolescents are lacking in physical activity; "low physical activity-high sedentary time" has become a widely-used descriptor of current physical inactivity among adolescents (8–10). The latest WHO guidelines recommend that children and

adolescents should engage in an average of 60 min per day of moderate to high intensity exercise (mainly aerobic exercise), and limit sedentary time, especially screen time (11).

A current study from 39 countries finds that only 23 and 19% of children aged 11–13 years old, respectively, meets the recommended levels of physical activity, and that contemporary adolescents engage in physical activity with less frequently and for shorter durations than their parents (12). In addition, since our society has launched into the digital age, smart devices such as television, computers and video games have become so accessible for children and adolescents as to become an integral and habitual part of their lives (13). The result is the frequency and duration of their screen time exceeds recommended limits (14, 15).

Screen-based sedentary behavior has ascended as an independent factor affecting the physical fitness of children and adolescents (16). At present, the declining tendency of physical fitness level in adolescents has gradually become a severe problem that we are faced with in China (17, 18). Recent studies find Chinese adolescents have the dual challenge of more daily homework and screen time, which greatly reduces leisure-time physical activity and increases a sedentary lifestyle (19, 20). The latest prevalence estimates are 35 and 37% of children and adolescents in China reported spending more than 2 h a day with electronic screens (i.e., TV, computers, smartphones, digital tablets and video games) from 2016 to 2017 (21).

Studies point out the relationship between the duration of screen use and physical fitness in adolescents, that is, the longer the duration of television-watching per day, the higher the risk of physical fitness decline (22–24). Sedentary behavior is associated with lower muscle strength and endurance (25) and lower physical fitness levels (26), which results in health hazards of reduced cardiorespiratory fitness, muscle strength and endurance, increasing adiposity and affects mental health, sleep, social behavior and quality of life (27, 28). The research demonstrates that children with high screen exposure have a negative relationship with sports development and are more likely to have gross motor development problems (29). The poor executive function and low level of motor development increases musculoskeletal risk (30), as well as reduced cardiopulmonary function, muscle strength and endurance (27, 28). Research suggests that children and adolescents who engage in 60 min or more of moderate to vigorous physical activity per day benefit greatly across multiple areas of physical fitness, with the resulting positive effects lasting into their lifetime (31). However, excessive screen time is likely to lead to reducing physical activity (32). Poor behavioral habits developed during childhood and adolescence may extend into adulthood and affect the construction of a healthy lifestyle (33). The health hazards of screen-based sedentary behavior are a long-term, cumulative process that may influence physical fitness in adulthood (34). However, the impact of screen behavior as an independent hazard feature to the health of children and adolescents has converted into an important public health issue (35, 36).

Fostering healthy lifestyles, improving physical activity levels and reducing screen behavior of children and adolescents are urgently needed to promote physical fitness in China, and are also imperative to accomplish the strategic target of Healthy China (37, 38). Although relevant studies have investigated the association between physical activity, sedentary behavior and physical fitness of adolescents (23, 39, 40), a larger population should be studied in order to verify the effects of these three variables among Chinese adolescents. The purpose of this study is to explore the relationship between screen-based sedentary behavior, physical activity and physical fitness among Chinese adolescents through a large of population and indentify demographic factors affecting physical fitness, such as age, BMI, and SES. We hypothesized that high physical activity and low screen-based sedentary behavior are associated with the better physical fitness of Chinese adolescents, and demographic factors (e.g., age, BMI, and SES) affecting physical fitness. The knowledge gained through this study may facilitate the development of physical fitness promotion policies and programs for Chinese adolescents.

MATERIALS AND METHODS

Design, Setting, and Participants

A cross-sectional study was conducted by students recruited from 100 schools of 10 districts in Shandong Province, China, in the 2017–2018 semester. According to the specific geographical, demographic and socio-economic levels of the districts (41), 30 high school and 70 middle schools were randomly selected from 10 administrative districts. Three high schools and 7 middle schools were randomly selected in each district, with at least 100 students in each grade and over 300 students in each school. After screening, a total of 10,002 students (14.39 ± 1.79 years; $BMI_{mean} = 20.36$) finally completed all the questionnaires and physical fitness tests of the research institute, of which 49.54% were girls ($n = 4{,}955$; $BMI_{mean} = 20.21$) and 50.46% were boys ($n = 5{,}047$ $BMI_{mean} = 20.50$).

A total of 90 evaluators were recruited from physical education (PE) teachers working in middle and high schools who had previous experience in evaluating youth fitness and who had operated National Student Fitness Test program. In order to ensure the standardization of the test and decrease the error of the test, all PE teachers completed two training for test procedures and other matters needing attention. The trained investigators employed the standardized guides to organized students to measure physical fitness and guided students to answer online questionnaires. It was well-noted by all participants that all data was collected voluntarily, anonymously and confidentially, reserved on a password-protected website and accessible only to direct researchers. Both parents and students completed informed consent forms before beginning this survey. This study has been approved by the Ethics Committee of Shandong University.

Study Variables

Demographic and Other Characteristics

Adolescents reported basic information, and socioeconomic status (SES) and body mass index (BMI) data were collected as well-because they are associated with dependent variables to have a confusing effect on the statistical results. The SES of guardians

was investigated from the aspects of educational background and occupational status (42). An individual's SES score was calculated by multiplying an occupation scale value by a weight of 5 and education scale value by a weight of 3. Educational scale value ranged from 3 to 18 while occupational scale value ranged from 5 to 30. The total SES index ranged from 8 to 48 and was categorized as high (35–48), moderate (22–34), and low (8–21) (43). The validity and reliability of this instrument were endorsed by Cirino et al. (42). Body mass index (BMI) was applied to assess adolescents' weight status. A digital electronic scale (HW-VB900, Lejia, China) was used to measure the weight and height of barefoot students wearing light clothing with an accuracy of 0.1 kg. The calculation formula is weight (kg)/height 2 (m2).

Physical Activity

Physical activity was assessed using the Physical Activity Questionnaire for Adolescents (PAQ-A). This scale is a revised version of the Physical Activity Questionnaire for Older Children (PAQ-C), which aims to assess the level of physical activity of adolescents (44). Its effectiveness and reliability have been verified among Chinese adolescents (45). This questionnaire mainly asks adolescents what they did in most of their free time in the past 7 days. The physical activity level is scored on a 5-point scale (1–5), with a higher score indicating a higher PA level. It can be divided into low PA level (1–1.9 points) and high PA level (2–5 points) (46). Reliability of the questionnaire was analyzed by Cronbach's alpha ($\alpha = 0.821$). Those question asked: Which of the following best describes your performance in the past week? "I spend almost all my free time doing activities that have nothing to do with physical activity"; "I sometimes (once or twice in the last week) do some physical activity in my free time (e.g., exercise, running, swimming, cycling, aerobics, etc.)"; "I often (3–4 times in the last week) do some physical activity in my free time"; "I often (5–6 times in the last week) do some sports in my free time"; "I do some physical activity in my free time very often (7 times or more in the last week)."

Screen-Based Sedentary Behavior

Adolescents' sedentary behavior was assessed by two YRBSS questions (47): "During the semester, on Monday through Friday, how many hours of TV did you watch on an average day? On an average day, Monday to Friday of this semester, how many hours per day do you spend playing video games or using the computer for non-study activities (including time spent on QQ, WeChat, iPad or other social software such as texting or other social software)?" Each question has seven response options ranging from I don't watch TV/play video games or use the computer for non-academic things when I'm at school to $\geq$5 h. In the analysis, according to this classification, the time spent on sedentary behavior was recoded as (I) $<$3 h and (ii) $\geq$3 h (48).

Physical Fitness

National Student Physical Fitness and Health 2014 (NSPFH 2014) (49) was used to evaluate proficiency in the following aspects of physical fitness: 50-m sprint, sit and reach, standing long jump, bent-leg sit-ups for girls, pull-ups for boys, 1,000-m run for boys, and 800-m run for girls. These test items are reliable and effective tools to measure the physique of teenagers in China.

50-m sprint: We took the 50-meter sprint test to assess the students' speed and explosive power. When the subjects heard the "go" command, they began a 50-meter run. They ran the whole course as fast as they could. Time was recorded in minutes and seconds.

Sit and reach: In order to evaluate low back flexibility, sit and reach activity was measured. Every barefoot subject sat on the instrument and gradually extended his or her knees forward. The test was recorded twice, and the better score was retained.

Standing long jump: To measure lower-limb explosive strength, standing long jump was introduced. Every subject was asked to stand at the starting line and jump forward as far as possible. It was measured in meters from the starting line to the heel of the closest foot. The test was recorded three times, and the better score was retained.

1,000/800-m run: Every student stood at the scratch line and was asked to complete the 800 or 1,000 meters as fast as possible. Time was recorded in minutes and seconds. All the girls ran 800 meters and the boys ran 1,000 meters.

Pull-ups: The upper body muscular strength was tested by pull-ups. The test was scored on the number of pull-ups. The subject jumped up and pulled on the railing with both hands. After standing still, subjects pulled up with both arms together. All the male students were tested.

Bent-leg sit-ups: Every subject was asked to lie on a mat with knees bent 90 degrees, the upper body raised and elbows touching knees. The number of bent-leg sit-ups finished in 1 min was recorded. All the female students were tested.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows (Statistics 25, IBM Corporation, Chicago, USA). Data were tested for normality with the Shapiro–Wilk test. The *t*-test and the chi-square test were used for all variables in terms of gender. Continuous variables were represented by the mean and standard deviation (mean $\pm$ standard deviation), while classified variables were represented by a number (n) and percentage (%). Linear regression was used to analyze the relationship between age, socioeconomic status, sedentary screen behavior, physical activity and physical fitness. In addition to screen-related sedentary behavior (regarding physical activity) and physical activity (regarding screen-based sedentary behavior), all models were adjusted for age, BMI, and SES. Results in all models were expressed as a non-standard coefficient (β) with a 95% confidence interval (95% CI). $P \leq 0.05$ was statistically significant.

RESULTS

A total of 10,002 adolescents in this study were chosen in the final statistical analysis, of which 49.54% were girls and 50.46% were boys. Descriptive statistical analysis based on gender (**Table 1**) showed that the mean age, BMI, 50-m sprint, standing long jump and sit and reach were 14.39 years, 20.36, 8.84 s, 184.09 cm and 11.16 cm, respectively, with significant differences existing between boys and girls. The average endurance for boys (1,000 m)

TABLE 1 | Characteristics of participants.

Variables	All (n = 10,002)	Boys (n = 5,047)	Girls (n = 4,955)	p-value
Age (years)*	14.39 (1.79)	14.32 (1.78)	14.45 (1.80)	0.00
BMI*	20.36 (4.06)	20.50 (3.87)	20.21 (4.25)	0.00
Overweightness/obesity (%)	18.82	19.24	18.39	0.00
50-m sprint (sec)*	8.84 (1.58)	8.26 (1.63)	9.43 (1.28)	0.00
Standing long jump (cm)*	184.09 (33.59)	202.67 (32.49)	165.17 (22.20)	0.00
Sit and reach (cm)*	11.16 (8.62)	9.68 (9.23)	12.68 (7.66)	0.00
1,000-m run (min)		4.52 (0.97)		
800-m run (min)			4.06 (0.68)	
Pull-ups (reps)		5.35 (6.40)		
Bent-leg sit-ups (reps)			30.35 (10.45)	
Screen-based sedentary behavior				
Television viewing, *n* (%)*				0.00
<3 h	9,048 (90.46)	4,507 (89.30)	4,541 (91.64)	
≥3 h	954 (9.54)	540 (10.70)	414 (8.36)	
Computer/videogame use, *n* (%)*				0.00
<3 h	8,826 (88.24)	4,286 (84.92)	4,540 (91.62)	
≥3 h	1,176 (11.76)	761 (15.8)	415 (8.38)	
Physical activity category, *n* (%)*				0.00
Active	5,964 (59.63)	3,212 (63.64)	2,752 (55.54)	
Inactive	4,038 (40.37)	1,835 (36.36)	2,203 (44.46)	
Regular exercise, *n* (%)*				0.00
<1 time pw	1,961 (19.61)	923 (18.29)	1,038 (20.95)	
1–2 times pw	4,104 (41.03)	1,912 (37.88)	2,192 (44.24)	
3–4 times pw	2,282 (22.82)	1,219 (24.15)	1,063 (21.45)	
≥5 times pw	1,655 (16.55)	993(19.68)	662 (13.36)	
SES, *n* (%)				0.32
High	2,696 (26.96)	1,392 (27.58)	1,304 (26.32)	
Moderate	3,057 (30.56)	1,540 (30.51)	1,517 (30.62)	
Low	4,249 (42.48)	2,115 (41.91)	2,134 (42.06)	

*Data were described as n (%) or mean ± SD; BMI, Body Mass Index; SES, socioeconomic status; Screen-based SB, Screen-based sedentary behavior; TV, Television viewing; C/V use, Computer/videogame use; pw: per week. *Significant difference between male and female, $p < 0.05$.*

and girls (800 m) was 4.52 s and 4.06 s. The average number of pull-ups for boys and bent-leg sit-ups for girls was 5.35 and 30.35 respectively.

9.54% and 11.76% of adolescents surveyed watched TV and play computer/video games more than 3 h daily, respectively. The average of 40.3% of adolescents had insufficient physical activity. The results showed the exercise frequency of adolescents as follows: 19.61% exercise 0 times/week, 41.03% 1–2 times/week, 22.82%, 3–4 times/week, 16.55% ≥5 times/week. Significant differences were shown between boys and girls in their screen-based sedentary behavior, physical activity, and frequency of physical activity in leisure time; however no significant differences in SES.

As shown in **Table 2**, the relationship between physical activity and screen-based sedentary behavior and demographic factors and physical fitness of adolescents was analyzed through a multiple linear regression model. Comparing participants on the variable of TV viewing time, the high TV viewing time had a significant impact on physical fitness of 50-m sprint (β:0.452; 95% CI:0.282–0.621), standing long jump (β: −4.562; 95% CI: −7.469 to −1.656) and 1,000-m run (β: 0.107; 95% CI: 0.013–0.201) in boys and 50-m sprint (β: 0.537; 95% CI: 0.388–0.686), sit and reach (β: −1.173; 95% CI: −2.072 to −0.274), 800-m run (β: 0.149; 95% CI: 0.072–0.227) and bent-leg sit-ups (β: −1.383; 95% CI: −2.597 to −0.169) in girls. In addition, there was no association between the amount of time spent playing computer/video games and physical fitness among adolescents. Compared with the the physically inactive (as a reference), those with a high level of physical activity were significantly positively associated with 1,000-m run (β: −0.082; 95% CI: −0.142 to −0.023) and pull-ups (β: 0.466; 95% CI: 0.039–0.894) in boys and standing long jump (β: 1.504; 95% CI: 0.078–2.93) and bent-leg sit-ups (β: 1.07; 95% CI: 0.378–1.762) in girls. Compared with physical activity <1 time per week, the 1–2 times per week was positively associated with the standing long jump (β: 3.461; 95% CI: 1.278–5.645) and 1,000-m run (β: −0.16; 95% CI: −0.23 to −0.089) in boys and 800-m run (β: −0.054; 95% CI: −0.105 to −0.002) in girls. The 3–4 times per week was associated with the standing long jump (β: 3.284; 95% CI: 0.702–5.866) and 1,000-m run-0.131(−0.215 to −0.047) in boys and 50-m sprint (β: −0.131;

TABLE 2 | Multivariable General Linear Models Evaluating the Association of Physical Activity and Screen-based Sedentary Behavior and Demographic Factors and Physical Fitness.

Physical fitness test	Demographic characteristics	Boys (n = 5,047) β (95% CI)		Girls (n = 4,955) β (95% CI)	
50-m sprint (s)	BMI	0.039 (0.028, 0.028)**	F = 38.500 R^2 = 0.069	0.019 (0.011, 0.028)**	F = 13.617 R^2 = 0.025
	SES (moderate vs. low)	−0.069 (−0.173, 0.035)		−0.081 (−0.165 to 0.002)	
	SES (high vs. low)	−0.061 (−0.168 to 0.046)		−0.232 (−0.32 to −0.145)**	
	Screen-based SB				
	TV (≥3 h vs. <3 h)	0.452 (0.282, 0.621)**		0.537 (0.388, 0.686)**	
	C/V use (≥3 h vs. <3 h)	−0.096 (−0.242 to 0.05)		−0.059 (−0.207 to 0.09)	
	Physical activity				
	Physical activity (Active vs. Inactive)	−0.066 (−0.173 to 0.04)		−0.015 (−0.1 to 0.07)	
	Regular exercise (1–2 times pw vs. <1 time pw)	−0.11 (−0.237 to 0.017)		−0.098 (−0.196 to 0.001)	
	Regular exercise (3–4 times pw vs. <1 time pw)	−0.096 (−0.247 to 0.054)		−0.131 (−0.255 to −0.007)*	
	Regular exercise (≥5 times pw vs. <1 time pw)	−0.178 (−0.338 to −0.019)*		−0.215 (−0.355 to −0.074)**	
Standing long jump (cm) Sit and reach (cm)	BMI	−1.239 (−1.434 to −1.043)**	F = 226.410 R^2 = 0.309	−0.312 (−0.452 to −0.172)**	F = 49.639 R^2 = 0.090
	SES (moderate vs. low)	2.591 (0.807, 4.375)**		1.453 (0.054, 2.853)*	
	SES (high vs. low)	3.007 (1.168, 4.845)**		2.139 (0.669, 3.609)**	
	Screen-based SB				
	TV (≥3 h vs. <3 h)	−4.562 (−7.469 to −1.656)**		−1.157 (−3.658, 1.344)	
	C/V use (≥3 h vs. <3 h)	1.106 (−1.406 to 3.618)		0.302 (−2.189 to 2.794)	
	Physical activity				
	Physical activity (Active vs. Inactive)	1.475 (−0.353 to 3.302)		1.504 (0.078, 2.93)*	
	Regular exercise (1–2 times pw vs. <1 time pw)	3.461 (1.278, 5.645)**		0.954 (−0.699 to 2.607)	
	Regular exercise (3–4 times pw vs. <1 time pw)	3.284 (0.702, 5.866)*		0.124 (−1.961 to 2.209)	
	Regular exercise (≥5 times pw vs. <1 time pw)	3.782 (1.046, 6.517)**		2.737 (0.386, 5.089)*	
	BMI	−0.101 (−0.168 to −0.035)**	F = 4.881 R^2 = 0.008	−0.008 (−0.058 to 0.042)	F = 7.099 R^2 = 0.012
	SES (moderate vs. low)	0.275 (−0.334 to 0.883)		−0.32 (−0.823 to 0.183)	
	SES (high vs. low)	0.211 (−0.416, 0.839)		0.142 (−0.387 to 0.67)	
	Screen-based SB				
	TV (≥3 h vs. <3 h)	0.059 (−0.932 to 1.05)		−1.173 (−2.072 to −0.274)*	
	C/V use (≥3 h vs. <3 h)	−0.514 (−1.371 to 0.342)		0.654 (−0.241 to 1.55)	
	Physical activity				
	Physical activity (Active vs. Inactive)	−0.39 (−1.013 to 0.233)		0.128 (−0.385 to 0.64)	
	Regular exercise (1–2 times pw vs. <1 time pw)	0.013 (−0.732 to 0.757)		0.33 (−0.264 to 0.924)	
	Regular exercise (3–4 times pw vs. <1 time pw)	−0.03 (−0.91 to 0.851)		0.429 (−0.321 to 1.178)	
	Regular exercise (≥5 times pw vs. <1 time pw)	0.964 (0.031, 1.897)*		0.987 (0.142, 1.833)*	
1,000-m run (min)	BMI	0.052 (0.046, 0.058)	F = 122.893 R^2 = 0.195		
	SES (moderate vs. low)	−0.072 (−0.13 to −0.014)*			
	SES (high vs. low)	−0.099 (−0.158 to −0.039)**			
	Screen-based SB				
	TV (≥3 h vs. <3 h)	0.107 (0.013, 0.201)*			

(Continued)

TABLE 2 | Continued

Physical fitness test	Demographic characteristics	Boys (n = 5,047) β (95% CI)		Girls (n = 4,955) β (95% CI)	
	C/V use (≥3 hvs. <3 h)	−0.032 (−0.113 to 0.05)			
	Physical activity				
	Physical activity (Active vs. Inactive)	−0.082 (−0.142 to −0.023)**			
	Regular exercise (1–2 times pw vs. <1 time pw)	−0.16 (−0.23 to −0.089)**			
	Regular exercise (3–4 times pw vs. <1 time pw)	−0.131 (−0.215 to −0.047)**			
	Regular exercise (≥5 times pw vs. <1 time pw)	−0.19 (−0.279 to −0.102)**			
800-m run (min)	BMI			0.023 (0.018,0.027)**	F = 42.410
	SES (moderate vs. low)			−0.084 (−0.128,−0.041)**	
	SES (high vs. low)			−0.053 (−0.099,−0.008)*	
	Screen-based SB				
	TV (≥3 h vs. <3 h)			0.149 (0.072,0.227)**	
	C/V use (≥3 h vs. <3 h)			0.03 (−0.047,0.107)	
	Physical activity				
	Physical activity (Active vs. Inactive)			−0.032 (−0.077,0.012)	
	Regular exercise (1–2 times pw vs. <1 time pw)			−0.054 (−0.105,−0.002)*	
	Regular exercise (3–4 times pw vs. <1 time pw)			−0.076 (−0.14,−0.011)*	
	Regular exercise (≥5 times pw vs. <1 time pw)			−0.16 (−0.233,−0.087)**	
Pull-ups (reps)	BMI	−0.164 (−0.209 to −0.118)**	F = 15.258 R^2 = 0.028		
	SES (moderate vs. low)	0.041 (−0.376 to 0.459)			
	SES (high vs. low)	0.595 (0.165 to 1.025)**			
	Screen-based SB				
	TV (≥3 h vs. <3 h)	0.183 (−0.497 to 0.863)			
	C/V use (≥3 h vs. <3 h)	−0.285 (−0.872 to 0.303)			
	Physical activity				
	Physical activity (Active vs. Inactive)	0.466 (0.039, 0.894)*			
	Regular exercise (1–2 times pw vs. <1 time pw)	−0.036 (−0.547 to 0.474)			
	Regular exercise (3–4 times pw vs. <1 time pw)	−0.114 (−0.718 to 0.49)			
	Regular exercise (≥5 times pw vs. <1 time pw)	0.934 (0.294 to 1.574)**			
Bent-leg sit-ups (reps)	BMI			−0.041 (−0.109 to 0.027)	
	SES (moderate vs. low)			1.915 (1.236, 2.594)**	
	SES (high vs. low)			3.204 (2.491, 3.918)**	
	Screen-based SB				
	TV (≥3 h vs. <3 h)			−1.383 (−2.597 to 0.169)*	
	C/V use (≥3 h vs. <3 h)			0.098 (−1.111 to 1.307)	
	Physical activity				
	Physical activity (Active vs. Inactive)			1.07 (0.378, 1.762)**	
	Regular exercise (1–2 times pw vs. <1 time pw)			0.19 (−0.612 to 0.992)	
	Regular exercise (3–4 times pw vs. <1 time pw)			−0.152 (−1.164 to 0.859)	
	Regular exercise (≥5 times pw vs. <1 time pw)			0.651 (−0.49 to 1.792)	

*BMI, Body Mass Index; SES, socioeconomic status; Screen-based SB, Screen-based sedentary behavior; TV, Television viewing; C/V use, Computer/videogame use; pw: per week. Data are presented as β coefficient (95% CI). *0.05, **0.01. The model was adjusted for age, BMI, socioeconomic status, physical activity and screen-based sedentary behavior.*

95% CI: −0.255 to −0.007) and 800-m run (β: −0.076; 95% CI: −0.14 to −0.011) in girls. Moreover, more than 5 times per week was significantly positively associated with most dimensions of physical fitness (except girls' bent-leg sit-ups).

DISCUSSION

This study examined the relationship between BMI, socioeconomic status, sedentary screen behavior, physical activity and physical fitness among Chinese adolescents. We found that all these factors were independently and significantly associated with physical fitness. Adolescents with high levels of physical activity and high socioeconomic status had better physical fitness. Adolescents with obesity and sedentary TV watching behaviors had worse physical fitness. No association was found between computer/video game sedentary behavior and physical fitness.

Regarding frequency of physical activity, previous studies demonstrated that girls generally have lower levels of physical activity than boys (50), and 27.9 % girls were sedentary, compared with 10.6% boys (51). This study found that 36.36% boys and 44.46% girls had low physical activity. The screen behavior of girls may be more severe than boys, so strategies to increase physical activity among adolescents should concentrate more on girls. Previous studies indicate that physical activity is crucial to improving cardiopulmonary endurance, muscle strength and endurance of adolescents (52, 53). The upper limb muscle strength and endurance of boys and the abdominal muscle strength endurance of girls are significantly correlated with physical activity (54), which is consistent with the results shown in this study that boys and girls with high physical activity levels had better upper limb muscle strength and endurance and better abdominal muscle strength and endurance. It is worth noting that the association between physical fitness components and physical activity has been recognized to be gender-specific (55) and that girls are more likely to engage in low to moderate-intensity exercise, while boys are inclined to high-intensity exercise (51). This may be one of the main reasons for this study concluded that boys with high physical activity have better cardiopulmonary endurance and girls with high physical activity have better lower limb explosive power.The World Health Organization (WHO) Guidelines on Exercise and Sedentary Behavior in 2020 suggest that children and adolescents who participate in 60 min or more per day, at least 3 times per week of strenuous aerobic exercise and musculoskeletal exercises, can improve physical fitness (11) and have significant benefits in multiple health and fitness domains and that these benefits persist throughout their lifetime (31). This is consistent with our findings that leisure physical activity five or more times per week was likely to have the greatest impact on physical fitness among adolescents. Therefore, families and schools should enhance intensity and the frequency of leisure physical exercise as one of the pathways for promoting physical fitness in adolescent.

Regarding socio-economic status and BMI, current studies find that physical fitness is related to a wide range of socioeconomic conditions (56). Adolescents with low socioeconomic status may have limited access to the resources and facilities needed to promote physical activity, resulting in less physical activity (57, 58). Physical fitness is positively correlated with regional socio-economic level as the developed districts may provide better educational resources and sport facilities for youth so they have more opportunities to participate in physical activity (57). In the other hand, parents of adolescents in high SES have stronger awareness and ability to supervise their children, resulting in less screen use time (59). However, this study also illustrated the importance of SES in that adolescents with high SES have better lifestyle habits.

The results of this study showed that the adolescents with higher BMI have worse level of physical fitness, which was consistent with previous studies that obesity leads to significant decline in cardiovascular endurance and pulmonary function, speed, strength, flexibility, and other physical qualities (60, 61). In addition, overweight and obesity are the major risk factors for non-communicable diseases that may cause death, musculoskeletal diseases and cancer (62, 63). Obesity may make children watch TV longer (64) and reduce physical activity (65), which will lead to a worse physical fitness. Therefore, government and school departments can improve the physical fitness of adolescents through the prevention or reduction of overweight or obesity.

From the perspective of sedentary behavior on screens, previous studies demonstrated that longer television viewing is associated with the physical fitness of adolescents (66). Watching television is not only positively correlated with metabolic risk factors, but also increases the casual food intake (66, 67) and impacts teens' physical abilities because of the passive nature of TV viewing and lack of social interaction (51). Children who watch TV for more than 2 h per day are more likely to be overweight or obese which implies a dose-response relationship with physical fitness. The more time adolescents spend watching TV each day, the higher the risk of physical fitness decline (24). All these aspects support the finding of this study that adolescents with high TV viewing time have a low level of physical fitness. The present study did not find an association between sedentary behavior (playing computer/video games) and physical fitness in adolescents, which was consistent with the results of previous studies (66). We suggest that some sports-related video game integrating physical activities into real life into the game concept may motive adolescents' interest in physical activities (68). Active video games may prevent weight gain, motivate children for longer periods of physical activity, and improve their healthy lifestyle, thereby improving physical fitness (69). In the future, when formulating strategies to improve the physical fitness of adolescents, we should not only consider screen-based sedentary behaviors, but also formulate more targeted strategies in terms of the classification of screen-based sedentary behaviors.

The strength of this study is that it is the first to use a large sector of the population to analyze the relationship between physical activity, screen-based sedentary behavior and physical fitness for adolescent in China. We hope this study will construct a foundation for future intervention of schools in risk behaviors. The results of this study revealed the current severe state of adolescent physical fitness in China, and provide suggestions for

government and schools looking for strategies to improve the physical fitness of Chinese adolescents. However, this study has some limitations that may influence the generalizability of its outcome. First, this study is a cross-section study that cannot accurately explain and analyze the causal relationship. Second, the screen-based sedentary behavior scale jointly considers only the use of computer/video games, but we do not indentify that adolescents can perform different tasks at computer than only playing electronic games, as scholar tasks an social media, which may have a certain impact on our research results. Third, the dietary assessment and sleep behavior was not evaluated so that we can not determine whether those variables are asscoscited with physical activity and physical fitness. Finally, the age stratified physical fitness with respect to BMI, SES and screen based sedentary behavior was not assessed in this study. We will futher explore those issues in the future.

CONCLUSIONS

This study examined the relationship between BMI, socioeconomic status, sedentary screen behavior, physical activity and physical fitness among Chinese adolescents. We found that adolescents with high levels of physical activity and high socioeconomic status were associated with better physical fitness. Adolescents with obesity and sedentary TV watching behaviors were linked to worse physical fitness. Most of these factors were independently and significantly related to physical fitness, but no association was found between computer/video game sedentary behavior and physical fitness. This study suggested that future strategies to improve the physical fitness of Chinese adolescents should focus on adolescents with low socioeconomic status and obesity that promote physical activity and reduce sedentary television-watching behaviors.

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 Shandong University (20180517). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

XD and XY: funding acquisition and writing—original draft. XD and RZ: methodology. XD, BW, and MD: project administration. XD, XY, RZ, and LD: writing—review and editing. All authors have read and approved the manuscript.

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Stool Saponified Fatty Acid, Behavior, Growth, and Stool Characteristics in Infants Fed a High-OPO Formula: A Randomized, Double-Blind Clinical Trial

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Objective: 1,3-Dioleoyl-2-palmitoylglycerol (OPO) is an ideal structured triglyceride for infant formula, with a similar structure to human milk fat. We conducted this randomized, double-blind controlled, single-center trial to evaluate the effects of an OPO formula in infants.

Study Design: One hundred seventy-four healthy term infants <14 days old were assigned to the standard formula-fed group ($n = 55$), high sn-2 palmitic acid (OPO) formula-fed infants ($n = 58$), and breastfed (BF) group ($n = 61$). The primary endpoint was the total saponified fatty acid content in feces at week 6 and week 12.

Results: Infants from the OPO group had lower concentrations of fecal saponified fatty acids than those from the standard formula group ($p < 0.0001$) at week 6 and week 12. The frequencies of crying per day and per night of infants in the OPO group were significantly less than those of infants in the standard formula group ($p < 0.0001$). After 12 weeks of feeding, the length of infants was significantly higher in the OPO group than in the other two groups ($p = 0.002$). Infants in the OPO group had a significantly lower stool calcium concentration and a higher stool frequency per day than infants in the standard formula group.

Conclusion: In summary, a high concentration of OPO in formula is beneficial to the growth and development of infants.

Keywords: OPO, formula, infant, stool, sleep

INTRODUCTION

Breast milk is the main energy source of infants and contains 3–5% fat. Triglycerides account for 98% of breast milk fat and contain more than 200 types of different fatty acids (1, 2). Breast milk contains 17–25% palmitic acid, 70–75% of which is distributed in the sn-2 position of triglycerides, while unsaturated fatty acids such as oleic acid and linoleic acid are mostly distributed in the sn-1 and sn-3 positions (3–5).

In contrast, saturated fatty acids such as palmitic acid in vegetable oils that are used in most infant formulas as fat sources are mostly distributed at the sn-1 and sn-3 positions, and <20% of palmitic acid is distributed at the sn-2 position as beta-palmitate (6). Pancreatic lipase secreted by the small intestine is a sn-1- and sn-3-site-specific lipase that hydrolyzes triglycerides to produce sn-2 monoglycerides and free fatty acids (7). Once the hydrolyzed free fatty acids are saturated fatty acids such as palmitic acid, they will form an insoluble fatty acid soap containing calcium, which increases the hardness of infant stools and causes constipation as well as calcium loss in infants (8). As a result, the difference in the structure of triglycerides is closely related to the digestion, absorption, and metabolism of fat in infants (9–11), and this may be one of the mechanisms underlying the differences in behavior, stool characteristics, and fat and calcium absorption between breastfed and formula-fed infants (5, 11).

1,3-Dioleoyl-2-palmitoylglycerol (OPO) is an ideal structured triglyceride for infant formula that has a similar structure to human milk fat and a variety of beneficial effects on infants (12). When OPO enters the gastrointestinal tract, the oleic acid at the sn-1 and sn-3 positions is degraded to oleic acid. As oleic acid is an unsaturated fatty acid, it will not form a fatty acid soap containing calcium that is excreted from feces, which may decrease constipation and improve calcium and fat absorption in formula-fed infants (13). Therefore, OPO has become one of the research hotspots in infant formula during the last two decades (14–17).

It has been validated in an animal model that OPO promotes the absorption of fat and calcium in the rat intestine (18, 19). Clinical studies have shown that compared with standard infant formula using vegetable oils as the fat source, infant formula with a high content of OPO improves the absorption rate of fatty acids, reduces stool hardness, enhances bone mineral density, and reduces the crying frequency of infants (20–25). Therefore, the objective of this randomized, double-blind, controlled, single-center clinical trial was to evaluate the effect of an infant formula with a high content of OPO on fatty acid absorption, behavior, growth and stool characteristics in infants.

MATERIALS AND METHODS

Study Design and Participants

This was a single-center, double-blind, randomized, parallel-controlled clinical trial. This trial was registered on the Chinese Clinical Trial Registration website with Registration number ChiCTR1800018813 on October 11, 2018. All of the infants were enrolled in Suzhou, Jiangsu Province, China, from June 2018 to June 2020. Fully formula-fed infants were randomized to the standard formula-fed group or OPO formula-fed group. The randomization was done *via* block randomization method with the block size randomly generated as four. Exclusively breastfed (BF) infants were assigned to the BF group. A standard infant formula with 23.6% palmitic acid esterified in the sn-2 position was used as the standard formula. An infant formula (Zhicai stage 1 milk formula for infants from 0 to 6 months, Beidahuang Wondersun Dairy Company Limited) with high sn-2 palmitic acid (MIKOPAS, Wilmar) was used for the OPO formula-fed group, in which 52.8% of triglycerides have palmitic acid in the sn-2 position. Energy, protein, carbohydrate, fat, and mineral contents were similar between the 2 formulas. The compositions of the 2 study formulas are generally similar, except the content of palmitic acid esterified in the sn-2 position of the triglycerides (**Table 1**).

Eligible subjects were full-term infants (37–41 weeks) with normal pregnancy and delivery (cesarean section is acceptable), birth weight between 2.5–4 kg, and age <14 days old. Exclusion criteria included the following: the mother had an illness (psychological or disability) or socioeconomic problems, which would affect her ability to take care of the baby; one of or both parents had a severe allergic constitution; infants with congenital chromosomal abnormalities; diseases requiring mechanical ventilation in the first 1 week (excluding phototherapy); Apgar score <7; breastfeeding for more than one 1 week (except the BF group); and other conditions that the researchers considered as rendering the subjects not suitable to participate in the study or not complying with the requirements of the study protocol. The study was conducted under the principles of the Declaration of Helsinki, and the study protocol was approved by the Ethics Committees of Suzhou Kowloon Hospital Shanghai Jiao Tong University School of Medicine (KY-2018–016). Informed consent was provided to all parents of the infants, and written permission was obtained before inclusion. This study was registered in the Chinese Clinical Trial Registry (ChiCTR1800018813).

Procedures

After randomization, eligible infants were exclusively fed with the study formulas or breast milk for 12 weeks. Baseline demographic information of the subjects was recorded, and this included infant gender, race, ethnicity, date of birth, age at enrollment, allergic history of the parents, birth length, birth weight, head circumference at birth and Apgar score. Infants in all groups were recommended to be fed based on their needs following the Chinese Nutrition Society and Chinese children's feeding and nutrition guidelines. Follow-up visits were set at week 6, week 12, and week 24 after infants were assigned to a feeding group.

Infant anthropometric measurements and infant behavior data were recorded at baseline, at each study visit and at the end of the study. Infant anthropometric measurements included length, weight, head circumference, and bone density. The crying frequency was counted as once if it lasted more than 10 min after pacification, and if the interval between two crying times was over 30 min, they were counted as two crying episodes. Infant stool samples were collected at the 6-week and 12-week follow-up visits.

Assessment

Infant stools were collected from diapers. Parents placed rice paper on the diapers of their infants in advance. After infant defecation, the parents wore disposable gloves to remove the rice paper from the diaper, transferred the feces into a 50 ml centrifuge tube, and screwed on the cover of the tube. A self-adhesive label recorded the sampling time was attached to the tube, which was then stored at−16 °C. The researchers transferred the samples to the clinical center within one 1 week,

TABLE 1 | Compositions of the standard formula and OPO formula.

	Standard formula	OPO formula
Energy, kcal	2,088	2,084
Protein, g	11.4	10.9
Fat, g	25.2	26
Linoleic acid, g	3.79	2.86
α-Linolenic acid, mg	379	286
Carbohydrate, g	56.2	53.2
Vitamin		
Vitamin A, μg	448	490
Vitamin D, μg	6.52	6.83
Vitamin E, μg	6.11	7.25
Vitamin K1, μg	32.8	40.4
Vitamin B1, μg	390	558
Vitamin B2, μg	537	650
Vitamin B6, μg	397	460
Vitamin B12, μg	1.1	2.7
Vitamin C, mg	65.2	72.1
Nicotinic acid, μg	3,700	4,000
Folic acid, μg	70	78
Pantothenic acid, μg	2,660	3,110
Biotin, μg	16	17.8
Mineral substance		
Sodium, mg	131	132
Potassium, mg	448	381
Copper, μg	329	340
Magnesium, mg	33.1	31.5
Iron, mg	2.85	4.2
Zinc, mg	3.14	4
Manganese, μg	31.3	40.5
Calcium, mg	313	340
Phosphorus, mg	177	210
Iodine, μg	69	81.4
Chlorine, mg	313	330
Selenium, μg	14.5	16
Other component		
Choline, mg	100	125
Inositol, mg	34.3	43.2
Taurine, mg	34.2	34.5
L-carnitine, mg	9.8	11.7
Fatty acid (% of total fatty acid)		
C6:0	0.3	0.3
C8:0	0.6	0.5
C10:0	0.9	0.8
C12:0	5.1	3.7
C14:0	4.6	4.3
C16:0	19	19.4
C16:1	0.1	0
C18:0	5.8	5
C18:1C	36.5	40.3
C18:2C	21.2	20.4
C18:3C	2.7	2
C22:6	0.24	0.31
C20:4	0.37	0.47
Fructo-oligosaccharides, mg	700	3,800
Nucleotide, mg	15	30
PA in sn-2 position, g	/	7
Lactoferrin, mg	36	/
Xanthophylls, μg	/	100

Data are the weight of each component per 100 g formula.

weighed the samples, and stored them at −70 °C for testing. The infant behaviors were collected *via* questionnaires from the parents.

Measurement of fatty acids and saponified fatty acids: A 500 mg sample was weighed and extracted with petroleum ether (boiling range, 30–60°C) for 4 h to obtain neutral fat. Then, the extracted sample was refluxed with a mixture of petroleum ether and acetic acid (petroleum ether: acetic acid = 2:3, v/v, $pH < 3$) for 4 h to obtain saponified fatty acids. The total fat amount was the sum of neutral fat and saponified fatty acids. The neutral fat and saponified fatty acid extracted above were evaporated to dryness, and 40 μg c19:0 and 5 ml of 2% sodium hydroxide methanol solution were added, followed by a water bath at 40°C for 20 min. Ten milliliters of 0.5 mol/l sulfuric acid methanol solution was added through the upper end of the condenser tube, and the mixture was incubated in 70°C water for 15 min, followed by the addition of 10 ml n-hexane and 1 min incubation. After the sample cooled to room temperature, 10 ml water was added and shaken for 4 min. The supernatant was then filtered out for further testing.

Total fatty acids and saponified fatty acids were analyzed by gas chromatography/mass spectrometry (GC-MS) using an Agilent-Technologies 7890A GC system equipped with an Agilent-Technologies 7000C Inert MSD with triple-axis detector (Agilent-Technologies, Little Falls, CA, USA). GC-MS analysis of volatile compounds was performed using an HP-5MS (30 m × 0.25 mm × 0.25 μm; J&W Scientific, Folsom, CA, USA). Electron ionization mode was used and with the mass range seat at m/z 50-550. GC was programmed to split mode with split ratio of 20:1. The oven temperature was kept at 60°C for 2 min, and then heated from 60 to 165°C at a rate of 10°C/min, kept at 165°C for 6 min. Finally, the temperature was increased to 220°C at a programmed rate of 15°C/min. The temperature of the GC injector line was 250°C and temperature of the MS transfer line was 230°C. The carrier gas was helium with the flow rate of 1.5 ml/min. The sum of C8-C18 (including C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C18:1, and C18:2) to was used to present the content of total fatty acids (18, 26). To ensure the stability and repeatability of the system, 10 μl of each sample was combined for quality control, which was inserted and analyzed in every 10 samples.

Calcium and bone density determination: All reagents (Sinopharm, China) were of at least analytical grade. Doubly distilled water was used for preparing solutions. In general, the collected feces sample was dried, quantified (0.2–3 g), then transferred into the digest tubes together with 10 ml HNO_3, 0.5 ml $HClO_4$, and subsequently heated by the microwave heating: 120°C, 1 h, 180°C, 4 h, and 220°C,0.5 h. After the heating digestion, the lanthanum solution (20 g/L) was added into the digested solution, and then diluted by ddH_2O until the concertation of lanthanum was 1 g/L. The WFX220 atomic absorption spectrometry (AAS; Beifen-Ruili Corporation, Beijing, China) was used with a flame atomization source (FAAS) and hollow cathode lamp (HCL) was used as light source. Determinations performed under the following condition: acetylene: 1.2 L/min; air: 5.0 L/min; the current for HCL: 8 mA; wavelength: 422.7 nm; and slit width: 0.02 mm. The analysis of the results was performed by the following equation:

$$X = \frac{(\rho - \rho_0) \times f \times V}{m}$$

Where X is the concentration of Ca, (mg/g). ρ is the Ca concentration of test sample solution, (mg/L). ρ_0 is the Ca concentration of the reference solution (mg/L), f is the dilution factor of the digest solution. V is the volume of the digest solution. m is the sample weight (g).

The bone density of infants was determined by the OSTEOKJ7000+ densitometer (Kejin Corporation NanJing, China) by following the recommended protocols. The bone density of infant Tibia was detected and recorded for the further analysis.

The teams took measurements within 12 h of birth using identical equipment that we provided to all sites: an electronic scale (Suhong, Suzhou, China) for birthweight, a specially designed Harpenden infantometer (Seca, Hangzhou, China) for recumbent length, and a metallic non-extendable tape (Seca, Hangzhou, China) for head circumference. The equipment, which was calibrated twice a week, was selected for accuracy, precision, and robustness, as shown in previous studies.

Measurement procedures are conducted in accordance with WHO recommendations to ensure maximum validity (27, 28). In the process of standardization, the error range of recumbent length measurement of intraobserver and interobserver was 0.3–0.5 cm, and the error range of head circumference measurement was 0.3–0.4 cm. Each measurement was done independently by two anthropometrists. If the difference of the two measurements exceeds the maximum allowable difference (birth weight 5 g, length 7 mm, head circumference 5 mm), the two observers re-measure the difference for the second and third times, if necessary.

Outcomes

The primary outcome was the total saponified fatty acid content in feces at week 6 and week 12. The secondary outcomes included the total fatty acid content in feces at week 6 and week 12; average daily sleep time in the first 12 weeks; average daily crying times and average crying days in the first 12 weeks; physical parameters at week 6 and week 12 (infant length, weight, head circumference; bone density); and fecal calcium content at week 6 and week 12.

Statistical Analysis

No formal statistical calculation was used to predetermine the sample size. Of the basic demographic characteristics, variable data of the three groups were statistically inferred by t-tests; attribute data of the three groups were statistically inferred by the chi square test.

The median and quartile of the primary and secondary outcomes were calculated to evaluate the effect of the three feeding methods on infants. Kruskal-Wallis tests were used to compare differences across the three study groups. Dunnett's t-test was used to compare differences between each pair of groups. All statistical analyses were conducted using R software v3.6.3. Hypothesis tests were performed using bilateral tests. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Baseline Characteristics

Between October 19, 2018 to August 31, 2020, a total of 174 eligible infants were enrolled in this study. Sixty-one were exclusively breastfed and assigned to the BF group, and 113 were randomized to either the standard formula group ($n = 55$) or OPO formula group ($n = 58$). As of the data cutoff on June 15, 2020, a total of 14 infants dropped from the study, including 8 in the BF group, 2 in the standard group, and 4 in the OPO group. As a result, 160 infants were included in the per protocol set (PPS) and used for activity and safety analyses (**Figure 1**).

The demographic and baseline characteristics of the infants in the three study groups are presented in **Table 2**. No significant difference was found among the 3 groups in terms of sex, APGAR scores, gestational age, weight or length at baseline. There were also no significant differences among the 3 groups in household characteristics, including proportion of vaginal deliveries, mother's age, mother's height, and father's height.

Saponified Fatty Acid and Total Fatty Acid in Stool

We compared the concentrations of fecal saponified fatty acids (including C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C18:1, and C18:2) across the three study groups. Significant differences were observed among these groups at both week 6 ($p < 0.0001$, Kruskal-Wallis test; **Figure 2A**) and week 12 ($p < 0.0001$, Kruskal-Wallis test; **Figure 2B**). Infants from the OPO group [week 6, 4.3 mg/100 mg (range 3.7–4.7); week 12, 3.9 mg/100 mg (range 3.3–4.2)] had significantly lower concentrations of fecal saponified fatty acids than infants from the standard formula group [week 6, 6.7 mg/100 mg (range 5.2–8.0); week 12, 6.5 mg/100 mg (range 5.6–7.6); $p < 0.0001$, Dunnett-t]. Both formula-fed groups had significantly higher concentrations of fecal saponified fatty acids than the BF group [week 6, 2.4 mg/100 mg (range 2.0–2.9); week 12, 2.1 mg/100 mg (range 1.8–2.5); $p < 0.0001$, Dunnett-t].

We further compared the concentration of total fatty acids (including C8:0, C10:0, C12:0, C14:0, C16:0, C18:0, C18:1, and

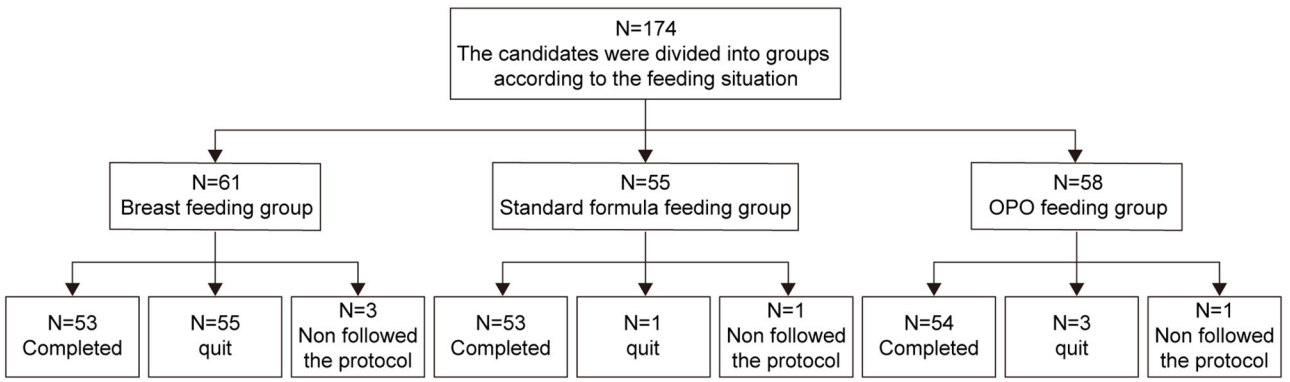

FIGURE 1 | Study flow diagram.

TABLE 2 | Demographic and baseline characteristics.

	OPO ($n = 54$)	Control ($n = 53$)	BF ($n = 53$)	*P*-value OPO vs. Control	*P*-value BF vs. OPO	*P*-value BF vs. Control
Gender (% male)	51.85	56.6	35.85	0.7648	0.1408	0.0514
APGAR scores (% 10)	98.15	96.23	96.23	0.6179	0.6179	1.0000
Delivery method (% vaginal)	64.81	73.58	50.94	0.5256	0.1676	0.0275
Mother's age (year)	29.5 ± 4.7	30.8 ± 6.8	29.4 ± 4.1	0.2455	0.9203	0.2022
Father's height (cm)	173.6 ± 4	174.1 ± 3.8	174.6 ± 4.1	0.5217	0.2299	0.5647
Mother's height (cm)	161.5 ± 3.8	157.1 ± 20.4	159 ± 20.8	0.1351	0.3941	0.6391
Gestational age (year)	40 ± 1.3	39.9 ± 1.2	39.7 ± 1	0.8773	0.2522	0.3197
Length at enrollment	50.5 ± 0.9	50.4 ± 1.1	50.8 ± 1.5	0.7612	0.1788	0.136
Weight at enrollment	3.4 ± 0.4	3.4 ± 0.4	3.6 ± 0.3	0.9077	0.0130	0.0135
HC at enrollment	34.6 ± 1.1	34.9 ± 0.8	35.1 ± 0.8	0.1347	0.0105	0.1708

Values are presented as the mean ± SD, unless otherwise specified. Significance was calculated for 2 groups using t-test for continuous parameters and chi square or Fisher's tests for categorical parameters. BF, breast-fed; HC, head circumference.

C18:2) in the stool of the three study groups. The results showed similar trends with those of saponified fatty acids. The concentration in the OPO group was significantly lower than that in the standard formula group and higher than that in the BF group at both week 6 and week 12 ($p < 0.0001$, Dunnett-t; **Figures 2C,D**). These results indicated that compared with the standard infant formula, the OPO formula decreased the total saponified fatty acids and total fatty acids in infant stool. Both the concentrations of fecal saponified fatty acids and total fatty acids in the OPO formula group were closer to the concentrations in the BF group than those in the standard formula group. The saponified fatty acids and total fatty acids calculated based on Z-scores showed similar conclusion as above results (**Supplementary Figure 1**).

Behavior

No significant difference in average sleeping duration was observed across the three study groups within 12 weeks after feeding ($p = 0.15$, Kruskal-Wallis test; **Figure 3A**). The frequencies of crying during the day and night in infants from the OPO group were significantly less than those in infants from the standard formula group ($p < 0.0001$, Dunnett's *t*-test; **Figures 3B,C**). No significant difference was found between the OPO feeding group and the BF group in the frequency of crying during the day and night (day, $p = 0.176$; night, $p = 0.459$; Dunnett's *t*-test; **Figures 3B,C**) within 12 weeks. The behavior parameters calculated based on Z-scores showed similar trends with above results (**Supplementary Figure 2**).

Growth

At baseline and at week 6, no difference was found in infant length across the three groups (**Figures 4A,B**). At the 12-week visit, infants from the OPO group were significantly longer than infants from the standard formula group and BF group [OPO group (median) = 63 cm vs. standard formula group (median) = 62 cm or BF group (median) = 61.6 cm, $p = 0.002$, Dunnett-t; **Figure 4C**], while no significant difference was found between the standard formula group and BF group.

In terms of body weight, infants from the BF group were heavier than those in the OPO and standard formula groups at baseline ($p = 0.852$, Dunnett's *t*-test; **Figure 4D**). No significant

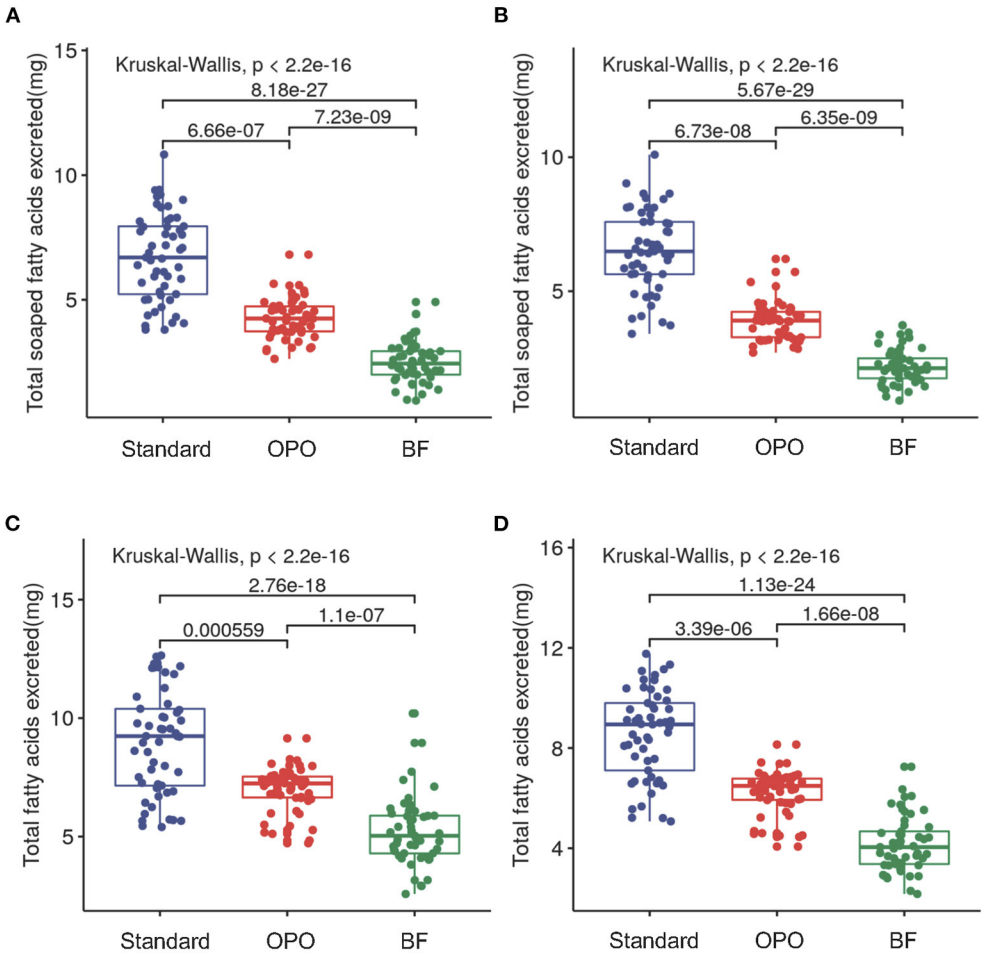

FIGURE 2 | Comparison of fecal saponified fatty acids and total fatty acids among the three study groups after feeding. **(A)** Concentrations of fecal saponified fatty acids at week 6. **(B)** Concentrations of fecal saponified fatty acids at week 12. **(C)** Concentrations of total fatty acids at week 6. **(D)** Concentrations of total fatty acids at week 12. Data are presented as the mean (range). A *p*-value of less than 0.05 was considered statistically significant.

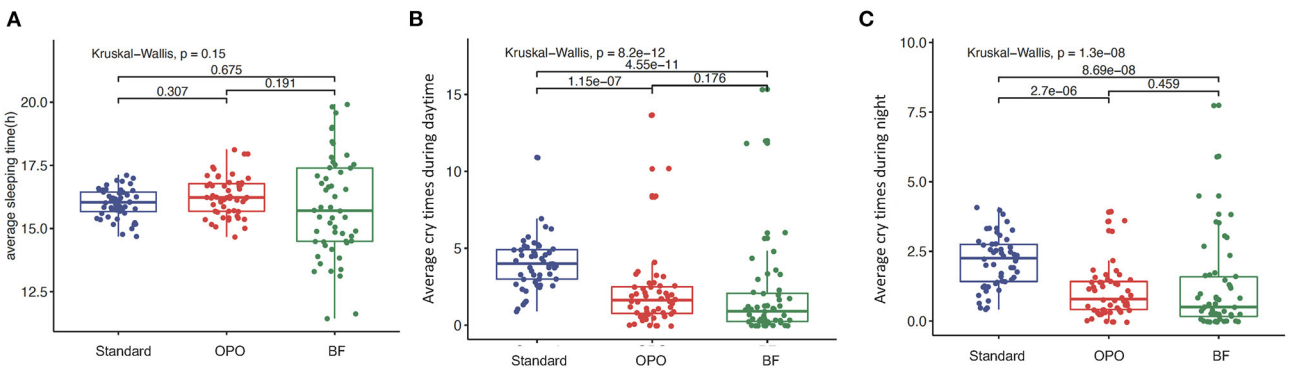

FIGURE 3 | Behavior status after feeding within 12 weeks among the three study groups. **(A)** Average sleeping duration. **(B)** frequencies of crying during the day. **(C)** frequencies of crying during the night. Data are presented as the mean (range). A *p*-value of less than 0.05 was considered statistically significant.

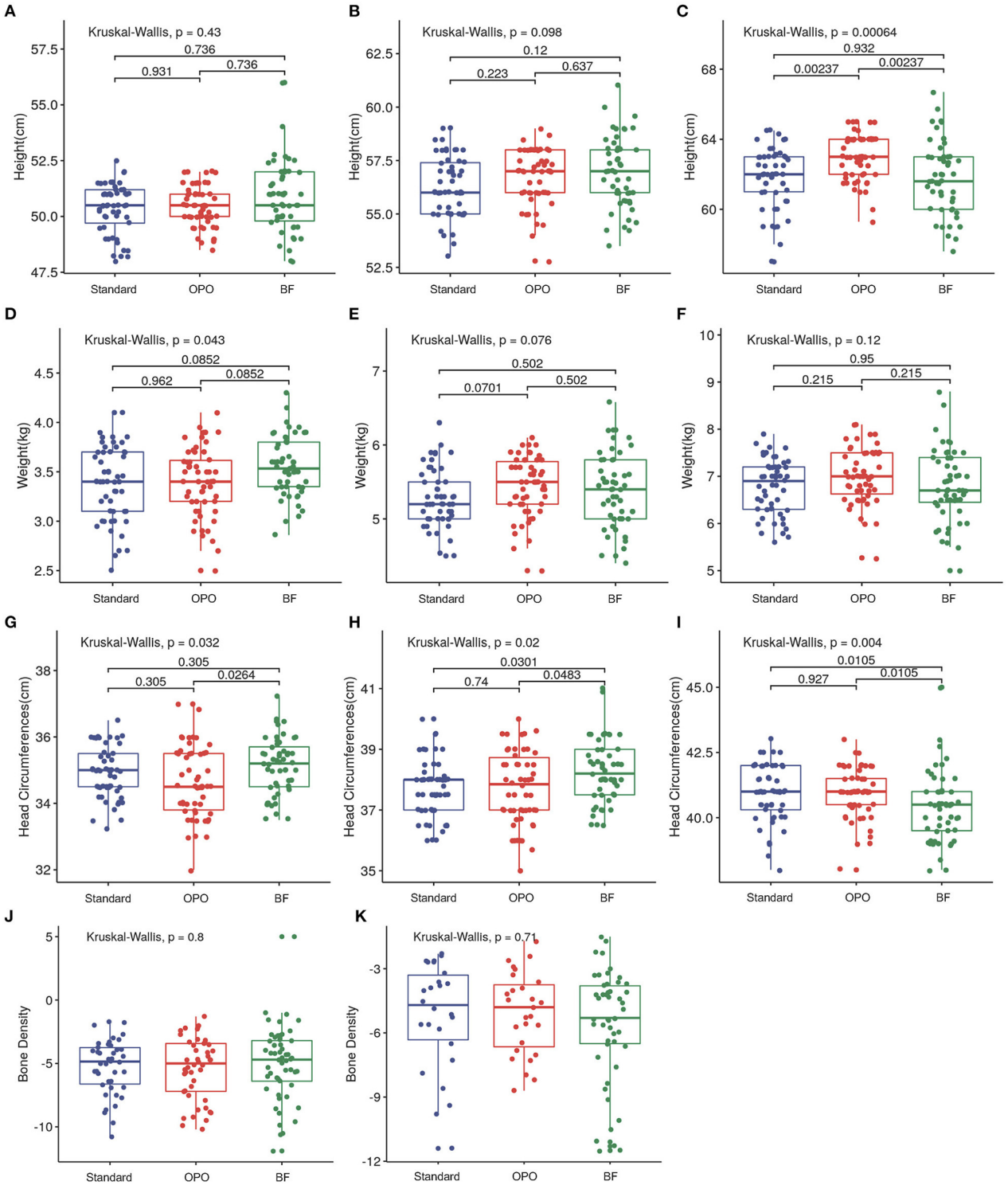

FIGURE 4 | Growth status after feeding among the three study groups. **(A–C)** Comparison of infant length of different groups at baseline, week 6, and week 12. **(D–F)** Comparison of infant body weight of different groups at baseline, week 6, and week 12. **(G–I)** Comparison of head circumference of different groups at baseline, week 6, and week 12. **(J,K)** Comparison of bone density of different groups at week 6 and week 12. Data are presented as the mean (range). A *p*-value of less than 0.05 was considered statistically significant.

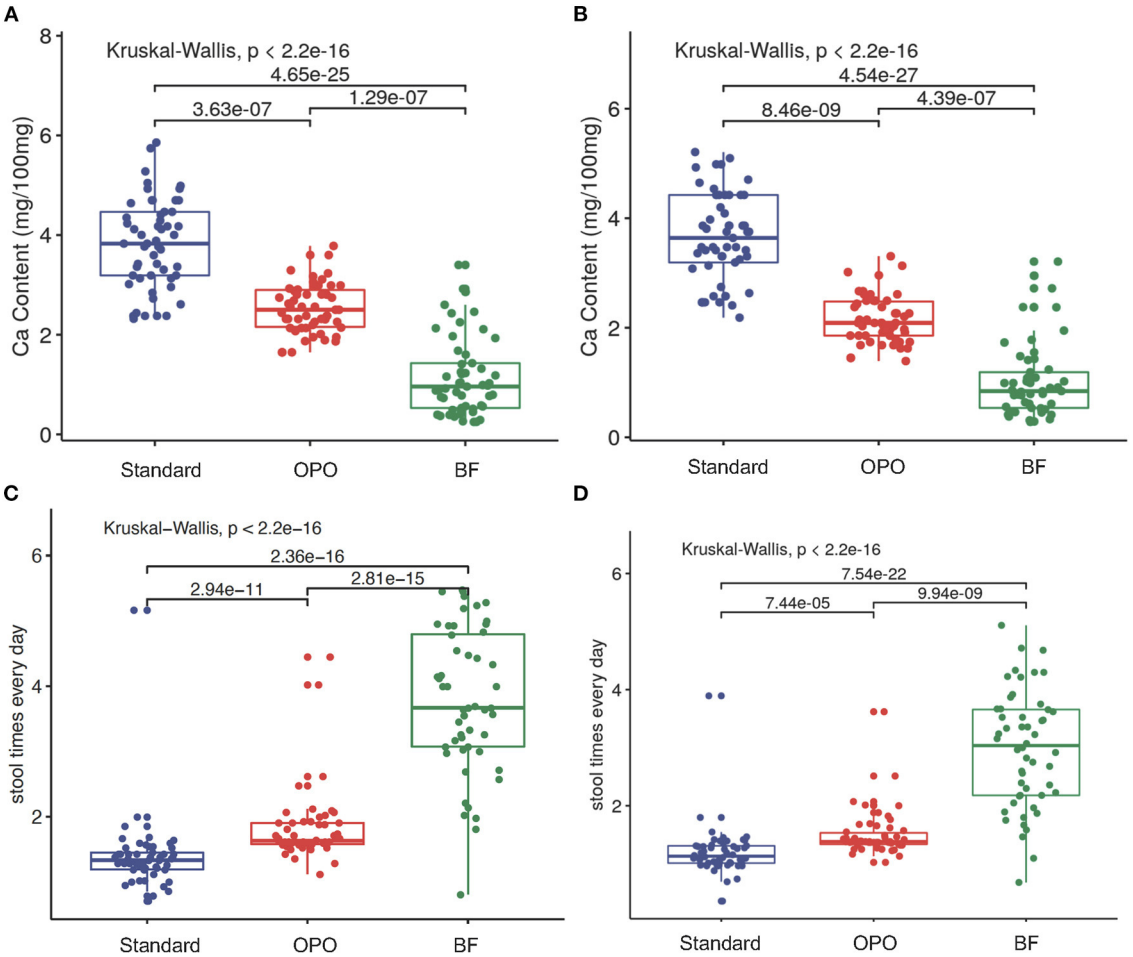

FIGURE 5 | Stool characteristics after feeding. **(A,B)** Comparison of stool calcium concentrations of the three feeding groups at week 6 and week 12. **(C,D)** Comparison of stool frequency per day of the three feeding groups within 6 weeks and within 12 weeks. Data are presented as the mean (range). A *p*-value of less than 0.05 was considered statistically significant.

difference was observed among the three groups at week 6 and week 12 (**Figures 4E,F**).

Infants from the BF group had a head circumference significantly higher than that of infants from the OPO group at baseline. At the 6-week visit, the head circumference of infants from the BF groups was higher than that of infants from the other two formula-feeding groups. However, at the 12-week visit, the head circumference of infants from the BF group was lower than that of infants from the other two formula-feeding groups. No significant difference in head circumference was found between the two formula-feeding groups at the baseline, 6-week or 12-week visits (**Figures 4G–I**).

We also compared the bone density of infants among the three groups, and no significant difference was found at the 6-week and 12-week visits (**Figures 4J,K**).

The growth parameters calculated based on Z-scores showed similar trends with above results (**Supplementary Figure 3**).

Stool Characteristics

We found that the stool calcium concentration in the OPO group was also significantly lower than that in the standard formula group and higher than that in the BF group at both week 6 [OPO group (median) = 2.5 vs. BF group (median) = 0.96 or standard formula group (median) = 3.83; $p < 0.001$, Dunnett-t; **Figure 5A**) and week 12 (OPO group (median) = 2.09 vs. BF group (median) = 0.84 or standard formula group (median) = 3.64; $p < 0.001$, Dunnett-t; **Figure 5B**]. The stool frequency per day in the OPO group was higher than that in the standard formula group and lower than that in the BF group at both week 6 [OPO group (median) = 1.14 vs. BF group (median) = 2.93 or standard formula group (median) = 1; $p < 0.0001$, Dunnett-t; **Figure 5C**] and week 12 [OPO group (median) = 1.38 vs. BF group (median) = 3.04 or standard formula group (median) = 1.13] (**Figure 5D**). The stool calcium concentration and stool frequency per day at week 6 and week 12 in the OPO group were closer to those in the BF group than to those in

the standard formula group. The stool characteristics calculated based on Z-scores showed similar trends with above results (**Supplementary Figure 4**).

DISCUSSION

In this study, we evaluated the stool saponified fatty acid level, infant behavior, infant growth and stool characteristics in healthy full-term infants fed different formulas. We compared two formulas and breast milk, which have different contents of OPO, the sn-2 palmitic acid structured lipid, as part of the formula fat blend. We found that our study formula was superior to the standard formula in terms of the above parameters.

A positive correlation between sn-2 palmitic acid content and fat absorption has been reported. Carnielli et al. (22) reported that triglycerides containing palmitic acid in the diet, which are mainly located in the sn-2 position, such as in human milk, have significant beneficial effects on intestinal fat absorption in healthy term infants. In our study, we found that the infants in the OPO group had lower fecal excretion of total fatty acids and saponified fatty acids, which was consistent with previous reports (9, 10, 29). The absolute content of fatty acids and saponified fatty acids per 100 mg fecal wet weight varies in different studies, because of the different sn-2 palmitic acid content of milk powder (9, 10, 20, 29).

Formula-fed infants generally have more difficulty defecating than breastfed infants (20). One of the reasons for the hard stools during formula feeding is the formation of saturated fatty acid soap containing calcium (30). Long-chain fatty acids are important nutritional elements in conventional formula, but their melting point is higher than intestinal temperature. However, the infant has poor digestive function and low level of lipase secretion. When infants intake too many long-chain fatty acids, long-chain fatty acids will form insoluble and indigestible fatty acids with calcium in the intestine, which is one of the major reasons causing hard stools and dissipation to infants (31). OPO is a kind of lipids which are easy to be metabolized in infants and produce unsaturated oleic acid and sn-2 palmitate (32, 33). It was reported that OPO metabolites can promote pancreatic secret and pancreatic lipase activity; (33) for example, the activity of carboxyl ester lipase could be stimulated by 11-folds (34). These lipases can cause esterification of long-chain fatty acids and the esterified long-chain fatty acids cannot be saponified, which reduces the content of long-chain fatty acids and saponified fatty acids in the infant intestine. In our study, we found that the levels of total fatty acids, saponified fatty acids, and calcium of stool in the OPO group was lower than that in the standard formula group, and the stool frequency per day of infants from the OPO group was significantly higher than that of infants from the standard formula group. It suggested that the potential mechanism of OPO to improve infant defecation may be that OPO metabolites promote the secretion of infant lipase.

In addition, because OPO eases the defecation of infants fed formula, it may also have an impact on their gastrointestinal comfort, which may lead to a change in infant behaviors, such as crying and sleeping (35). The crying behavior of newborns can be regulated by external and internal stimuli. Savino et al. demonstrated that OPO may affect the crying behavior of infants. In his study, he found that compared with that of the standard formula group, the crying behavior of the experimental group was significantly reduced (25). In the follow-up study, after 12 weeks of feeding with a high-OPO formula, the frequency of crying was significantly reduced, and the duration of crying (especially during the night) was also reduced (25). Our results echoed the above evidence, further supporting the advantage of our study formula with a high OPO content for improving the behavior of infants.

Litamanovitz et al. conducted a randomized double-blind study to evaluate the effect of OPO on infant bone development (21). The results showed that the bone development-related parameters of infants in the OPO group were significantly better than those in the standard formula group, but not significantly different from those of infants in the BF group. These results indicated that OPO may promote the development of infant bone, which may be caused by the improvement in the calcium absorption in infants fed with high OPO formula. In our study, we found a significant decrease in calcium content in the stools of infants fed the formula with high OPO content. However, no significant difference was found in bone density among the three groups, both at weeks 6 and 12. This inconsistent results from the two studies might be caused by the limited sample size of our study or the different methods used for measuring bone density in the two studies. Most of the available methods for measuring bone density have only been validated in adults, since the bones of infants are still in the development stage and with different conditions relative to adult bones. It is not clear what method and time period would be optimal to measure bone parameters in infants, so further investigation is warranted.

Instead of bone density, we found a significantly greater length of infants fed formula with a high content of OPO at the 12-week visit. This effect may be related to the effect of OPO in improving calcium absorption in infants because of its structure, which leads to better development of infant bones.

The strength of this study is that we used a randomized, double-blinded design with 3 study arms to compare the effect of the special sn-2 palmitate triglyceride structure in infant development with the corresponding effect of standard formula and human milk. We also set up two follow-up visits at 6 and 12 weeks to compare whether there were any time-dependent effects of OPO used in infant formula. However, there are certain limitations of this study. One limitation is that this was a single-center trial that only included infants in the Suzhou area. Human milk compositions might differ among areas because of differences in eating habits. As a result, whether there are any differences in the benefit to infant health between formulas high in OPO and human milk still needs to be clarified with further research conducted in different areas.

In this study, we found that a high concentration of OPO in infant formula can reduce the content of fatty acids in fetal feces, promote the absorption of fat and calcium ions, increase the number of bowel movements, reduce the frequency of crying, and improve infant growth in length. It is concluded that a high concentration of OPO in infant formula is beneficial to infant growth.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The study protocol was approved by the Ethics Committees of Suzhou Kowloon Hospital Shanghai Jiao Tong University School of Medicine (KY-2018-016). This study was registered in the Chinese Clinical Trial Registry (ChiCTR1800018813). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

XY was responsible for the conception and design of the study. LS and WH contributed to the data collection and the statistical analysis. LW, XX, QW, and SL were responsible for administrative support. All authors were responsible for data interpretation and manuscript writing, reviewing, and approving for submission.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.712201/full#supplementary-material

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

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Dietary Patterns, Adherence to the Food-Based Dietary Guidelines, and Ultra-Processed Consumption During the COVID-19 Lockdown in a Sample of Spanish Young Population

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Purpose: The aim of this study was to explore the dietary patterns, adherence to Food-Based Dietary Guidelines, and the ultra-processed consumption during the COVID-19 lockdown among a Spanish young population aged 3–17 years.

Methods: Parents/legal guardians of preschoolers, children, and adolescents aged 3–17 years were enrolled through social networks. The eating habits were assessed by a Food Propensity Questionnaire applied in the ENALIA (*Encuesta Nacional de Alimentación en la población Infantil y Adolescente*) Spanish survey, which aims to collect food intake information and other data about eating habits on children and adolescents (0–18 years old). Participants were dichotomized following the Food-Based Dietary Guidelines for the Spanish young population offered by the Spanish Society of Community Nutrition. The ultra-processed food score was determined following the principles established in the NOVA classification.

Results: Data from 604 children and adolescents were included. An association between age group and the recommendations of snacks ($p = 0.002$), fruits ($p = 0.010$), and diaries ($p < 0.001$) was found. Adolescents showed a lower mean compliance with these guidelines than children ($p = 0.004$) and preschoolers ($p < 0.001$). Similarly, children reported lower Food-Based Dietary Guidelines than preschoolers ($p = 0.015$). Regarding ultra-processed consumption, it was also observed a higher intake in adolescents than in children ($p = 0.037$), as well as in preschoolers ($p < 0.001$).

Conclusions: The associations that were found highlight the low proportion of the young population (especially adolescents) meeting the Food-Based Dietary Guidelines and the high consumption of ultra-processed foods during COVID-19 lockdown.

Keywords: healthy diet, nutrition, healthy lifestyle, youths, health behavior, social distance

INTRODUCTION

As a result of the current COVID-19 crisis, public health recommendations and Spanish governmental measures have implemented restrictions and lockdown, such as stay-at-home orders, mandatory mask requirements, limitation of the freedom of people movement, suspension of the on-site educational activities (replaced by online educational activities), and/or close of the public establishments (with the exception of those essential) (1). Although these strategies assist to decrease the rate of infection, such restrictions (e.g., increased social distancing) involve adverse consequences by restraining engagement in physical activity, normal day-to-day routines, and access and travel to several ways of exercise (2).

Dietary risk factors are ranked among the principal risk factors for disability and have been identified as responsible for a large proportion of chronic non-communicable diseases worldwide (3). Supporting this notion, holistic and integrated approaches across all sectors and policy areas are needed to deal with the worrying prevalence of non-communicable diseases with an emphasis on primary prevention (4). Similarly, providing assistance based on evidence for healthier lifestyles and dietary patterns could exert an essential role for public health (5). In this sense, food-based dietary guidelines are helpful tools for public health strategies and nutrition policies to encourage healthier eating habits (6, 7).

The World Health Organization has strongly recommended to follow a healthy diet (8) during the periods of lockdown. Thus, this diet should include fruits, legumes, whole grains, vegetables, and healthy fats. In this sense, one study performed by Ammar et al. (9) during the COVID-19 lockdown indicated that this situation alters eating behaviors (eating out of control, an overall greater number of main meals, higher intake of unhealthy food, and more snacking between meals) in a health-compromising direction. Also, other studies performed in Spain showed food consumption changes (i.e., nut, homemade dessert, confectionary, snack, and jelly bean intakes increased) (10), as well as a trend toward greater consumption of healthy foods, lower consumption of foods of less nutritional interest, and an increase in the practice of cooking at home during the lockdown (11).

On the other hand, the intake of ultra-processed foods has been linked with a higher dietary risks of associated non-communicable diseases (12), as well as a less desirable cardiometabolic risk status and a higher risk of both cardiovascular and cerebrovascular diseases, depression, and all-cause mortality (13). Correspondingly, most of the scientific literature on the relationship between intake of ultra-processed foods and adiposity presents a positive direction (i.e., a higher intake leads to increased adiposity) (14). In addition, a recent systematic review with meta-analysis has pointed out the connection between intake of ultra-processed food and metabolic syndrome in youths and dyslipidemia in children (15).

Consequently, it appears reasonable that governments should support policies that promote more efficiently consuming healthy food during periods of lockdown. Although COVID-19 vaccines are being administered in several countries, this fact does not imply that the emergency is almost finished, since we are just beginning a next stage of the pandemic (16). To the best of our knowledge, studies on the effect of the COVID-19 lockdown in food patterns among the young population are still scarce. In this sense, this is the first study which assessed dietary patterns and eating habits during the COVID-19 lockdown among preschoolers, children, and adolescents. Thus, the aim of this study was to explore the diet-related patterns, adherence to Food-Based Dietary Guidelines, and the ultra-processed consumption during the COVID-19 lockdown among the Spanish young population aged 3–17 years. We hypothesize that, during the COVID-19 lockdown, eating habits were inadequate, compliance with nutritional recommendations was low, and consumption of ultra-processed foods was high among the Spanish young population. It is also speculated that these inadequate eating habits were most prevalent in older participants.

MATERIALS AND METHODS

Population Sample and Study Design

Parents/legal guardians of preschoolers/children/adolescents aged 3–17 years were enrolled through social media (Facebook, Instagram, Twitter, and LinkedIn). An online survey was generated and sent by a snowball sampling technique. In this sense, apart from recruiting through social media, we invited researchers from various regions of Spain to disseminate our survey, with the aim of trying to reach a more varied and larger number of participants. To fulfill the online survey, around 15 min were needed. Prior to filling in the online survey, data about the aim of the research were explained and an informed consent was required. Data were collected for 15 days (from March 29 to April 13, 2020). In this period, the entire Spanish population should remain at home (except essential workers) and was only allowed to go out for basic food shopping, healthcare, and some justified exceptions (1). Of the first 720 respondents, 77 participants were excluded since they were under 3 years or over 17 years of age. Furthermore, 41 participants were excluded due to missing information. Finally, data from 604 respondents were incorporated in the final analysis.

In terms of inclusion criteria, only parents/legal guardians of the Spanish young population aged 3–17 years who signed the informed consent were included. Conversely, regarding the exclusion criteria, participants were not enrolled when they did not completely fill out the online survey.

This study was conducted following the Helsinki Declaration for Human Studies and approved by the Ethical Committee of the Universidad Católica de Murcia (UCAM) (code: CE112001). All participants and their parents/legal guardians were informed of the aim of the research, and then a written informed consent was required.

Procedures

General Information

Parents/legal guardians were requested to fulfill the online survey. The initial section informed participants about the study design and aims of the study. Parents'/legal guardians' information about sex and age (calculated from date of

birth) of their children, educational level, and socioeconomic status [through the Family Affluence Scale—FAS-III (17)] was required. Information on geographic location was also requested. Similarly, anthropometric information was reported by parents/legal guardians about the minors. Weight was self-declared in kilograms and height in meters. Both the z-score for body mass index and the categorization of excess weight (overweight/obesity) were computed adhering to the World Health Organization standards (18, 19).

Food-Based Dietary Guidelines

The eating habits were assessed by a Food Propensity Questionnaire (FPQ) (20) applied in the ENALIA (*Encuesta Nacional de Alimentación en la población Infantil y Adolescente*) Spanish survey, which aims to collect food intake information and other data about dietary patterns on children and adolescents (0–18 years old). A detailed explanation of this survey was published elsewhere (21). Participants were dichotomized following the Food-Based Dietary Guidelines for the Spanish young population offered by the Spanish Society of Community Nutrition (SENC) (22). A detailed explanation about the establishment of the adherence to the Food-Based Dietary Guidelines is shown in **Supplementary Table 1**.

Ultra-Processed Food Score

The ultra-processed food score was determined, following the principles established in NOVA classification (12). The NOVA system classifies all beverages and foods into four groups based on their own nature, purpose, and extent of factory food manufacturing: 1—minimally processed foods or unprocessed; 2—processed cooking ingredients; 3—processed foods; and 4—ultra-processed foods. Group of foods were considered ultra-processed when they contain any formulation made mainly or completely from products derived from additives and foods (i.e., savory or sweet packaged snacks, soft drinks). Thus, 20 groups of foods were considered as ultra-processed food. Due to the lack of a specific score to determine the consumption of these foods, responses were scored as follows: 0—never, 1—one to three times a month; 2—once a week; 3—two or three times a week; 4—four to six times a week; 5—once a day; 6—more than once a day. The final score varied from 0 to 120 points.

Covariates

Sex (females or males), socioeconomic status (SES) (high, medium or low) (17), educational level (complete higher education, incomplete higher education, complete secondary education, incomplete secondary education, complete primary education, or incomplete primary education), region (Southern or Northern Spain), BMI (z-score) (18, 19), and physical activity were incorporated as potential covariates. The level of physical activity was according to the next question: "Normally, how many days was your child physically active for a total of at least 60 min?". The possible options varied from 0 to 7 days weekly. This measure has revealed to have good validity and reliability (23).

Statistical Analysis

Data were shown as means and standard deviation for continuous variables and frequencies and percentages for categorical variables. Data normality was checked by Kolmogorov-Smirnov tests with Lilliefors correction, and the homogeneity of variances by the Levene test. Kruskal-Wallis H test or one-way ANOVA for three-group comparisons (preschoolers, children, and adolescents), according to the normality assumption. Conversely, Pearson's chi square test was applied to determine associations between qualitative variables. Binary logistic regression analyses were performed to determine the association between meeting the different Food-Based Dietary Guidelines across age groups [preschoolers (aged 3–5), children (aged 6–12), adolescents (13–17)]. Furthermore, analysis of covariance (ANCOVA) was performed to verify the association between means of adherence to the Food-Based Dietary Guidelines across age groups. Preliminary analysis showed no interaction between sexes and both the meeting of the Food-Based Dietary Guidelines ($p = 0.162$) and the ultra-processed food score ($p = 0.331$). For this reason, the analysis was carried out with both sexes together to increase the statistical power. All analyses were conducted with SPSS statistical software version 24 for Windows. The statistical significance level was established at $p < 0.05$.

RESULTS

Table 1 indicates the descriptive information of participants. The average age was 12.1 (4.6). The sex distribution was similar (50.2% girls). The prevalence of participants with high SES was 22.4%. Moreover, 31.0% of the participants' breadwinner completed higher education. Twenty percent of the sample showed excess weight. Participants from Southern Spain (74.0%) were higher than those from Northern Spain (26.0%). Moreover, the average number of days being physically active was 4.1 (2.3).

Supplementary Table 2 depicts the food frequency during the COVID-19 lockdown among the Spanish young population. A percentage of 58.6% of participants ate vegetables/salads at least one time per day. The proportion of the young population who ate fruits at least one time per day was 10.5%. Regarding legumes, 65.6% of the participants never ate this type of food. Also, 19.5% indicated they never ate nuts and dried fruit. **Figure 1** indicates the prevalence of adherence to the Food-Based Dietary Guidelines in the different age groups analyzed. An association between age group and the recommendations of snacks ($p = 0.002$), fruits ($p = 0.010$), and diaries ($p < 0.001$), was found.

Figure 2 shows the association between meeting individual Food-Based Dietary Guidelines in relation to age group, after adjusting for several covariates. A lower association with meeting the sweets recommendation was found in children (OR = 0.30; CI95%, 0.14–0.62), as well as in adolescents (OR = 0.18; CI95%, 0.05–0.63).

The mean differences of the number of Food-Based Dietary Guidelines met and ultra-processed consumption score

TABLE 1 | Descriptive information of the Spanish analyzed sample ($n = 604$).

Variables	Preschoolers ($n = 75$; 12.4%) M (SD) / *n* (%)	Children($n = 208$; 34.4%) M (SD) / *n* (%)	Adolescents ($n = 321$; 53.1%) M (SD) / *n* (%)	*p*-value for trend
Age (years)	4.2 (0.8)	9.1 (2.0)	15.7 (1.8)	<0.001
Sex				
Males	44 (58.7)	116 (55.8)	141 (43.9)	0.008
Females	31 (41.3)	92 (44.2)	180 (56.1)	
Anthropometric data				
Weight (kg)	18.00 (5.54)	32.68 (11.19)	59.11 (13.17)	<0.001
Height (cm)	105.2 (11.8)	134.8 (15.0)	166.4 (9.5)	<0.001
BMI (z-score)	0.55 (2.02)	0.74 (2.08)	1.11 (1.82)	<0.001
SES				
High SES, (%)	17 (22.7)	60 (28.8)	58 (18.1)	0.008
Breadwinner's educational level				
Complete higher education, (%)	38 (50.7)	96 (46.2)	53 (16.5)	<0.001
Geographical location				
Southern Spain, (%)	48 (64.0)	159 (76.4)	239 (74.5)	0.163
Physical activity				
Physically active ≥ 60 min (days)	5.1 (2.0)	4.4 (2.3)	3.5 (2.3)	<0.001

BMI, body mass index; SES, socioeconomic status.

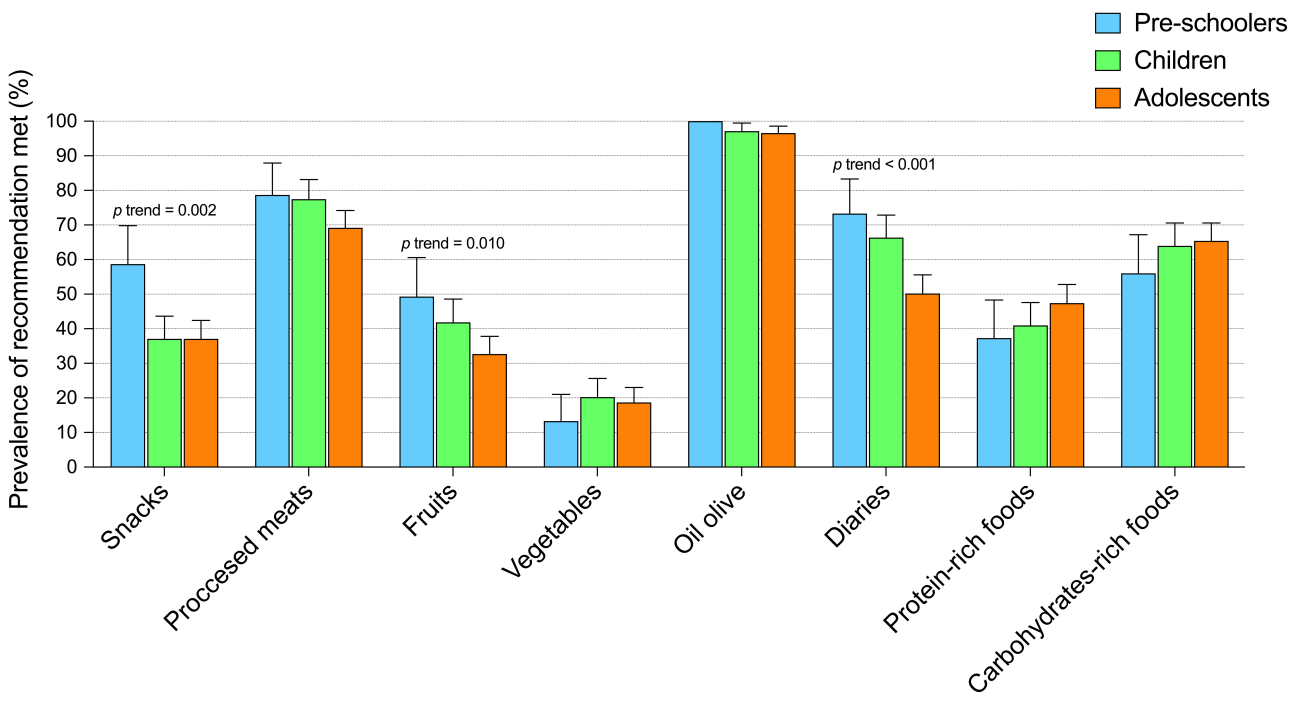

FIGURE 1 | Prevalence of meeting of the Food-Based Dietary Guidelines stratified by age group.

according to age group are shown in the **Figure 3**. In relation to the Food-Based Dietary Guidelines (**Figure 3A**), adolescents showed a lower average of the meeting of these guidelines than both children ($p = 0.004$) and preschoolers ($p < 0.001$). Similarly, children reported a lower Food-Based Dietary Guidelines than preschoolers ($p = 0.015$). Regarding ultra-processed consumption (**Figure 3B**), we also observed a higher intake in adolescents than in children ($p = 0.037$), as well as in preschoolers ($p < 0.001$).

DISCUSSION

As far as we are concerned, this is the first study to report evidence of the adherence to Food-Based Dietary

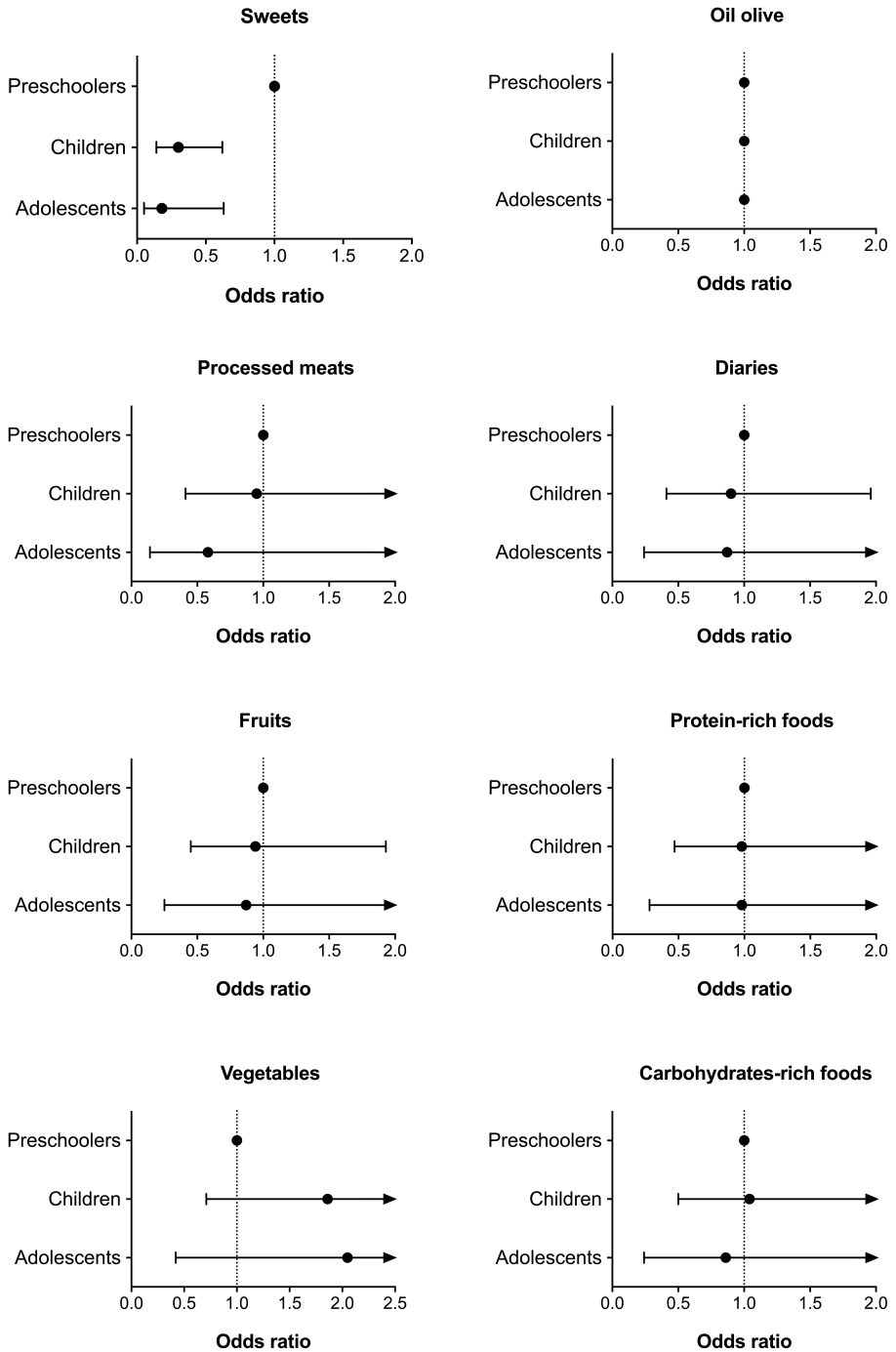

FIGURE 2 | Association of meeting the different Food-Based Dietary Guidelines according to age group. Data expressed as odds ratio (confident intervals 95%). Adjusted by sex, socioeconomic status, educational level, geographical location, body mass index (z-score), and physical activity level.

Guidelines and ultra-processed consumption during the COVID-19 lockdown among the Spanish young population. The current findings suggest low adherence to the Food-Based Dietary Guidelines among preschoolers, children, and adolescents during the COVID-19 lockdown, which is lower as age increases. Similarly, it has been pointed out a high ultra-processed consumption, mainly in adolescents.

In reference to dietary habits, the urgent need to improve them worldwide has recently been highlighted (4), since an inadequate diet constitutes a risk factor that causes more deaths than other factors, such as smoking (3). Food-Based Dietary

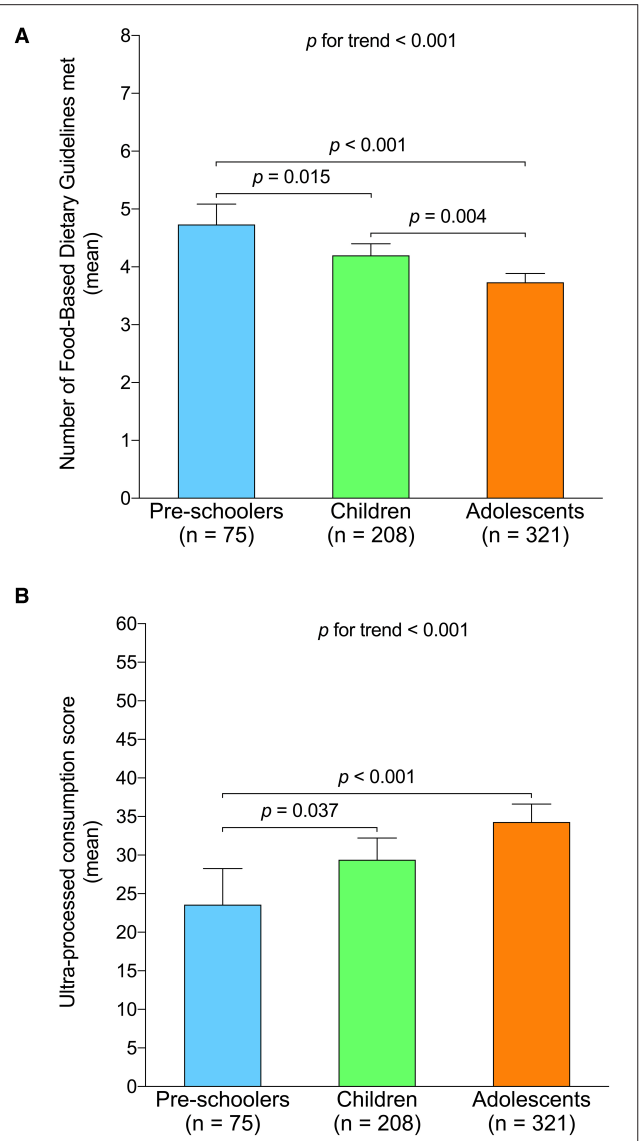

FIGURE 3 | Mean differences of the number of Food-Based Dietary Guidelines met and ultra-processed consumption score according to age group. **(A)** Number of Food-Based Dietary Guidelines met. **(B)** Ultra-processed consumption score. Adjusted by sex, socioeconomic status, educational level, geographical location, body mass index (z-score), and physical activity level.

Guidelines are helpful resources to clearly communicate an easy-to-understand information to a larger number of people, with the objective to aid the adherence of healthier eating habits (6, 7) based on the best available scientific evidence. However, as our findings suggested, most of the participants did not meet the national Food-Based Dietary Guidelines. Furthermore, a negative trend has been observed in older age groups, emphasizing the importance of encouraging the adherence to a healthy dietary pattern (and active lifestyle) during the early stages of life (24). In adults, the scientific evidence is not clear, with some studies showing an increase during the COVID-19 lockdown in healthy foods (11) and others in unhealthier foods (10). In young populations, the findings of the longitudinal study performed by Pietrobelli et al. (25) showed undesirable changes in lifestyle (e.g., eating healthy) in obese participants during the lockdown period. Likewise, one study that reported information after the COVID-19 lockdown in Spain showed a lower adherence to the Mediterranean diet [recognized as healthy dietary pattern (26)] among participants aged 11–16 (27). Conversely, one study among Spanish adolescents showed an increased consumption of fruit, as well as a decreased consumption of soft drinks, sweets and pastries, and convenience foods (28). However, these same authors found no statistically significant differences between groups. We hypothesize that the number of health-related behaviors of young populations (i.e., consumption of vegetables or fruits) as well as of their parents/legal guardians might have changed progressively during the COVID-19 lockdown, as one study in youths (29) has shown. In addition, another possible explanation is that the younger they are, the more responsibility parents/guardians have in making decisions about feeding. Nonetheless, caution is necessary to interpret these results, since we are not able to conclude that the findings obtained are exclusively favored by the COVID-19 lockdown.

Focusing on adherence to the Food-Based Dietary Guidelines at the individual level, the low consumption of fruits and, specially, vegetables among the young population was noteworthy. These foods are rich in micronutrients that are essential for the proper functioning of the immune system and have a vital influence on the promotion of health and nutritional well-being; they are even more necessary especially during the COVID-19 pandemic, as recommended by the WHO (8). One possible explanation could be related to work–life balance problems, as many parents/legal guardians had to telework while caring for their children during the closure of COVID-19. Thus, this scenario could lead to the adoption of less healthy eating habits, especially among those who are more dependent (e.g., young population) (29). Another possible justification could be the limited access to daily food shopping as a result of the COVID-19 lockdown, which may decrease the choice of fresh foods (e.g., fruits, vegetables), in favor of processed/ultra-processed foods, such as junk food or snacks, which tend to be higher in sugars, fats, or salt (30).

Regarding ultra-processed food, the results of a previous research with children and adolescents match with those achieved in the present study, highlighting the great influence of ultra-processed foods in the diet of adolescents. Ruíz-Roso et al. (31) showed that the habitual ultra-processed consumption was greater during the COVID-19 lockdown in their study performed in five different countries (Colombia, Chile, Brazil, Italy, and Spain). Notwithstanding, the differences on methodology to assess the consumption could influence the results obtained. There are some possible reasons for the high intake of ultra-processed foods during the COVID-19 lockdown. Firstly, the greater practicality characteristic of ultra-processed foods (i.e., durable, accessible, hyper-palatable) favors the intake of this unhealthier type of food (12), especially during periods of social isolation. Another possible reason is emotional eating, understood as the trend to overeat as a coping factor for controlling and decreasing undesirable feelings (e.g., stress,

anxiety, depression) (32). In this sense, one study performed in Saudi Arabia (33) pointed out the usual influence of emotional eating in young females during the pandemic COVID-19, highlighting the importance of choosing healthy food during this health emergency situation.

Among the limitations of the present study, we declare the difficulty to compare our results with other studies because of the high variability of methods applied to research frequency food intake, as well as the lack of a specific score to determine the intake of ultra-processed food. Also, some types of food were not distinguished according to energy composition (e.g., cheese, chocolate), which made it difficult to categorize them into one group or another to establish compliance with the recommendations. There is no specific recommendation for the consumption of carbohydrate-rich foods according to the level of physical activity. However, the SENC advises that foods from this group should be consumed at each main meal. In this sense, a recent systematic review performed by Rabassa et al. (34) highlights the need to systematize, revise, and improve the development processes of Spanish Food-Based Dietary Guidelines. Accordingly, we tried to approximate the intake of carbohydrate-rich foods to this premise. Furthermore, the reliability on parent-reported data was also a limitation of this study. In addition, due to the cross-sectional nature of our study, it is not possible to determine causal inferences. Thus, future studies (mainly longitudinal and intervention designs) are required to report adherence to the Food-Based Dietary Guidelines and ultra-processed consumption to safeguard an adequate status during possible future scenarios of social isolation. Moreover, efforts should be directed toward parents influencing youths' eating behaviors by modeling their own eating behaviors, feeding practices they implement with their children, and their beliefs and attitudes about food (35). Also, responsible feeding and nutrition practices that support the child's autonomy to eat, as a response to their physiological requirements, which can promote self-regulation of feeding and assistance for young children's social, cognitive, and emotional development, should be encouraged (36). This fact is crucial at younger ages, since children acquire dietary habits from their personal experiences, but external experiences have a significant influence on preferences for what they prefer to eat (37, 38). In addition, we did not collect information on habitual dietary patterns before the COVID-19 lockdown. Therefore, we cannot infer whether the observations obtained changed during this scenario. Lastly, we used a snowball sampling to recruit participants. This approach, although prone to selection bias, is applicable in populations that are difficult to access because of their closed nature (39). Thus, due to the COVID-19 restrictions, this choice is justified.

The associations found highlight the low proportion of the young population meeting the Food-Based Dietary Guidelines and the high ultra-processed consumption during the COVID-19 lockdown. Similarly, there are important differences in meeting of Food-Based Dietary Guidelines and ultra-processed consumption among different age groups. The current results highlight the relevance of establishing public health policies and strategies for the young population, focusing on actions to encourage the adoption of healthy eating habits, particularly during and after phases of social isolation, with special emphasis in adolescents.

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 this study was approved by the Ethical Committee of the Universidad Católica de Murcia (UCAM) (code: CE112001). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JFL-G designed the study. JFL-G contributed to the interpretation of the data and to the analysis and writing of the draft. AG-H, JB-S, and PJT-L contributed to the revision of the manuscript. All authors approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.702731/full#supplementary-material

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Prevalence of the Acute Respiratory Infections and Associated Factors in the Rural Areas and Urban Slum Areas of Western Maharashtra, India: A Community-Based Cross-Sectional Study

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Acute respiratory infections (ARIs) continue to be the most important cause of morbidity and mortality among under-five children. Some demographic and environmental factors are associated with ARIs among under-five children. This study was conducted with the objective to estimate the prevalence of ARIs among under-five children in the rural areas and densely populated urban slum areas in Maharashtra, India and to assess the association of the selected sociodemographic and household environmental factors with ARI. This study was conducted in 16 selected clusters from the rural areas and densely populated urban slum areas of the two districts in Maharashtra, India. Structured and validated proforma was used for collecting the data on the sociodemographic and household environmental risk factors. A total of 3,671 under-five children were surveyed. The prevalence of ARIs for the preceding month was 50.4%. It was higher among the children living in the rural areas (54.2%) compared to the children living in the urban areas (46.7%) ($p = 0.01$). The prevalence of ARIs was reported to be 51.4 and 49.4% in boys and girls, respectively. In the multivariate analysis, the researchers found that living in rural areas ($p = 0.01$) and parental smoking ($p = 0.04$) were significantly associated with the ARIs. An intervention such as reducing parental smoking habits at the household level may reduce ARIs.

Keywords: acute respiratory infections, under-five children, rural area, urban slums, parental smoking

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INTRODUCTION

Acute respiratory infection (ARI) is a disease of public health significance. It is caused by a heterogeneous group of organisms that affects the human airways (1). It affects all ages, but the effects are particularly life-threatening among under-five children (2).

Globally, ARIs (predominantly pneumonia) have a 20% of mortality among children <5 years old. If neonatal pneumonia is also considered, the mortality increases to 35–40% among under-five children, accounting for 2.04 million deaths/year. Southeast Asia has the highest incidence of ARI followed by the sub-Saharan African countries; together, they contribute to more than 80% of the total global cases (3). Multiple social and environmental factors affect the morbidity and mortality of ARI in childhood. Factors include poverty, poor nutrition, poor housing conditions, indoor air pollution (including parental smoking), poor ventilation, overcrowding, industrialization, sociocultural values, overuse and misuse of antibiotics, lack of basic health services, and lack of awareness (4). It is also important to note that a quarter of ARI deaths in children are attributable to passive smoking (5). The National Family Health Survey 5, conducted in 2019–2020, reported a 2.4% prevalence of ARI in the preceding 2 weeks in the urban areas and a 3.8% in the rural areas in Maharashtra state (6). In the Indian slum areas, ARI constitutes more than two-thirds of all childhood illnesses (7). Globally, in 2010, nearly 265,000 in-hospital deaths of young children were attributed to ARI, 99% of which were reported in developing countries (8). In the urban slum areas, ARI constitutes over two-thirds of all childhood illnesses (9). In India, 14.3% of the deaths among infants and 15.9% of the deaths among children between 1 and 5 years of age are due to ARIs and most of these deaths are preventable. Because of the high morbidity and mortality rates associated with ARIs, its control continues as a major challenge to the healthcare system (10).

Hence, a comprehensive understanding of the prevalence and associated factors of ARI in rural areas and urban slum areas is essential. The majority of the previous studies on ARI had been conducted either in rural areas or in urban areas. By inclusion of both the urban and rural areas, this study attempts to meet the gap. Therefore, the main objective of this study was to estimate the prevalence of ARIs among under-five children in the rural areas and densely populated urban slum areas in Maharashtra, India and to assess the association of the selected sociodemographic and household environmental factors with ARI.

MATERIALS AND METHODS

This was a community-based cross-sectional study conducted among the children aged <5 years in 16 clusters of the two districts of western Maharashtra, India. Here, cluster means a revenue village or densely populated urban area, and it is also known as an urban slum. In this study, eight trained field supervisors collected the data with the cooperation of the accredited social health activist (ASHA) and the Anganwadi workers (AWWs). A faculty from either the community medicine or pediatrics monitored the quality of the collected data.

This was a part of the baseline survey of a cluster randomized controlled trial. The trial was registered with the Clinical Trial Registry of India. The duration of the main study was from December 15, 2015, to March 14, 2018. Data collection of this study was done between February 15, 2016, and May 14, 2016.

Selection of Clusters

In both the districts, urban field practice areas were grouped into two, i.e., the East or West regions, and rural areas were grouped into the areas of two primary healthcare (PHC). From each region, two clusters each were randomly selected by using the random numbers generated by Microsoft Excel. Thus, a total of 16 clusters were selected. **Figure 1** shows a flowchart of the selection of the clusters from the study area.

Study Population and Sample Size

The estimated (based on the population and age group distribution 2011 census) average number of under-five children per cluster was 250. Considering the ARI prevalence of 27% (11) with a 95% CI and allowable difference of 10%, the sample size calculated by using the $Z^2\alpha\ p\ (1\text{-}p)/d^2$ formula was 1,691. With a design effect of two, the sample size was estimated to be 3,382.

Research Tool

The interview schedule was prepared in English. It was validated by the experts and then translated into the local language (Marathi) and retranslated to English. A unique identification code was given to each house, the mother of a child below 5 years and the child.

Data Collection

Investigators had appointed the eight field supervisors (FSs) for carrying out the survey. Their work was monitored by the eight site investigators (SIs). We obtained written informed consent from the mother of under-five children. Field supervisors collected the data through house-to-house visits with the support of the ASHA and the AWWs. FSs were cross-checked the data collected by the SIs to ensure completeness and accuracy before the data entry.

All the households with at least one under-five children in the selected clusters were visited. All the eligible children from the particular household were enrolled. Information about the locked houses was solicited from the neighbors. These houses were visited again in the evening, in the early morning, or on the weekends. Locked houses during the second visit and the families who had permanently migrated from the area were excluded from this study. Information about the sociodemographic and household environmental factors such as overcrowding, the type of fuel used for cooking, parental smoking habits, and ventilation in the house was documented. Information about the total floor area of the house in square feet excluding the bathroom and water closet area and the number of doors and windows was obtained for the assessment of ventilation of the household. The supervisors asked the mothers regarding information related to ARIs in the preceding 1 month and recorded the responses from the mothers.

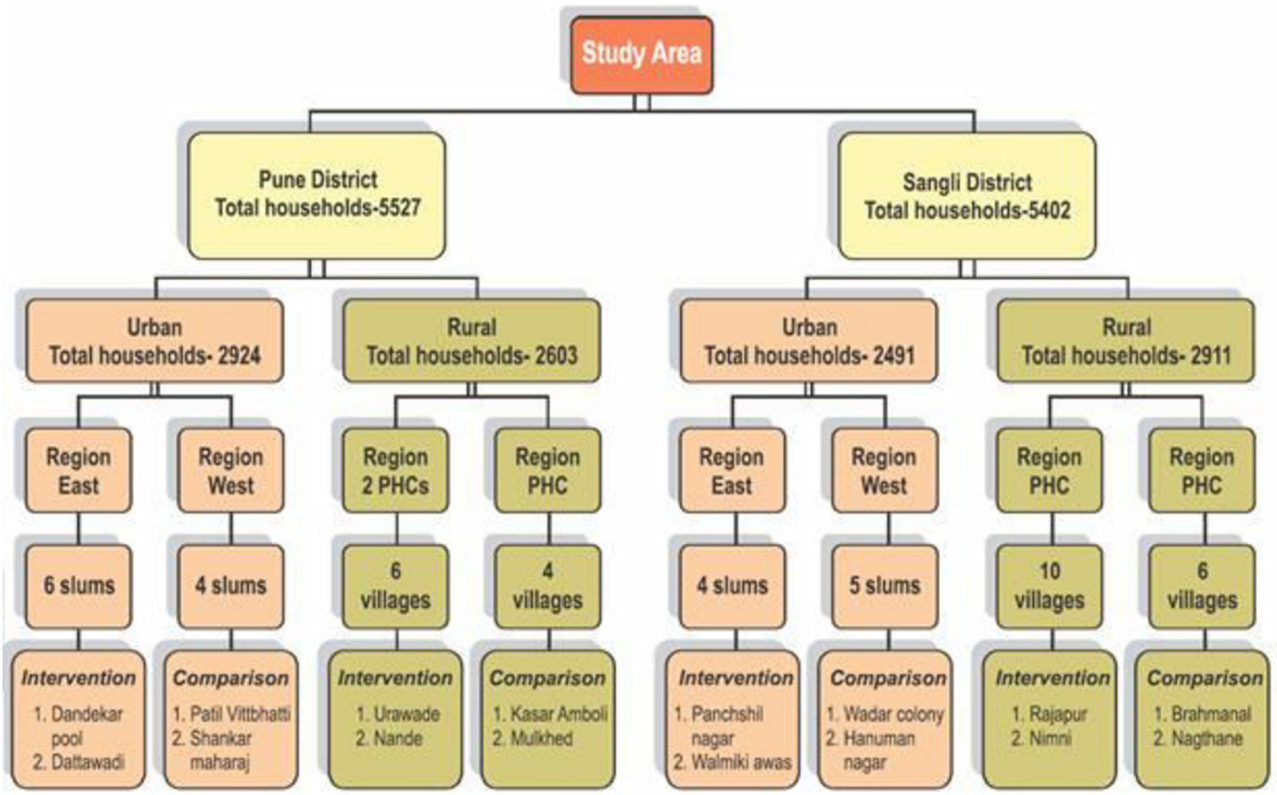

FIGURE 1 | Study area and selection of clusters.

Definition of Study Variables and Other Definitions Used in This Study

1. **Urban slum:** A compact area of at least 300 population or about 60–70 households with poorly built and congested tenements in the unhygienic environment usually with inadequate infrastructure and lacking the proper sanitary and drinking water facilities (12).
2. **Types of the family:** The family type was divided into only two groups; the nuclear family consists of the husband, wife, and unmarried children staying together and the joint family included all the other families including the three-generation family and extended family.
3. **The economic status of the family:** In the state of Maharashtra, under the Public Distribution System (PDS), cards of the three different colors are provided to the families according to their annual income as follows: families who earn up to Rs. 15,000 (US $205.97) receive a yellow ration card, families who earn between Rs. 15,000 to 1 lakh (the US $205.97–1373.15) receive an orange ration card, and families who earn more than Rs. 1 lakh (the US $1373.15) receive a white ration card (13). The color of the ration card was considered a proxy for income.
4. **Level of education of the mothers:** The level of education was classified according to the number of years of schooling. A person was considered illiterate if he/she was unable to read or write (14). According to the years of schooling, educational status was classified as education up to 6th standard, 7th−10th standard, 12th standard/Diploma, Graduate, and above.
5. **Exclusive breastfeeding:** Child fed only breast milk, except taking the vitamins, mineral supplements, or medicines, until 6 months of age, was considered as exclusive breastfeeding (15).
6. **Ventilation:** Inadequate ventilation was defined as <50 square feet of floor space area per person and the absence of the doors and windows facing each other (16).
7. **Overcrowding:** Accepted standards of the number of per person per room were used. If the number of persons per room is more than these criteria, overcrowding was considered to be existing (16).
8. **Types of fuel:** The fuel used in a household was classified as either clean or unclean by considering the most common fuel used for cooking. Clean fuels included liquefied petroleum gas (LPG) or electricity and unclean fuels included biomass, coal, and kerosene (14).
9. **Acute respiratory infection:** ARI was defined as an episode of coughing accompanied by nasal discharge and/or shallow, rapid breathing, and/or difficulty in breathing (17) in the month preceding the survey as reported by the mother of the child.

10. **Accredited social health activist:** The ASHA works at the village level under the National Health Mission program of India. She creates awareness of the health in the community (16).
11. **Anganwadi worker:** Under the Integrated Child Development Services (ICDS) scheme, the AWWs (part-time workers) are appointed to render the health services in the community (16).

Data Management

All the filled forms were entered into a software database. Critical fields in the tool were identified to check the completeness and accuracy of the form. All the critical fields and few non-critical fields were monitored. Discrepancies up to 0.1% for the critical data and up to 1% for the non-critical data were considered acceptable. For the discrepancies related to data entry, the alternate forms were physically cross-checked. Statisticians cleaned and analyzed the data by excluding the missing data.

Data Analysis

Data were analyzed by using the Statistical Package for the Social Sciences (SPSS) (IBM SPSS Chicago USA version 25). Descriptive statistics (mean and SD) were calculated for the continuous variables and the frequencies and percentages were calculated to summarize the qualitative variables. The multivariate logistic regression analysis was carried out to identify the determinants of ARI. $p < 0.05$ was considered as statistically significant.

RESULTS

A total of 3,671 under-five children were included in this study. There were 1,834 under-five children in the urban slum areas and 1,837 under-five children in the rural areas. There were 1,732 girls and 1,939 boys in the study areas. The mean age of the children was 2.38 years (±SD 1.36) and the mean age of the mothers was 24.25 years (±SD 6.37).

Housing Environment

Overcrowding has existed in 43% of the households. A majority, i.e., 94.4% of the households were inadequately ventilated. A higher proportion of households in urban clusters was inadequately ventilated compared to the rural clusters ($p < 0.05$). The prevalence of indoor smoking was 3.2 and 2.1% in the urban and rural clusters, respectively ($p < 0.05$). Out of the total households, 15.1% used unclean fuel. The use of unclean fuel is higher in the rural clusters (24.0%) compared to the urban clusters (6.0%).

The children with ARIs stratified by the sociodemographic factors are described in **Table 1**. The overall prevalence of ARIs in the study was 50.4%. It was higher among the children living in the rural areas (54.2%) compared to the children living in the urban areas (46.7%) ($p = 0.01$). Most of the mothers were literate and their educational status was not associated with the prevalence of ARI.

Most of the houses in the study area were overcrowded and the majority of the households used clean fuels for cooking. Most of the children who had ARIs were exposed to parental smoke (**Table 2**).

In the multivariate logistic regression analysis, researchers found that residence in the rural areas ($p = 0.01$) and parental smoking ($p = 0.04$) were significantly associated with the higher prevalence of ARIs. Strangely inadequate ventilation did not have a negative association ($p = 0.01$).

DISCUSSION

It is reported that Bangladesh, India, Indonesia, and Nepal together account for 40% of the global mortality of ARI (18). ARI is the third most common individual cause of death in both developed and developing countries (1). The prevalence of ARI reported by the various studies ranges from 20 to 30% (7, 19, 20). This study found the prevalence of ARI to be 50.4% among under-five children which is similar to the other studies (6, 11). A study was done in Karnataka (a state in India) noted an ARI prevalence of <10% in under-five children (18). Based on the differences in the socioeconomic, cultural, and environmental factors present in the different geographical regions, the prevalence of ARI varies. Some studies have reported a higher prevalence of ARIs in the rural areas compared to the urban areas as observed in this study (4, 11). In this study, inadequate ventilation did not lead to higher ARI. There may be several reasons, such as pets in the family and history of ARI in the family members, which the authors did not substantiate. A few studies reported that the children living in homes with poor ventilation in the rural areas developed more ARIs compared to the children living in the homes with poor ventilation in the urban areas (1, 4, 7, 19). Under-five children living in houses with inadequate ventilation contract more ARIs compared to under-five children living in well-ventilated houses because a lack of ventilation implies that indoor smoke is trapped and the toxic components accumulate in the houses and affect the respiratory systems of the children, leading to the development of ARIs (21). The burning of unclean fuel such as dung, wood, crop residues, and coal leads to the accumulation of smoke in houses with inadequate ventilation. This smoke has a powerful effect on the lungs of under-five children, who spend a substantial amount of time indoors, leading to an increase in the risk of developing repeated ARIs. In India, the government launched Pradhan Mantri Ujjwala Yojana (PMUY) in 2016, providing free LPG connections to the below poverty line (BPL) families. Successful implementation of such schemes will empower the women and protect their health and the health of their children (22). In this study, the use of unclean fuel for cooking was more common in rural areas compared to the urban areas, but the use of unclean fuel was not found to be a significant contributor to ARIs in under-five children. Another important household environmental factor responsible for ARI among under-five children is parental smoking habits. The prevalence of ARI is usually higher among the children from the rural areas with a history of parental smoking (4, 11, 23) compared to the children from the densely populated urban areas with a history of parental smoking (7, 24). The effect of smoke

TABLE 1 | Distribution of the children with acute respiratory infection (ARI) according to the sociodemographic factors.

Variables	ARIs (*N* = 1,852) (%)	No ARIs (*N* = 1,819) (%)	*P*-value	Adjusted odds ratio 95%CI
Age group (months)				
≤23 months	809 (53.22)	711 (46.78)		1
>23 months	1,043 (48.49)	1,108 (51.51)	0.99	NA*
Sex of children				
Male	997 (51.42)	942 (48.58)		1
Female	855 (49.36)	877 (50.64)	0.77	0.94 (0.62–1.42)
Type of family				
Nuclear	763 (49.97)	764 (50.03)		1
Joint	1,081 (50.80)	1,047 (49.20)	0.62	0.89 (0.55–1.42)
Income of family				
≤1373.15 USD	1,033 (48.89)	1,080 (51.11)		1
>1373.15 USD	790 (52.70)	709 (47.30)	0.072	1.51 (0.96–2.36)
Place of residence				
Rural	996 (54.22)	841 (45.78)		1
Urban	856 (46.67)	978 (53.33)	0.005	0.50 (0.31–0.82)
Exclusive Breastfeeding				
Yes	54 (46.15)	63 (53.85)		1
No	187 (58.07)	135 (41.93)	0.62	1.14 (0.68–1.90)
Maternal education				
≤6th Std	257 (47.24)	287 (52.76)		1
>6th Std	1,538 (51.03)	1,476 (48.97)	0.14	0.63 (0.34–1.16)

**Range is from 0 to almost infinity.*

TABLE 2 | Distribution of the children with ARI according to the household environmental factors.

Variables	ARIs (*n* = 1,852) (%)	No ARIs (*n* = 1,819) (%)	*P*-value	Adj. odds ratio 95%CI
Type of fuel				
Clean	1,553 (49.79)	1,566 (50.21)		1
Unclean	291 (54.29)	245 (45.71)	0.88	1.05 (0.53–2.08)
Overcrowding				
Yes	1,226 (49.12)	1,270 (50.88)	0.08	1
No	617 (53.42)	538 (46.58)		1.56 (0.95–2.56)
Ventilation				
Adequate	64 (52.03)	59 (47.97)		1
Inadequate	1,719 (50.60)	1,678 (49.40)	0.006	0.12 (0.03–0.54)
Parental smoking				
Yes	73 (55.73)	58 (44.27)		1
No	1,769 (50.27)	1,750 (49.73)	0.035	0.32 (0.11–0.92)

on the prevalence of ARI might be enhanced by inadequate ventilation (25).

This study showed an equal prevalence of ARIs among boys and girls, which was similar to a study performed in Eastern Indonesia in the urban areas (26). However, other studies have reported a greater prevalence of ARIs in boys compared to girls (1, 10). Only one study (7) found that girls were more prone to ARIs than boys.

Generally, education helps to improve the knowledge of maternal caretaking with respect to the risk factors responsible for ARIs, but this study revealed no difference in the prevalence of ARIs in the children born to mothers with varied educational levels. This was in contrast to the results of many studies (1, 10, 17, 19), which have shown a higher prevalence of ARIs in the children born to mothers with primary education levels compared to those born to highly educated mothers.

Strengths and Limitations

This study had several strengths. First, this community-based multisite study was conducted among a vulnerable group of children from the rural and densely populated urban areas of India. Information regarding the household environment was not self-reported by the head of the household but rather it was collected and confirmed during the house-to-house survey.

Second, support of the ASHA and the AWWs (health workers of the government sector) was sought in the data collection. The institute of the authors is a private medical college that represents the public-private relationship.

Seasonal variations could not be captured in this study, as it was performed over a shorter duration that would be necessary to investigate the seasonal swings in the occurrence of ARI.

CONCLUSION

The prevalence of ARI was higher in the children living in the rural areas and among under-five children with parental smoking habits. An intervention, such as reducing the parental smoking habits at the household level may reduce ARIs.

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 Bharati Vidyapeeth Deemed University, Medical College Pune, Institutional Ethics Committee (ECR/313/Inst/MH/2013/RR-16) and Department of Pharmacology Bharati Vidyapeeth Deemed University Medical College and Hospital Sangli (ECR/276/Inst/MH/2013/RR-16). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

JG, PD, PP, GD, and SL contributed to the framing of the design of the study. SQ, SM, RP, SP, VW, RDh, KR, and NM were responsible for the data collection. JG, PP, GD, and PD analyzed and interpreted the data with inputs from SL, SQ, SM, RP, NM, SP, VW, RDe, and KR. SM has drafted the manuscript. All authors were involved in revising the manuscript critically.

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SUPPLEMENTARY MATERIAL

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Chinese Parent Intention to Vaccinate Children With Special Diseases Against COVID-19

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Background: Information on the intention of parents of children with special diseases to vaccinate their children against coronavirus disease 2019 (COVID-19) is scarce.

Methods: In this survey, all participants ($n = 914$) were enrolled from a tertiary children's hospital between September 2020 and April 2021. A face-to-face questionnaire interview was conducted to collect information on the special diseases of children and parental attitudes about the COVID-19 vaccine. We compared the demographic and disease factors between the group of parents who were willing to vaccinate their children against COVID-19 and the group who were unwilling to vaccinate.

Results: Among 941 children, 58.1% ($n = 547$) were boys. The Mean age was 1.4 (SD 1.9) years. If the COVID-19 vaccine becomes available for the child, 470 (49.9%) of parents were willing to provide vaccination for their children. The less the education levels of the father or mother, the more likely they were to vaccinate their children ($P = 0.003$, $P = 0.007$). However, more intentions to vaccinate were provided in parents of children with COVID-19 prevention and control education ($P < 0.001$).

Conclusion: Our findings provided evidence that some parents are willing to vaccinate their children with special diseases against COVID-19. Professional knowledge about COVID-19 prevention and control may contribute to increased parental intention.

Keywords: COVID-19, vaccine, children, special diseases, China

INTRODUCTION

Coronavirus disease 2019 (COVID-19) is caused by SARS-CoV-2, and it has resulted in a global pandemic (1, 2). Vaccination is one of the most effective strategies to prevent and control the spread of COVID-19 and is also one of the most basic public health services provided by the government (3, 4). Given possible concerns about the safety and needs of the new vaccine, it is unclear whether people will overcome their skepticism about the COVID-19 vaccine. At this point, positive public opinion and public trust in the COVID-19 vaccine are critical to promoting widespread acceptance of the vaccine (5).

Currently, the COVID-19 vaccine is administered to adults aged 18 years in China (6). In terms of the development of the global pandemic, the proportion of cases in children showed an increasing trend (7). Although the symptoms in children are less severe than those in adults (8), studies have shown that the viral load in the nasopharynx in children is equal to or greater than that in adults (9). Children, who also need to attend school and other frequent gatherings, may play an important role in the spread of the virus. At present, clinical trials of the COVID-19 vaccine in children are underway, but there is still insufficient data on children vaccinated with COVID-19 (10). Understanding the intention of parents to vaccinate children and the influence factors can help to achieve wider acceptance of the vaccine, leading to higher levels of immunity in the population. Among children, there is a special group with a high risk of infection, which involves several special disease states such as tumors, hematological system diseases, nervous system diseases, heart diseases, newborns, and so on. Such special populations might also be taken into account when developing future strategies to cover children with vaccination.

The timing for the availability of a safe and effective COVID-19 vaccine for children is uncertain, but it is important to anticipate and reduce barriers to its widespread use. To be more scientific and to provide vaccination for children with special diseases in the future, we evaluated the COVID-19 vaccine intentions of 941 cases in typical parents of children with special diseases. In addition, in the clinical real world, these parents were randomly assigned to two different pediatricians to assess their COVID-19 vaccine intentions with or without COVID-19 prevention and control education. We explored the differences in the intention of these parents with or without this education.

TABLE 1 | Overview of the special diseases in children.

Disease	Frequency	Proportion (%)
Jaundice	48	5.1
Congenital heart disease	177	18.8
Febrile convulsion	40	4.3
Epilepsy	32	3.4
Preterm birth	103	10.9
Cerebral palsy	11	1.2
Intracranial bleeding	43	4.6
Crissum abscess	61	6.5
Repeated infection	10	1.1
Asthma	7	0.7
Intravenous use of gamma globulin	25	2.7
Thrombocytopenic purpura	11	1.2
Eczema	31	3.3
Using hormones	6	0.6
Thrush	11	1.2
Respiratory infections, intestinal infections	14	1.5
Neutrophilic granulocytopenia or deficiency	59	6.3
Suspected vaccine allergy	46	4.9
Liver disease	17	1.8
Kidney disease	10	1.1
Allergic purpura	5	0.5
immunodeficiency	7	0.7
Before and after chemotherapy	3	0.3
Genetic metabolic diseases	7	0.7
Other diseases	354	37.6

Seven hundred and eighty eight children with one special disease, One hundred and eighteen children with two special diseases, Twenty seven children with three special diseases, Seven children with four special diseases, and One child with five special diseases.

MATERIALS AND METHODS

Study Design and Participants

Our study included children with special diseases who attended the Children's Hospital of Nanjing Medical University between September 2020 and April 2021, and their parents agreed to participate in this investigation, so one of the parents was invited for an investigation of intention to vaccinate their children against COVID-19. A face-to-face questionnaire interview was conducted to collect demographic characteristics, information on the special diseases of children, and attitudes about the COVID-19 vaccine.

We asked parents to answer these questions: "There is currently no COVID-19 vaccine for children. If there was a COVID-19 vaccination available in the future, would you give it to your child?" to obtain information about their intention to vaccinate. Besides, "what would you rate your child's vaccination risk score?" with a score between 0 (no risk at all) and 100 (highest risk).

In addition, children's age, gender, height, weight, preterm birth, cesarean delivery, food allergy, drug allergy, vaccination allergy, passive smoking, paternal education level, maternal education level, and special diseases of children were collected from questionnaire interview. The study was approved by the Medical Ethics Committee of Children's Hospital of Nanjing Medical University. We obtained signed informed consent from the parents of their children. Data used in this work were anonymous, and no individually identifiable information was available here.

Statistical Analysis

There were 25 special diseases in children, namely, jaundice, congenital heart disease, febrile convulsion, epilepsy, preterm birth, cerebral palsy, intracranial bleeding, crissum abscess, etc. Data are presented as mean ± SD or frequency (%). To compare demographic and disease status between willing to vaccinate children against COVID-19 group and unwilling group, the chi-squared test was used for categorical variables and *t*-test for continuous variables. The level of significance was a two-sided $P < 0.05$. All analyses were performed in the SAS 9.2 (SAS Institute, Inc., Cary, NC, USA).

RESULTS

A total of 941 surveys were completed face to face. Of the 941 children, 788 children had one special disease, 118 children had two special diseases, 27 children had three special diseases, seven

TABLE 2 | Demographic characteristics of children with special diseases.

Characteristics		Total (n = 941)	Willing (n = 470)	Unwilling (n = 471)	P-values[a]
Age	(year)	1.4 ± 1.9	1.4 ± 1.7	1.3 ± 2.0	0.740
Gender	Boy	547 (58.1)	277 (58.9)	270 (57.3)	0.616
Height	(cm)	74.2 ± 18.9	193 (41.1)	201 (42.7)	0.154
Weight	(kg)	10.8 ± 6.5	75.1 ± 18.4	73.3 ± 19.5	0.744
	Girl	394 (41.9)	10.9 ± 6.1	10.7 ± 6.9	
Preterm birth	No	838 (89.1)	418 (88.9)	420 (89.2)	0.908
	Yes	103 (10.9)	52 (11.1)	51 (10.2)	
Cesarean delivery	No	559 (59.4)	281 (59.8)	278 (59.0)	0.811
	Yes	382 (40.6)	189 (40.2)	193 (41.0)	
Food allergy	No	825 (87.7)	411 (87.4)	414 (87.9)	0.833
	Yes	116 (12.3)	59 (12.6)	57 (12.1)	
Drug allergy	No	898 (95.4)	444 (94.5)	454 (96.4)	0.158
	Yes	43 (4.6)	26 (5.5)	17 (3.6)	
Vaccination allergy	No	885 (94.0)	447 (95.1)	438 (93)	0.171
	Yes	56 (6.0)	23 (4.9)	33 (7)	
Passive smoking	No	612 (65.0)	450 (95.7)	459 (97.5)	0.255
	Yes	329 (35.0)	20 (4.3)	12 (2.5)	
Paternal education	Technical secondary school and below	225 (23.9)	133 (28.3)	92 (19.5)	**0.003**
	College	231 (24.5)	117 (24.9)	114 (24.2)	
	Bachelor degree and above	485 (51.5)	220 (46.8)	265 (56.3)	
Maternal education	Technical secondary school and below	248 (26.4)	144 (30.6)	104 (22.1)	**0.007**
	College	226 (24.0)	113 (24)	113 (24)	
	Bachelor degree and above	467 (49.6)	213 (45.3)	254 (53.9)	

[a] *Statistically significant results (P-values) are bolded.*

TABLE 3 | Self-assessment score of vaccination in parents of children with specific diseases.

Self-assessment score	Mean ± SD	Range	5th	25th	50th	75th	95th
Risk score	39.2 ± 27.4	(0, 100)	0	17.5	41	52	99

children had four special diseases, and one child had five special diseases. The proportion of congenital heart disease in children is the highest (18.8%) among all disease groups except for other unclassified diseases (**Table 1**).

Among 941 children, 58.1% (n = 547) were boys. The mean age was 1.4 (SD 1.9) years. The mean height was 74.2 (SD 18.9) cm, and the mean weight was 10.8 (SD 6.5) kg. A small number of children (10.9%) were preterm birth, and 40.6% were cesarean delivery. The majority have no history of allergies to food (87.7%), drugs (95.4%), or vaccines (94.0%). There were 35% (n = 329) of parents who confirmed passive smoke exposure of children. Most of the fathers (51.5%) or mothers (49.6%) had a bachelor's degree and above. If the COVID-19 vaccine becomes available for the child, the demographic characteristics of comparison between parents who were willing or unwilling to vaccinate their children against COVID-19 were showed in **Table 2**. A total of 470 (49.9%) of parents are willing to provide vaccination for their children and 471 (50.1%) of those are unwilling. The less the education levels of the father or mother, the more likely they are to vaccinate their children (P = 0.003, P = 0.007). Other basic characteristics did not differ between the willing and unwilling groups. **Table 3** shows the distribution of parental self-assessment scores of children's vaccination risk, ranging between 0 and 100, and the 50th percentile is 41.

Table 4 provides the comparison of the parental intention of children with special diseases to vaccinate their children against COVID-19. Greater willingness to vaccinate was showed in parents of children with congenital heart disease (P = 0.038). For other specific diseases, there was no difference between the willing and unwilling groups.

Table 5 shows the comparison of the intention of parents of children with special diseases to vaccinate their children against COVID-19 with or without COVID-19 prevention and control education. During the survey, these parents were randomly assigned to two different pediatricians to assess their COVID-19 vaccine intentions. Pediatrician A promoted professional knowledge about the prevention and control of COVID-19 for parents, while pediatrician B conducted a direct survey without a professional knowledge education.

TABLE 4 | Comparison of the intention of parents of children with special diseases to vaccinate their child against COVID-19.

	Willing ($n = 470$)	Unwilling ($n = 471$)	*P*-values[a]
Jaundice	450 (95.7)	443 (94.1)	0.239
	20 (4.3)	28 (5.9)	
Congenital heart disease	394 (83.8)	370 (78.6)	**0.038**
	76 (16.2)	101 (21.4)	
Febrile convulsion	447 (95.1)	454 (96.4)	0.329
	23 (4.9)	17 (3.6)	
Epilepsy	454 (96.6)	455 (96.6)	0.995
	16 (3.4)	16 (3.4)	
Preterm birth	418 (88.9)	420 (89.2)	0.908
	52 (11.1)	51 (10.8)	
Cerebral palsy	466 (99.1)	464 (98.5)	0.365
	4 (0.9)	7 (1.5)	
Intracranial bleeding	452 (96.2)	446 (94.7)	0.278
	18 (3.8)	25 (5.3)	
Crissum abscess	439 (93.4)	441 (93.6)	0.888
	31 (6.6)	30 (6.4)	
Repeated infection	466 (99.1)	465 (98.7)	0.753
	4 (0.9)	6 (1.3)	
Asthma	467 (99.4)	467 (99.2)	1
	3 (0.6)	4 (0.8)	
Intravenous use of gamma globulin	459 (97.7)	457 (97)	0.547
	11 (2.3)	14 (3)	
Thrombocytopenic purpura	467 (99.4)	463 (98.3)	0.13
	3 (0.6)	8 (1.7)	
Eczema	452 (96.2)	458 (97.2)	0.358
	18 (3.8)	13 (2.8)	
Using hormones	467 (99.4)	468 (99.4)	1
	3 (0.6)	3 (0.6)	
Thrush	463 (98.5)	467 (99.2)	0.361
	7 (1.5)	4 (0.8)	
Respiratory infections, intestinal infections	464 (98.7)	463 (98.3)	0.593
	6 (1.3)	8 (1.7)	
Neutrophilic granulocytopenia or deficiency	437 (93)	445 (94.5)	0.342
	33 (7)	26 (5.5)	
Suspected vaccine allergy	451 (96)	444 (94.3)	0.229
	19 (4)	27 (5.7)	
Liver disease	461 (98.1)	463 (98.3)	0.803
	9 (1.9)	8 (1.7)	
Kidney disease	465 (98.9)	466 (98.9)	1
	5 (1.1)	5 (1.1)	
Allergic purpura	466 (99.1)	470 (99.8)	0.369
	4 (0.9)	1 (0.2)	
Immunodeficiency	467 (99.4)	467 (99.2)	1
	3 (0.6)	4 (0.8)	
Before and after chemotherapy	468 (99.6)	470 (99.8)	0.999
	2 (0.4)	1 (0.2)	
Organ transplantation or stem cell transplantation	470 (100)	471 (100)	–
Genetic metabolic diseases	466 (99.1)	468 (99.4)	0.998
	4 (0.9)	3 (0.6)	
Other diseases	285 (60.6)	302 (64.1)	0.27
	185 (39.4)	169 (35.9)	

[a]*Statistically significant results (P-values) are bolded.*

TABLE 5 | Comparison of the intention of parents of children with special diseases to vaccinate their child against COVID-19 with or without COVID-19 education.

Characteristics		Total ($n = 941$)	Willing ($n = 470$)	Unwilling ($n = 471$)	*P*-values[a]
COVID-19 education	No	280	32 (6.8)	248 (52.7)	**<0.001**
	Yes	661	438 (93.2)	223 (47.3)	

[a]*Statistically significant results (P-values) are bolded.*

More intentions to vaccinate were provided in parents of children with COVID-19 prevention and control education ($P < 0.001$).

DISCUSSION

Coronavirus disease 2019 (COVID-19) is highly infectious and the transmission process is complex. Children with special diseases are easy to be neglected, and once they are infected with the virus, it is easy to cause an outbreak. Vaccination of children with special diseases is necessary not only to prevent COVID-19 in them but also important for other general populations, including normal children and adults.

In our survey, overall, nearly one-half (50.1%) of participants indicated intentions to vaccinate their children with special diseases against COVID-19 when a vaccine for the child becomes available. In addition, more willingness to vaccinate was showed in parents of children with congenital heart diseases. For other specific diseases, there was no difference between the willing and unwilling groups. Previous studies have shown that parents of children with chronic conditions are less likely to vaccinate their children against COVID-19 (3). However, one study of other vaccines (such as the influenza vaccine) for children with chronic conditions suggested that children with chronic conditions were more likely to be vaccinated against influenza than children without chronic conditions (11). Our finding is especially striking considering that the survey was conducted with parents of children with special diseases, whose concerns about the safety of the vaccine, the state of diseases, and the stress of therapy may be more likely to influence their intentions to vaccinate their children against COVID-19.

To our surprise, we found that less parental educational attainment was a favorable factor in the willingness to vaccinate children against COVID-19, contrary to the findings of a national survey conducted by the prior reports. For example, higher education level was a factor associated with more willingness to vaccinate their children against A/H1N1 (12, 13). In the current study, concern about the safety of the COVID-19 vaccine may be one of the common reasons for uncertainty about vaccination. Therefore, we hypothesized that higher education might lead to more exposure to relevant information about vaccine risk reports, and therefore, more hesitation from parents to vaccinate their children.

However, our findings highlight the importance of professional COVID-19 prevention and control education.

More intentions to vaccinate their children were provided in parents receiving this education. The spread of professional knowledge about COVID-19 may contribute to increased willingness to vaccinate. Furthermore, understanding why individuals may be hesitant to vaccinate their children may provide clues for developing policies to allay fears about vaccines (14, 15).

Taken together, these findings suggested that rational and accurate reporting of COVID-19 and vaccine characteristics in a way (e.g., through healthcare providers) that parents at all levels of education can understand may be an effective strategy for increasing vaccination of children in the future. Since children with special diseases are more vulnerable to infection than general children, 1 day, if there is a COVID-19 vaccine available for children, and children with special diseases are also applicable, special attention should be paid to this group of children.

The advantage of our study was that we focused on vaccination intentions of children with several special diseases, an understudied population group. Given the high prevalence of COVID-19, our finding might be meaningful to public health in the future. In addition, professional COVID-19 prevention and control education is a modifiable factor and may provide a clue to increased willingness to vaccinate. Although there was a relatively larger sample size of our survey about vaccination intentions of children with special diseases, the power of this single-center cohort study is still limited. Also, in our study, if more than one parent accompanied by a special disease in children, we only invited one of the parents to investigate, we asked the parents about their willingness to vaccinate children and their self-rating of the risk of vaccination for children. We did not further investigate the reasons for their reluctance to vaccinate their children.

In conclusion, in our survey, nearly one-half of the parents indicated intentions to vaccinate their children with special diseases against COVID-19 when a vaccine for the child becomes available, and the professional knowledge about COVID-19 may contribute to increased willingness to vaccinate.

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 Children's Hospital of Nanjing Medical University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

XW: conception and design of the study. LL, LC, and YT: acquisition of data. WY: analysis and interpretation of data. XW and WY: drafting the article or revising it critically for important intellectual content. YT: epidemiological investigation guidance, verification of the full text, and payment of open access fee. XW and KZ: final approval of the version to be submitted. All authors contributed to the article and approved the submitted version.

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Social-Emotional Problems Among 3-Year-Olds Are Associated With an Unhealthy Lifestyle: A Population-Based Study

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Introduction: Little attention has been paid to the association between preschool children's social-emotional problems and lifestyle at the population level.

Objective: This study aimed to overcome this knowledge gap by investigating to what extent children's social-emotional problems are associated with their lifestyle and if there are any gender differences.

Methods: This cross-sectional, population-based study used data from the regional Salut Register in northern Sweden, including 7,179 3-year-olds during 2014–2017. Parents responded to a questionnaire including the 36-month interval of the Ages and Stages Questionnaires: Social-Emotional (ASQ:SE) and questions regarding family and lifestyle characteristics. Single and multiple logistic regression were used to assess the association between children's social-emotional problems and multiple family lifestyle characteristics.

Results: More reports of social-emotional problems were found among children who did not have parents living together or had markers of an unhealthy lifestyle. Children who ate vegetables less frequently, whose parent/-s brushed their teeth less often and did not read to them regularly were more likely to have social-emotional problems. Playing outdoors <3 h during weekdays and >1 h of sedentary screen time during weekends increased the risk of social-emotional problems among boys only, while >1 h of sedentary screen time during weekdays increased the risk among girls. When it comes to lifestyle and gender differences, a high proportion of the 3-year-olds had an unhealthy lifestyle, more so for boys than for girls. The dietary quality and tooth brushing were somewhat more adequate for the girls than for the boys, but boys spent more time playing outdoors compared to the girls.

Conclusions: This study provides us with an important overview picture of the family life situation of three-year-olds, including those with social-emotional problems. Such problems were significantly associated with markers of unhealthy lifestyle, with significant

gender differences. Therefore, this study suggests that in order to maintain children's social-emotional ability and support children at risk of problems, public health intervention programs should have a broader perspective on improving children's lifestyle rather than merely focusing on their social and emotional problems, and the gender differences found may be taken in account.

Keywords: ages and stages questionnaires, child behavior, cross-sectional studies, family characteristics, preschool children

INTRODUCTION

The concept of social- and emotional ability includes the child's experience, expression, and management of emotions and the ability to establish positive and rewarding relationships with others (1). Childhood development underpins lifelong behavior, learning and health, and it has been strongly linked to mental health in adulthood (2–4). Preschool age is a usual age to find signs of social, emotional and behavior problems (4, 5). There are several epidemiological studies regarding psychosocial and behavioral problems among children within and between countries. Swedish children, as the other Scandinavian countries, have a low occurrence of parental-reported behavioral and emotional problems compared to many other countries (6). Almost one in ten Swedish 3-year-olds has social-emotional problems as reported by their parent/-s (7). Gender differences are evident with twice as many boys compared to girls having such problems, which has been reported earlier for this study group of children (boys 12.3 and girls 5.6%, $p < 0.001$) (7). During the last decade mental health complaints have increased among school-age children in Sweden (8) and mental health problems have become a public health concern. Therefore, it is imperative not only to detect children at risk as early as possible, but also to identify associated family and lifestyle characteristics.

A healthy lifestyle is a way of living that lowers the risk of developing non-communicable diseases, becoming seriously ill or dying early (9). When adopting a healthy lifestyle as an adult, a more positive role model is given to other members of the family, especially children (9). Unhealthy behavior or lifestyle during childhood has been shown to track into later life (10, 11). Healthy nutritional behavioral and physical active choices are vital in order for a child to grow into a healthy adulthood (12). Preschool-aged children who have sleeping problems (13, 14) or unhealthy feeding practices (15) experience social-emotional problems to a higher extent. Evidence on the role of physical activity and sedentary behavior for the mental health of preschool-aged children is nearly non-existent. However, results from observational studies suggest that promoting physical activity and decreasing sedentary behavior might protect mental health in children and adolescents (16). Some family characteristics are associated with social-emotional problems among children, e.g., exposure to domestic violence (17), depression among mothers (14, 18), and custody arrangements (7). Among many risk factors, early childhood caries is associated with family characteristics such as oral health and feeding behaviors (19).

Regardless of how lifestyle characteristics are causally related to social-emotional problems, it is pertinent to study the association between multiple lifestyle characteristics simultaneously and social-emotional problems, especially among preschool children at the population level where little is known. Neither unhealthy lifestyle behaviors, nor social-emotional problems among preschool children happen in isolation. The interrelation between these may reflect the broader family context in which children live and grow up and can help to inform public health policies aimed at improving children's health and wellbeing. Therefore, this study aimed to overcome this knowledge gap by addressing the associations between 3-year-olds' social-emotional problems and lifestyle taking into account any gender differences.

METHODS

Study Design and Context

This population-based, cross-sectional study was performed in Västerbotten County in northern Sweden with an annual birth rate of about 3,000. It takes advantage of data from the Salut Child Health Promotion Program, an ongoing universal intervention and epidemiological survey of expectant parents and children (20). The data originates from a questionnaire used in 3-year-olds at the county's 40 Child Health Care centers. The parents fill in the questionnaire at home and brings it to the regular visit. The questionnaire is including the 36-month interval of the Ages and Stages Questionnaires: Social-Emotional (ASQ:SE) and questions regarding family and lifestyle characteristics. The questionnaire is used to increase nurses and parent's awareness of children's social and emotional problems and lifestyle, giving a possibility to identify children in need of extra support.

Study Participants

From January 2014 to September 2017, 8,214 3-year-olds' parents responded to the questionnaire, corresponding to 80% of those living in the county. The age of each child was calculated by deducting the birth date from the Child Health Care centers' visit date. Only children within the questionnaires age range were included (33–41 months) (1). From the initial sample, 1,035 children were excluded due to any of these three reasons: the parent/-s did not consent to the research ($n = 447$); the age of the child could not be determined or was outside the recommended age range of the 36-month interval of the ASQ:SE ($n = 513$); and the number of unanswered ASQ:SE questions were more than three ($n = 75$). In total, 7,179 3-year-olds were included,

corresponding to 70% of all children living in the county during the study period. A majority of the families lived in an urban area, and place of residence did not differ between boys and girls, which has been reported earlier (7).

Data Collection Procedure

The first edition of the ASQ:SE 36-month interval was included in the questionnaire used in this study (1, 21). The ASQ:SE reflects the risk of social-emotional problems among children and it is considered to have adequate psychometric properties that includes validity and reliability internationally (7, 21–23). ASQ:SE consists of 31 items and three open-ended questions, the latter not used in this study. Out of the 31 ASQ:SE items, up to three missing values were replaced by using average value imputation from all the other responses, according to ASQ:SE User's Guide (1). A three-point Likert scale was used to enable parents to indicate how often they perceive their child's behavior, and whether the behavior is a concern for them. This results in a total score ranging 0–465 points. Children on the cut-off value of 59 points or above are considered to be at risk of social-emotional problems (1). A back-translation was used in order to get a Swedish version of the ASQ:SE, based on established recommendations (24). In addition to the ASQ:SE, the questionnaire included information on family characteristics such as the child's gender, custody arrangement, number of siblings, and attendance at preschool and different lifestyle characteristics. The child's parental-reported lifestyle (both at home and in preschool) do not go into details, but gives us an overview of the child's lifestyle. The lifestyle questions included dietary quality in terms of food-frequency for low-fat milk, vegetables, fruit/berries, fish and sweets/soft drinks. Physical activity and sedentary screen time were included in terms of frequency of time playing outdoors (weekdays and weekends) and sedentary screen time (during weekdays and weekends). The frequency of parents brushing the child's teeth and reading to the child was also parts of the lifestyle questions (**Table 1**).

Statistical Analyses

This study used cross-sectional descriptive and comparative statistical analyses. The distribution of responses was calculated for girls and boys, respectively. Pearson's chi-squared test was used to analyze gender differences for all categorical variables. To analyze the overall associations between social-emotional problems and the explanatory variables among 3-year-olds, simple and multiple logistic regression analyses were performed, and odd ratios (OR) and Confidence Intervals (CI) were reported. A backward elimination procedure was performed until only significant variables ($p < 0.05$) were left in the final analyses. The data was analyzed using Stata/SE version 16.0 (StataCorp, College Station, Texas 77,845 US).

Ethical Considerations

Only children whose parents have given written informed consent were included in the study. The Regional Ethical Review Board in Umeå approved the study (2013-268-31O).

TABLE 1 | Characteristics of 3-year-olds within the Salut Child Health Programme (2014–2017).

Characteristics	Boys, *n* (%) *n* = 3,719	Girls, *n* (%) *n* = 3,460	*P*-value[a]
Custody arrangement			0.091
Parents living together	3,327 (91)	3,147 (92)	
Parents not living together or single parent	315 (9)	257 (8)	
Having siblings			0.936
Yes	2,717 (75)	2,531 (75)	
No	887 (25)	830 (25)	
Attending preschool			**0.042**
Yes	3,587 (97)	3,368 (98)	
No	108 (3)	74 (2)	
Drinking low-fat milk			**0.009**
Twice a day or more often	2,444 (68)	2,342 (69)	
Once a day	581 (16)	582 (17)	
Less than once a day	584 (16)	461 (14)	
Eating vegetables			**0.000**
Twice a day or more often	1,471 (40)	1,513 (44)	
Once a day	1,364 (37)	1,305 (38)	
Less than once a day	843 (23)	606 (18)	
Eating fruit/berries			0.393
Twice a day or more often	1,839 (50)	1,727 (50)	
Once a day	1,433 (39)	1,352 (39)	
Less than once a day	413 (11)	350 (10)	
Eating fish			**0.023**
Twice a week or more often	1,330 (36)	1,339 (39)	
Once a week	1,721 (47)	1,559 (46)	
Less than once a week	610 (17)	513 (15)	
Eating sweets/drinking soft drinks			0.353
Once a week or less often	1,616 (44)	1,447 (42)	
A few times a week	1,924 (53)	1,848 (54)	
Once a day or more often	125 (3)	115 (3)	
Tooth brushing			**0.000**
Twice a day or more often	2,964 (80)	2,869 (84)	
Once a day or less often	718 (20)	546 (16)	
Playing outdoors, weekdays			**0.001**
≥3 h	1,800 (51)	1,547 (47)	
<3 h	1699 (49)	1,717 (53)	
Playing outdoors, weekends			**0.000**
≥3 h	1,904 (54)	1,573 (48)	
<3 h	1,629 (46)	1,706 (52)	
Sedentary screen time, weekdays			0.170
≤1 h	2,308 (65)	2,194 (66)	
>1 h	1,254 (35)	1,111 (34)	
Sedentary screen time, weekends			0.299
≤1 h	1,095 (31)	1,057 (32)	
>1 h	2,487 (69)	2,274 (68)	
Reading to the child			0.066
Every day	2,354 (64)	2,268 (66)	
A few times a week	1,051 (28)	937 (27)	
Once a week or less often	297 (8)	237 (7)	

[a] *Chi-squared test was used to report significant differences between boys and girls. P < 0.05 was considered as significant and marked with bold values.*

RESULTS

A majority of the questionnaires were completed by the parents jointly (62%) and the remaining by mothers alone (34%), fathers alone (4%) or by another person (1%). Characteristics of the 3-year-olds and gender differences are shown in **Table 1**. Most of the 3-year-olds had parents living together (boys = 91%, girls = 92%), three out of four had siblings and almost all 3-year-olds attended preschool (mean 29 h per week, SD 11). When it comes to lifestyle, a high proportion of the 3-year-olds had markers of unhealthy lifestyle, more so for boys than for girls and gender differences were evident. Parents reported that boys less often drank low-fat milk, ate vegetables and fish and less frequently had parent/-s who brushed their teeth and read to them compared to girls ($p < 0.05$). On the other hand, boys spent more hours playing outdoors, both during weekdays and weekends compared to girls ($p \leq 0.001$).

There were statistically significant associations between most of the lifestyle characteristics and children's social-emotional problems ($p < 0.05$) as shown in **Table 2**. However, some gender differences appeared here as well. Not having siblings, drinking low-fat milk less than once a day, <3 h playing outdoors during the weekdays and ditto during the weekends increased the risk of social-emotional problems only for boys, while eating fruit/berries once a day or less than once a day were significant only for girls.

After multiple logistic regression with backward elimination (**Figure 1**), higher risk of social-emotional problems were found among children without parents living together, with less frequently vegetable consumption and among those children whose parent/-s brushed their teeth and read to them less often. However, less time for playing outdoors and more sedentary screen time during weekends increased the risk of social-emotional problems among boys only, while more sedentary screen time during weekdays increased the risk of social-emotional problems among girls only.

DISCUSSION

In this study, we found significant associations between most of the lifestyle characteristics and children's social-emotional problems, which gives us an overall picture of the family life situation of children with such problems. A high proportion of the 3-year-olds had an unhealthy lifestyle, more so for boys than for girls. In general, an unhealthy lifestyle increased the children's risk of having social-emotional problems measured by ASQ:SE and using the recommended cut-off (1). Below we discuss our findings, one lifestyle characteristic at a time, and implications for practice and research are proposed.

Our findings suggested that *custody arrangement* was associated with social-emotional problems among the children. Children who did not live with both parents were more likely to be at risk, especially girls. We have discussed this finding in detail in our previous publication (7). The same applies to the *gender differences* we found. Parents of boys more often reported social-emotional problems than parents to girls (7), which is similar to other previous studies of gender differences in preschool-aged children (5, 25, 26).

Overall, lifestyle of the child might mirror the family's life situation, as there were significant associations between many unhealthy lifestyle characteristics and children's social-emotional problems. We do not claim any causal relationship between lifestyle and children's social-emotional problems, as we with this cross-sectional study design cannot clarify which comes first, the unhealthy lifestyle or the social-emotional problems. However, our findings suggest that children are more likely to have social-emotional problems in a context in which unhealthy lifestyle is prevailing.

The dietary quality in terms of *food-frequency* reported in our study were somewhat more adequate for the girls than for the boys regarding drinking low-fat milk and eating fish and vegetables as reported by their parents. Almost 70% of the children drank the recommended frequency of low-fat milk, but only half when it came to eating fruit/berries. Even fewer were eating the recommended frequency of vegetables and fish. The gender differences in dietary quality in our study are in accordance with studies during pregnancy, where women generally have healthier food habits than men (27). In schoolchildren, gender differences seems to be rare, but girls seems to like fruit and vegetables more compared to boys (28).

In girls, it was more likely to have social-emotional problems among those who ate insufficient frequencies of vegetables, fish and fruit/berries. For vegetables, the results remained significant in the multiple logistic regression analysis for both boys and girls. This is in accordance with two different systematic reviews that concluded that healthy foods such as vegetables, salads, fruit and fish, are associated with better mental health of children and adolescents, and to some extent the reverse was found (29). Increased intake of high-sugar products and lower diet quality have been reported to be associated with higher likelihood of emotional symptom in children (30, 31). Interestingly, no study had included children below 4.5 years, highlighting that this study contributes with new knowledge about 3-year-olds' dietary quality and the association with social-emotional problems.

When it comes to fulfillment of the recommended *tooth brushing* twice a day, we found the same gender pattern among adults during pregnancy (27) and adolescents (32) as among the 3-year-olds in our study, where fewer boys than girls fulfilled the recommendation. Thus, it seems as parents transfers their tooth brushing habits to their child in a gendered mode, thus, treating girls and boys differently. Another explanation could be that boys have more social-emotional problems, and additionally, their expressions of such problems are more externalized than those of girls (23), and therefore more difficult to manage for the parents. Besides that, there were considerably higher risk of social-emotional problems among both boys and girls whose teeth were brushed less than twice a day. Another study with parents from poor areas have reported that the main barriers for brushing their children's teeth regularly were skills in managing their children's behavior and their stressful lives (33). Eating patterns and tooth brushing are important for dental health and have additive impact on prevention of caries (34). In Sweden, dental hygienists are meeting all children regularly,

TABLE 2 | Associations between 3-year-olds' lifestyle and social-emotional problems as measured by ASQ:SE[a] using simple logistic regressions.

Characteristics	Boys OR (95% CI)	*P*-value[b]	Girls OR (95% CI)	*P*-value[b]
Custody arrangement				
Parents living together	1		1	
Parents not living togetheror single parent	1.8 (1.3-2.4)	**0.000**	2.5 (1.7-3.8)	**0.000**
Having siblings				
Yes	1		1	
No	1.4 (1.1–1.7)	**0.004**	1.1 (0.8–1.5)	0.718
Attending preschool				
Yes	1		1	
No	1.0 (0.5–1.7)	0.936	0.5 (0.1–1.9)	0.284
Drinking low-fat milk				
Twice a day or more often	1		1	
Once a day	1.1 (0.8–1.4)	0.568	1.3 (0.9–2.0)	0.129
Less than once a day	1.6 (1.3–2.1)	**0.000**	1.4 (1.0–2.1)	0.082
Eating vegetables				
Twice a day or more often	1		1	
Once a day	1.3 (1.0–1.7)	**0.017**	1.2 (0.9–1.8)	0.220
Less than once a day	1.9 (1.5–2.5)	**0.000**	2.5 (1.8–3.6)	**0.000**
Eating fruit/berries				
Twice a day or more often	1		1	
Once a day	0.9 (0.7–1.1)	0.260	1.4 (1.0–1.9)	**0.037**
Less than once a day	1.2 (0.8–1.6)	0.311	2.0 (1.3–3.2)	**0.001**
Eating fish				
Twice a week or more often	1		1	
Once a week	1.2 (1.0–1.6)	0.059	1.1 (0.8–1.6)	0.405
Less than once a week	1.5 (1.1–2.0)	**0.005**	2.4 (1.7–3.6)	**0.000**
Eating sweets/drinking soft drinks				
Once a week or less often	1		1	
A few times a week	1.1 (0.9–1.3)	0.418	1.0 (0.7–1.3)	0.981
Once a day or more often	1.9 (1.2–3.0)	**0.007**	2.1 (1.1–3.9)	**0.026**
Tooth brushing				
Twice a day or more often	1		1	
Once a day or less often	2.3 (1.8–2.8)	**0.000**	2.3 (1.7–3.2)	**0.000**
Playing outdoors, weekdays				
≥3 h	1		1	
<3 h	1.4 (1.1–1.7)	**0.003**	1.3 (1.0–1.8)	0.103
Playing outdoors, weekends				
≥3 h	1		1	
<3 h	1.3 (1.1–1.6)	**0.015**	1.2 (0.9–1.7)	0.207
Sedentary screen time, weekdays				
≤1 h	1		1	
>1 h	1.5 (1.2–1.8)	**0.000**	2.2 (1.6–2.9)	**0.000**
Sedentary screen time, weekends				
≤1 h	1		1	
>1 h	1.5 (1.2–1.9)	**0.000**	1.6 (1.2–2.3)	**0.006**
Reading to the child				
Every day	1		1	
A few times a week	1.4 (1.1-1.7)	**0.005**	1.6 (1.1-2.2)	**0.004**
Once a week or less often	1.9 (1.4-2.6)	**0.000**	3.4 (2.2-5.2)	**0.000**

[a] *The first edition of the Ages and Stages Questionnaires: Social-Emotional (ASQ:SE) for 36-month interval.*

[b] *$P < 0.05$ was considered as significant and marked with bold values. Logistic regression was used to assess the association between each explanatory variable and 3-year-olds' social-emotional problems.*

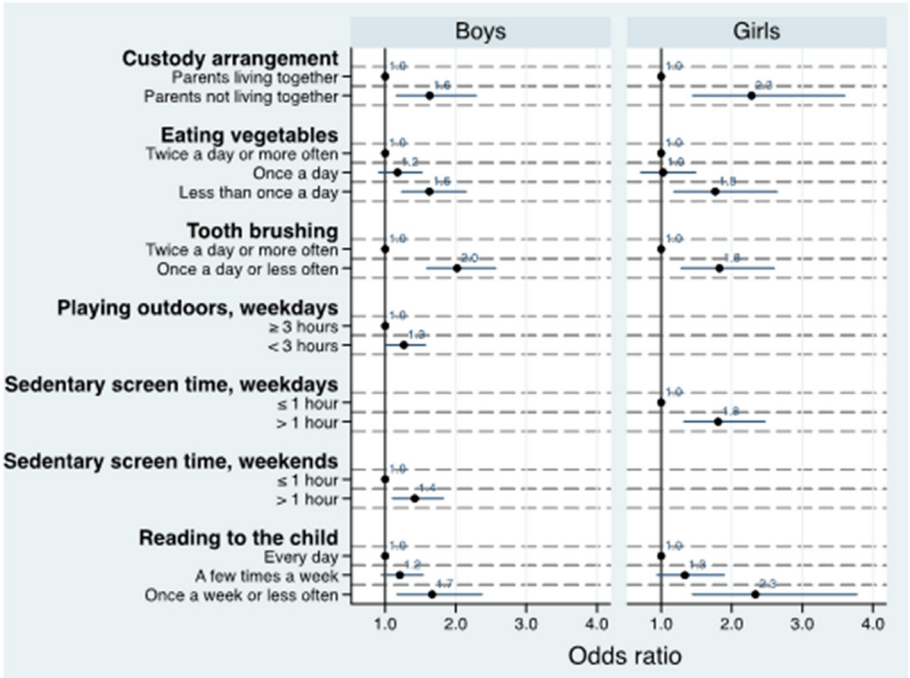

FIGURE 1 | Adjusted estimates[a] of the association between 3-year-olds' lifestyle and social-emotional problems as measured by ASQ:SE[b]. [a]Multiple logistic regression with backward elimination included only variables that were still significant in the final analyses. [b]The first edition of the Ages and Stages Questionnaires: Social-Emotional (ASQ:SE) for 36-month interval.

often accompanied by a parent. This is particularly important for promoting equal dental and oral health among children, although there are measurable differences between boys and girls in frequency of tooth brushing as shown in our study.

The variable *playing outdoors* used in our study was chosen as a proxy for the recommended physical activity at any intensity for 180 min, of which at least 60 min should be moderate to vigorous, spread throughout the day (35). More than half of the boys and less than half of the girls were playing outdoors during weekdays as well as weekends. These gender differences in physical activity found in our study are in accordance with previous studies at preschool age (36–38) and the same pattern is seen in adolescence. Playing outdoors for <3 h during weekdays increased the risk of social-emotional problems among boys but not girls in our study. A study of children aged 1 to 5 years found that increased temperamental behaviors were associated with less time playing outdoors among boys, but not among girls (39).

WHO has clarified that *sedentary screen time* is spent passively watching screen-based entertainment (TV, computer, mobile devices) which does not include active screen-based games for which physical activity or movement is required (35). We have considered this aspect in our study while asking for sitting in front of the screen. The recommended maximum limit from WHO for sedentary screen time is 1 h per day for those aged 3–4 years (35), and two-thirds of both boys and girls fulfilled that recommendation. More than 1-h of sedentary screen time during weekends increased the risk of social-emotional problems among boys, and the same was true during weekdays among girls in our study. The time spent in outdoor play and sedentary screen time was a little <3 and 2 h, respectively (data not shown) in accordance with a recent study of proxy-reported data (36). Another study showed further interesting findings in line with our results, that preschool children's social skills are adversely associated with screen time and favorably associated with outdoor play (36).

In the adjusted analyses, both girls and boys whose *parent/-s read to them* seldom were about two times more likely to have social-emotional problems. A randomized controlled trial of children up to the age of three found that reading has important positive effects on social-emotional development (40) and the authors recommended this as a primary prevention of social-emotional problems. Our study result could be looked through two lenses; that children develop social-emotional problems because their parent/-s do not give them enough attention, including lack of reading, *or* parents of children with social-emotional problems do not read to their children because their overall family life situation is difficult to handle, including the problems of the child. The latter is supported by a study which demonstrates a close link between mothers' psychological distress and their ASQ:SE ratings of infant's (41). This means that on the one hand, high total scores can reflect the parent's mental health problems more than the child's ditto can, on the other hand, a healthy child can be negatively affected if the parent has such problems.

The current study is population-based with high participation rate, as almost hundred percent of parents and their child attend

the 3-year's health check-up at the Child Health Care center. We used the well-established ASQ:SE, which has been shown to be an appropriate tool to investigate children's social and emotional problems (21, 22). Since ASQ:SE is so far only validated in an U.S. context (1) it brings a limitation into our study. The cut-off used (59 points) may not be optimal in the Swedish context, although it is used in many other countries. In a recent Nordic review of the evidence of reliability, validity and norms of different psychological tests including ASQ:SE, the reliability was considered satisfactory, although there is a lack of Nordic up-to-date norming and validation studies (42).

The present study used both the English and the Swedish versions of the ASQ:SE, which means that non-Swedish speakers who have English as their first or second language could still answer the questionnaire. However, parents who do not have strong skills in any of these languages were not able to answer the questionnaire, which can be assumed to have contributed to a lower proportion of immigrants in our study. In addition, the data collection was done through parent/-s' assessment of their child's behavior. On one hand, this is a strength, as most parents know their child best, on the other hand, as already mentioned, parent's own problems and wishes may also reflect how they report their child's abilities and problems, as parents' well-being directly affects that of their children (43, 44).

There are both strengths and weaknesses with proxy reports and markers of lifestyle characteristics compared to objectively measured data. The reports do not go into details, but gives us an overview of the child's lifestyle. On the other hand, we don't know the daily amount of food intake or the exact frequency, duration and intensity for physical activity. Most 3-year-olds were in preschool with a mean duration of 29 h. At preschool breakfast, snacks (at morning and afternoon) and lunch are served and contains fruit, berries, vegetables and low-fat milk daily, while fish is served about once a week. They also spend time playing outdoors before and/or after lunch. Knowledge of food-frequency and time playing outdoor may be difficult for parents to report exactly. When it comes to physical activity and playing outdoors, we do not know the type of the activity either. From other research on children living in Sweden, we know that children spend more time playing indoors than outdoors (38), and we only measured outdoor activity in this study. However, it is rather difficult to do any more than light physical activity indoors, both at home and in preschool on a limited space, and the health benefits of light physical activity is unknown. In the light of studies with objective measurement methods, our proxy reports appear to show an overestimated time in outdoor play and an underestimated screen time (37, 38). Sedentary screen time, which is also difficult to report, is an ambiguous variable that can include the positive aspects of engaging in reading and storytelling on a screen with a caregiver (35). Finally, custody arrangement has been used as a reflection of socioeconomics, since no other ones were included in the analyses. It would be helpful in further studies to bring in data on ethnicity and socioeconomic status, as it has been recommended in research on child health (45).

In order to support children with social-emotional problems, our study calls for intervention programs with a broader perspective on improving children's lifestyle rather than merely focusing on their social and emotional health. Today, there is a major focus on improving mental health and lifestyle in public health, but often as two separate tracks. This study demonstrates the importance of considering both as these are intertwined. Gender differences in lifestyle and in the development of social-emotional health deserve attention and should be highlighted within Child Health Care. As nurses are the main professional meeting the parents' and their child through the first critical 5 years in Swedish Child health services, they are key for promoting physical activity, healthy food habits and preventing sedentary behavior for being established in early childhood (46). This also applies to other lifestyle characteristics and social-emotional development. To strengthen and promote a healthy lifestyle in preschool-age children is a challenge as multiple factors seem to influence physical activity and sedentary behaviors at various levels, including intrapersonal, interpersonal, environmental, organizational, and policy (46).

CONCLUSIONS

Our study provides us with an important overview picture of the family life situation of 3-year-olds, including those with social-emotional problems. Such problems were significantly associated with markers of unhealthy lifestyle, with significant gender differences, already at 3-years-of age. Therefore, this study suggests that in order to maintain children's social-emotional ability and support children at risk of problems, public health intervention programs should have a broader perspective on improving children's lifestyle rather than merely focusing on their social and emotional problems. The gender differences found may be taken in account.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors after application to Umeå University and approval by the Regional Ethical Review Board. Requests to access the datasets should be directed to eva.eurenius@umu.se.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Regional Ethical Review Board, Umeå University, SE-901 87 Umeå, Sweden. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

EE, AM, ML, AI, and MV designed the study. EE was responsible for data collection and designed the questions in collaboration with AI and finally revised the manuscript after all authors had critically reviewed the manuscript. MV, ML, and EE prepared the data for analysis. AM analyzed and interpreted the data in collaboration with ML and MV. EE, AM, and ML drafted the initial manuscript. AI and IÖ contributed in interpretation and

editing of the manuscript. All authors have read and approved the final manuscript for submission.

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Bridging the Gap for Children With Compound Health Challenges: An Intervention Protocol

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Background: During the last decades, there is a major shift in the panorama of diseases in children and adolescents. More children are referred to the specialized health care services due to less specific symptoms and more complex health challenges. These children are particularly difficult to care for in a "single-disease" oriented system. Our objective was to develop an alternative and more holistic approach better tailored to the complex needs of these children.

Method: The target patient population is children between 6 and 13 years with three or more referrals including both the pediatric department and the mental health services. Furthermore, to be included in the project, the child's actual complaints needed to be clinically considered as an unclear or compound condition in need of an alternative approach. This paper describes the process of developing an intervention where a complementary professional team meets the patient and his/her family altogether for 2.5 h. The consultation focus on clarifying the complex symptomatology and on problem solving. The bio-psycho-social model is applied, emphasizing the patient's story as told on the whiteboard. In the dynamic processes of development, piloting, evaluating, and adjusting the components, feed-back from the patients, their families, professional team members, and external team coaches is important.
The professional teams include pediatricians, psychologists and physiotherapists. Achieving the transformation from a logistic oriented team where members act separately toward a real complementary team, seems to be a success factor.

Discussion: Composing multi-disciplinary and complementary teams was an essential part of the re-designed intervention. Team interaction transforming the professionals from working as a logistic team to act as a complementary team, was one of the important requirements in the process. When re-designing the specialist health service, it is mandatory to anchor all changes among employees as well as the hospital leadership. In addition, it is important to include patient experiences in the process of improvement. Evaluation of long-term outcomes is needed to investigate possible benefits from the new intervention.

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Keywords: health, child, compound condition, health services, intervention

BACKGROUND

During the last decades, there has been a major shift in the panorama of diseases in children and adolescents (1). Today better diagnostics and improved treatments have allowed more children with previously life-threatening diseases to survive into adulthood. At the same time increasing sub-specialization of medical care is required (2). Concurrently, a growing number of children are referred to the specialized health care services due to less specific symptoms and more complex health challenges (3). Many of these children experience poor quality of life, impaired school attendance, and may end up unemployed as adults (4).

These shifts are challenging the specialized health services and their "single-disease" organization. Too many children with complex or unclear conditions receive un-coordinated services from different medical disciplines and units within the health care system. Patients "crossing over" between somatic and mental health care seem to be particularly affected. Many of these children end up with multiple referrals to the specialized health services (5, 6). Multiple referrals are a conundrum with high risk of unsatisfactory and delayed diagnosis and treatment. To improve the care offered these children, it is necessary to redesign the organization of services and develop new interventions with a more holistic approach. So far, no standardized guidelines have been developed for the care of these children.

To explore the patterns of specialized care for this patient group, we performed a register study in 2016, concentrating on repeated referrals as suggested by the WHO-definition of complex care (6–8). Our findings demonstrated that over a third of young patients had repeated referrals, and nearly 10 percent were referred to both somatic and mental health care during the observation period of 3 years. In addition, when considering non-specific diagnoses as an indicator of unresolved and unclear conditions, we found that a third of the patients still had a non-specific main diagnosis at the end of their hospital contact. Typically, specialists from different medical disciplines meet children with numerous symptoms from different organ systems, consecutively. Each specialist tends to make independent medical decisions. Often the symptoms do not merit for a diagnosis, and because of the unspecific nature of the symptoms, the specialists tend to focus their assessment on the exclusion of specific diagnoses (7). This makes joint and coordinated decisions and problem solving for patients with multiple or ill-defined symptoms difficult. Complementary skills and competence are warranted (9).

To prepare for the development of a more holistic intervention model, families of children with multiple referrals to our hospital were asked about their experiences and expectations of the health care providers (10). Similarly, we asked the family doctors and hospital professionals about their experiences in assessing this patient group. To improve the specialist health care service, it was considered important to focus not only on the logistics, but to create an approach including the perspective of clarifying the condition and problem solving.

To our knowledge, no previous study re-designing specialist health care services for this patient group has been conducted, despite the need. Our objective was to develop an alternative approach better tailored to the complex needs of this patient group in our clinical setting. The Medical Research Council (MRC) framework for evaluating complex interventions was taken as the basis for the present research (11). In **Figure 1**, we present our modification of the model, including the four major steps in the transformation process: Development, Piloting, Evaluation, and Adjustment, as well as their specific elements.

METHODS/ DESIGN

Key factors in designing an intervention model of this kind are target population, components of the intervention, professional team composition and interaction, as well as process and feasibility measures.

Population and Inclusion Criteria

As reported in a preceding hospital register study of children between 6 and 13 years, more than a third of patients had repeated referrals, and 9% of all patients were referred to both the pediatric department and the child and adolescent mental health services (CAMHS) (6). The pediatric sub-specialties most often included in such combined referrals were found to be gastroenterology and neurology. In an audit of 250 medical records randomly selected from these patients with multiple and combined referrals, we found that most of them were settled with well-established treatment- and follow-up programs. However, almost 15% of the children had multiple unclear health complaints and cumbersome and non-conclusive care pathways within the hospital (7).

According to the register research (6, 7), the initial four criteria were included in the operationalization of inclusion criteria:

1. Children aged 6 to 13 years referred to specialist health care services (Haukeland university hospital).

Abbreviations: WHO, World health Organization; MRC, Medical Research Council; TpT, Transitioning young patient's health care Trajectories; CAMHS, Child Mental Health Service; CARE, Consultations And Relational Empathy; ADHD, Attention Deficit Hyperactivity Disorder; QoL, Quality of Life; PREM, Patient Reported Experiences Measures; RCT, Randomized Controlled Trial.

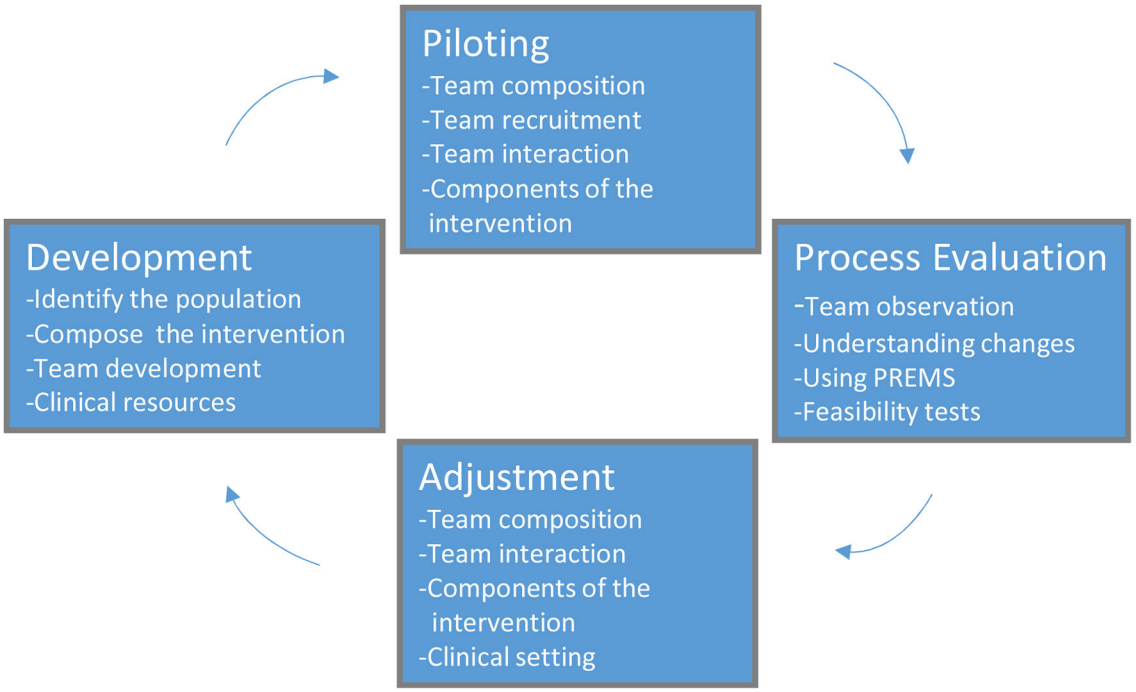

FIGURE 1 | The process of developing and adjusting the clinical intervention.

2. Three or more previous referrals within the last three years where at least one referral to CAMHS and one to the pediatric department.
3. The different referrals should all be independent of each other, and the most recent referral should be to ambulatory care.
4. The current referral further needed to be medically evaluated whether the actual health complaint(s) could be considered as an unclear or compound condition and in need of an alternative intervention. This evaluation was performed based on information from the referral letter and the patient's medical record/history by a senior clinician (IBE). Typically, selected patient histories were characterized by repeated referrals without any diagnostic conclusion or with unsuccessful treatment resulting in increased functional loss like school absence.

Parents of selected children meeting the inclusion criteria were invited by a phone call from a research nurse and given written information regarding the study. They were informed that the hospital had received a referral from the family doctor to a pediatrician; however, the medical record indicated need of a more interdisciplinary approach. The parents could decide whether they wanted to participate in the study or follow standard procedure meeting only the pediatrician. Written consent was obtained on the day of the consultation.

Team Composition and Interaction

After register studies in 2016–18, we started in 2019 developing the intervention. The project was initiated to improve the medical services offered in our hospital to children with multiple referrals for combined mental and somatic issues. Thus, it was reasonable to include both a pediatrician and a psychologist in the team. In our registry study, children with health problems related to gastrointestinal or neurological systems constituted the largest groups (6, 7). Thus, colleagues with long experience in gastroenterology and neurology were invited to participate in the professional teams. From the reviews of 250 medical records, it was perceived that many of the tangible patients ended up seeing a physiotherapist (7). Thus, physiotherapists with long experience in testing children both with somatic and mental health problems were invited to join the teams. The intention was that the teams should work to take mutual advantage of their professional background as pediatricians, psychologists, and physiotherapists.

In the hospital there is a long tradition for collaboration between different professions and professionals from different fields e.g., in the surgical theaters and trauma teams. However, most well-functioning hospital teams generally have highly defined roles and responsibilities (12). In the new chosen model of intervention, no such pre-defined roles were established.

The intention was to develop *complementary teams* where the team members use each other as "diagnostic tools" both in understanding what the patients and their families communicate as well as observing them. We judged it almost impossible for the professional members of the teams to reach this goal independently. Even more so if they should be able to include patient and parents in the team to reach a consensus on how to understand the patient's condition i.e., shared decision-making

TABLE 1 | Alternative outcomes of teamwork: Green cells illustrate better outcome than if the members work individually, orange means equal outcome as if the team members work individually, and red means worse outcome than if the team members work individually.

		Well-defined team task	
		Yes	**No**
Well-functioning team	Yes		
	No		

regarding both assessment and treatment of the child. Therefore, it was decided to engage an experienced external team coach. Simultaneously, the team development was included in a team research project using participating observational methods.

In the process of piloting the teamwork, the coach organized individual sessions and day seminars with the team members, and furthermore, observed all teams in action during the interventions. Different aspects of teamwork were addressed, focusing on team function and team tasks as illustrated in **Table 1**.

The coach challenged the team members on how to define the team task for each patient/clinical setting. Usually, the team task is well-defined, like in trauma teams. However, in the present setting the teams needed to define each time what tasks could best be approached together and what to approach individually. No cases were alike, and it often ended with a mix of joint and individual assessments. The team members found the variability difficult, but the awareness of this challenge really speeded up the team development resulting in almost a transformation of the teams.

A prerequisite for the intended team development was more stability in the teams, i.e., less swapping of members between teams and that they worked together more frequently. First, we restricted the possibility to move between teams. Such movements resulted not in four teams as planned, but rather 9 or 10 different team compositions. Secondly, we invited a second psychologist to join the project. Today, we have four different teams, two focusing on gastroenterology and two on neurology. Four pediatricians, three physiotherapists and two psychologists are engaged in the teams.

It might appear easy, but it is not, to use each other as *diagnostic tools* in reaching a joint perception of the patient and his/hers family. Most professionals are educated to make individual assessments and decisions but are far less trained in using other team member's different backgrounds as complementary instruments. Despite the professional part of the teams had a "flat" hierarchical structure with all professional team members as equal participants, it soon became obvious that one team member had to orchestrate the intervention to ensure that the program with the different components was followed and completed. It was necessary to choose the team leader before the intervention started. We have also experienced that how the different participants are seated in the room, who starts the conversation, and the use of tools like whiteboard, are important factors for the outcome of the intervention.

TABLE 2 | The initial draft for the components of the intervention.

Time schedule	Patient
20 min	Introduction
	Meets the whole team
10 min	Short discussion in the team without patient
45 min	Meets the pediatrician
45 min	Meets the physiotherapist
45 min	Meets the psychologist
15 min	Short discussion in the team without patient
15 min	Whole team, summary, conclusion and further plan
4 weeks later	Follow up
45 min	Whole team

To summarize, team composition and interaction transforming the professionals from working as a logistic team to act as a *complementary team,* is one of the important requirements in this new intervention.

Components of the Intervention

Based on the Bio-psycho-social model and the guidelines from Kozlowska and Turn the intervention took form. Kozlowska has outlined a framework for interviewing families whose children present with medically unexplained symptoms (13). This model aims to connect body, mind and social environment in understanding the symptom presented in the child (14). Factors maintaining the symptoms should be explored as well as components of stress. Further, self-regulation is another issue that should be addressed in order to promote health to the child and his/her family.

Based on our traditional thinking, the first draft of intervention was a well-organized setup of three consecutive consultations with the three professionals individually. Afterwards the professional team members had a secluded discussion of their findings before they presented a conclusion and a plan to the patient and the family (**Table 2**). However, already after a few tests, this setup seemed too stressful and time consuming for the families. Families also expressed dissatisfaction with having to repeat their history and the child's health problems three times to the different professional team members.

According to the experiences disclosed above, a revised schedule for the intervention was set up (**Table 3**). Before the intervention starts, the patient and her/his family answer questionnaires regarding health status and previous experiences with the health care systems. Concurrently, the professional team prepares together for the intervention based on information obtained from the medical record and referral letter, and decide who should be orchestrating the intervention. The intervention starts with patient and parents sharing their concerns and health complaints to the joint team. Then the professional members of the team discuss secluded and customize a program for the rest of the intervention emphasizing on what further information is needed and what subjects to assess. Then the assessment takes place. This part is individualized to each patient and could include further interviews and/or clinical examination. Given

TABLE 3 | Final structure for the intervention.

Time schedule	**Patient and family**	**Professional team**
30 min pre-intervention	Meet the research nurse and fill out the questionnaires	Prepare the intervention
15–30 min	Patient and its family share their concerns and health complaints to the joint team	
15 min		Secluded planning of the intervention
45–60 min	Intervention/ Diagnostic assessment	
15 min		Secluded reflection on findings
	Summarizing the day and agreement on further interventions.	
4–6 weeks later	Follow-up	

the heterogeneous nature of this patient group, no standardized approach is given, but must be individualized according to the situation presented. Before rounding up, the professional part of the team summarizes the assessment secluded. Finally, the complete team including patient and his/her parents make a shared decision on how to understand the condition, if further clinical examinations are needed, and establish a treatment plan.

As requested by family doctors, it has been emphasized that the assessment should conclude with one joint statement from the professional team, where the pediatrician, physiotherapist, and psychologist reach a consensus. Further, the team was encouraged to include the patient and his/ her family in a common understanding of the problem and the proposed treatment- or follow-up plan.

Narrative Diagnostics

Aiming to support the child with life-coping strategies one has to take the perspective of the child regarding communication. It is too easy to address the child by many questions regarding symptoms. Addressing the symptom of the child through externalizing children's "problem" using play or narrative elements is described as an alternative tool when children are unable to verbalize their inner ailment (15). Grant and Ushers (16) highlight using whiteboard as a tool that not only slow down the conversation, but also help the professionals to listen and humbly take part in the child's world and understanding of their situation. Instead of words, the child can draw a picture expressing themselves in a different way. Initially in our pilot testing the intervention, this method was tried out by the teams. Feed-back from the families supported such a concept as an important tool in communication with the child, and furthermore, that the child experience that they are listened to.

Treatment Plan

After listening to the story of the patient and his/her parents and understanding the child's health challenges, it must be decided if further medical evaluations are necessary in order to fully understand the child's s health problems. Agreeing on and creating a treatment plan is the final step of the consultation. After the first 10 pilot tests, it became obvious that most families wanted to make a new appointment with the team after 4 to 6 weeks. Meanwhile, eventually further assessment or psychological support from team members could be accomplished.

Clinical Setting

Our project acquired resources from the national research council to perform the register studies (6, 7). However, it has been more difficult to get external support to develop and test the new intervention. Accordingly, we have chosen to implement the pilot in the ordinary clinical setting. To make this possible, it was necessary to include the leaders of the involved departments in our planning as the project's steering committee. Their acceptance and support have been mandatory to be able to prioritize the involvement of the team members. In addition, the core researchers have used a lot of time on information regarding the objectives of the new intervention as well as our experiences in composing teamwork.

Process and Feasibility Measures

The Process

The process of developing an alternative and innovative intervention model, recognizing the need for a structured and holistic clinical outpatient approach, has been long and challenging. Understanding and recognizing the need for changing attitudes and ways of cooperation has been essential. There has been a continuous communication with the team members through regular lunches for the professional team members and core research group where different aspects of the project have been addressed. Midway we organized a workshop focusing on feedback from the users, coach, experiences from the team members, and the researcher following the teams. The final intervention model as described was anchored at the steering committee.

Feasibility Measures

The project has developed a set of feasibility outcome measures. User's experiences are mandatory in the evaluation and further improvement of the provided health care. In the present study, three users are identified: Patient (child), parents, and professionals. Questionnaires targeting the different users have been developed for the present study.

In order to get information from *the children* themselves on how they experience meeting a complementary team of different professionals, they are asked to answer a five items questionnaire;

TABLE 4 | Areas covered in the different questionnaires regarding feasibility of the new intervention.

Responder	Questions
Patient	How content are you with the help you received today?
	1 = Not at all to 4 = Very content
	If a friend needed help like what you have received today would you recommend this intervention:
	1 = Not at all to 4 = Yes
Patient	How was the team at making you feel happy and relaxed?
CARE*	*(Being friendly and caring and making you feel calm)*
	1 = Not very good to 5 = Excellent
	How was the team at asking questions and letting you talk?
	(Being interested in you and giving you time to speak)
	1 = Not very good to 5 = Excellent
	How was the team at listening and understanding?
	(Paying attention and knowing the things you find difficult)
	1 = Not very good to 5 = Excellent
	How was the team at explaining things?
	(Answering questions, giving you a clear information and instructions)
	1 = Not very good to 5 = Excellent
	How was the team at making a plan?
	(Encouraging you, talking about what to do next, involving you as much as you want)
	1 = Not very good to 5 = Excellent
Parents	How content are you with meeting the team?
	1 = Not at all to 4 = Very content
	If a friend needed help like you have received today would you recommend it?
	1 = Not at all to 4 = Yes
Team	Was the intervention today useful for the child?
	1 = Not at all to 4 = Very useful
	Was the intervention today useful for the parents?
	1 = Not at all to 4 = Very useful

CARE: The consultations and relational empathy questionnaire, Mercer S.

The consultations and relational empathy (CARE) measures are given in **Table 4** (q 17–20) (18–21).

Prior to the intervention, *the parents* will answer a questionnaire regarding their previous experiences with the specialist health services. After the intervention, they answer a questionnaire regarding their opinion/experience with the intervention and the professional team (**Table 4**). After each intervention, the *professionals in the team* are evaluating themselves by answering a questionnaire together. Areas addressed are how the team perceived the complexity of the patient's condition, as well as giving their evaluation of how useful the team anticipated this intervention was for the child and the family (**Table 4**).

DISCUSSION

Based on our clinical experiences, the demonstrated complex patterns of care for patients with repeated referrals, as well as the experiences of families, we aimed to develop and pilot a new intervention. The intervention include multidisciplinary, complementary teams consisting of pediatricians, psychologists, and physiotherapists. In the process, a stepwise progression was applied using repetitive evaluations and adjustments was followed as described in **Figure 1** (11).

Population—Inclusion Criteria

Children with multiple and unclear health complaints and, therefore, multiple referrals, are well-known in clinical practice. However, to define and operationalize their characteristics unequivocally is challenging. Our project aims to identify the children who might benefit from this specific innovation of redesigned health care.

Only focusing on multiple referrals are not suitable as a single criterion for complexity even if they include referrals both to somatic and mental health care. Many children have entirely independent health complains like a broken leg, medial otitis, and ADHD, which are better managed separately. However, from our previous registry study, there was a difference in children with less compared to more than three referrals including one to pediatrics and one to CAMHS (6). Therefore, we used more than three referrals including one to pediatrics and one to CAMHS for the primary selection of children. However, the complexity and the unclear symptom picture are important features as well as the functional status like school attendance. Therefore, an experienced clinician making a secondary and final selection based on the referral letter and the child's medical record is recommended.

The professional team members argued already from the beginning for including children with unclear health problems resulting in school refusal without having been referred to CAMHS, and for a higher upper age limit. In their clinical practice, the main problems were related to teenagers, 13–16 years of age. This criterion needs to be tested in future intervention studies. In the registry study (6, 7), children with referrals to either the gastroenterology or the neurology units made up the majority of patients. Thus, pediatricians working within these two units were recruited to the teams. The pediatricians were, however, reluctant to include patients in need of assessment from other medical disciplines. Accordingly, only patients with the latest referral to either gastroenterology of neurology were included in the pilot study. However, there is reason to assume that our intervention is generalizable to other medical disciplines.

Team Composition and Interaction

The construction of teams consisting of a pediatrician, physiotherapist and psychologist was hitting the target already from the start (6, 7). The teams appear able to deal with patients with a broad specter of complex, unsolved and unspecific health problems. However, there are some prerequisites; i.e., one should pick experienced professionals who still have maintained a relatively broad medical perspective. Thus, it is a great advantage

that all the pediatricians in the teams participate in general on-calls in the pediatric department.

Transforming teams from "logistic" interdisciplinary teams to "complementary" teams was more demanding than predicted. All the team members are used to work in interdisciplinary teams where their roles and responsibilities are well-defined. They are also used to discuss patients with colleagues from other professions. It is necessary for the professionals in the teams to know each other well-enough to have confidence in each other professionally, but also in facing the patient and the parents. Trust is built over time and requires stable teams that meet frequently enough not to start over again every time. Thus, we recommend that all teams meet at least every second week, and swapping between teams should be avoided. Another lesson learned is the need of debriefing for the team due to the complexity and often heavily burdened situation for the patient and family. This also contributed to the building of trust within the teams.

Initially, the hierarchical thinking that the physician should lead the conversation prevailed. This always led the intervention in a somatic direction. However, the patient and the family could more readily address other and even non-medical issues when other team members opened and orchestrated the conversation. The importance of this shift was encouraged by the external coach who often commented on the hierarchical culture within the teams, and challenged the professionals to change mindset. Therefore, recommendations from piloting is to let non-medical professional lead the conversation.

Intervention Components

Meeting a team of three professionals in addition to both parents, could be overwhelming for a child. However, in the test period both children and parents expressed their contentment with the holistic approach and were comfortable in the situation. Having the psychologist in the team was a strength reported from several parents even when they beforehand expressed skepticism toward participation of a psychologist.

In its final setup, each intervention last 2.5 h, where patient, family members and the professionals in the team spend most of the time together. This could seem too long, but after testing the model both professionals and families agreed that spending that long time together, gave the family confidence that the professionals had understood their problems and taken the family seriously. Early it appeared that many patients and their families need a second appointment, sometimes after further examinations or individual appointments with either the physiotherapist or psychologist. Four to six weeks after the first intervention has shown to be the best in most cases. Nevertheless, it is mandatory that the children meet the same team as the first time.

Process and Outcome Measures

In the processes described here, we have focused on creating the intervention and the feasibility measures. Both feasibility measures as well as short- and long- term outcome measures are needed. So far, children have been able to provide useful information through the CARE questionnaire and we recommended this in future studies.

For effect measures, mental and somatic health status, QoL, PREMs, as well as school attendance and the use of health services following the intervention, are fundamental dimensions that will be covered in our future studies. Further, we plan to include a control group in the last step of a RCT study.

Another aspect of outcome measures are the financial consequences for the health care system as previous mentioned by Heggestad (6). No consensus is given in how to economically evaluate implementation of new interventions (17). However, economic outcomes will be obtained both in terms of use of healthcare services, parent's work ability as well as children's school attendance.

CONCLUSION

To develop an alternative approach better tailored to the complex needs of children referred repeatedly to different medical disciplines, turned out to be a demanding process. Composing multi-disciplinary and complementary teams was essential. The interaction within the teams, transforming the professionals from working as a logistic team to act complementary, was a decisive in the process. Furthermore, this transformation seems to be the success-factor. When re-designing the specialist health service, it is mandatory to anchor all changes among employees as well as the hospital leadership. In addition, it is important to include patient experiences in the process of change.

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 Regional Committee for Medical Research Ethics (REK Vest) (REC 2018/344). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

IE, TH, RT, and GG have contributed in developing the protocol and writing the manuscript and fulfill the Vancouver criteria for participation. All authors read and approved the final manuscript.

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SYSTEMATIC REVIEW
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Is the Health Behavior in School-Aged Survey Questionnaire Reliable and Valid in Assessing Physical Activity and Sedentary Behavior in Young Populations? A Systematic Review

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Backgrounds: Using the self-reported questionnaire to assess the levels of physical activity (PA) and sedentary behavior (SB) has been a widely recognized method in public health and epidemiology research fields. The selected items of the Health Behavior in School-aged (HBSC) Survey Questionnaire have been used globally for measurements and assessments in PA and SB of children and adolescents. However, there are no comprehensive and critical reviews to assess the quality of studies on reliability and validity of selected items for PA and SB measurement and assessment derived from the HBSC. Thus, this review aimed to critically assess the quality of those studies and summary evidence for future recommendations.

Methods: A systematic review protocol was used to search potentially eligible studies on assessing reliability and validity of PA and SB measures of the HBSC questionnaire. electronically academic databases were used. The information on the reliability and validity of the PA and SB measures were extracted and evaluated with well-recognized criteria or assessment tools.

Results: After a literature search, six studies were included in this review. The reliability of PA measures of the HBSC questionnaire showed a moderate agreement while the reliability of SB measures showed a great variation across the different items in the different subgroups. The validity of the PA measures had acceptable performance, whereas no studies assess the validity of the SB measures. The included studies all had quality weaknesses on reliability or validity analysis.

Conclusions: The PA and SB measures of the HBSC questionnaires were reliable in assessing PA and SB among adolescents. However, a little evidence showed that PA measures are partially valid in assessing PA, but no evidence confirmed the validity of SB

measures. The included studies all had methodological weaknesses in examining the reliability and validity of the PA and SB measures, which should be addressed in the future. Further studies are encouraged to use a more standardized study design to examine the reliability and validity of the PA and SB measures in more young populations.

Keywords: behavioral epidemiology, physical activity, sedentary behavior, measurement, children and adolescents, health behavior in school-aged children

INTRODUCTION

It is well-known that sufficient physical activity (PA) and limited sedentary behavior have been two key determinants of health outcomes among children and adolescents, such as improved fitness, reduced body fat, increased cognitive ability, lower levels of depression and anxiety as well as fewer suicidal attempts (1–8). The World Health Organization (WHO) and some national health sectors have released the guidelines on PA and SB based on epidemiological evidence, which recommend that children and adolescents should amass at least of 1 h for moderate to vigorous PA and <2 h of SB during leisure time (9, 10). Despite numerous health benefits resulting from PA and SB based on convincing evidence, the prevalence of meeting the PA and SB guidelines was not ideal. Specifically, a global study including 1.6 million participants by Guthold et al. (11) reported that only about 20% of adolescents were physically active according to the PA guidelines. This result was highly similar to another study published in the Lancet 2012 PA Research Series (12). In the face of this concerning public health issue, it is of vital significance to promote PA while discouraging SB concurrently among children and adolescents (13).

To increase PA and decrease SB, an essential step is to know and understand the actual levels of PA and SB (e.g., prevalence of meeting the PA or SB guidelines, or time spent in PA or SB) accurately (12, 14–16). At a populational level, using self-reported questionnaires to collect data or information on PA and SB is a feasible and economical measurement because of its lower costs, reduced testing burdens, and easy data management (17–20). To date, there are many specific questionnaires to assess PA and SB level, such as the International Physical Activity Questionnaire (IPAQ), the Global Physical Activity Questionnaire (GPAQ) (21), the Health Behavior in School-aged Questionnaire (HBSC) (22). These questionnaires have been used frequently across the populations in different countries (23–30). Among the three questionnaires, the HBSC questionnaire is typically designed for assessing child and adolescent health behaviors, including PA and SB. In the HBSC questionnaire, some selected items are used for PA and SB measurement, of which four items were used for PA measurement and eight items were used for SB measurement. Using the measures from the HBSC questionnaire for PA and SB (selected items), many national estimates, reports, or studies of levels in PA and SB at the young population level have been published previously (31–33), which in turn provide national comparable evidence.

Although the PA and SB measures derived from the HBSC questionnaire has been tested for reliability and validity in multiple young populations (e.g., Chinese, Japanese, and Slovakian) (34–36), no systematic review studies assess those studies comprehensively and summarize evidence on reliability and validity of the PA and SB measures. This would be a barrier to making an overview of the studies using the PA and SB measures of the HBSC questionnaire. Also, being unaware of the quality of these studies is indeed a critical question for further behavioral epidemiological research and populational monitoring and surveillance. Another issue on this research topic is that there are no studies to assess the quality of studies on reliability and validity of the PA and SB measures. If researchers understand the information on reliability and validity, it would be beneficial to understand the assessed PA and SB levels among the young population through the HBSC questionnaire.

Thus, this review aimed (1) to comprehensively assess the studies on reliability (test-retest) and validity (criterion) of PA and SB measures derived from the HBSC questionnaire; (2) to evaluate the testing performance of PA and SB measurements of the HBSC questionnaire. It could be expected that this review can provide valued and supportive information for future studies using the HBSC questionnaire to assess PA and SB, and then offer implications for future research recommendations.

METHODS

Literature Search

To achieve the research aims of this study and followed PRISMA guidance, 6 electronic databases were used to perform the literature search, including EBSCO (Full), Elsevier, Medline, PubMed, SPORTDiscus, and Web of Science. The following search terms were used: (1) measure*(i.e., measures, measurement), assess*(i.e., assessed, assessment), (2) reliab* (i.e., reliable, reliability), (3) valid*(i.e., valid, validation, validity), (4) accura*(i.e., accurate, accuracy), (5) observ* (i.e., observed, observation), (6) propert*(i.e., property, properties), (7) consistency, (8) agreement, and (9) health behavior in school-aged children as well as 10) HBSC. The literature search was done on 31 December 2020, by two authors (SC and JH).

Selection Criteria

Papers based on the searches were screened against the following inclusion criteria: (1) full-text original report published in a peer-reviewed journal; (2) the study participants were healthy or typically developed; (3) the study participants were children or adolescents; (4) the study that reported either reliability or validity information of PA or SB measurement; (5) published language is English. The exclusion criteria for study selections

detailed: (1) studies published as a conference paper, review, or meta-analysis; (2) studies published not in English; (3) studies not using measures for PA and SB from the HBSC questionnaire. Finally, following the literature search protocol and study screening process (see **Figure 1**), 6 eligible studies (34–39) meeting the literature selection criteria were included in this review.

Data Extraction

Information was extracted from the included studies regarding the first author, published year, sample characteristics (e.g., sample size, % of sex), PA and SB measures (questions of PA and SB measures), statistical analyses, information on reliability (e.g., intraclass correlation coefficient, ICC; interval days) or validity (e.g., criteria validity correlation coefficient; objective standard). Two independent reviewers (YS and YZ) conducted data extraction, and any disagreement of them was discussed with and resolved by a third author (HW). If some studies reported the information on reliability and validity by age (grade) groups, sex, or other sociodemographic factors, those results were also extracted. The extracted data from the included studies are shown in tabular format.

Methodological Quality Assessment of the Included Studies

Using the consensus-based standards for the selection of health measurement instruments (COSMIN) (40), the included studies were rated. This checklist was used for the assessment of the methodological quality of the included six studies. Two authors (YS and YZ) of the review independently conducted the quality assessment; any differences between the independent assessments were resolved through discussion between the third author (HW) until they reached an agreement. For test-retest reliability, 10 mandatory items involved study design for quality assessment, and 4 optional items involved depended on each the statistical analysis of each study (some studies used ICC while others used Cohen's kappa to assess the reliability). Hence, the full score the of test-retest reliability analysis of each study were not the same (11–14 scores). For criterion validity, five mandatory items involved study design for quality assessment and two optional items involved depended on each study's statistical analysis. Hence, each study's full score of validity analysis varied (6 or 7 scores).

For the results of reliability and validity (coefficients), the criterion developed recommended by Landis and Koch (41) was used to assess the performance of reliability and validity of each included study. This criterion has been used frequently across the previously published studies (42–46). In detail, coefficient values of < 0.2 were considered poor, 0.21–0.4 were considered fair, 0.41–0.6 were regarded as moderate, 0.61–0.8 were deemed substantial, and 0.81–1.0 was almost perfect.

RESULTS

Table 1 summarizes the specific questions or items for PA and SB measures derived from the HBSC questionnaire. In detail,

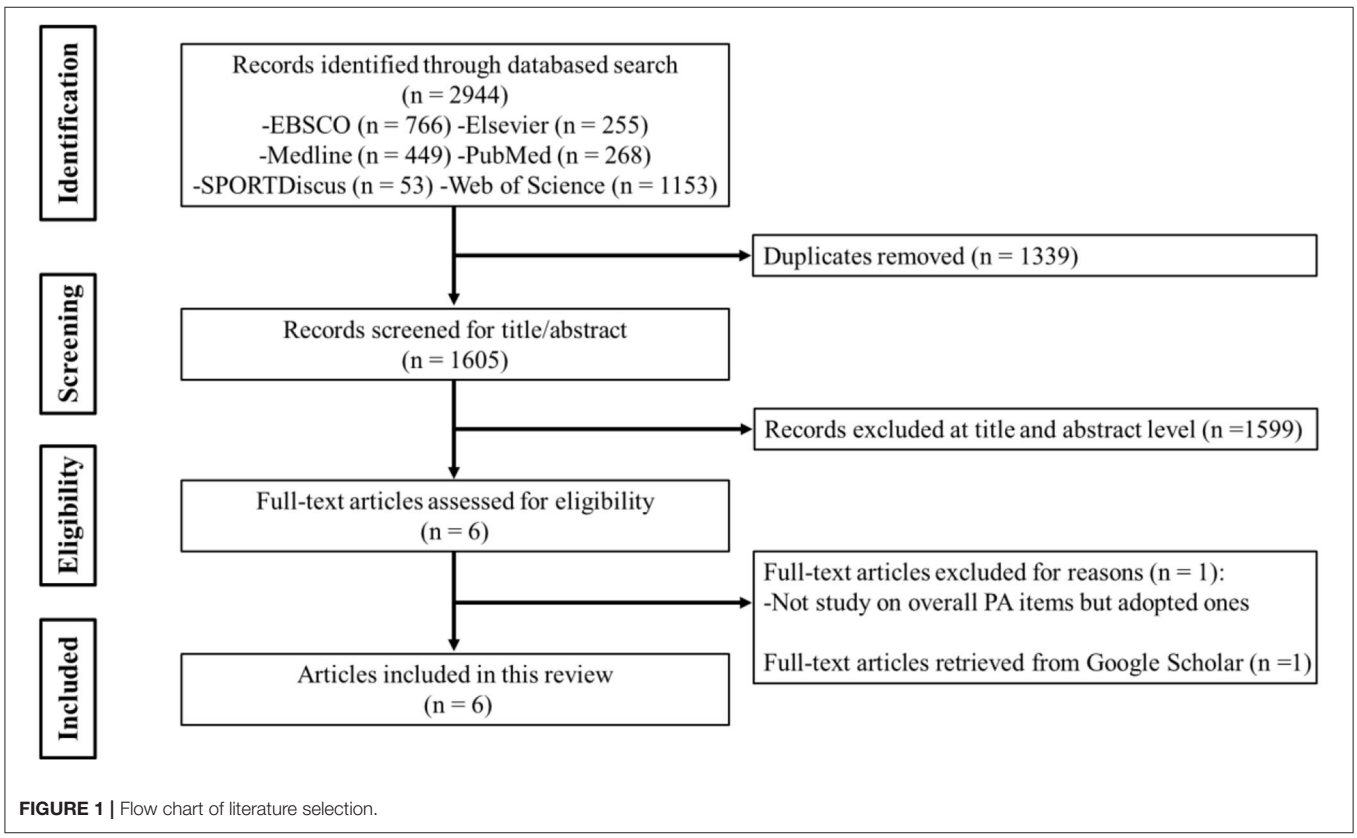

FIGURE 1 | Flow chart of literature selection.

TABLE 1 | Specific questions and their responses of each included study used as physical activity and sedentary behavior in this review.

HBSC measures	Questions	Measured domains	Responses
Physical activity	Over the past 7 days, on how many days were you physically active for a total of at least 60 min per day?	Moderate to vigorous physical activity over the past week (past week MVPA)	0 days; 1; 2; 3; 4; 5; 6; 7 days
	Over a typical or usual week, on how many days are you physically active for a total of at least 60 min per day?	Moderate to vigorous physical activity over the usual week (typical week MVPA)	0 days; 1; 2; 3; 4; 5; 6; 7 days
	Outside school hours: How often do you usually exercise in your free time so much that you get out of breath or sweat?	Frequency of vigorous physical activity (VPA frequency)	Daily; 4–6 times a week; 2–3 times a week; Once a week; Once a month; Less than once a month; Never
	Outside school class: How many hours a week do you usually take physical exercise in your free time so that you lose your breath or sweat?	Duration of vigorous physical activity (VPA duration)	None; About. half an hour; About. an hour; About. 2–3 h; About 4–6 h; 7 hours or more
Sedentary behavior	How many hours a day, in your free time, do you usually spend watching TV, videos (including YouTube or similar services), DVDs, and other entertainment on a screen on weekday and weekend days, respectively?	TV time	None at all/About half an hour a day/About 1 h a day/About 2 h a day/About 3 h a day/About 4 h a day/About 5 h a day/About 6 h a day/About 7 or more hours a day
	How many hours a day, in your free time, do you usually spend using electronic devices such computers, tablets (like iPad), or smartphones for other purposes, for example, homework, emailing, tweeting, Facebook, chatting, surfing the internet on weekday and weekend days, respectively?	Computer time	
	Outside school hours: How many hours a day do you usually spend time sitting in your free time (for example, watching TV, using a computer or mobile phone, traveling in a car or by bus, sitting and talking, eating, studying)?	Sitting time	

HBSC, Health Behavior in School-aged Children; TV, television.

PA measures of the HBSC questionnaire cover four indicators of PA, including moderate to vigorous PA (MVPA) over the past week or over the usual week, frequency of vigorous PA (VPA), and duration of VPA. Concerning SB measures of the HBSC questionnaire, TV time, computer time, and sitting time are three main domains of assessed SB. The responses to each question or item are shown in **Table 1** as well.

Table 2 presents specific information of the included study in this systematic review. The published year of the included studies ranged from 2001 (39) to 2019 (37), with an interval of 18 years. The sample size of the included studies ranged from 70 (36) to 2,752 (37). The six included studies were conducted in Finland (37), Japan (36), Slovakia (35), Czechia (35), Poland (35), China (34), Norway (38), and Australia (39). Most studies targeted study participants as adolescents aged 11–15 years. Five studies conducted test-retest reliability analysis for PA measures (34, 35, 37–39) while only two studies conducted test-retest reliability analysis for SB measures (34, 35). Only three studies performed validity analysis for PA measures (36, 38, 39). No studies assess the criterion validity for SB measures in the included studies. Concerning the statistical method for test-retest reliability and criterion validity, intraclass correlation coefficient and Spearman rank correlation were used frequently across the included studies.

Supplementary Table 1 shows the summarized results of coefficients of reliability and validity as well as their evaluated performance of the included studies in this review. In terms of the reliability of PA measures, most included studies reported that coefficient test-retest reliability coefficient ranged from about 0.5 to about 0.8, regardless of PA measurement items and subgroups, which indicated that PA measures showed moderate (or above) test-retest reliability (34, 35, 37, 38). In the two studies reporting the reliability coefficients of SB measures (34, 35) and the coefficients of different SB measures varied greatly (from 0.16 to 0.90; signifying poor to almost perfect) (34, 35). The two studies that reported the validity coefficients of PA measures showed, indicating a fair level of validity performance in PA measures (36, 38).

Table 3 exhibits the methodological quality assessments of the included studies for reliability analysis using the COSMIN tool. The scores of quality assessment varied from 4 to 7. Although four studies had a full score of 11 while another study had a full

TABLE 2 | Basic information of the included studies.

References	Sample characteristics	Test-retest reliability				Criterion validity			
		PA	SB	Intervals	Statistics	PA	SB	Standard	Statistics
Ng et al. (37)	*n* = 2,752 Age: 11 yrs, 13 yrs, and 15 yrs	Past week MVPA	/	/	ICC	/			
Tanaka et al. (36)	*n* = 70 (boys = 33) Mean age: 11.3 yrs		(1) Past week MVPA (2) VPA frequency (3) VPA duration	/	Accelerometer	Spearman rank			
Bobakova et al. (35)	*n* = 693 (11 yrs = 362; 15 yrs = 331) Slovakia (*n* = 227) Czech (*n* = 353) Poland (*n* = 113)	(1) Past week MVPA (2) VPA frequency	(1) TV use (weekdays and weekend) (2) Computer use for play (weekdays and weekend) (3) Computer use for other purposes (weekdays and weekend)	1–4 w	ICC	/			
Yang et al. (34)	*n* = 95 (11 yrs, 15 yrs)	(1) Past week MVPA (2) Typical week MVPA (3) VPA frequency (4) VPA duration	(1) TV use (weekdays and weekend) (2) Computer use for play (weekdays and weekend) (3) Computer use for other purposes (weekdays and weekend)	3 w	ICC	/			
Rangul et al. (38)	*n* = 71 (boys = 31); Mean age: 14.9 yrs (13–18 yrs)	(1) VPA frequency (2) VPA duration	/	8–12 d	ICC	(1) VPA frequency (2) VPA duration	/	VO_2max; Energy expenditure; Physical activity level	Spearman rank
Booth et al. (39)	Reliability study 8 yrs (*n* = 121) and 10 yrs (*n* = 105); Validity study 8 yrs (*n* = 1,072) and 10 yrs (*n* = 954)	(1) VPA frequency (2) VPA duration	/	2 w	Kappa and Agreeme-nt (%)	(1) VPA frequency (2) VPA duration	/	Aerobic fitness test	Regression

PA, physical activity; SB, sedentary behavior; MVPA, moderate to vigorous physical activity; VPA, vigorous physical activity; w, week(s); d, day(s); /, not available or not studied.

TABLE 3 | Methodological quality assessment for test-retest reliability of the included studies.

References	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Item 12	Item 13	Item 14	Total score
Ng et al. (37)	No	No	Yes	No	No	No	Yes	No	No	No	Yes	/	/	/	5*
Bobakova et al. (35)	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	/	/	/	8*
Yang et al. (34)	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	/	/	/	7*
Rangul et al. (38)	No	No	No	No	Yes	Yes	Yes	No	Yes	No	Yes	/	/	/	6*
Booth et al. (39)	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No	/	Yes	No	No	8[&]

*/, not available in this study; item 10 is negative counting (No = 1 score); *full score is 11; [&]full score is 13.*

TABLE 4 | Methodological quality assessment for validity of the included studies.

References	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Total score
Tanaka et al. (36)	No	No	No	Yes	No	Yes	/	3*
Rangul et al. (38)	No	No	No	Yes	No	Yes	/	3*
Booth et al. (39)	No	No	Yes	No	No	Yes	/	3*

*/, not available; item 5 is negative counting (No = 1 score); *full score is 6; COSMIN (40): consensus-based standards for the selection of health measurement instruments.*

score of 13, the results of each study's quality assessment were not high.

Table 4 displays the methodological quality assessments of the included studies for validity analysis using the COSMIN tool. The three studies that conducted validity analysis all gained 2 scores on quality assessment, indicating low quality.

DISCUSSIONS

This comprehensive review summarized the evidence on the reliability and validity of PA and SB assessments derived from the HBSC questionnaire. This review also assessed the methodological quality of each study included that conducted reliability or validity analysis using the COSMIN tool (40). This systematic review had some research findings as follows. First, we found that only a few studies have examined the reliability and validity of PA and SB measures derived from the HBSC questionnaire. Second, the reliability of PA measures showed an acceptable level across the included studies while the validity of PA measures presented a fair level. Third, the reliability of SB measures showed a great variation in the performance while no studies assess the validity of SB measures. Fourth, the quality assessment revealed that studies that conducted reliability and validity of PA and SB measures derived from the HBSC questionnaire all showed a low quality, which casts doubts on those studies' results and findings.

PA and SB measures of the HBSC questionnaires have been used in many national surveys, such as in China (47–49) and some European countries (24, 50, 51). However, this review revealed that only a few studies have examined the properties of these measurements in particular populations (34–39). The limited number ($n = 6$) of targeted studies indicated that these PA and SB measures have limited feasibility and utility in other young populations. On this standing, more studies in the future are encouraged to examine the reliability and validity of the PA and SB measures because adequate and vigorous validation on PA and SB measures derived from the HBSC questionnaire is an essential foundation for large-scale use (34, 36). With more studies on the reliability and validity of PA and SB measures of the HBSC questionnaires, its adaptability can be enlarged into different cultures, countries, and societies (39).

Another interesting finding in addition to a few studies that conducted reliability and validity assessments is that some age groups were missing from the reliability study. For example, in Yang et al. (34), the authors' study failed to examine the reliability of PA measures in adolescents aged 13 years. In Ng et al. (37), they did not include adolescents aged 12–14 years. Such issues also occurred in other studies (35, 39). Thus, theoretically, the current evidence can only inform the PA measures had satisfactory reliability in some particular adolescents with specific ages instead of all the adolescent populations. We thereby advocate that more studies should address this issue to expand the generalizability that PA measures are reliable for adolescents with a wider age range.

This review found that PA measures of the HBSC questionnaire show an acceptable test-retest reliability. This in turn indicates that the PA measures of the HBSC questionnaire are a reliable measure to collect PA data or information in adolescent populations. Interestingly, only one study by Yang et al. (34) examined the reliability of PA over the usual week and this study showed that this question for PA measure had satisfactory reliability in Chinese samples (Beijing). However,

the current evidence is insufficient to support this kind of PA measure having good reliability. It is therefore urgently needed to examine the reliability of measurement of usual weekly PA by more studies in the future.

Concerning the reliability of SB measures, only two studies reported the coefficient values (34, 35), which indicated that different questions of SB measures had varying coefficients of reliability across different subpopulations. For example, in Polish samples, the questions of sitting measures had coefficients over 0.9 of reliability, indicating a perfect performance (35). However, those measures showed a poor performance in the Chinese samples of 15 years in Yang et al.'s study (34). Such a large inconsistency may be owing to different measurement protocols, sociocultural country differences (34, 35). However, overall, the SB measures of the HBSC questionnaire showed moderate (acceptable) reliability regardless of sex, age, and national difference. This suggests that SB measures of HBSC are reliable in capturing information on SB among adolescents. We still recommend that more studies should re-examine the reliability of SB measures of the HBSC questionnaire in more young populations.

There were two included studies in this review that examined the validity of PA measures of the HBSC questionnaire (36, 39), demonstrating fair to moderate performance in validity. This evidence could illustrate that PA measures of the HBSC questionnaire are partially valid in assessing young people's PA. However, only two studies examining the validity of PA measures are inadequate to inform any robust conclusion that PA measures of the HBSC questionnaire are valid when assessing PA in younger populations with different socio-cultural backgrounds. More studies are encouraged to conduct validity analysis in other young populations.

Surprisingly, no studies so far assessed the validity of SB measures of the HBSC questionnaire in the current review. It is therefore acknowledged that the SB measures of the HBSC questionnaire may not be valid in assessing SB among adolescents. We also have to admit that assessing SB is a complex scientific issue (15, 52). However, because SB measures of the HBSC have been used frequently in many national surveillances, knowing the validity of SB measures is a vital foundation to estimate SB more accurately. Thus, addressing this research gap would be greatly beneficial to increase the use of SB measures of the HBSC questionnaire across the world. To achieve these research aims, well-designed measurement protocols are strongly recommended in the future.

This systematic review assessed the study quality of the included studies, which found that the included studies had quality shortcomings when conducting test-retest reliability and validity. For the studies that conducted test-retest reliability, there were some methodological issues. For example, according to the COSMIN guidelines, some studies did not include sufficient sample size (recommended sample size = 100) to perform the test-retest reliability analysis (34, 38). One study by Ng et al. even failed to report the interval days for test-retest reliability (37). Similar quality weaknesses of the included studies that conducted validity analysis were also observed. For example, Booth et al.'s (39) study used an aerobic fitness test to examine the validity of PA measures. However, it is well-known that the aerobic fitness test can be viewed as a goal-standard for PA measures validity examination. In addition, there were research issues involving sample size for validity study (36, 38). In this regard, it is noticeable that previous studies that conducted reliability or validity analysis for PA and SB measures of the HBSC questionnaire had some inherent study design shortcomings, which may negatively influence the interpretations of the results of the studies. It is strongly recommended that future studies should undertake more standardized and rigorous study design to examine the reliability and validity of PA and SB measures of the HBSC questionnaire.

Study Strengths and Limitations

A primary strength of this review is that we firstly assessed literature for evidence on reliability and validity of PA and SB measurements derived from the HBSC questionnaire. This study highlights the challenges of using the HBSC questionnaires in many populational surveillance surveys across the world. Second, concerning the studies that examine the reliability and validity of PA and SB measures of the HBSC questionnaire, this review is first to assess the study quality, which can identify research gaps for future similar studies. Third, this study provides strong evidence of the validity and reliability of PA and SB items from the HBSC questionnaire, standardizing the use of the questionnaire in future research. However, one study limitation should be mentioned in our review. This limitation is that the literature search and included studies are restricted in English, which may omit some studies published in other languages.

CONCLUSIONS AND RECOMMENDATIONS

This study offers systematic evidence on the reliability and validity of the HBSC questionnaire (selected items) in assessing PA and SB among young populations across the world. This systematic review study indicates that PA and SB measures of the HBSC questionnaire are reliable (moderate agreement) in assessing PA and SB among adolescents. However, when assessing PA, the PA measures show fair to moderate performance, indicating being partially valid. The validity of SB measures remains unknown, which should be filled by future research.

Based on the present review study, it is highly recommended that more studies should re-examine the reliability and validity of the PA and SB measures of the HBSC questionnaire in more young populations using a more standardized study design. By doing this, the PA and SB measures of the HBSC questionnaire can be used for health surveillance in a wider range of populations in the world.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

YS and HW contributed to the conception and design of the study. S-TC and J-TH performed the literature search. YS, YZ, and HW conducted data extraction and quality assessment. HW oversaw the literature search and data analysis and supported the development of the original draft. YS wrote the first draft of the manuscript. YZ, S-TC, and J-TH wrote and edited the Introduction, Methods, and Results sections. All authors contributed to manuscript revision, read, and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.729641/full#supplementary-material

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Prevalence of Visual Impairment in Preschool Children in Southern China

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Purpose: The goal of this study is to assess the prevalence and distribution of visual impairment in preschool children in southern China.

Methods: Preschool children aged 36–83 months were enrolled in a vision screening program in Shantou City. Visual acuity test and non-cycloplegic refraction were conducted. According to the American Academy of Ophthalmology (AAO) guidelines, visual impairment was defined as uncorrected visual acuity (UCVA) in either eye <20/50, 20/40, and 20/32 in children aged 36–47, 48–59, and 60–83 months, respectively, as well as an interocular difference (IOD) of ≥ two lines of UCVA.

Results: The UCVA test was successfully performed on 7,880 children (94.6% of the enrolled population). A total of 938 (11.9%; 95% CI 11.2–12.6) children were found to have reduced UCVA in the worse eye, and 393 (5%; 95% CI 4.5–5.5) of the children had an IOD of two or more lines. Combining the reduced UCVA with the IOD criteria identified 1,032 (13.1%; 95% CI 12.4–13.8) children with visual impairment. UCVA in preschool children improves with age naturally and boys have slightly better age-adjusted UCVA than girls. Causes of reduced visual acuity included uncorrected refractive error, amblyopia, congenital cataract, and others. The cylindrical diopter in the right eye of children with reduced vison was higher than that of children with normal vision (1.19 ± 1.05 vs. 0.52 ± 0.49, $P < 0.001$). A total of 146 (1.9%, 95% CI 1.6–2.2) of the preschool children wore spectacles. The proportion of wearing spectacles increased with age ($\chi^2 = 35.714$, $P < 0.001$), but with IOD increasing by.1 logMAR, the odds of wearing spectacles decreased by 44.8%.

Conclusion: This study provided data on the prevalence of visual impairment in preschool children in China by large-scale school-based vision screening. Further studies should be conducted to verify the benefit from vision screening.

Keywords: preschool children, vision screening, spectacles, interocular difference, visual impairment

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INTRODUCTION

Childhood visual impairment and blindness are major public health issues in the world, and are also one of the priorities in disease control of the global initiative for the elimination of avoidable blindness (1, 2). Preschool stage is a special period in which the physiology and anatomy of the visual system are malleable, and visual deprivation during this critical period can result in permanent visual loss that cannot be fixed by any corrective means (3, 4). On the other hand, even

if one is not amblyogenic, visual problems at preschool age, such as uncorrected refractive error, can interfere with daily life and schoolwork (5). Therefore, as recommended by many healthcare specialists and governments, vision screening for preschool children is an integral part of preventive pediatric healthcare, which has utility for identification of children with vision problems and leads to interventions to improve the quality of life (6, 7).

However, representative and comparative data regarding the prevalence of visual impairment in preschool children are still scarce. Major barriers to preschool vision screening, as reported, are time-consuming screening tests and uncooperative children, along with some social barriers including lack of awareness, inconvenience, and insufficient eye care providers (6). Specialists in Taiwan investigated the accuracy of vision-screening tests and suggested that uncorrected visual acuity (UCVA) was probably the best single-instrument test for preschool vision screening in developing countries with low resources (8). Similarly, Mingguang He provided that using UCVA or interocular difference (IOD) in vision screening and referral in preschool children is pragmatic (9).

Recently, the National Health Commission (NHC) of the People's Republic of China (PRC) has published service specifications for pediatric eye care and vision examination, which has an important practical significance for preschool children vision screening. In order to evaluate the eye health of preschool children, it is essential to have updated information on the prevalence of visual impairment. Nevertheless, there were only few studies conducted on large-scale school-based vision screening for preschool children in China.

This study aimed to assess the prevalence and distribution of reduced visual acuity (VA) in preschool children in southern China in a setting of fast school-based vision screening.

METHODS

Subjects and Sites

This was a cross-sectional school-based study conducted from 2017 to 2019 in Shantou, a city in eastern Guangdong province, southern China. The city of Shantou, with representative demographic and socioeconomic characteristics, has a relatively stable population of 5.59 million (in 2017) and an average annual disposable income per capita of 22,521 Yuan (US $3,521, ranking No. 9 among the 21 cities in Guangdong province), which was comparable to the national average level (25,974 Yuan, US $4,061 in 2017). Shantou has six districts and one county. According to statistical yearbooks from the Shantou City Bureau of Statistics (link: https://www.shantou.gov.cn/tjj/tjsj/tjnj/index.html), in 2017, there was a total of 923 kindergartens serving 185,089 children in Shantou.

With the approval and support of the Shantou City Bureau of Education and Bureau of Health, the Joint Shantou International Eye Center (JSIEC), one of the top tertiary ophthalmic hospitals in southern China, has been carrying out a long-term large-scale vision screening program for preschool children in Shantou since 2017. This study, as a part of the screening program, was mainly focused on the prevalence of visual impairment in preschoolers.

Preschool children aged 36–83 months attending selected kindergartens were enrolled. Based on the statistical parameters prevalence (20%), error expected (1%), confidence (95%), upward adjustment for cluster sampling design (25%), and non-participation (5%), we calculated a sample size requirement of 7,828. The sampling process was as follows: we first listed kindergartens and the corresponding number of preschoolers; to ensure screening efficiency, we ruled out kindergartens with $<$100 preschoolers; then, we performed simple random sampling to select kindergartens in the screening list one by one, and simultaneously accumulated the number of preschoolers until it reached the sample size requirement. All preschoolers in the selected kindergartens were enrolled. This study adhered to the Declaration of Helsinki and was approved by the Human Medical Ethics Committee of JSIEC.

Vision Screening

We conducted fast vision screening tests in a sequential order: visual acuity, non-cycloplegic autorefraction (NCAR), strabismus detection, and slit-lamp examination. All the tests were carried out by trained and experienced technicians from the JSIEC.

Before the UCVA test was conducted, the preschool children were taught to be familiar with the shape of letter "E" and the definition of directions by the technicians until they passed a binocular pretest using the biggest optotype at near distance. A retro-illuminated (300 cd/m^2) standard logarithm of the minimum angle of resolution (LogMAR) chart with tumbling-E optotypes (GB 11533-2011, a national standard published by NHC of PRC) was used for UCVA test at 5 m. The standard operating protocol of VA measurements was started at a distance of 5 m with the top line (20/200) and then continued by dropping down line by line if all the optotypes were correctly identified. If, at any level, a child failed to complete a line, the test was finished and, VA was recorded as the smallest size in which the child correctly identified at least half of the optotypes. If the top line at 5 m was missed, the child was asked to step forward until the first line was successfully completed, and then VA would be recorded as 20/1,000 multiplying the distance between the child and the chart. If no optotypes could be identified on the chart, the visual acuity was assessed as counting fingers, hand movements, light perception, or no perception of light. For each testable child, we first covered the left eye to test the right eye. Then, the same procedure was followed for the left eye. For children younger than 4 years old, a re-test was conduct to confirm the results. Children with VA difference of more than one line in any eye were treated as uncooperative. In addition, for children wearing glasses, presenting VA (using current spectacles) was also measured. Then, the technicians used handheld Spot Vision Screener (Welch Allyn, Skaneateles Falls, NY, United States) to simultaneously detect the NCAR for both eyes 3 times and obtain the average value. If the difference between any of two readings from an eye was $>$0.5 diopters (D), re-measurement was conducted for that eye. Cylinder values and interocular difference of spherical equivalent were used for analysis of astigmatism and anisometropia, respectively, since it has been reported that astigmatism has no significant association

with cycloplegia (8), and that Spot Vision Screener was efficient in detecting anisometropia (10). Besides, corneal light reflex and cover-uncover tests, near and at a distance, to detect strabismus, as well as slit-lamp examination to examine the eyelids, cornea, and lens, were conducted.

Referral Criteria and Definition

We used referral criteria based on a monocular distance visual acuity test and interocular difference from the Pediatric Eye Evaluations Preferred Practice Pattern guidelines 2017 (11) by the American Academy of Ophthalmology (AAO) for referral (**Table 1**).

Reduced VA is defined as uncorrected or present VA in either eye worse than 20/50, 20/40, and 20/32 for children aged 36–47, 48–60, and 61–83 months, respectively. Spherical equivalent refraction (SER) is defined as the spherical diopters added to half of the cylindrical diopters (12). Refractive errors include myopia, hyperopia, astigmatism, and anisometropia. Myopia is defined as a non-cycloplegic SER < -0.5 D with reduced UCVA. Hyperopia is defined as non-cycloplegic SER >0.5 D. Astigmatism is defined as absolute NCAR cylindrical diopter >0.75 D. Anisometropia is defined as interocular difference of SE $>$ 2 D. Amblyopia is defined as reduced corrected VA with definitive amblyopic causes.

Children requiring medical or surgical treatment beyond what could be provided on-site were referred to the JSIEC for further diagnosis and therapy. Uncooperative children were informed for retest within 6 months. If retesting could not be performed, referral for a comprehensive eye evaluation was suggested.

Data Management and Analysis

Children with successful VA testing on both eyes were considered as the study population for analysis. Forms for vision screening were reviewed for completeness and accuracy before data entry. The children were divided based on age: 36–47 months (3-year-old), 48–59 months (4-year-old), 60–71 months (5-year-old), and 72–83 months (6-year-old). We also divided the children into 2 groups according to birth month: January to August and September to December, since in China, the latter would attend preschool in the next year.

Descriptive statistics were conducted to analyze the prevalence and distribution of reduced VA and current use of spectacles. We assessed for age and sex difference in distribution of reduced VA by chi-square tests. A linear mixed effects model (random intercept and slope) was used to investigate the association of visual acuity in both eyes with fixed factors (sex, month age, birth month, and year of examination) and random factors (kindergartens), with interocular correlation and clustering effect in kindergartens adjusted. Logistic regression was performed to analyze the influence of IOD on odds of wearing spectacles. Qualitive data were presented as ratio and 95% confidence interval (CI), and quantitative data were presented as mean ± standard deviation (SD). A statistical analysis was conducted using the SPSS software (Version 23.0). A $P < 0.05$ was considered to be significant.

TABLE 1 | Age-specific criteria for referral in preschool vision screening.

Age, month	Uncorrected or present visual acuity in either eye	Interocular difference
36–47	<Snellen 20/50 (0.4 logMAR)	≥two lines or ≥0.2 logMAR
48–60	<Snellen 20/40 (0.3 logMAR)	≥two lines or ≥0.2 logMAR
61–83	<Snellen 20/32 (0.2 logMAR)	≥two lines or ≥0.2 logMAR

RESULTS

Subjects

Thirty-two kindergartens were selected as sites for vision screening, and 8,332 preschool children were enrolled (**Table 2**). These kindergartens were distributed in six districts or one county across Shantou, with 20 (62.5%) in urban areas and the others in rural areas. All of the selected kindergartens participated in the vision screening program. UCVA tests were successfully performed on 7,880 (94.6%; 95% CI 94.1–95.1) children. Considering the device, transport expense, and human cost, the average cost of vision screening for each child in this study was 43 Yuan (US $6.7).

The refraction of children cooperative with the VA testing was detected using Spot Vision Screener. Cooperation rate was significantly lower in boys (93.7%; 95 CI 93.0–94.4) than in girls (95.5%; 95% CI 94.8–96.1) ($\chi^2 = 12.674$, $P < 0.001$).

Boys constituted 50.2% (95% CI, 49.1–51.3) of the cooperative children, ranging from 44.2% (95% CI 40–48.4) in 3-year-olds to 51.5% (95% CI 49.4–53.6) in 6-year-olds. The average age of the examined children was 64.15 ± 10.12 months, with the boys, on average, 0.6 months younger than the girls (64.45 ± 9.96 vs. 63.85 ± 10.27, P =0.008).

Uncorrected Visual Acuity

A total of 938 (11.9%; 95% CI 11.2–12.6) children were found to have reduced UCVA in the worse eye. Reduced UCVA in both eyes was found in 453 (5.7%; 95% CI, 5.2–6.3) of the children. Distributions of UCVA in the worse eye by age are shown in **Figure 1**. The prevalence of reduced VA differed among the age groups ($\chi^2 = 58.526$, $P < 0.001$). UCVA improved with age

TABLE 2 | Demographic characteristics of the study population.

	Enrolled children / *N*	Examined children /*N* (%)
No. of children	8,332	7,880 (94.6)
Boy	4,225	3,959 (93.7)
Girl	4,107	3,921 (95.5)
Age, month		
36–47	769	539 (70.1)
48–59	2,188	2,019 (92.3)
60–71	3,196	3,151 (98.6)
72–83	2,179	2,171 (99.6)

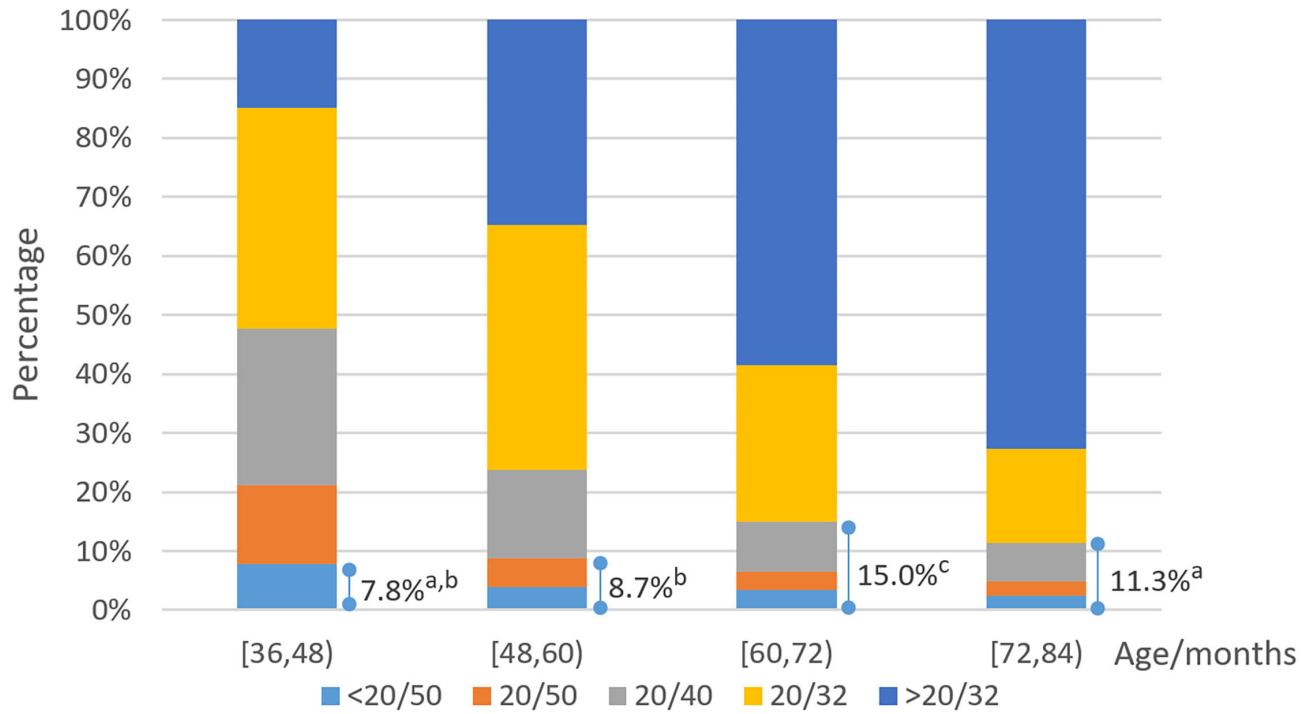

FIGURE 1 | Distribution of uncorrected visual acuity (UCVA) in the worse eye. Lines and corresponding accumulating percentages denoted reduced visual acuity proportions that should be referred according to target conditions. Each subscript letter denotes a subset of age categories whose column proportions do not differ significantly from each other at the 0.05 level.

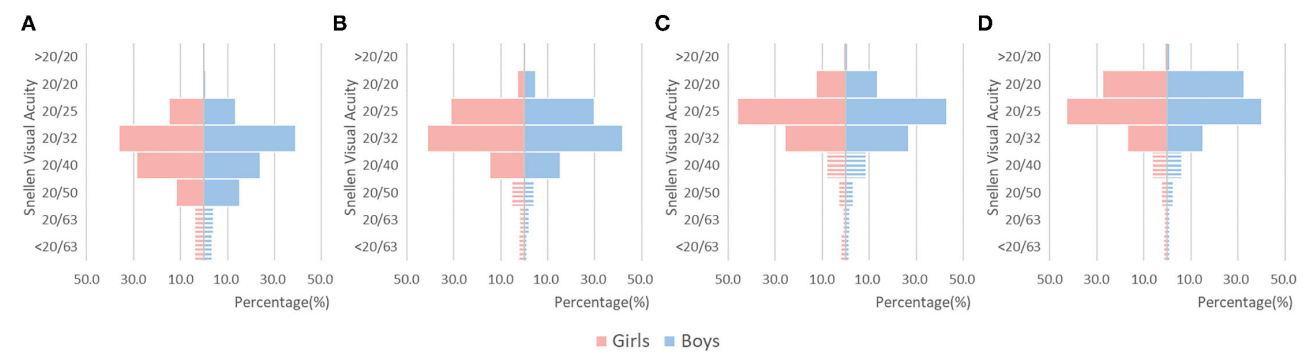

FIGURE 2 | Distribution of UCVA in the worse eye by sex. Bars in strip showed reduced visual acuity proportions. **(A)** Children aged 36-47 months. **(B)** Children aged 48-59 months. **(C)** Children aged 60-71 months. **(D)** Children aged 72-83 months.

($r = -0.302$, $P < 0.001$, Pearson correlation analysis for age in months with logMAR visual acuity in the worse eye).

The boys had slightly better age-adjusted UCVA than the girls in the worse eye (LogMAR.161 ± 0.002 vs.0.168 ± 0.002, $P = 0.03$). Distributions of UCVA in the worse eye by sex are presented in **Figure 2**. There was no significant difference in the prevalence of reduced VA between the boys and the girls ($P =$ 0.86, 0.16, 0.348, and 0.618, chi-square analysis for children aged 36–47, 48–59, 60–71, and 72–83 months, respectively).

A further analysis adjusting for the clustering effect on kindergartens and the interocular correlation with linear mixed effects models (**Table 3**) confirmed the trend or association between UCVA and factors including age and sex. In addition, UCVA was significantly correlated with year of examination, with a trend of increasing UCVA year by year ($P < 0.001$). The difference in UCVA of children born before and after September was not statistically significant ($P = 0.795$).

Interocular Difference of Uncorrected Visual Acuity

There were 393 (5%; 95% CI 4.5–5.5) children with an IOD of two or more lines. Most of the children showed an IOD of less than

two lines at all ages (**Table 4**), without significant sex differences ($P = 0.255$). The prevalence of IOD of two or more lines ranged from 6.7% in children aged 3 to 4.5% in children aged 6.

Combining the reduced UCVA in the worse eye with significant IOD increased the number of referred children to 1,032 (13.1%; 95% CI 12.4–13.8), with 94 more when only the criteria for UCVA were used.

Current Use of Spectacles

In total, 146 (1.9%, 95% CI 1.6–2.2) of the preschool children wore spectacles, and there was a trend of increased proportion of wearing spectacles with age ($\chi^2 = 35.714$, $P < 0.001$). Among the children wearing spectacles, there were 113 with binocular reduced UCVA and 23 with monocular reduced UCVA. Sixteen of the children wearing spectacles had a UCVA of not less than 20/40 but without amblyopic risks. Distributions of the present VA by age are shown in **Table 5**. There were 53 children with reduced present VA in at least one eye and 27 children with bilateral reduced present VA.

Among the 393 children with significant IOD, 46 (11.7%; 95% CI 8.5–14.9) wore spectacles. After controlling for the effect of sex, age, and UCVA in the worse eye by binary logistic regression, the association between wearing spectacles or not and IOD was shown to have a statistical significance: with IOD increasing by 0.1 logMAR, the odds of wearing spectacles decreased by 44.8% ($P = 0.003$).

Causes of Reduced Visual Acuity and Other Ocular Anomalies

Among the 938 children with reduced VA in the worse eye, astigmatism of at least 0.75 D in NCAR cylinder was found in 71.4% of right eye and in 74.9% of left eye, and in 82.3% of either eye. Astigmatism of 2 D or greater in either eye was found in 372 (39.7%) of the children. The astigmatism in children with reduced vison in the right eye was significantly severer than that in children with normal vision (1.19 ± 1.05 vs. 0.52 ± 0.49, $P < 0.001$). The mean non-cycloplegic spherical equivalent in the right eye of children with reduced vision was -0.16 ± 1.68 D. Other findings included 63 with anisometropia 2 D or more, 3 with ptosis of at least one eye, 3 with corneal opacity, 1 with corneal foreign body, 1 with postoperative corneal suture, 2 with intraocular lens, 4 with congenital cataract, and 26 with manifest strabismus.

TABLE 3 | Linear mixed effects model assessing the effect of factors on uncorrected visual acuity[a], adjusting for clustering effect on kindergartens and interocular correlation.

Variable	β coefficient[b]	*P*
Age (month)	-0.004 ± 0.0001	<0.001
Sex[c]		
Boy	-0.005 ± 0.003	0.039
Birth month[d]		
January to August	-0.001 ± 0.003	0.795
Year of examination[e]		
2019	-0.035 ± 0.004	<0.001
2018	-0.012 ± 0.003	<0.001

a. Uncorrected visual acuity (UCVA) recorded in logarithm of minimal angle of resolution (LogMAR). b. β coefficients of variables in the linear mixed effects model were presented as standard error. c. The variable "Girl" was set to 0. d. The variable "September to December" was set to 0. e. The variable "2017" was set to 0.

DISCUSSION

This study conducted a school-based vision screening in southern China on about 8,000 enrolled preschool children. Using the UCVA and IOD criteria, we identified that 13.1% of the preschool children required referral for further ophthalmic evaluation.

The cost-benefit analysis revealed that the cost of vision screening for each child was lower in the current large-scale school-based screening compared with a previous study (13, 14). In practice, preschool vision screening is thought as an intractable issue. Besides the low cooperation degree with a series of time-consuming screening tests, another significant challenge is that the screening test protocols and results may vary among different countries or areas (5–7, 15). The UCVA test is less time-consuming and easier to master for screening technicians, and has high value in large-scale population-based screening,

TABLE 4 | Distribution of UCVA interocular difference (IOD) in the reference population.

	n	UCVA IOD, lines and logMAR equivalent			
		0, 0.0	**1, 0.1**	**2, 0.2**	**>2, >0.2**
Age, month					
36–47	539	312 (57.9)	191 (35.4)	29 (5.4)	7 (1.3)
48–59	2,019	1,275 (63.2)	637 (31.6)	80 (4.0)	27 (1.3)
60–71	3,151	2,064 (65.5)	933 (29.6)	107 (3.4)	47 (1.5)
72–83	2,171	1,443 (66.5)	632 (29.1)	71 (3.3)	25 (1.2)
Sex					
Boys	3,959	2,522 (63.7)	1,233 (31.1)	155 (3.9)	49 (1.2)
Girls	3,921	2,572 (65.6)	1,160 (29.6)	132 (3.4)	57 (1.5)

Data presented in the form of N (%).

TABLE 5 | Distribution of present visual acuity of the children wearing spectacles.

Present visual acuity	Worse eye	Better eye
36–47 m	3	
≥0.4	3	3
<0.4–0.3	0	0
<0.3	0	0
48–59 m	15	
≥0.5	8	12
<0.5–0.3	5	3
<0.3	2	0
60–71 m	62	
≥0.6	37	48
<0.6–0.3	21	13
<0.3	4	1
72–83 m	66	
≥0.6	45	56
<0.6–0.3	18	9
<0.3	3	1

especially in areas with insufficient vision-screening technicians (8, 9). Most of the preschool children in the study were testable and cooperative with the tumbling-E chart, comparable with other studies (9, 15, 16).

However, a difference in the prevalence of visual impairment between this report (13.1%) and previous studies [42.8% for 3–6-year-old children in Shenzhen (9), 4.1% for 6-year-old children in Australia (17), 7% for 2–7-year-old children in Taiwan (8)] should be noted, which could be partly attributed to methodology. For instance, most of the previous studies reported and set the UCVA cutoff of visual impairment based on the Early Treatment Diabetic Retinopathy Tumbling E chart (5 optotypes in a line) or HOTV test, while GB 11533-2011 Tumbling E chart was used in this study.

Generally, the adopted UCVA cutoffs were based on clinical evidence on the relationship between UCVA and refraction. However, selecting proper UCVA cutoffs for preschool children is not straightforward, and different criteria were used across different studies (9). We selected the conservative AAO guidelines to define the target condition, which could reduce unnecessary referral, although a group of children with hyperopia and astigmatism who have unaffected vision might be excluded.

This study provided evidence that UCVA in preschool children improved with age naturally. As shown in the mixed effects model analysis, the annual cumulative change in UCVA was −0.048 logMAR, less than the change in the AAO referral criteria, which partly explained the increasing prevalence of reduced VA from age 3 to age 5. The AAO criteria identify many children with reduced UCVA at age 5. Nevertheless, the relatively lower prevalence of reduced UCVA at age 6 (using the same cutoff for age 5) suggested that most of the children have increased UCVA within 1 year without any need for intervention. A large longitudinal survey revealed that 69.8% of children with a visual acuity of 20/32 in the worse eyes at age 7 achieved a 20/20 acuity by age 16 (18). Even so, longitudinal studies should be conducted to confirm the natural improvement of VA with age in preschoolers.

The sex difference in visual acuity varied from different studies. We found that boys had slightly better UCVA than girls, which is in accordance with findings from some studies (12, 17, 19) but also in contrast with those from others (20). The causes of visual impairment included uncorrected refractive error (myopia, high hyperopia, astigmatism, and anisometropia), amblyopia, strabismus, congenital cataract, and others. In children with reduced vision, astigmatism was severer than that in children with normal vision.

It was reported that the prevalence of myopia was significantly higher in higher grades for children of same age (21). However, our findings revealed no significant difference in UCVA in preschool children born before and after September. This could be attributed to very low prevalence of myopia among preschoolers (17) and less near work in kindergarten. In addition, we used age in months as a variable in the mixed effects model analysis, which accounted for much more variance than when age in years was used. Further studies based on cycloplegic refraction should be conducted to confirm the relationship between refractive change and entrance age in preschoolers.

Purposes of wearing glasses included refractive correction, amblyopia therapy, and controlling ocular alignment (22). It was recommended that prescript of spectacles for preschool children could be postponed if without amblyogenic risks, even if UCVA is less than Snellen 20/40, since the visual demands were low (23). Our study revealed that the proportion of wearing spectacles decreased with IOD. This could be reasonable, because for children with high IOD, the UCVA in the better eye might meet the need for daily life, so, they might not complain about blurred vision. Therefore, the parents were not aware of the issue and ignored the eye health assessment and intervention. However, significant IOD of UCVA was evidence of binocular imbalance and a potential hint for monocular amblyopic risk. If with normal vision in the better eye, the reduced UCVA in the worse eye would be easily ignored, especially for 3-year-old children. What is worse, even if they were informed by ophthalmologists about risks of significant IOD, most parents still indicated that wearing glasses might be harmful to the eyes and should be delayed in children (24).

Based on what were found in this study, we recommended that routine vision screening for preschool children should be conducted. Kindergarten-based annual screening, including uncorrected and present visual acuity tests, non-cycloplegic autorefraction (NCAR), strabismus detection and slit-lamp examination, is feasible and cost-effective for detecting children who require referral for further evaluation and therapy. Besides, propaganda and education should be conducted for parents and kindergarteners to facilitate the recognition of preschoolers' visual problems.

Limitations of this study should be taken into consideration. First, we did not conduct cycloplegic refraction, which is regarded as the gold standard in previous studies focusing on the verification of vision screening tests. Therefore, the SE refraction was more myopic in preschool-aged children. Nevertheless, this time-consuming test was not suitable for

large-scale screening, and our vision screening tests were fast and simple. Second, the selected kindergartens were derived from a screening list rather than statistical sampling, which reduced the representativity. Since this study was a part of a long-term vision screening program, further analyses for more representative and comprehensive reports would be conducted.

Notwithstanding its limitations, this study had several strengths, including relatively large sample size, as well as well-organization and arrangement of school-based screening with the support of the government.

In conclusion, we provided school-based data on the prevalence of reduced VA in preschool children in China with a large sample. A significant portion of preschool children with visual impairments, such as uncorrected refractive error and amblyopia, required referral for ophthalmic evaluation. Further studies should be conducted to verify the program's sustainability and benefit from vision screening.

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 Human Medical Ethics Committee of Joint Shantou International Eye Center. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

HW and MZ designed this study. DD, YD, BC, SY, and HW collected and measured data. HW and JJ analyzed data. HW, KQ, and MZ prepared the first draft and finalized the manuscript based on comments from all other authors. All authors discussed the results and commented on the manuscript. All authors contributed to the article and approved the submitted version.

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Parents' Beliefs and Behaviors About Their Children's Literacy Development: A Cross-Sectional Study in Saudi Arabia

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Background: A home environment that promotes learning is a significant factor in school performance in which children's parents are involved in their education. However, little study has focused on parents' reading-related beliefs or the relationship between parents' literacy beliefs and behaviors.

Methods: This cross-sectional study describes the range of parents' reported literacy beliefs and behaviors and examines whether an association exists in Saudi Arabia. It was conducted on a convenient sample of 100 parents using a web-based self-administrated shared with families in Developmental and Behavioral Pediatrics clinics at multiple sites utilizing the Parents' Perceptions of Literacy Learning Interview Schedule (PPLLIS).

Results: There were 83 mothers and 17 fathers; 90% had a university degree or higher. Parents' beliefs ranged between 87 and 123, with a mean of 103.54 ± 8.05, indicating more holistic perceptions than skills-based ones. There was only a positive significant correlation between parents' beliefs and behaviors regarding literacy activities. However, those participating in literacy activities with their kids were more holistic parents and scored the top one-third on the PPLLIS.

Conclusion: Parents' beliefs and their reported behaviors are found to be significantly impacted by their educational levels. Therefore, future investigations and national campaigns are encouraged to improve parents' educational levels, especially in urban areas.

Keywords: literacy beliefs, Saudi Arabia, literacy behaviors, children literacy, Perceptions of Literacy Learning Interview Schedule

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INTRODUCTION

Literacy is defined as having the ability to read and write as introduced within a significant context (1). Many techniques to improve literacy skills and enhance the significance of outcomes among children have been previously reported. For instance, exposure to storybooks and reading shared books are some of the commonly studied literacy aspects. However, evidence regarding the efficacy of these modalities in enhancing literacy skills is controversial among studies in the literature (2, 3). Among children, it has been previously reported that early acquisition of literacy skills within the first 5 years of life can significantly enhance the academic performance of these children (4, 5).

On the other hand, it has also been reported that lacking these skills can negatively impact the child's academic performance and significantly persist through adolescence (6, 7). However, parents' involvement in literacy development in their children is a fruitful practice with favorable outcomes on education (8). Leslie et al. (9) previously showed that parents' involvement in children's literacy activities was associated with a significant enhancement in the educational outcomes in elementary school children. It has been reported that less involvement with preschool children and reduced supervision periods from the caregivers was associated with the reduced acquisition of essential phenomics and vocabulary skills (10). Parents' beliefs may fluctuate on how children can become literate regarding their study and literacy education knowledge. Previous evidence revealed that when parents were questioned about their beliefs about learning, reading, and writing, it mainly occurred when children were already in regular education (11, 12).

The role of the family has become of great importance in educating preschool children, almost equivalent to the educational services offered at schools. However, little study has focused on parents' reading-related beliefs or the relationship between parents' literacy beliefs and behaviors. Understanding parents' beliefs about literacy is vital in identifying the children's home environment and activities parents engage in. In Saudi Arabia, reports show that many families have recently begun to be interested in enrolling their children in kindergarten at least 1 year earlier, despite being non-mandatory at that age group (13). However, no previous studies have been conducted in Saudi Arabia to assess parents' beliefs and attitudes toward literacy enhancement practices. Therefore, this study describes the range of parents' reported literacy beliefs and behaviors and examines whether an association exists in Saudi Arabia.

METHODS

Study Design and Data Collection

This cross-sectional study was conducted on a convenient sample of 100 parents using a web-based self-administrated shared with families at Developmental and Behavioral Pediatrics clinics in various private or governmental institutes around Saudi Arabia. Initially, the sample size was obtained through cluster sampling methods with an expected response rate of 90% and a sample size of 145. However, only 100 parents were involved in the final study after applying the inclusion and exclusion criteria. Inclusion criteria were all the children attending the behavioral pediatric clinics between March and June 2021 and who are regularly following up while those who are not known to regularly follow-up in the clinic or have an incomplete file were excluded. Data were collected by medical student volunteers from secondary and tertiary hospitals between March and June of 2021. All parents consenting to undertake the survey were included, and couples with no children were excluded. The survey utilized the Parents' Perceptions of Literacy Learning Interview Schedule (PPLLIS) (14, 15) questionnaire, and answers were collected in an excel sheet. This tool evaluated parents' beliefs on how children learn to read and write and gave information on the varieties of literacy exercises parents are involved in with their kids. Given the responses, parents' perceptions of literacy were described as more emergent or more traditional. We modified the PPLLIS score by excluding three questions (items 3, 4, and 27) (**Supplementary Material 1**). All the questions were scored on a 5-point Likert scale (strongly agree to strongly disagree), with a greater score given for answers that represented a more emergent or holistic literacy perspective (strongly agree scored 1 and strongly disagree 5 except for questions: 1, 2, 3, 6, 7, 8, 16, 17, 19, 20, 22, 23, 24, 25, 26, and 28 where strongly agree scored 5 and strongly disagree scored 1). Scores were calculated by summing the raw scores, which means the lowest possible score on the questionnaire is 30 and the highest possible score is 150.

One question included in the questionnaire to assess "parents' beliefs" was asking the parents to name the five most important ways they help their children learn to read and write. The responses were scored based on the frequency and were categorized into five categories based on the answers. The first category: teaching literacy skills, included parents' direct attempts to instruct children about reading and writing. Second category: being involved in supporting children's literacy by encouraging and valuing children's literacy development. Third category: participating in literacy activities included literacy events in which parents and children collaboratively participated. Fourth category: knowledge development had parents' attempts to promote children's general intellectual or cognitive development. Fifth category: involving those who did not fit any of the previous categories.

Statistical Analysis

Reports were collected, then coded and revised, and data were introduced on statistical software IBM SPSS version 26.0. All the statistical analysis was done using two-tailed tests and an alpha error of 0.05. A P-value < 0.05 was considered to be statistically significant. Frequencies and percentages were used to describe the distribution of items and scale. Finally, the questions were assessed and scored. The Cronbach's alpha test was used for overall ranking and objects and the Cronbach's alpha coefficient of more than 0.70 was considered acceptable. In this study, the Cronbach's alpha was 0.682, indicating an average internal consistency for our scale with this specific sample.

To facilitate data analysis, the included parents were grouped based on their PPLLIS score. Out of the 100 parents that completed the questionnaire, 32 parents scored the lowest on the PPLLIS and were placed in group 1. The following 33 parents whose scores fell in the middle were placed in group 2. Meanwhile, the 35 parents whose holistic beliefs were high and scored in the top third on the PPLLIS were placed in group 3. Finally, the groups were as follows; group 1: more skills-based group with the lowest scores, group 2: combination group of both the skills-oriented and holistic beliefs, in comparison to the other groups, group 3: more holistic orientation to literacy learning with the highest score.

The Shapiro–Wilk test was used to verify the normal distribution of continuous variables. For normally distributed variables, the ANOVA test was used to examine whether parents' education was examined differed in parents' beliefs. The Pearson's chi-squared was used to assess the differences between categorical

TABLE 1 | Socio-demographic and educational characteristics of the participants.

Variable	Count	%
Parent's sex		
Male	17	17
Female	83	83
Province		
Aseer	2	2
Eastern	78	78
Qassim	4	4
Makkah	7	7
Madinah	5	5
Riyadh	4	4
Highest education of the parent		
None	1	1
High school	9	9
University and higher	90	90
Older sibling age (Mean ± SD)	12.33 ± 7.75	
Older sibling sex		
Male	54	54
Female	46	46
Younger sibling age (Mean ± SD)	4.49 ± 3.82	
Younger sibling sex		
Male	54	54
Female	46	46
Languages spoken at home		
Arabic	66	66
Arabic + other	34	34
Languages spoken by the child		
Arabic	60	60
Arabic + other	40	40

variables. The Fisher's exact test was used in the cases where the conditions were not satisfied (≥20% of the expected values are <5 and the minimum is <1). In addition, partial correlations were used to examine relationships between parents' beliefs and their behaviors, controlling for children's age (15). The control for the age was done because parents' behaviors may vary with children's age (16).

RESULTS

Participant's Characteristics

Overall, 100 participants completed the data. **Table 1** shows participants' sociodemographic characteristics. There were 83 mothers and 17 fathers involved in this study and most of them were from the eastern province of Saudi Arabia (78%). Their education level ranged from high school completion to doctorate degrees, with 90% having a university degree and higher education. On average, the children in this study had the older sibling's mean age of 12.33 ± 7.75 years, while the younger sibling was 4.49 ± 3.82 years. In addition, 66 participants spoke Arabic in the house, while 34% of parents spoke another language.

Parent's Beliefs

Table 2 describes the overall participants' scores. Parents' beliefs ranged between 87 and 123, with a mean of 103.54 ± 8.05, indicating more holistic perceptions than skills-based ones (a higher score). The following five statements on the PPLLIS were those on which parents scored the lowest: real reading begins only when a child starts to say the words as they are printed on the page, a child can begin to write before she has learned the correct spelling of the terms, a child can begin to write (e.g., notes and stories) before she knows how to read, only gifted children learn to read and write before receiving formal instruction in preschool or elementary school, schools should be responsible for teaching children to learn to read and write, and children have to be of a certain age before they can begin to learn to read and write.

Parents scored highest on the following five statements of the PPLLIS: a child benefits from hearing favorite stories that she has memorized read, again and again, you are helping a child learn to read by encouraging her to discuss what is being read, talking to them, having them pretend to write grocery lists with you, and reading to them. However, when testing the associations between the PPLLIS score and different sociodemographic characteristics, none of the variables was significantly associated with parents; perceptions, as shown in **Table 3**.

Parents' Behaviors

In the questionnaire, parents were asked about the most important things to help the child learn to read and write. We categorized the answers into five categories, each containing different responses, as shown in **Table 4**. There was a significant relationship between parents' total score on the PPLLIS and parents' participation in literacy activities ($N = 62$, $P = 0.002$). This suggests that those participating in literacy activities with their kids were more holistic parents, scoring in the top one-third on the PPLLIS, as shown in **Table 5**.

The division of parents' beliefs into the three groups showed that parents with more skills-based beliefs were less likely to participate in activities grouped in the "participation in literacy activities" category, such as reading to children, playing games with them, and writing with them (**Figure 1**). Nearly twice as many parents in the groups 2 and 3 reported these activities types compared to the group 1. Within our sample, no clear trends could be identified.

DISCUSSION

Our aim in this investigation is to assess the behaviors and beliefs of parents about their children's literacy development in Saudi Arabia. Our results showed that the estimated PPLLIS scores for the included participants were higher, indicating overall holistic beliefs than the overall scores of skills focused on perception. We also found that the place of residency (province) and the high educational status of the parents were the only two significant factors associated with having high PPLLIS scores.

Our results are consistent with the previous investigation by Lynch et al. (16) that showed that higher educational levels were also associated with firmer holistic beliefs. Earlier research by Fitzgerald et al. (17) also reported that having more skill-based

TABLE 2 | The Parents' Beliefs of Literacy Learning Interview Schedule (PPLLIS) score.

Number	Questions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	A child learns to read by first learning the letters of the alphabet and their sounds, then words, then sentences and then stories.	44 (44%)	37 (37%)	14 (14%)	4 (4%)	1 (1%)
2	Teaching a child to recognize isolated words on sight is a suitable technique for teaching her to read.	21 (21%)	53 (53%)	15 (15%)	9 (9%)	2 (2%)
3	A child benefits from hearing favorite stories that she has memorized read again and again.	58 (58%)	40 (40%)	2 (2%)	0 (0%)	0 (0%)
4	You should not encourage a child to join in sometimes while you read a book with which he is familiar for is it better that the child listens to the story without interruption.	7 (7%)	8 (8%)	20 (20%)	44 (44%)	21 (21%)
5	You will be teaching your child a bad habit if you point to the print as you read.	3 (3%)	9 (9%)	21 (21%)	43 (43%)	24 (24%)
6	You are helping a child learn to read by encouraging her to discuss what is being read.	60 (60%)	35 (35%)	4 (4%)	1 (1%)	0 (0%)
7	It is necessary to check a child understands by asking him questions at the end of each story.	47 (47%)	41 (41%)	9 (9%)	3 (3%)	0 (0%)
8	You should permit your child to read familiar books by retelling the story from memory using the pictures.	36 (36%)	54 (54%)	10 (10%)	0 (0%)	0 (0%)
9	Real reading begins only when a child begins to say the words as they are printed on the page.	6 (6%)	32 (32%)	27 (27%)	23 (23%)	12 (12%)
10	It is necessary for a child to know the letters of the alphabet, and the sounds of the letters of the alphabet before she begins to write.	47 (47%)	26 (26%)	21 (21%)	3 (3%)	3 (3%)
11	A child should learn to print neatly the letters of the alphabet before attempting to print messages, notes, stories and so forth.	42 (42%)	29 (29%)	16 (16%)	12 (12%)	1 (1%)
12	It is necessary for a child to have lots of experience copying words, then sentences, and finally stories before she attempts to write on her own.	24 (24%)	36 (36%)	23 (23%)	13 (13%)	4 (4%)
13	A child should be encouraged to write only easy words and short sentences when he begins to write.	41 (41%)	45 (45%)	10 (10%)	2 (2%)	2 (2%)
14	A child's early scribbling are related to later development in writing stories, messages, etc.?	37 (37%)	48 (48%)	12 (12%)	3 (3%)	0 (0%)
15	A child needs workbooks to learn how to write.	39 (39%)	42 (42%)	14 (14%)	4 (4%)	1 (1%)
16	A child can begin to write before she has learned the correct spelling of the words.	19 (19%)	33 (33%)	24 (24%)	23 (23%)	1 (1%)
17	You SHOULD correct your child if she writes "kt" for the word "cat."	38 (38%)	46 (46%)	11 (11%)	5 (5%)	0 (0%)
18	A child's confusion of "b" and "d" or "p" and "q" in printing indicates a major problem	2 (2%)	11 (11%)	32 (32%)	33 (33%)	22 (22%)
19	A child can begin to write (e.g., notes, stories) before she knows how to read.	5 (5%)	22 (22%)	25 (25%)	38 (38%)	10 (10%)
20	Learning to read and learning to write are similar to learning to talk in that children learn these skills gradually.	37 (37%)	59 (59%)	2 (2%)	2 (2%)	0 (0%)
21	Only gifted children learn to read and write before receiving formal instruction in preschool or elementary school.	13 (13%)	26 (26%)	33 (33%)	20 (20%)	8 (8%)
22	Reading to, and with children helps them learn to write	43 (43%)	48 (48%)	9 (9%)	0 (0%)	0 (0%)
23	Children learn important things about reading and writing before they begin formal reading programs at preschool or elementary school.	31 (31%)	44 (44%)	21 (21%)	4 (4%)	0 (0%)

(Continued)

TABLE 2 | Continued

Number	Questions	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
These activities help children learn to read and to write:						
24	Talking to them.	56 (56%)	39 (39%)	4 (4%)	1 (1%)	0 (0%)
25	Having them pretend to write grocery lists with you.	56 (56%)	36 (36%)	7 (7%)	1 (1%)	0 (0%)
26	Reading to them	56 (56%)	36 (36%)	6 (6%)	2 (2%)	0 (0%)
27	Schools should be totally responsible for teaching children to learn to read and to write.	10 (10%)	8 (8%)	24 (24%)	41 (41%)	17 (17%)
28	It is very important that children see their parents reading and writing.	54 (54%)	38 (38%)	7 (7%)	1 (1%)	0 (0%)
29	Children have be certain age before they can begin to learn to read and write.	10 (10%)	23 (23%)	34 (34%)	26 (26%)	7 (7%)
30	Children need training in hand-eye coordination recognizing shapes, and so forth before they begin to learn recognizing shapes, to read and to write.	35 (35%)	55 (55%)	9 (9%)	1 (1%)	0 (0%)
Total Score (Mean ± SD)				103.54 ± 8.05		

TABLE 3 | Associations between PPLLIS and different socio-demographic characteristics.

Variable	Group 1 $N = 32$	Group 2 $N = 33$	Group 3 $N = 35$	*P*-value (Pearson chi-square)
Parent's sex				
Male	7 (38.8%)	9 (50%)	2 (11.1%)	0.058
Female	25 (30.5%)	24 (29.3%)	33 (40.2%)	
Province				
Aseer	1 (50%)	1 (50%)	0 (0%)	0.777*
Eastern	25 (32.5%)	27 (35%)	25 (32.5%)	
Qassim	1 (25%)	2 (50%)	1 (25%)	
Makkah	2 (25%)	2 (25%)	4 (50%)	
Madinah	2 (40%)	1 (20%)	2 (40%)	
Riyadh	1 (25%)	0 (0%)	3 (75%)	
Highest education of the parent				
None	1 (100%)	0 (0%)	0 (0%)	0.148*
High school	6 (60%)	3 (30%)	1 (10%)	
University and higher	25 (28.1%)	30 (33.7%)	34 (38.2%)	
Older sibling age (Mean ± SD)	13.53 ± 8.46	12.87 ± 7.08	10.57 ± 7.64	0.263
Older sibling sex				
Male	16 (29%)	16 (29%)	23 (42%)	0.256
Female	16 (35.6%)	17 (37.8%)	12 (26.7%)	
Younger sibling age (Mean ± SD)	4.92 ± 5.17	4.59 ± 3.03	3.93 ± 3.08	0.566
Younger sibling sex				
Male	15 (27.2%)	18 (32.7%)	22 (40%)	0.354
Female	17 (37.8%)	15 (33.3%)	13 (28.9%)	
Languages spoken at home				
Arabic	23 (35.4%)	22 (33.8%)	20 (30.8%)	0.343
Arabic + other	9 (25.7%)	11 (31.4%)	15 (42.8%)	
Languages spoken by the child				
Arabic	23 (38.3%)	19 (31.6%)	18 (30%)	0.260
Arabic + other	9 (22.5%)	14 (35%)	17 (42.5%)	

** Fisher's exact test.*

TABLE 4 | The Parents' Behaviors of Literacy Learning Interview Schedule (PPLLIS) score.

Category	*N*	%
1. Direct teaching activities (total responses = 46)		
- Teach the alphabet (help children recognize letters and sounds and to Write the alphabet)	13	28.3
- Help child write his/her name and the name of things (animals,...)	12	26.1
- Use workbooks with their child	14	30.4
- Teach him the right way to hold a pen and reading by using his finger	7	15.2
2. Participation in literacy activities (total responses = 62)		
- Read to them (mostly stories)	18	29.0
- Play games with them (tracing using bullets, coloring the alphabets,…)	27	43.5
- Write with them (alphabet, grocery lists, and notes)	17	27.4
3. Encouragement/demonstrating/valuing of literacy (total responses = 37)		
- Provide books, workbooks, and stories for the child	10	27.0
- Provide literacy computer games with stories and letters and cassette tapes	8	21.6
- Let children see parents reading and writing	7	18.9
- Encouraging by words or giving gifts	12	32.4
4. Knowledge development (total responses = 31)		
- Talk to them/answer their questions and discussing different things	10	32.3
- Draw pictures with them	16	51.6
- Go on outings with them especially to libraries	5	16.1
5. Other (total responses = 12)		
- Reading the sign and advertisement boards when going out	4	33.3
- Start at young age	5	41.7
- Support continuously with patience	2	16.7
- Make new songs on spot	1	8.3

TABLE 5 | Partial correlations between parents' behaviors and parents' total score on the PPLLIS.

Parents' behaviors	Parents beliefs			
	N	df	*r*	*P*-value
Direct teaching activities	46	43	−0.149	0.063
Participation in literacy activities	62	59	0.314	0.002*
Encouragement/demonstrating/valuing of literacy	37	34	−0.191	0.057
Knowledge development	31	28	0.004	0.972
Other	12	9	0.013	0.928

**Statistically significant.*

beliefs were significantly related to well-educated parents. On the other hand, Stipek et al. (18) reported that parents with higher educational levels were significantly associated with less support for didactic methods, including flashcards. In comparison, the opposite was noticed with parents with lower educational levels. Moreover, according to a previous report by the Organization for Economic Cooperation and Development, the parenteral different socioeconomic factors were not as significant as reading enjoyment in achieving higher educational success rates among children (19). The most reported literacy behaviors were reading stories, talking/discussing with them, and using picture clues grouped in the "Participation in literacy activities" category. In the same context, the current evidence supports graph phonemic (phonics, sounding out words, books with structured vocabulary, and spelling) and constructivist (readers rely on their general knowledge, the language, pictures, and the context of the text) as primary dimensions of beliefs about how children should be taught to read (20).

Our results also showed that participants with the highest scores believed that being more involved with their children in reading, writing, and making shopping lists can enhance literacy according to the PPLLIS score. Senechal and LeFevre previously reported that reading was the most sensitive subject that can be affected by the involvement of parents with their children (21). Furthermore, it has been reported that successful reading practices can, in turn, enhance the educational outcomes of other school subjects (22). Previous investigations have demonstrated that daily activities are significantly associated with many benefits on children in the home, such as language comprehension, reading achievement, more frequent

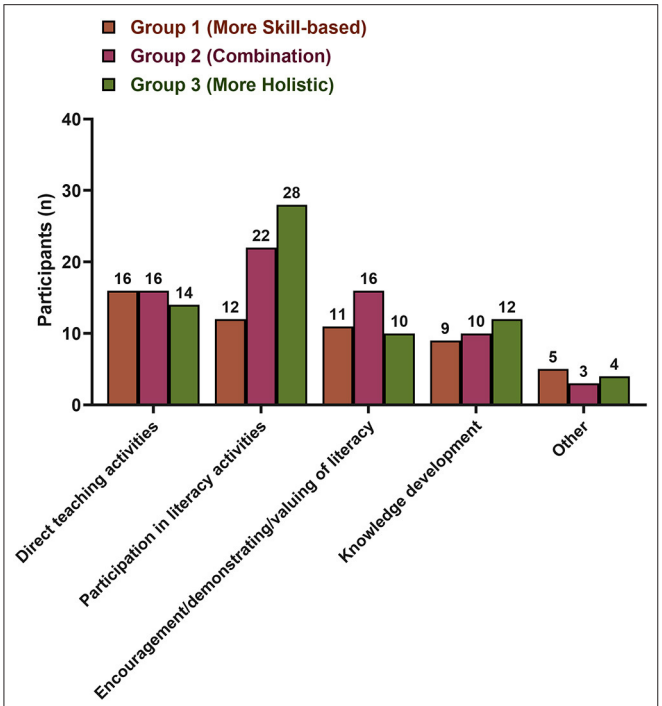

FIGURE 1 | Parents' behaviors and the grouping of parents' beliefs.

expression of the acquired linguistic skills, and enhanced attitude about reading in schools (23, 24). Besides, it has also been previously reported that being involved with the child's literacy-relevant practices was a more significant predictor for educational success than parenteral family size, social class, and level of education (25). However, we did not find a significant correlation between direct teaching activities or valuing or encouraging literacy practices. On the other hand, Feinstein and Symons reported that achievement and success at 16 years of age were significantly associated with parents' enthusiasm and interest in their children's education and related outcomes (26).

Previous investigations have also reported that the early involvement of parents in literacy practices with their children can significantly enhance the educational outcomes and is usually associated with more lasting effects (27). However, it should be noted that although the early inauguration of parents' involvement with children is essential, it is also necessary that participation in the successful habits should also continue in the latter years, even during the adult and teenage years (27). In addition to the educational outcomes, evidence also shows that parents' involvement with children can also positively impact their emotional status, including more enhanced mental health and self-control, in addition to reduced delinquent behaviors (27, 28). Furthermore, the effect of dynamic interaction between the parents and their children cannot be ignored. Previous investigations reported that mother book reading had a positive association with children's development of early literacy skills (16).

We believe that our findings would imply future national investigations and campaigns that should enhance educational outcomes among both the parents and children. Such campaigns should raise awareness about reading for pleasures practices associated with favorable results on all the education parameters, especially for children in need. Moreover, it has been previously reported that children to parents who value reading are more frequently associated with higher motivations for reading for pleasure and enhanced educational outcomes (26). In the same context, a previous investigation by Baker and Scher also reported that parents who read to entertain their children were more likely to have children who enjoy, value reading, and feel sufficient in their reading activities (29).

It is worth reporting that our findings might be limited. First, the study sample and selection of participants might not adequately represent the general population in Saudi Arabia. Therefore, further studies with larger sample sizes and a random broad selection of the participants are encouraged. Moreover, the lack of temporality associated with the cross-sectional design and the potential social desirability bias is another limitation to this study that future investigations should consider. In addition, the majority of the respondents were mothers which do not reflect the actual population of fathers in the whole population.

CONCLUSION

Our findings indicate the overall holistic beliefs than the overall scores of skills that focused on the perception among our Saidu population. Parents' beliefs can influence their behaviors toward their children and higher educational levels can significantly influence such outcomes. We also found that parents' participation in literacy activities with their children was correlated considerably with good behavioral scores. For further validation of our evidence, future national studies are encouraged, together with campaigns aiming to increase the degree of awareness among parents about the benefits of reading for joy in enhancing their children's literacy outcomes.

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

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

FA contributed to conceptualizing, drafting, data collecting, writing, editing, and rechecking references accordingly.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2022.708217/full#supplementary-material

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ORIGINAL RESEARCH
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Associations Between Fitness, Physical Activity, and Fatness in Preschool Children With Typical and Atypical Motor Coordination

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Purpose: Increased adiposity in children confers a higher risk of cardiovascular disease in later life, with low cardiorespiratory fitness strongly linked to poorer metabolic health. Children with motor coordination problems are likely to be less physically fit and at a higher risk of obesity. In this study, we examined the associations between aerobic and anaerobic fitness, device-measured physical activity, and body adiposity in children (aged 4–5 years) with typical and atypical motor coordination.

Methods: Baseline data from the Coordination and Activity Tracking in CHildren (CATCH) cohort study were utilised. The assessments included aerobic and anaerobic fitness *via* time-to-exhaustion on Bruce treadmill test and normalised mean power on Wingate cycling test, respectively; light physical activity (LPA), moderate-to-vigorous physical activity (MVPA), and sedentary time *via* accelerometry; and body adiposity (%) *via* bioelectrical impedance analysis (BIA). The Movement Assessment Battery for Children-Second Edition (MABC-2) was used to assess motor coordination and classify children as typically developing (TD, >16th percentile) or at risk of developmental coordination disorder (DCD, ≤16th percentile). General linear regression models were fitted to examine associations.

Results: The analyses included 495 participants (5.0 ± 0.6 years, 56% male, and body adiposity 22.7 ± 4.2%). Aerobic fitness ($\beta = -0.006$, $p < 0.001$) and MVPA ($\beta = -0.018$, $p = 0.045$) were negatively associated with body adiposity when adjusted for age, sex, and MABC-2 score. There was no relationship between sedentary time and body adiposity. There were no interactions of sex or MABC-2 score with any variable.

Conclusion: Lower aerobic fitness and MVPA were associated with higher body adiposity in preschoolers, regardless of motor coordination. Interventions targetting improved aerobic fitness and MVPA are therefore warranted in both TD and atypically developing preschoolers. Whether maintaining high aerobic fitness in children with possible DCD confers protection against obesity requires longitudinal investigation.

Keywords: obesity, cardiorespiratory fitness, developmental coordination disorder, anaerobic capacity, aerobic capacity

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INTRODUCTION

An increased adiposity in childhood confers a higher risk of cardiovascular disease (CVD) and mortality in later life (1–3). Obesity has been shown to be the principle contributor to the cumulative risk of CVD (4). This is concerning as the global prevalence of childhood obesity was 7–8% in 2017 (5, 6), with 50–70% of children with obesity remaining obese in adulthood (7). Moreover, the metabolic milieu that precede the development of CVD (e.g., dyslipidaemia, elevated blood pressure, and hyperinsulinaemia) have been observed in adolescents and children as young as 9 years of age (8). Notably, low levels of cardiorespiratory fitness and an elevated body mass index (BMI, kg/m^2) are strongly linked with these CVD risk factors (8). Beyond cardiometabolic health, obesity in childhood has also been linked with poorer academic skills and coping strategies (9).

There is a complex interplay between physical activity, aerobic fitness, and body adiposity. In both children and adolescents, higher cardiorespiratory fitness is associated with improved cardiovascular profiles in adulthood and a lower risk of premature death (1, 10). There is also an inverse association between moderate-to-vigorous physical activity (MVPA) and adiposity in children and adolescents (11). However, with only weak-to-moderate associations between physical activity and aerobic fitness in children (12–14), understanding the role of each component of health-related fitness and their relative influence on body adiposity is important to delineate to inform public health policy. In early-to-mid childhood (∼5–12 years, Tanner stage <3), associations between aerobic fitness and body adiposity have been observed (15–17), although conclusions have been limited by submaximal measures of aerobic fitness (15, 16) and the lack of control for device-measured physical activity levels and sedentary behaviour (15–17).

There is some evidence to suggest that obesity, determined by BMI, is associated with lower aerobic fitness in preschool-aged children (18, 19). However, there is a weak correlation between BMI and body adiposity (% fat mass) in the preschool-aged population (20), and aerobic fitness levels have been shown to differ by body adiposity irrespective of the BMI classification (16). Few studies in preschool-aged children have examined the relationships between the health-related components of physical fitness and body adiposity using accurate and reliable tools and adjusted for device-measured physical activity and sedentary time. Henriksson et al. (21) observed that a higher fat mass index (kg/m^2 through air displacement plethysmography) was associated with a poorer cardiorespiratory and motor fitness (*via* 20 m shuttle run and 4 × 10 m shuttle run test, respectively), when adjusted for age, sex, and vigorous physical activity in 303 preschool-aged children (21). However, to our knowledge, no studies have examined these relationships within the context of motor coordination development using robust methods and controlling for habitual light physical activity (LPA), MVPA, and sedentary time.

Motor skills and motor function are likely determinants of physical activity participation and aerobic fitness in children and adolescents (22). Consequently, children with neurodevelopmental problems [for example, those with developmental coordination disorder (DCD)] have been shown to be less active, less physically fit, and are at a higher risk of having overweight or obesity than typically developing (TD) children (23). DCD affects 5–6% of the paediatric population and is characterised by impairments in fine and/or gross motor coordination impacting on everyday functions, such as play and academic ability (24). This is likely to impact on engagement in skill-related physical activity as children with DCD age and is a likely contributor to a decline in physical fitness. However, recent findings suggest that young children (aged 4–5 years) at risk for DCD are not yet deficient in physical activity accumulation (25), likely reflecting the unstructured patterns of play in this age group. Moreover, while there were no differences in body composition, there were differences in aerobic fitness in those with motor delays (26); however, the interactions between fitness, physical activity, sedentary time, and body composition are still unknown.

Describing the relationships and interactions between physical fitness, physical activity, sedentary time, and body adiposity in young childhood may help to understand predictors of body adiposity and inform targets for public health messages and lifestyle intervention for children to prevent obesity-related chronic diseases. Therefore, the primary aim of this study was to examine the associations between aerobic and anaerobic fitness, device-measured physical activity and sedentary time, and body adiposity in a cohort of young Canadian children (aged 4–5 years). We also aimed to examine the differences in associations between children with typical and atypical motor coordination. Based on the observations from BMI-derived associations and evidence in older children, we hypothesised that there would be an inverse relationship between aerobic and anaerobic fitness, MVPA, and body adiposity, and a positive association between sedentary time and body adiposity. With a paucity of evidence for the association between LPA and overall health outcomes, we hypothesised that there would be no associations between LPA and body adiposity. Finally, given the lack of differentiation in physical activity levels based on neurodevelopment in preschool-aged children, we further hypothesised that these relationships would be similar regardless of motor coordination classification in this population.

MATERIALS AND METHODS

Participants

This study used cross-sectional baseline data from the Canadian longitudinal cohort study: Coordination and Activity Tracking in CHildren (CATCH). The CATCH study is a longitudinal cohort study including 588 children aged 4–5 years (48–71 months) at baseline (2015). Based on the child's performance on a standardised motor test [Movement Assessment Battery for Children-Second Edition (MABC-2)], 301 children were classified as TD (overall MABC-2 score >16th percentile) and 287 were classified at risk for developmental coordination disorder (rDCD, overall MABC-2 score ≤16th percentile).

The participants were recruited from a community-based sample from Hamilton, Ontario and the surrounding areas through community organisations and events, school mail outs, recruitment posters, and social media between October 2013 and June 2017. A detailed description of the design, eligibility, and outcome measures of the CATCH longitudinal cohort study (27) and the complete cohort baseline profile (28) have been previously published. In brief, children who were not eligible were those who did not speak/understand English, had low birthweight (<1500 g), or were diagnosed with a physical disability or medical condition that affects motor coordination (e.g., cerebral palsy or muscular dystrophy). Children were also ineligible if scoring an IQ < 70 based on the Kaufman Brief Intelligence Test, Second Edition (29), to exclude deficiencies that may be due to an intellectual delay. The legal guardians of participants signed a written informed consent before participating in data collection. The study was approved by the Hamilton Integrated Research Ethics Board. In this cross-sectional sub-study, children were also excluded if they did not have a valid measure of body fatness (n = 5), or valid measures of aerobic fitness (n = 4) or anaerobic fitness (n = 17) or device-measured physical activity (n = 75). Collectively, 93 children were excluded from the sub-study due to one or more missing variables. Further details on these missing data have been previously reported (25, 26).

The baseline study appointment included a motor coordination assessment, anthropometric measures, followed by non-invasive physical fitness measures including aerobic fitness, followed by anaerobic fitness after a minimum 10-min rest. The children were fitted with an accelerometer and the parents were instructed on its use. All questionnaires were completed by parents/guardians during the baseline visit.

Measurements

Anthropometry and Body Composition

Height (cm) and the body mass (kg) were measured in duplicate without shoes and in light clothing using a stadiometer (SECA 264, Chino, CA, United States) and digital scale (SECA 896), respectively. A third measure was taken if repeat measures were >0.1 cm and >0.1 kg apart, respectively, with the average of the two closest measured used. BMI (kg/m^2) was calculated and BMI percentile determined based on the growth charts of the US Centre for Disease Control and Prevention (30). Waist circumference was measured in duplicate midway between the top of the iliac crest and lowest rib against the skin during normal exhalation. A third measure was taken if the differences between the measures were >0.5 cm with the average of the two closest measures taken.

Body adiposity (body fat %) was assessed using bioelectrical impedance analysis (BIA) (RJL Systems – Quantum IV Body Composition Analyzer) *via* a whole-body impedance method using a tetrapolar model, with the child lying in the supine position. Fat-free mass was calculated using the standardised age-specific equations using the resistance values (31), validated against doubly labelled water, and percentage body fat was calculated as [(body weight − FFM)/body weight] × 100.

Aerobic Fitness

Aerobic fitness was assessed using the full Bruce protocol (32) on a treadmill (Valiant, Lode BV, Groningen, Netherlands). The full Bruce protocol has been shown to be a more accurate measure of maximal exercise fitness/endurance (i.e., time-to-exhaustion) in 4- and 5-year olds than the modified Bruce protocol. Participants began the test at a slow walking pace of 2.7 km/h at 10% grade for 3 min, with the speed and incline of the treadmill increasing every 3 min in a standardised manner until volitional fatigue. A researcher was positioned behind the child to ensure safety. The test was terminated when participants were unable to continue with increasing speed or grade, or refused to continue despite verbal encouragement. To assist with coordination and balance, the participants were instructed to hold onto the handrails of the treadmill for the duration of the test. The heart rate was continuously monitored *via* a chest-worn monitor (Polar H7, Polar Electro FTI, Kempele, Finland). Aerobic fitness was determined as the total time on the test. Maximal exertion was verified by the peak heart rate achieved and only the children who reached a maximum heart rate of 180 bpm or greater were included in analyses (33).

Anaerobic Fitness

Anaerobic fitness (muscle power) was assessed *via* the Wingate anaerobic cycling test using a paediatric cycle ergometer (Paediatric Corival, LODE). The maximum pedal speed was firstly determined by the participants sprinting as fast as possible against the initial resistance of the ergometer for 20–30 s. Then the participants were asked to stop pedalling and once the revolutions per minute (rpm) dropped below 50% of the maximum pedalling speed, the test was commenced. When the pedal speed reached 80% of the maximum pedal speed, a predetermined breaking force of 0.55 N/m/kg was applied. A verbal encouragement was provided to the participants to keep pedalling as fast as they could for 30 s. The power outputs were determined using the Wingate software package (Lode BV). The mean power was calculated as the average power over 30 s and normalised to body mass (W/kg). Participants were excluded from the analysis if they refused to pedal for the entire duration of the test.

Physical Activity and Sedentary Time

Time spent in LPA, MVPA, and in sedentary time was assessed as average minutes per day using an accelerometer (Actigraph GT3X+ activity monitor) worn around the waist. The devices were worn for seven consecutive days, except during sleep or prolonged water-based activities (e.g., bathing, swimming). The parents were asked to keep a record of the time of day that the monitor was placed on and removed each day. Data were analysed using ActiLife 6 software (ActiGraph, Pensacola, FL, United States) and have been previously described (25). Due to the short sporadic activity bursts typical of young children, 3-s epochs were used. Children who did not meet the accelerometer wear time criteria (≥10 h per day for 3 or more days per week)

were removed from the analysis. Sedentary time as well as the time spent in LPA and MVPA were determined using the 2008 Evenson activity cut points for children. These established cut points have been validated in the children aged 5–8 (34) and they have been shown to have the highest accuracy in activity classification in children and adolescents aged 5–15 (35).

Demographic and Health-Related Questionnaires

The primary parents/guardians of the enrolled children were asked to complete questionnaires regarding family demographics, level of education of themselves and their partners, and whether children had a diagnosis of one or more of the following: asthma or reactive airway disease, speech or language issues, non-corrected hearing issues, ear tubes or non-corrected vision issues.

Identifying Children at Risk for Developmental Coordination Disorder

The MABC-2 was used to assess motor coordination and to identity children with rDCD based on the established threshold cut points (≤16th percentile) (36). The MABC-2 is a standardised and validated test for the children and the adolescents aged 3–16 years (37). The test is individually administered including eight motor tasks across the following three categories: manual dexterity (three tasks), aiming and catching (two tasks), and balance (one static and two dynamic). The raw scores on these items are converted into standardised scores based on the child's chronological age, and converted into an overall percentile. Children who score at or below the 16th percentile are categorised as rDCD and those scoring above the 16th percentile are categorised as TD. The test–retest reliability and standard of error of measurement for the standardised test scores have been reported as 0.80 and 1.30 (corresponding to 0.45 SDs), respectively (38).

Statistical Analysis

All descriptive data are presented as mean ± SDs and proportions. The data were verified for normality through the Shapiro–Wilk and Kolmogorov–Smirnov tests and visual inspections of histograms and residuals Q–Q plots. Independent *t*-tests were used to compare baseline data between the analytical sample and those with missing data from the full cohort. Bivariate Pearson's correlations were conducted between body adiposity [total body fat percentage (%)] and demographic variables, aerobic and anaerobic fitness, MABC-2, physical activity levels, and sedentary behaviour. The strength of correlation coefficients was interpreted as ≤0.10 small association; ≤0.30 moderate association; >0.50 large association. The independent variables that showed an association ($p < 0.20$) with the dependent (body adiposity) in the bivariate analysis, and that are not mediators in the causal pathway between health-related fitness and body adiposity, were considered confounding variables and included in regression analyses as covariates. We fitted general linear regression models to examine crude (unadjusted) and adjusted associations between aerobic and anaerobic fitness, physical activity and body adiposity. The assumption for linear regressions were verified. In the cases where standardised residuals ±3 SD, data were included if the values were physiologically plausible. There were no significant interactions by sex or MABC-2 total percentile score and body adiposity, aerobic fitness or physical activity levels, and therefore all primary analyses were conducted in the full analytical cohort. Linear regression models were used to assess the associations between aerobic and anaerobic fitness, physical activity and sedentary time and body adiposity (Model 1), and after adjusting for confounding variables. Age and sex were entered as covariates in Model 2 and age, sex, and MABC-2 total percentile score were entered as covariates in Model 3. To aid interpretation of the analyses, the results are expressed as predictive margins for body adiposity for increments in (a) aerobic fitness (seconds on Bruce treadmill test), (b) anaerobic fitness (W/kg from mean 30 s power on Wingate test), (c) sedentary time (min/day), and (d) MVPA (min/day). The coefficients for predicative margins were generated using all participant data. To limit estimates to realistic values of body adiposity, predictive margins estimates were restricted to body adiposity values between the 5th and 95th percentiles of the body fat percentage distribution. While there was no interaction between MABC-2 and body fatness, we stratified the predictive models by MABC-2 classification for illustrative purposes. Data were analysed using Statistical Package for the Social Sciences (SPSS version 25.0; IMB Corp., Armonk, NY, United States). The predictive margins were performed using Stata 16.1; *p*-values were based on two-sided tests and considered statistically significant at $p < 0.05$.

RESULTS

Participant Characteristics

The analytical sample included 495 participants (83% of the enrolled cohort). Overall, sociodemographic characteristics, health-related fitness variables, physical activity, and sedentary behaviour variables for the enrolled cohort and the analytical sample are presented in **Table 1**. The majority of children had no medical conditions at baseline with asthma or reactive airway disease in 50 children (10%) and speech or language issues in 34 children (7%). The number and nature of diagnoses did not influence any outcome. Children with and without valid data for all included outcomes did not differ in sociodemographic characteristics; however, the analytical sample had statistically significantly higher scores for the overall MABC-2 total test percentage and each component of the MABC-2. These differences were not considered clinically meaningful. The reasons for missing data included: refusal or unable to undertake BIA ($n = 5$), did not achieve a maximal heart rate >180 bpm ($n = 4$), refusal or unable to pedal >25 rpm on the Wingate test ($n = 11$), equipment failure/data error on Wingate ($n = 6$), did not meet minimum wear criteria for the accelerometer ($n = 75$). On average, the analytical sample were 5.0 ± 0.6 years, 56% male, had a mean body adiposity of 22.7 ± 4.2% and mean aerobic fitness (time-to-exhaustion on the Bruce treadmill test) of 602.9 ± 99.4 s (**Table 1**). This level of aerobic fitness falls within the 50th–75th and 25th–50th percentile for boys and girls aged 5 years,

respectively (39). Further description of the full CATCH baseline cohort has been previously published (27).

Bivariate Correlations and Simple Regressions

The bivariate associations between body adiposity, demographic variables, health-related physical fitness variables, MABC-2 test scores, physical activity and sedentary behaviour are presented in **Supplementary Table 1**. There was a strong association (r = 0.647, $p < 0.001$) between body adiposity and sex, with girls having ∼5% higher body fat than boys. There was no association between BMI percentile and body adiposity. There was a small negative association between body adiposity and age (r = −0.187, $p < 0.001$), aerobic fitness (r = −0.285, $p < 0.001$), and anaerobic fitness (r = −0.217, $p < 0.001$). A moderate inverse association was observed between body adiposity and MVPA (r = −0.344, $p < 0.001$). Small positive associations were found between body adiposity and mean daily sedentary minutes (r = 0.184, $p < 0.001$) and LPA (r = 0.111, p = 0.012). There were no associations between body adiposity and total MABC-2 test percentile score. **Table 2** shows the crude (unadjusted) associations between body adiposity, demographics, aerobic and anaerobic fitness, MABC-2 test scores, physical activity and sedentary time, stratified by sex. In both boys and girls, age (β = −1.058 for boys; β = −1.606 for girls, $p < 0.001$), MABC-2 total test percentile score (β = −0.023 for boys, $p < 0.001$; β = −0.015 for girls, p = 0.032), aerobic fitness (β = −0.010 for boys; β = −0.011 for girls, $p < 0.001$), and anaerobic fitness (β = −0.612 for boys; β = −0.979 for girls, $p < 0.001$) were negatively associated with body adiposity. MVPA was associated with body adiposity in boys only (β = −0.040, $p < 0.001$).

TABLE 1 | Cohort characteristics: demographics, health-related fitness, and physical activity.

	Enrolled cohort (n = 589)	Analytical sample (n = 495)
Age (years)	4.9 (0.6)	5.0 (0.6)
Sex [boy, *n* (%)]	338 (57%)	279 (56%)
BMI percentile	56.1 (27.1)	55.8 (27.5)
Parental education:		
Bachelor's degree or higher [*n* (%)]	365 (62%)	318 (64%)
Bachelor's degree or higher, partner [*n* (%)]	274 (47%)	242 (49%)
MABC-2 total test percentile score	33.2 (29.1; *n* = 588)	35.4 (29.5)*
Manual dexterity	41.4 (29.1; *n* = 588)	43.2 (29.5)*
Aiming and catching	38.1 (26.6)	40.2 (26.6)*
Balance	33.4 (30.1; *n* = 588)	35.1 (30.4)*
Grouping, rDCD [*n* (%)]	288 (49%)	223 (45%)*
Body adiposity (%)	22.8 (4.2; *n* = 583)	22.7 (4.2)
Aerobic fitness		
Total treadmill time (s)	596.5 (102.2; *n* = 585)	602.9 (99.4)*
Anaerobic fitness		
Mean 30 s normalised power (W/kg)	3.3 (1.2; *n* = 572)	3.3 (1.2)
Physical activity and sedentary behaviour (min/day)		
Average sedentary time	451.7 (46.1; *n* = 514)	451.5 (45.7)
Average light physical activity time	200.6 (28.3; *n* = 514)	200.6 (28.2)
Average moderate-vigorous activity time	71.7 (19.8; *n* = 514)	71.7 (19.8)

*Data are means (SD; n) *p < 0.05 independent t-test (continuous data) or Chi-squared (categorical data) between analytical sample and sample not included due to missing data.*

Multiple Regressions

The crude and adjusted cross-sectional associations between aerobic and anaerobic fitness, sedentary time, LPA and MVPA and body adiposity are presented in **Table 3** and **Figures 1**, **2**. Aerobic fitness (β = −0.006, 95% CI: −0.009, −0.003, $p < 0.001$), and MVPA (β = −0.018, 95% CI: −0.036, <0.001, p = 0.045) were negatively associated with body adiposity, when adjusted for age, sex, and MABC-2 total test percentile score. Higher anaerobic fitness was associated with lower levels of body adiposity when adjusted for age and sex, but the association did not persist when adjusted by MABC-2 total test percentile score. The inverse cross-sectional associations of aerobic fitness (**Figure 1A**), anaerobic fitness (**Figure 1B**), and MVPA (**Figure 2B**) with body adiposity were consistent for boys and girls, for both TD and rDCD classifications. Similarly, the positive association between sedentary time and body adiposity was consistent across sex and developmental classification (**Figure 2A**).

DISCUSSION

The aim of this study was to examine the cross-sectional associations among aerobic and anaerobic fitness, device-measured physical activity and sedentary time, and body adiposity using laboratory-based measures in early childhood. We further explored these associations in children classified as TD and at rDCD. Across our whole sample that included 495 children (83% of enrolled cohort, 56% boys), we observed that aerobic fitness and MVPA were inversely associated with body adiposity and that these relationships were consistent across sex and motor coordination classification. Higher anaerobic fitness was also associated with lower body adiposity, but the association did not persist when adjusted by MABC-2 score in our final model. LPA showed no association. Contrary to our hypothesis, we did not observe a relationship between mean daily time spent in sedentary time and body adiposity. Consistent with previous findings (20), the BMI percentile had no association with the body adiposity in this population.

This is the first study to investigate these relationships in an early childhood cohort, and our observations highlight that the relationships between physical fitness, MVPA, and body adiposity are present even in early life stages, regardless of motor coordination. Increasing aerobic fitness and levels of MVPA are therefore important dual targets for lifestyle recommendations in all children of preschool age. These data reinforce the observations in older childhood and adolescents that physical fitness is a potent marker of health in children and adolescents (10). In consonance, Henriksson et al. (21)

TABLE 2 | Crude associations of demographics, health-related physical fitness variables, motor coordination, physical activity, and sedentary time with body adiposity for boys and girls.

	Boys β (95% CI)	*p*-Value	Girls β (95% CI)	*p*-Value
Age (years)	−1.058 (−1.642, −0.473)	<0.001	−1.606 (−2.240, −0.972)	<0.001
BMI percentile	0.003 (−0.010, 0.016)	0.650	0.012 (−0.003, 0.027)	0.118
Number of diagnoses at baseline	0.330 (−0.109, 0.769)	0.140	−0.284 (−1.024, 0.456)	0.450
MABC-2 total test % score	−0.023 (−0.035, −0.010)	<0.001	−0.015 (−0.028, −0.001)	0.032
Aerobic fitness (treadmill time, s)	−0.010 (−0.013, −0.007)	<0.001	−0.011 (−0.015, −0.007)	<0.001
Anaerobic fitness (W/kg)	−0.612 (−0.894, −0.329)	<0.001	−0.979 (−1.324, −0.635)	<0.001
Sedentary time (min/day)	0.009 (0.001, 0.017)	0.026	0.004 (−0.005, 0.014)	0.366
Light physical activity (min/day)	−0.002 (−0.016, 0.012)	0.768	0.008 (−0.007, 0.022)	0.310
Moderate-vigorous physical activity (min/day)	−0.040 (−0.058, −0.022)	<0.001	−0.023 (−0.048, 0.001)	0.061

Crude unadjusted associations between body adiposity and independent variables. β = unstandardized beta. BMI, body mass index (kg/m^2); MABC-2, movement assessment battery for children – Second Edition.

TABLE 3 | Associations between aerobic and anaerobic fitness, physical activity, and body adiposity.

	Model 1 β (95% CI)	*p*-Value	Model 2 β (95% CI)	*p*-Value	Model 3 β (95% CI)	*p*-Value
Aerobic fitness (treadmill time, s)	−0.007 (−0.011, −0.004)**	<0.001	−0.006 (−0.009, −0.003)**	<0.001	−0.006 (−0.009, −0.003)**	<0.001
Anaerobic fitness (W/kg)	−0.199 (−0.529, 0.132)	0.238	−0.300 (−0.569, −0.030)*	0.029	−0.248 (−0.535, 0.038)	0.089
Sedentary time (min/day)	0.003 (−0.007, 0.012)	0.569	0.006 (−0.002, 0.013)	0.132	0.006 (−0.002, 0.013)	0.124
Light physical activity (min/day)	0.006 (−0.009, 0.020)	0.448	0.011 (<0.001, 0.022)	0.060	0.010 (−0.001, 0.021)	0.066
Moderate-vigorous physical activity (min/day)	−0.063 (−0.086, −0.040)**	<0.001	−0.018 (−0.036, 0.1 × 10^{-2})*	0.045	−0.018 (−0.036, 0.1 × 10^{-2})*	0.045
R^2	0.160**	<0.001	0.523**	<0.001	0.524**	<0.001
Adjusted R^2	0.152**	<0.001	0.516**	<0.001	0.516**	<0.001

***p < 0.001, *p < 0.05. β = unstandardised beta. Model 1: crude associations; Model 2: adjusted for age and sex; Model 3: adjusted for age, sex, and MABC-2 total test percentile score.*

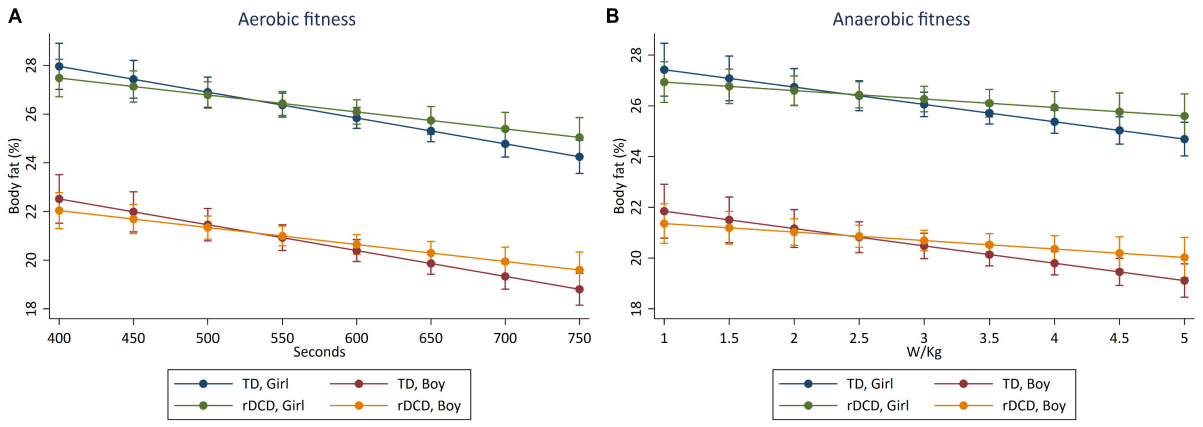

FIGURE 1 | Predictive margins for reductions in body adiposity (%) with increments in **(A)** aerobic fitness (time on Bruce test, s) and **(B)** anaerobic fitness [Wingate mean 30 s power (W/kg)]. Cross-sectional association between aerobic fitness **(A)** and anaerobic fitness **(B)** with body adiposity in boys and girls classified as TD and rDCD. The highest values on the *x*-axes represent the 95th percentile of aerobic fitness **(A)** and anaerobic fitness **(B)** distributions.

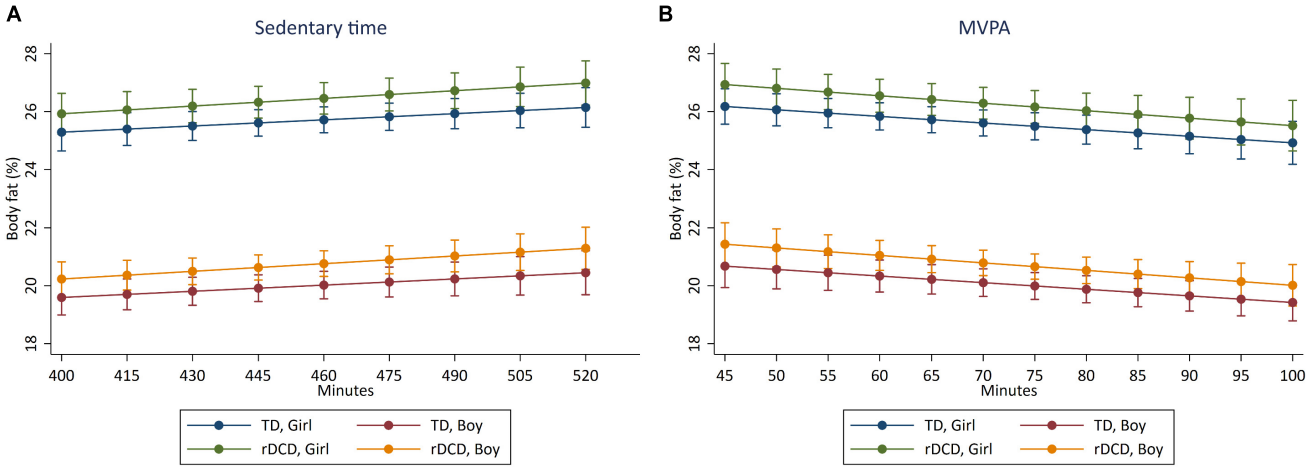

FIGURE 2 | Predictive margins for reductions in body adiposity (%) with increments in **(A)** sedentary time (min/day) and **(B)** MVPA (min/day). Cross-sectional association between sedentary time **(A)** and MVPA **(B)** with body adiposity in boys and girls classified as TD and rDCD. The highest values on the *x*-axes represent the 95th percentile of sedentary **(A)** and MVPA **(B)** distribution.

demonstrated that a higher fat mass index (fat mass (kg)/height^2 (m), *via* air displacement plethysmography) was associated with lower cardiorespiratory fitness (*via* 20 m shuttle run; $\beta = -0.17$, $p = 0.002$), lower body muscle strength (through standing long jump; $\beta = -0.17$, $p = 0.003$), and lower motor fitness (*via* 4 m × 10 m shuttle run; $\beta = -0.21$, $p < 0.001$), when adjusted for age, sex, and both the fat- and fat-free mass indices. Cardiorespiratory fitness was also beneficially associated with the fat-free mass index. Collectively, these data demonstrate that lean body mass and body adiposity have opposing associations with health-related components of physical fitness.

School-aged children with DCD have increased levels of obesity (23), lower cardiorespiratory fitness, with a higher likelihood of being below the 20th percentile for $\dot{V}O_{2peak}$ (40), and lower physical activity levels (41, 42) than TD peers. Our findings demonstrated that the inverse relationship between aerobic fitness and body adiposity was not different between children at risk of DCD and TD children at this young age. This is consistent with observations, using the same CATCH cohort sample by King-Dowling et al., that preschool-aged children at risk for DCD are no less active than their TD peers (25), potentially due to the relative low skill requirement for motor behaviour involved in play and activity at this age. Importantly, children with DCD will be increasingly challenged by the higher motor skill demands of activity and play (43). Whether early intervention targetting physical fitness and appropriate levels of MVPA in rDCD children can prevent the observed decline in physical activity and fitness and increased levels of overweight/obesity is yet to be elucidated and requires longitudinal investigation.

Our findings should be considered in the context of study limitations. While time-to-exhaustion on the Bruce maximal graded exercise test is strongly correlated with direct measurement of $\dot{V}O_{2max}$ using indirect calorimetry (44), the young age of the cohort prohibited us from obtaining a gold-standard $\dot{V}O_{2peak}$ result. To verify the maximal nature of the tests, we excluded children who did not reach maximal hearts rates 180 bpm or more (33). Notably, the time on test outcome for TD children were consistent with published reference data in preschool children (39). Body adiposity was determined *via* bioelectric impedance analysis, based on differences in tissue resistance to an electrical current when conducted through lean or fat tissue. Total fat mass is calculated by subtracting fat-free mass from total body mass and lean mass measures are influenced by hydration status. Hydration status was verbally confirmed and if required, the bladder voided, to minimise the influence of hyper-hydration. Due to the nature of the larger cohort study, children were tested at various time throughout the day, and as the testing protocols involved physical fitness measures, fasting conditions were not appropriate. Moreover, given that fat-free mass and body adiposity were both derived from the BIA method, we were unable to examine independent associations with indices of fat-free mass. Further, we did not examine the association of physical activity as the independent variable with body fatness and physical fitness as dependents; future studies could examine these associations to understand the comparable effects of physical activity on fatness and fitness in children, regardless of their motor coordination capabilities. As is common in cohort studies, our analytical sample had significantly higher aerobic fitness and MABC-2 percentile scores; however, the mean differences were not clinically meaningful. As detailed in Cairney et al. (28), the relatively homogenous sample consists of predominantly white and English-speaking children, who had higher average levels of family education and a relatively low proportion of families with low income. By the design of the prospective cohort study, the children at risk for DCD were oversampled to achieve an approximately equal distribution of children classified with typical motor coordination and

atypical motor coordination, which would not be expected in a contemporary cohort of children (expected prevalence 16% based on the MABC-2 threshold). Moreover, given the time course of diagnosis of DCD, which requires repeat motor assessment, not all those classified as rDCD would meet the DCD criteria in future years. Finally, residual confounding variables due to unmeasured outcomes cannot be ruled out. For example, genetics, socio–environmental factors, energy intake and dietary composition may also independently influence body adiposity.

From a public health perspective, a key implication of these findings is that early intervention is vital for pre-school aged children who have poor physical fitness and/or physical activity deficits, regardless of their motor coordination abilities, who have poor physical fitness and/or physical activity deficits. Newly promoted 24 h movement guidelines for children and young people (aged 5–17 year) encourage several hours of LPAs and limiting sedentary time to no more than 2 h/day in addition to promoting 60 min of MVPA (45). The present study highlights that for body adiposity, implementing lifestyle strategies early in life that specifically target activates to improve aerobic fitness and promote MVPA (rather than LPA or sedentary time) may potentiate life-long cardioprotective habits. This would likely also positively influence other variables of body composition such as bone mineral content and density and lean mass in young children. Further highlighting the importance of an early-age approach, Baquet et al. observed that adolescents who were less active at baseline, but increased physical activity at 4-year follow up, still did not reach the fitness levels of children who were more active at baseline (46).

In adults, there is clear and consistent evidence for the relative importance of aerobic fitness, arguably one of the most important single health outcomes across the lifespan, for cardiovascular events and all-cause mortality (47). Accordingly, the American Heart Association have called for cardiorespiratory fitness to be assessed as a "vital sign" in clinical practice (48). As levels of cardiorespiratory fitness in youth are strongly and inversely associated with future cardiometabolic risk profiles (49), considering cardiorespiratory fitness as a vital sign in children is also warranted. Currently, public health guidelines and strategies for children focus on accruing at least 60 min of MVPA daily; however, there are no specific recommendations regarding cardiorespiratory fitness. Standardising measurement and promoting age and sex-specific criteria based on normative data could be a future addition to guideline materials. In early childhood, an increased adoption of valid and reliable physical fitness assessment tools that are feasible to conduct outside of the laboratory setting, such as the PREFIT battery (50), could help identify children requiring targetted intervention and clinical follow-up.

Beyond achieving MVPA targets, activities that promote improvements in aerobic fitness should be advocated in early childhood. However, activities that increase aerobic fitness in adults (e.g., moderate intensity continuous training and/or structured high intensity interval training) do not align with the unstructured nature of child's play, making recommendations challenging. In early childhood, encouraging risky independent play may provide children with a greater opportunity for more vigorous-intensity activity, while being more fun.

CONCLUSION

In preschool-aged children, lower levels of aerobic fitness and MVPA were associated with higher levels of body adiposity, regardless of motor coordination classification. Early-life interventions promoting current MVPA targets and improvements in aerobic fitness are therefore warranted in both typically and atypically developing pre-schoolers to prevent obesity-related morbidity and mortality. A longitudinal follow-up is required to examine whether improving and/or maintaining a high aerobic fitness in children with DCD prevents the decline in physical activity and physical fitness and associated levels of overweight and obesity typically observed in this population.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available. Where applicable, anonymized data might be provided. Requests to access the datasets should be directed to SK, s.keating@uq.edu.au.

ETHICS STATEMENT

The study was approved by the Hamilton Integrated Research Ethics Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

SK, GM, and JC conceived and designed the study, conducted the analyses and wrote the first draft of the manuscript, contributed to data interpretation, and approved the final manuscript. SK-D, BT, and MK contributed to survey design, data collection and interpretation, and reviewed, edited, and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2022.756862/full#supplementary-material

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Construction of the Ohio Children's Opportunity Index

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Objective: To describe the development of an area-level measure of children's opportunity, the Ohio Children's Opportunity Index (OCOI).

Data Sources/Study Setting: Secondary data were collected from US census based-American Community Survey (ACS), US Environmental Protection Agency, US Housing and Urban Development, Ohio Vital Statistics, US Department of Agriculture-Economic Research Service, Ohio State University Center for Urban and Regional Analysis, Ohio Incident Based Reporting System, IPUMS National Historical Geographic Information System, and Ohio Department of Medicaid. Data were aggregated to census tracts across two time periods.

Study Design: OCOI domains were selected based on existing literature, which included family stability, infant health, children's health, access, education, housing, environment, and criminal justice domains. The composite index was developed using an equal weighting approach. Validation analyses were conducted between OCOI and health and race-related outcomes, and a national index.

Principal Findings: Composite OCOI scores ranged from 0–100 with an average value of 74.82 (SD, 17.00). Census tracts in the major metropolitan cities across Ohio represented 76% of the total census tracts in the least advantaged OCOI septile. OCOI served as a significant predictor of health and race-related outcomes. Specifically, the average life expectancy at birth of children born in the most advantaged septile was approximately 9 years more than those born in least advantaged septile. Increases in OCOI were associated with decreases in proportion of Black (48 points lower in the most advantaged vs. least advantaged septile), $p < 0.001$) and Minority populations (54 points lower in most advantaged vs. least advantaged septile, $p < 0.001$). We found R-squared values > 0.50 between the OCOI and the national Child Opportunity Index scores. Temporally, OCOI decreased by 1% between the two study periods, explained mainly by decreases in the children health, accessibility and environmental domains.

Conclusion: As the first opportunity index developed for children in Ohio, the OCOI is a valuable resource for policy reform, especially related to health disparities and health

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equity. Health care providers will be able to use it to obtain holistic views on their patients and implement interventions that can tackle barriers to childhood development using a more tailored approach.

Keywords: area-level deprivation, opportunity, children well-being, social determinants of health (SDoH), neighborhood

INTRODUCTION

Unmet basic needs are likely to result in poor health outcomes across the lifespan (1, 2) making children living in poverty extremely vulnerable. Approximately 2.6 million of Ohio's 11.5 million population are children. About 20% of these children in Ohio live in poverty, 16% are chronically absent from school, and 14–15% have a disability. Further, over 20,000 children in Ohio are homeless (3). Those who are most disadvantaged, while shouldering a disproportionately higher burden of poor health and risk factors for poor health, are also the least likely to access care when needed (4). Risk factors tend to cluster within individuals, families, and communities, worsening the inverse relationship between the need for healthcare and access to it (5). This phenomenon is apparent, for example, among vulnerable populations who have higher utilization of out-of-hours emergency health care rather than preventive health care, perpetuating the cycle of expensive, reactive care (6).

The high infant mortality in Ohio (7), especially the wide disparity between infants born to White vs. Black mothers prompted the Ohio Department of Medicaid (ODM) to develop the Ohio Opportunity Index (OOI) (8) and the Ohio Children's Opportunity Index (OCOI) through the Infant Mortality Research Partnership and as a general movement to monitor deprivation among individuals from childhood and onwards. The objective was to aid the identification of deprived areas for targeted allocation of resources to improve health care delivery and health services, which has been shown to decrease disparities (9). Area-level indices of deprivation have been used in New Zealand and the United Kingdom not simply to study risk factors and outcomes but also for incorporation into healthcare delivery (10).

Individual factors only partially capture determinants of health and disease, drawing attention to the "place" effect (11, 12)—the social, economic, and physical conditions in the environment where people live, also called social determinants of health (SDoH) (13). Several studies have formally decomposed the contributors of health outcomes into clinical care, health behaviors, socio-economic factors and physical environment (14–17). Characterizing the individual effect of any of these factors, particularly socioeconomic and environmental conditions that contribute between 20 and 50 percent to health outcomes, do not provide adequate guidance on how interventions or policies can be developed with greater precision for target populations (16, 18). Hence, there is a need for nuance about modifiable attributes within a domain that can truly influence health outcomes.

The influence of SDoH vary based on the ecological level at which they operate. Poverty places a greater health burden on society than either of the leading behavioral risk factors—smoking or obesity (19). Individual poverty combined with living in an affluent neighborhood was not associated with negative health consequences, whereas living in a deprived neighborhood was associated with adverse health outcomes more so among poorer individuals, who may be more dependent on collective neighborhood resources (20). Deprivation is "a state of observable and demonstrable disadvantage relative to the local community or the wider society or nation," and poverty on the other hand is the lack of resources to escape deprivation (21). Many indices have been created to show deprivation or opportunity, including the Human Opportunity Index, but many of these operate at a country or state level without comparing inequality on a more granular level (22–24). An area-level deprivation index (ADI) reflects aggregate measures of SDoH at the neighborhood level.

Advances in computing power, geographic information systems (GIS), and statistical techniques like multi-level modeling allow for more sophisticated and detailed examination of area level SDoH than in the past (25). The Public Health Disparities Geocoding Project assessed a variety of single indicators and composite measures of socioeconomic deprivation and demonstrated gradients with outcomes like childhood lead poisoning, mortality, and low birth weight (26, 27). Moreover, Krieger and colleagues demonstrated that indices of area level deprivation facilitated detection of larger socioeconomic gradients than more focused area level measures of education and wealth. Linking the area deprivation index with county-level mortality revealed widening inequalities in area level mortality on account of slower declines in mortality in deprived areas (28). These are but a few examples of the wealth of research suggesting that place matters.

Neighborhoods possess physical and social attributes that could affect health (25). Empirical research examining neighborhood effects on children and adolescents have established that there is considerable socioeconomic and racial segregation and that indicators like crime, social, and physical disorder tend to cluster at the neighborhood level (29). Predictors common to many childhood outcomes include concentrated poverty and racial isolation (29). Neighborhood disadvantage has been shown to be associated with child health outcomes such as behavioral problems and verbal ability (30, 31). The influence of neighborhood can be recognized through the Moving to Opportunity Experiment. Moving to a more affluent neighborhood when children are younger than 13 was argued to have to an increase in college attendance and earnings (32). The seminal Whitehall studies have highlighted the social gradient or the socioeconomic differences in physical and mental illnesses and mortality (9).

The OCOI is a measure of SDoH at the census tract level conveying opportunity information for children across the state of Ohio. We define children as anyone between birth and below the age of 18. As a neighborhood's effect on children's health is not exerted by a single factor but by a combination of them, the OCOI is a composite index of 53 neighborhood indicators spanning eight domains associated with healthy child development. The OCOI is not the first index associated with healthy childhood. The similarly-named Child Opportunity Index consists of 29 indicators corresponding to three domains: *educational*, *health and environment*, and *social and economic*. The Child Opportunity Index is available for all US census tracts for both 2010 and 2015 (33). Our measure, however, consists of more, higher resolution variables measuring the prevalence of SDoH factors within the state.

In this article we describe the development of the OCOI. The purpose of the OCOI is to provide a measure of children's opportunity in Ohio. Public health practitioners, policymakers, researchers, and healthcare providers can use the OCOI to identify neighborhoods of low and high opportunity in Ohio. In this article we first discuss the process of domain and input data selection followed by data extraction. Next, we discuss the four-step process involved in the construction of the OCOI based on seminal approaches and their analysis across two time periods (34, 35). Finally, we report the association of the OCOI with life expectancy and proportions of minority populations to validate the index and report changes in children's opportunity in Ohio with time as explained by changes in the domain scores. The goal of our paper is to present an approach to developing an area deprivation index of higher resolution compared to what currently exists, and provide researchers and other key stakeholders the opportunity to pursue a similar approach regarding the development and validation of an area deprivation index for children.

DATA AND METHODS

Measures of social determinants of children's health and well-being were collected at the census tract level for Ohio. Census tracts are geographical sub-divisions of counties that contain an average of 4,000 people (3). Because of similar neighborhood characteristics, federal and state agencies often collect tract level aggregates as a proxy for area-based information. Study data pertain to 2,940 tracts out of the total 2,952 census tracts in Ohio. Twelve tracts were excluded because of zero population. Data were procured from federal sources such as the US census based-American Community Survey (ACS) data set, which is a freely available resource, and other state and federal agency administrative data sets (e.g., Medicaid claims and Department of Education school report card data). The Government Resource Center at the Ohio State University compiled the measures used for the construction of the OCOI. Information was gathered to represent two time periods, 2010–2014 (Period I) and 2013–2017 (Period II), inclusive.

Domains and Variables

Deprivation indices are either represented by simple indicators measuring social deprivation alone, such as poverty (36), or as a composite score articulated from multiple mutually exclusive indicators or "domains" (35). Using the framework developed by Peter Townsend and Exeter (21, 37), the current study adopted a multi-dimensional and a multi-domain approach. The domains refer to a collection of constituent measures pertaining to economic, material, and psychosocial influences in humans. Additional details about these measures and associated attributes can be found in a study conducted by Pearce and colleagues (38). Guided by Townsend's framework (35), the subject matter experts (maternal-child health and geospatial area deprivation measure development) and the study team identified a list of eight domains: *family stability, infant health, children's health, access (to health care and food), education, housing, environment, and criminal justice* for OCOI construction. The study domains mostly overlap with the SDoH factors identified by the Center for Disease Control and Prevention (CDC) (life-enhancing resources such as food supply, housing, transportation, education, and health care) further substantiating their use (39). A brief description of the domains are as follows (40, 41):

(1) **Family Stability:** Measures early influences of family settings on children including family breakdown, parental relationship, and family income.
(2) **Infant Health:** Determinants of children's health that operate from before conception through birth. Maternal influences such as mother's health, lifestyle, and social and physical environments have immediate effect on children's health.
(3) **Children's Health:** Presence of chronic conditions in children that may affect their overall development.
(4) **Access:** Poor geographical access to key local services.
(5) **Education:** Scholastic attainment and skills in local population that may lead to low health literacy.
(6) **Housing:** Barriers to affordability of housing and stable housing conditions.
(7) **Environment:** Physical space and characteristics, both natural and built, that influence health.
(8) **Criminal Justice:** Likelihood for personal and material victimization at the local level.

The number of constituent measures used in the study differed across the two-time frames due to their availability. Information was available for 37 constituent measures in Period I, and 53 constituent measures in Period II (including those from Period I). For comparison purposes, Period II was divided into two subsets: reduced and complete. The Period II reduced subset comprised of the 37 measures common to Period I, while the Period II complete subset included all the 53 constituent measures. We used the Period II complete dataset as an example for outlining the OCOI construction methodology in this paper and the same process was used to construct scores for the remaining datasets. The constituent measures in this along with their corresponding data sources are listed in **Supplementary Table S1**. These measures were summarized

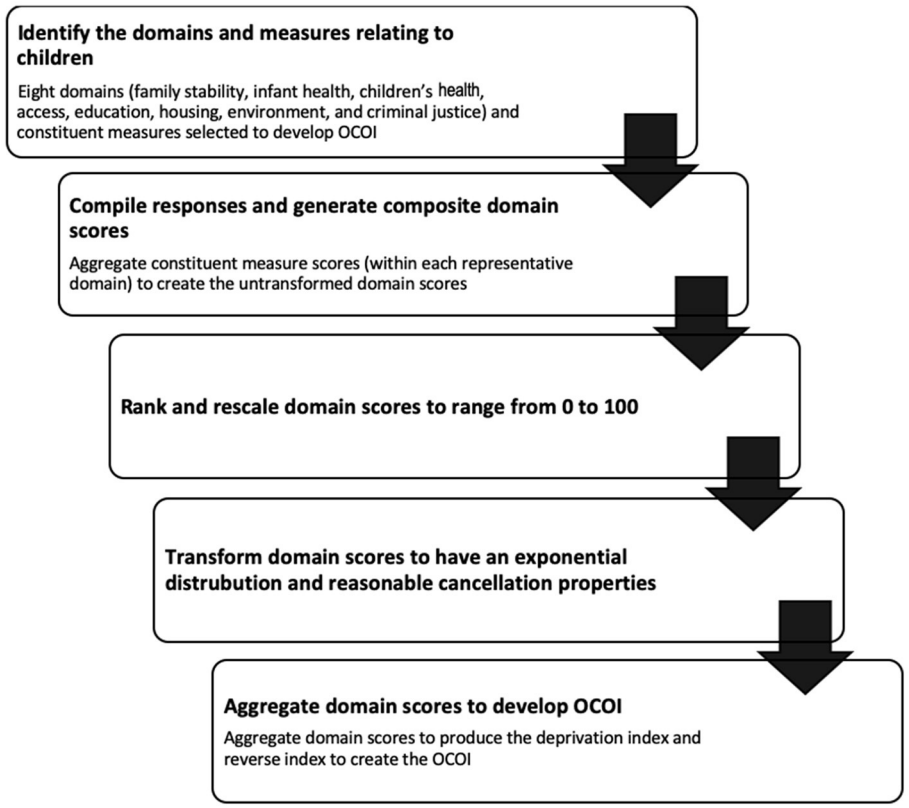

FIGURE 1 | Flowchart representing steps involved in developing the Ohio children's opportunity index.

(within respective domains) to yield domain scores, which were further summarized to form the final OCOI. **Figure 1** represents an outline of the process used to create the OCOI.

Of the 53 constituent measures, five were assigned to the family stability domain, seven to infant health, eight to children's health, seven to access, eight to education, seven to housing, six to environment, and five to the criminal justice domain. Some constituent measures were reverse coded to maintain a consistent direction with respect to what higher (opportunity) vs. lower (opportunity) values mean.

Validation Outcomes

The study-generated OCOI scores were tested for association with outcomes previously linked to area-level deprivation for construct validity (42). Probability of life expectancy was used as a health outcome criterion for prediction based on OCOI. Life expectancy represents the expected average years of survival at birth. Data for this outcome was collected at the census tract level from 2010–2015 and retrieved from National Center for Health Statistics, CDC (43). Variability in racial distribution in the population, for Black and minority groups were examined. Information regarding the percent of Black and minority population living within a tract were obtained from ACS (44). We assessed criterion validity by comparing the Period II complete OCOI and the national Child Opportunity Index scores (33).

Analysis

Statistical analyses were performed using R version 4.0.3. Raw data were obtained for measures across the 2,940 census tracts in Ohio. A multi-stage approach was adopted to generate the OCOI. First, univariate and bivariate analyses were conducted to explore the statistical distribution of variables, their missingness, and their relationship with other variables. Missing values were replaced with median values of the corresponding measure. Also, at this stage, we performed correlational analysis on the constituent measures to assess the grouping of the 53 variables (see **Supplementary Figure S1** for the correlation matrix). The next steps included a series of transformations to create a composite measure from raw scores. Following Townsend (35) and Noble's (34) work, the OCOI was computed based on the following procedures:

(1) Standardizing and averaging:

Data were collected across 53 measures in different units such as proportions and counts. The first step in the analysis was to standardize these raw scores such that they have a mean of 0 and a standard deviation of 1 (i.e., z-scores) as illustrated

in Equation 1, wherein Z is the standardized score, x is a value, μ and σ are the mean and standard deviation of a specific measure i within domain d:

$$Z_{d,\,i} = \frac{x - \mu_{\,i}}{\sigma_i} \quad (1)$$

The standardized scores were then averaged (within domains) to form domain scores, for example, Z is the standardized scores for measures $i = 1$ to n for the first domain and N is the total number of measures in the first domain, D_1.

$$Domain_{d=1\ldots n} = \sum \left\{ \frac{Z_{d=1,\ i=1\ldots n}}{N_{d=1}} \right\} \quad (2)$$

The scores are subsequently transformed in the following manner (37).

(2) Ranking:

The domain scores are ranked and scaled to range between zero and one, wherein R is the rank of census tract ct, d=domains between 1 and 8.

$$R_{d=1\ldots n,ct=1\ldots 2940} = \left(\frac{Domain_{1\ldots n}}{2940} \right) \quad (3)$$

(3) Exponential distribution:

The scaled rankings were then transformed to have an exponential distribution. According to Noble et al. (34) this helps each domain to have a common distribution, the same range, and identical maximum and minimum values of 0 and 100 respectively. The exponential distribution stretches out the distribution so that greater levels of deprivation score more highly. The transformed domain was given by Noble et al. (34) Equation 4, wherein X is the transformed domain value, δ is a constant and R is the rank on the domain for census tract ct and d = domains between 1 and 8.

$$X_{d=1\ldots n,ct=1\ldots 2940} = -\delta \ln \left\{ 1 - R_{d=1\ldots n,ct=1\ldots 2940} \left[1 - \exp - \left(\frac{100}{23} \right) \right] \right\} \quad (4)$$

(4) Equal weighting:

These transformed final domain scores were then aggregated using a weighing technique. For this study we used the equal weighting method, wherein each domain was assigned a weight of 1/8 and aggregated to form the deprivation index. The equal weighting method is a seminal approach used by many European countries for calculating area-level deprivation scores (45). By doing so, we assume equal importance of all deprivation domains. This technique is known to produce valid area-level measures and significantly predict health outcomes such as mortality (45). The resultant tract-level scores represented deprivation index for Ohio and were reversed and scaled between 0 and 100 to create the OCOI for each census tract. Septiles were computed from the tract-level score to simplify interpretation.

$$COI_{ct=1\ldots 2940} = \left(100 - \sum \left(\frac{X_{ct=1\ldots 2940}}{8} \right) \right) \quad (5)$$

(5) Validation and sensitivity analysis:

We used the same regression-based validation approach as previous studies to predict health-related outcomes (45). OCOI score categories (i.e., septiles) were used to predict life expectancy. The distribution of minority and Black population against OCOI categories were also examined using ordinary least squares (OLS) regression model specifications. R-squared values were calculated between the OCOI scores and the state normed and national normed Child Opportunity Index scores. Equation 6 represents an example regression with *Outcome* that is a vector for a validation measure such as life expectancy for census tract *ct and* β is a vector *jth* regression intercept and slope for each Domain *(d = 1...8)* of the COI.

$$Outcome_{ct} = \beta_j Domain_{d=1\ldots 8} \quad (6)$$

Readers can refer to our github page: https://github.com/ChildrensOpportunityIndex/The-Ohio-Opportunity-Index-Project, which provides detailed information on the construction and applications of the OCOI and can aid with replication in future studies. The OCOI and domain scores data linked to census tract FIPS codes can be obtained at the main project page: https://grc.osu.edu/Projects/OhioOpportunityIndex.

OCOI RESULTS

Univariate Descriptive Statistics

Table 1 presents descriptive statistics for the 53 constituent measures using aggregated data from 2013–2017. Out of 53 measures, responses for eleven measures were reversed to maintain a consistent direction: labor market engagement index, proportion of children with six or more well child primary care provider visits, proportion of children between ages three and six with one or more well-child primary care provider visits, low transportation cost index, behavioral health visits for children that meet access standards, proportion of primary care visits for children that meet the access standards of CMS, free lunch distribution, graduation rate, school performance index, schools value-added score, and environmental health hazard index.

OCOI Scores

Graphical distribution and descriptive statistics for the study-generated OCOI scores are reported in **Supplementary Figure S2** and **Table 2** respectively. As shown by the histogram, the distribution of OCOI scores displayed a negative skew, indicating higher opportunities for children in Ohio for most tracts compared to normally distributed outcomes. The average OCOI score was 74.82 (SD, 17.00).

Figure 2 presents a choropleth map of the OCOI across the state census tracts. Census tracts in the metropolitan

TABLE 1 | Univariate descriptive statistics of Ohio children's opportunity index.

Domain	Constituent measures	Median	Mean	SD	Min	1st quartile	3rd quartile	Max
Family stability	1) Proportion of parents enrolled in Medicaid with a primary SMI diagnosis	0.08	0.08	0.03	0.00	0.07	0.10	0.27
	2) Proportion of children living in a household with below-poverty income	0.18	0.24	0.21	0.00	0.07	0.36	1.00
	3) Proportion of births that include no father's first/middle/last name	0.12	0.18	0.16	0.00	0.07	0.24	0.81
	4) Proportion of families with a parent served by Medicaid who has an SUD diagnosis	0.06	0.06	0.03	0.00	0.04	0.07	0.43
	5) Labor Market Engagement Index (HUD) (reversed)	44.00	45.10	28.85	0.00	20.75	68.00	99.00
Infant health	1) Proportion of births that resulted in an infant mortality	0.00	0.01	0.01	0.00	0.00	0.01	0.33
	2) Proportion of Medicaid infants who had an injury or poisoning in the first year of life	0.15	0.15	0.05	0.00	0.12	0.18	0.50
	3) Proportion of Medicaid-enrolled infants with neonatal abstinence syndrome	0.04	0.05	0.05	0.00	0.02	0.08	0.67
	4) Proportion of Medicaid-enrolled infants with NICU stay	0.11	0.11	0.06	0.00	0.07	0.14	1.00
	5) Proportion of infants born preterm	0.10	0.10	0.04	0.00	0.08	0.12	0.50
	6) Proportion of Medicaid children with six or more well-child visits in first 15 months of life (reversed)	0.54	0.54	0.13	0.00	0.46	0.62	1.00
	7) Proportion of infants born to Medicaid-enrolled women with severe maternal morbidity	0.04	0.04	0.03	0.00	0.02	0.05	1.00
Children health	1) Proportion of Medicaid-enrolled children ages 1–5 with a diagnosis of developmental delay including sight and hearing impairment	0.27	0.28	0.04	0.00	0.25	0.30	0.63
	2) Proportion of Medicaid children age 3–6 meeting continuous enrollment criteria with one or more well-child visits with a PCP (reversed)	0.41	0.42	0.08	0.00	0.37	0.46	1.00
	3) Proportion of Medicaid-enrolled children ages 6–17 with a diagnosis of asthma	0.09	0.10	0.03	0.00	0.07	0.11	0.50
	4) Percent of children ages 6–17 with a diagnosis of mental illness	0.09	0.09	0.03	0.00	0.07	0.11	0.40
	5) Proportion of children ages 6–17 with a diagnosis of a developmental disability	0.08	0.08	0.03	0.00	0.07	0.10	0.75
	6) Proportion of children ages 6–17 with a diagnosis of diabetes	0.01	0.01	0.01	0.00	0.00	0.01	0.17
	7) Proportion of children ages 6–17 who received psychotropic BH medication	0.16	0.17	0.05	0.00	0.14	0.19	1.00
	8) Proportion of children ages 6–17 with a diagnosis of obesity	0.04	0.04	0.02	0.00	0.02	0.06	0.20
Access	1) Proportion of Medicaid behavioral health visits for children that meet the access standards of CMS (reversed)	0.39	0.44	0.30	0.00	0.17	0.70	1.00
	2) Proportion of primary care visits for children that meet the access standards (driving time, driving distance) of CMS (reversed)	0.56	0.57	0.23	0.00	0.36	0.77	1.00
	3) Geographic isolation (rurality) of the census tract	−0.12	0.05	0.63	−1.17	−0.40	0.34	2.36
	4) Low transportation cost index (reversed)	41.00	42.07	21.12	0.00	25.00	58.00	99.00
	5) Percent occupied housing units in tract without a vehicle	6.05	9.77	10.52	0.00	2.90	12.44	71.37
	6) Percent tract population within a distance from the supermarket	1.08	7.50	12.77	0.00	0.00	9.71	91.92
	7) Distance to nearest elementary school	0.38	0.00	1.00	−6.25	−0.18	0.62	0.88
Education	1) Percent youth who have dropped out	0.00	4.44	9.17	0.00	0.00	5.47	100.00
	2) Percent of adults in the tract with less than high school education	9.71	11.56	8.16	0.00	5.75	15.23	67.84
	3) Percent of youth (age 5–17) not enrolled in school	0.02	0.03	0.04	0.00	0.00	0.05	0.46
	4) Proportion of children not meeting third grade reading standards	0.04	0.07	0.08	0.00	0.01	0.10	0.50
	5) Free lunch distribution (reversed)	−0.08	0.00	1.00	−2.13	−0.73	0.69	1.96
	6) Graduation rate (reversed)	−0.33	0.00	1.00	−1.42	−0.73	0.45	3.77
	7) School performance index (reversed)	−0.30	0.00	1.00	−1.86	−0.77	0.74	4.09
	8) School's value-added score (reversed)	0.04	0.00	1.00	−4.43	−0.62	0.64	4.47
Housing	1) Percentage putting 50 percent of income toward mortgage	7.06	8.06	5.42	0.00	4.89	9.87	100.00
	2) Percentage of households with less than one person per room	0.81	1.43	1.95	0.00	0.00	2.09	32.86
	3) Percentage putting 50 percent of income toward rent	19.42	20.62	11.71	0.00	12.42	27.70	100.00
	4) Percent housing identified as vacant	9.01	11.45	8.87	0.00	5.53	14.54	82.61
	5) Percentage renting	32.55	36.31	21.74	0.00	18.93	51.25	100.00
	6) Percentage living in same housing unit for <1 year	13.64	15.60	9.60	1.11	9.19	19.42	93.21
	7) Rate of evictions among renters	2.50	3.31	2.68	0.00	1.41	4.55	25.00

(Continued)

TABLE 1 | Continued

Domain	Constituent measures	Median	Mean	SD	Min	1st quartile	3rd quartile	Max
Environment	1) Tract land area *not* covered by vegetation	78.61	64.51	35.47	3.64	27.20	98.25	100.00
	2) Tract land area covered by open development (e.g., pavement, parking)	0.14	0.16	0.12	0.00	0.06	0.24	0.64
	3) Percent of housing units constructed prior to 1980	74.77	71.26	22.36	0.00	57.09	90.59	100.00
	4) Annual average of daily pm 25 measurements	11.51	11.39	0.48	9.78	11.06	11.72	12.21
	5) Count of tobacco retail outlets within a 3/4th mile buffered tract boundary	16.00	17.49	11.17	0.00	9.00	23.00	74.00
	6) Environmental Health Hazard Index (air quality) (reversed)	58.00	57.84	28.56	8.00	33.75	80.00	100.00
Criminal Justice	1) Average number of homicide, assault, and sexual assault incidents per person reported to police each year during the period 2017–2018	0.01	0.02	0.03	0.00	0.00	0.02	0.87
	2) The average number of robbery incidents per person reported to police each year during the period 2017–2018	0.00	0.00	0.00	0.00	0.00	0.00	0.17
	3) The average number of burglary, larceny-theft, and motor-vehicle theft incidents per person reported to police each year during the period 2017–2018	0.01	0.02	0.04	0.00	0.00	0.03	0.73
	4) The average number of drunkenness and driving under the influence incidents per person reported to police each year during the period 2017–2018	0.01	0.01	0.02	0.00	0.00	0.02	0.57
	5) The average number of drug crime incidents per person reported to police each year during the period 2017–2018	0.00	0.01	0.02	0.00	0.00	0.01	0.36

TABLE 2 | Summary of Ohio children's opportunity index scores and domains.

	Median	Mean	SD	Min	1st quartile	3rd quartile	Max
OCOI	79.35	74.82	17.00	0.00	65.64	87.84	100
Septile 1	44.01	42.49	9.50	0.00	37.10	49.99	54.30
Septile 2	62.59	62.01	4.20	54.31	58.27	65.62	68.41
Septile 3	72.47	72.50	2.31	68.42	70.47	74.48	76.32
Septile 4	79.35	79.23	1.64	76.32	77.78	80.50	82.12
Septile 5	84.50	84.53	1.37	82.12	83.40	84.57	86.73
Septile 6	88.85	88.90	1.26	86.73	87.83	89.92	91.09
Septile 7	93.68	94.10	2.10	91.1	92.34	95.56	100

cities of Cleveland, Columbus, Cincinnati, Toledo, and Dayton contained 29.28, 15.47, 13.33, 9.4, and 8.09% (together a total of 75.7%) of the total census tracts in the lowest OCOI septile (Q1), respectively.

Figure 3 Illustrates patterns in OCOI scores within a single neighborhood in Columbus, Ohio. Upper Arlington anecdotally represents a neighborhood of high opportunity and living standards. There are 46% of tracts in Upper Arlington in the top three OCOI septiles, albeit 26% of the tracts in this neighborhood are in the bottom three septiles. The tracts with low OCOI scores in this neighborhood reflect a contrast to the immediately adjacent tracts in regard to domains such as children's health and family stability.

Validation Results

We tested the construct validity of our OCOI measure using regression analysis wherein OCOI scores (collapsed to septiles, with the lowest used as the reference) were used as predictors for reference measures: health-related outcomes and neighborhood proportion of minority populations. OCOI scores were a significant predictor of each reference measure ($p < 0.001$). The average life expectancy of children born in septile 7 was approximately 9 years more than those born in septile 1. The variability in Black and Minority population on OCOI scores was also examined based on OCOI septiles. The percentage of Black population living in septile 7 was 48 points lesser than those in septile 1. Likewise, the percentage of Minority population living in septile 7 was 54 points lesser than septile 1. From our test of trends, we found that trends were present in our outcomes across the ordered levels or septiles of OCOI ($p < 0.001$). See **Supplementary Table S2** for estimates from the validation analyses. In regard to criterion validity, the R-squared between the OCOI and Child Opportunity Index scores were 0.52 (state normed Child Opportunity Index) and 0.55 (nationally normed Child Opportunity Index). This demonstrates that our measure captures something very similar to those national indices. Differences are likely due to the finer grain of information we have available specific to Ohio.

Temporal Changes

Using the proposed steps, we developed OCOI scores for reduced datasets across Periods I and II, and compared them for temporal changes. The average OCOI reduced from 73.89 to 72.96 from Period I to Period II, which is a reduction by approximately 1%. We found, at the area level, notable declines (>10 points in COI score) across both rural and urban tracts and notable gains (>10 points in COI score) among urban tracts between the two time periods. We also investigated change in domains scores across the two-time periods. Our results, as indicated in **Supplementary Table S3**, indicate a noteworthy decline (>3% points) in the children's health and environment domains. Alternatively, improvements were present for domains representing housing stability, with the highest increase of 9% points over time, followed by family stability, education, criminal justice, and infant health.

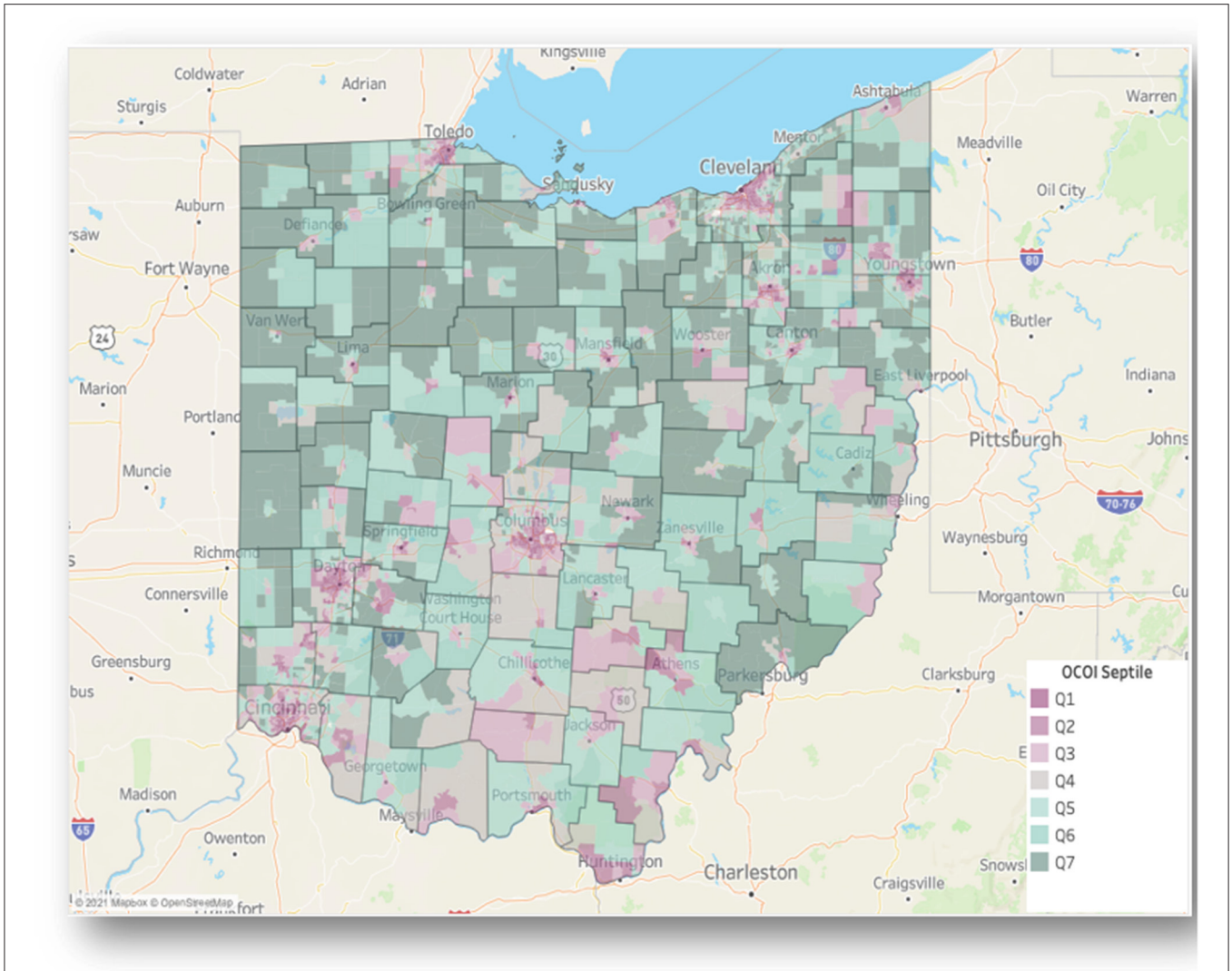

FIGURE 2 | Ohio children's opportunity index scores on a choropleth map of Ohio. Ohio Children's Opportunity Index (OCOI) distribution (as septiles of scores) displayed across tracts and counties. Q1 represents least advantaged census tracts.

DISCUSSION

The OCOI was created to codify the geographic distribution of SDoH in the state of Ohio, particularly those that are likely to impact infants and children. The final OCOI was made up of eight domains comprising 53 variables that vary geographically. Analysis of the OCOI by census tract also shows that it captures variations by census tract that may be missed at coarser geographies. We found that increases in the OCOI scores were associated with higher tract-average life expectancy and minority population proportion.

The OCOI was inspired by the Ohio Opportunity Index (OOI), a related index that describes general deprivation of geographic areas in Ohio and consists of a different set of variables and domains. The researchers and stakeholders who developed the OOI realized that there were factors affecting children's health and development that do not affect adults in the same way, along with factors in the OOI that do not influence children as much, motivating the development of a more specific index for children. The OCOI domains of family stability, environment, infant health, and children's health are not in the OOI, but are important predictors of children's health because they are associated with adolescent and adult health, social, and educational development (46–50). There is significant evidence that children living in more deprived areas are more likely to experience poor social, behavioral, health, and economic outcomes not only in childhood but throughout life, highlighting the importance of a children's index (51–54). Moreover, both indices are based on data that contains information specific to Ohio and its population.

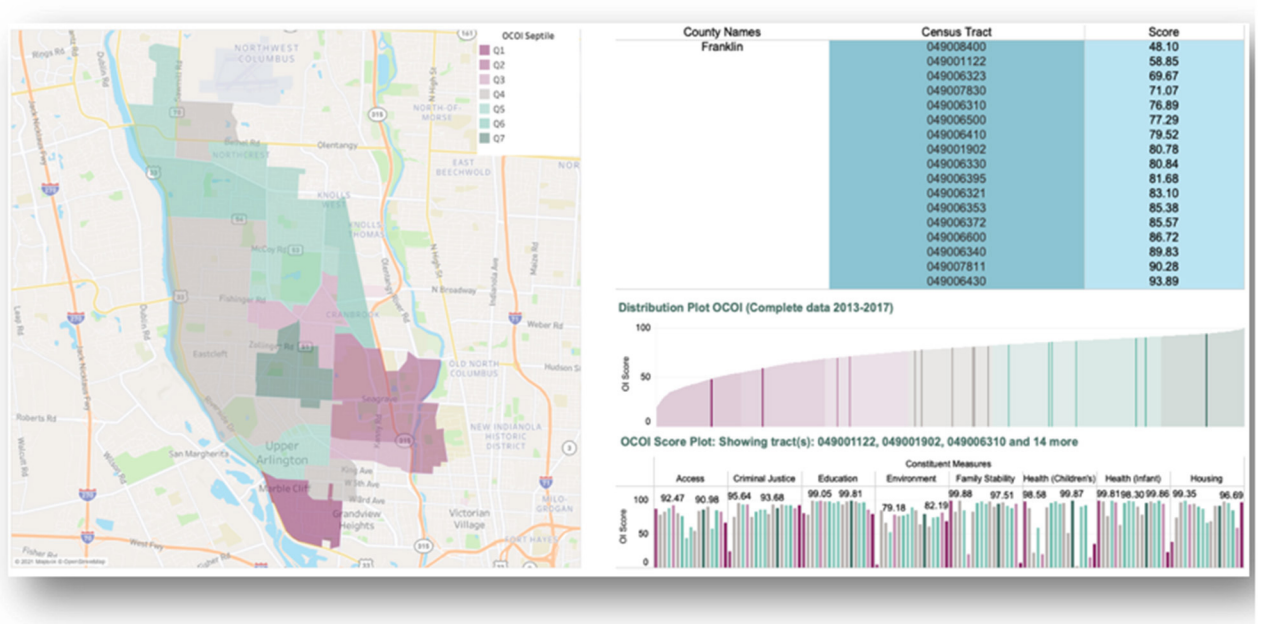

FIGURE 3 | Illustrating distribution of Ohio children's opportunity index scores using a neighborhood view. Ohio Children's Opportunity Index (OCOI) distribution (as septiles of scores) and sub-domain scores displayed across tracts for one neighborhood in Columbus, Ohio. Q1 represents least advantaged census tracts.

There is conflicting evidence regarding the extent to which children's outcomes are affected by poverty on the family level vs. the neighborhood level. Some research shows children in poor families may experience worse outcomes, a form of "double disadvantage," when they live and attend school alongside more affluent vs. similarly positioned peers as opposed to those who live near peers in similar levels of poverty (55). Other research, including data from the Moving to Opportunity (MTO) Study, provides conflicting evidence that growing up in better quality neighborhoods can improve the adult earnings of low-income children that move out of more deprived areas (32). The OCOI shows that many of the census tracts with the lowest opportunity are in urban areas, where children may be very close to tracts with extremely different OCOI scores, which could negatively affect their subjective social status (55). In addition, there are some possible negative effects of moving children from a low opportunity area to a high opportunity area other than their comparatively low social status, including low academic achievement (56) and antisocial behavior (57). Efforts to improve OCOI scores should focus on providing resources and helping areas with the most deprivation to increase equality of opportunity, rather than moving children out of low opportunity areas at the expense of the children who remain in them.

This is the first children's opportunity index developed for the state of Ohio, however, there are similar efforts to map children's deprivation or opportunity in other parts of the United States. There is a national Children's Opportunity Index that uses data for all US neighborhoods and provides data for the overall Index, three domains, and individual component indicators (58). The Opportunity Atlas is a national index that shows the likelihood of a child in different census tracts experiencing certain economic and educational outcomes as an adult. This contrasts with the OCOI because it focuses more on economic outcomes including income, employment, graduation rates, and other individual variables rather than health. Additionally, the Opportunity Atlas focuses on the likelihood of adult outcomes but not problems that may affect the children living in those areas in the present, such as crime or family stability, which could influence stress and other mediators of those later outcomes. Other countries or groups of countries including South Africa (59) and the European Union (60) have also created deprivation or opportunity indices for children, and some states in the United States have limited indices studying childhood poverty alone (61, 62), but no sources were found for multidimensional child deprivation indices on a state or regional level.

When looking at changes in neighborhood indices, it is imperative to examine the performance of contributing domains/facets for completeness and accuracy. As indicated in our results, while the reported reduction in the overall OCOI with time was approximately 1% point, the increase in housing stability by 9% points provides a more nuanced picture in to the gains achieved for child development between our study periods. Likewise, declines in other domains such as children's health and environment indicate that opportunities for improvement in these domains exist. Recognizing these changes at the small area level provided increases clarity in to specific patterns in the improvement in child development. Studying child deprivation

at this level offers state and local government agencies the ability to allocate funding for specific interventions on a local level. Moreover, the availability of domain specific information further helps to pin point specific areas for the judicious use of financial and other resources.

The OCOI showed a significant relationship between percentage of minorities in a census tract and overall scores, with higher minority populations associated with lower scores. This is similar to results from the National Opportunity Index, with their index showing across 100 metro regions Child Opportunity Scores for White children (score = 73) that were higher than for Black (score = 24) or Hispanic (score = 33) children (58). There is a complex relationship between race, geography, and deprivation in the United States due to segregation, discrimination, White flight, redlining, and institutional racism (63). The poverty rates for Black and Hispanic children are more than double that of White children in the United States (64, 65). The compounding of low family wealth and living in deprived regions make it even less likely for minority children to escape poverty. It was found that upward mobility, defined by a child in the lowest income quintile reaching the highest as an adult, was greatest for areas with less segregation, less income inequality, better schools, greater social capital, and more family stability (66). Investing in the most deprived areas by improving education and decreasing income inequality may help alleviate some of the effects that are continuing to disproportionately hurt minority neighborhoods (51).

The OCOI has potential for improvements that may further enhance its ability to communicate deprivation information. We are working on visual tools and dashboards that describe and map OCOI and the individual domains. These visual tools could incorporate race and ethnicity information to show the compounding of race and deprivation (67). These tools will allow researchers, public health, and government initiatives map areas to target for interventions, and learn more specifically which resources may be most needed in low opportunity areas. Additional years of data are being added as they become available, and will assist researchers in seeing changes in trends over time. Linking this change data with outcome data will enable researchers to study whether public programs and initiatives affected change in deprived areas and further inform decisions regarding specific resources needed.

LIMITATIONS

The OCOI has limitations that could affect its scope and intended use. There is individual variation in deprivation within census tracts, and these measures should not be used alone to infer an individual's risks. The use of varied data sources may limit the frequency of data updates, and some variables may update at different rates than others. We currently plan to update the OCOI measures on a biennial basis to account for this discrepancy. The lengthy reference time period of 2013–2017 averages over rapidly changing conditions. Therefore, the OCOI is most useful when the need is to understand longer-term health-relevant patterns in area-level social determinants (68). Those using deprivation measures should remain cautious when interpreting what "low opportunity" means and make efforts to not promote negative characterizations of neighborhoods that need help. The intention is to help reduce inequity. However, if resources are allocated improperly, tools like the OCOI could even further divide communities. For example, if the OCOI is used by businesses or housing developers to find higher opportunity areas and avoid lower opportunity areas, they may continue investing in and improving places that do not need help. Policymakers should use these tools to specifically target areas and outcomes that need the most help, and also be careful to not waste resources on interventions that are unnecessary based on the data.

CONCLUSION

Health is multifaceted and influenced by a constellation of physical, environmental, social, and economic factors that in turn interact with individual characteristics. Generally, individuals residing in more deprived areas suffer worse health outcomes. Children born and raised in more deprived neighborhoods may have more health, social, behavioral, and economic problems as adolescents and adults (51–54), and are less likely to escape their low economic positions than children with similar family socioeconomic status living in more affluent areas (69). Moreover, the factors affecting the health of adults and children differ somewhat, highlighting the importance of deprivation (or opportunity, conversely) measures targeted specifically for younger populations. Therefore, measuring age-appropriate area-level conditions is an important contribution to identifying and addressing health disparities. Collaboration between health and social services in lower opportunity areas could be encouraged to address the many needs, and the OCOI would be useful for geographically targeting those efforts to optimize the health returns from investments.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: Some of the data used for this study was provisioned by the Ohio Department of Medicaid. Requests to access these datasets should be directed to https://medicaid.ohio.gov/wps/portal/gov/medicaid/.

AUTHOR CONTRIBUTIONS

NF, PS, PJ, CS, CO, and ND contributed to the conceptualization, analysis, and writing of this manuscript. All authors contributed to the article and approved the submitted version.

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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.2022.734105/full#supplementary-material

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Associations between reading and writing postures and myopia among school students in Ningbo, China

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Background: We conducted this study to investigate the prevalence of myopia among school students in Ningbo and to explore the associations between reading and writing postures and myopia.

Methods: A population-based and cross-sectional study was conducted, and 3,256 school students aged 8–19 years were recruited. Each enrolled subject was assessed for uncorrected distance visual acuity (UDVA) using a standard logarithmic visual acuity E-chart and a non-cycloplegic autorefraction examination. Self-administered questionnaires were used to investigate myopia-related reading and writing postures and behavioral habits among school students.

Results: The prevalence of myopia among primary school, middle school, and high school students was 61.49, 81.43, and 89.72%, respectively. Regarding the associations between reading and writing postures and myopia, we identified that a reading distance >33 cm is a protective factor for myopia in female students [odds ratio (OR) = 0.31, 95% confidence interval (CI) = 0.15–0.64], in both primary school (OR = 0.55, 95% CI = 0.30–0.99) and middle school (OR = 0.37, 95% CI = 0.15–0.90).

Conclusions: A reading distance >33 cm can be used as an additional measure to prevent and control myopia. Proper postural measures for reading and writing may have educational and public health benefits.

KEYWORDS

reading and writing posture, myopia, school students, public health, near work

Introduction

In recent decades, myopia in children and adolescents has become a major public health problem (1). In addition to genetic factors (2), environmental factors and habits and customs play an important role in the onset and development of myopia in children and adolescents, such as higher educational attainment and school achievement (3), a greater amount of near work (4), body stature (5), degree of urbanization (6), and degree of outdoor activity (7). The study and control of environmental factors are currently the focus of myopia prevention. Among them, reading and writing posture-related near vision behavior is one of the focal points of intervention (8).

To supervise and correct children's bad writing posture at any time, there is "one Chi, one fist, and one Cun" principle in China (Chi and Cun are units of measurement in ancient China, one Chi = 33 cm, one Cun = 3.3 cm, one fist is the width of a fist), and the distance between the eyes and the book should be about 33 cm, the distance between the chest and the desk should be about the width of a fist, and the distance between the fingers holding the pen and pen tip should be about 3.3 cm. In China, almost all of the criteria for reading and writing postures are based on the "three ones" principle. Some studies further refined or supplemented the abovementioned criteria, and a few studies adopted only one of them (9). The distance between the eyes and the book is the most commonly used, and the standard of judgment is usually 30–33 cm. Other research-related standards mainly include reading and writing distance, short-distance reading time, determining whether the body is sitting upright, and determining whether there is a forward or backward skew.

Despite several decades of research, the role of reading postures and near work in myopia remains conflicting, with some studies reporting no relationship and other studies finding the opposite (9). Rather than the daily duration of near work, there has been increasing interest in absolute working distance and duration of continuous near vision. Several studies found that shorter working distances (<30 cm) and continuous near-work activity (>30 min) are risk factors for the onset and progression of myopia. For example, in a population study in Canada, the refraction became more myopic by 0.43 and 0.30 D with an increase in near work by every hour after controlling for age, gender, and education of participants aged 5–14 and 15–30 years, respectively (10). Mavrakanas et al. conducted research on 1,738 Greek high school students aged 15–18 years and found that a significantly higher proportion of students with myopia studied 5 h/days more than students with no myopia (43.14 vs. 28.62%, $p < 0.001$) (11). In an Australian population-based study, Ip et al. reported that close reading distance (<30 cm) and continuous reading (>30 min) independently increased the odds of having myopia (12).

We conducted this study to investigate the prevalence of myopia among school students in Ningbo and the associations between reading and writing postures and myopia.

Methods

Study population

A population-based and cross-sectional study was conducted to investigate the associations between reading and writing postures and myopia in Ningbo, Zhejiang. Participants were selected using a complex, stratified, multistage sample design. We randomly selected one urban area and one suburban county in Ningbo, with seven schools (two primary schools, two middle schools, two high schools, and one vocational high school) randomly selected in the urban area and five schools (two primary schools, two middle schools, and one high school) randomly selected in the suburban county. Investigations were conducted on whole classes at each grade level in primary, middle, and high schools, with at least 80 students selected from each grade. A total of 3,256 school students aged 8–19 years were recruited for our study, of whom 1,088 were primary school students, 1,088 were middle school students, and 1,080 were high school students.

Informed consent was obtained from all participants. The study was approved by the ethics committee of Ningbo Municipal Center for Disease Control and Prevention and followed the tenets of the Declaration of Helsinki.

Ocular measurements

Ocular measurements included distance vision examinations and refraction tests. The staff consisted of at least one specialist ophthalmologist and several technicians or nurses in specialist areas. All testers were trained to be proficient in the testing methods and could only start work after passing the test. Uncorrected distance visual acuity (UDVA) was uniformly performed using a standard logarithmic visual acuity E-chart, and the test results were recorded using the five-point recording method. Non-cycloplegic autorefraction examinations were conducted using Topcon RM-800 computer optometry (Topcon Co., Japan) to read the values of spherical lenses, cylinder, and axial length. Spherical equivalent (SE) was calculated as spherical lenses plus 1/2 cylinder. Myopia was defined as UDVA < 5.0 and SE < −0.50D. Subjects wearing keratoconus lenses were excluded.

Questionnaire study

Self-administered questionnaires, including students' basic information, myopia-related reading and writing postures, and behavioral habits, were used. After the unified training, investigators sent questionnaires to schools, asked the students to fill in, and requested the teachers to collect them back. After collecting and reviewing the questionnaires, in case of incomplete and illogical questionnaires, investigators contacted the respondent to explain it and refill the questionnaire.

Statistical analysis

The survey data were entered into the EpiData 3.1 database. After the logical check and data check, statistical analysis was performed using SPSS 20.0 software. Participants' characteristics were described using means and standard errors

for continuous variables, and numbers and percentages for categorical variables. To determine the associations between reading and writing postures and myopia, we applied logistic regression analysis to different gender groups and different school-type groups. The regression model was adjusted according to age, gender, and grade. A p-value <0.05 was considered to be statistically significant.

Results

The main characteristics of the study participants are reported in Table 1. Of the 3,256 school students, 33.42% were primary school students, 33.42% middle school students, and 33.17% high school students. The average age of the three groups was 10.66, 13.59, and 16.59 years. The proportion of male students in the three groups was 53.77, 50.37, and 46.20%, respectively. The situation of reading and writing postures is also shown in Table 1.

The prevalence of myopia among primary school students was 61.49, 58.63% for male students and 64.81% for female students. The prevalence of myopia among middle school students was 81.43%, 78.28% for male students and 84.63% for female students. The prevalence of myopia among high school students was 89.72, 87.17% for male students and 91.91% for female students (Figure 1).

As seen in Table 2, after adjusting for age and grade, a reading distance of more than 33 cm was identified as a protective factor for myopia in female students. The higher the frequency of the reading distance more than 33 cm, the lower the risk of students getting myopic. Compared with female students who chose "never" for "the eyes are more than 33 cm away from the book," the odds ratio (ORs) and 95% confidence intervals (CIs) for subjects who chose "sometimes," "usually," and "always" were 0.52 (0.28, 0.97), 0.49 (0.25, 0.96), and 0.31 (0.15, 0.64), respectively. In male students, keeping the finger 3.3 cm away from the nose tip was also found to be a protective factor. Compared with male students who chose "never" for "the finger is about 3.3 cm away from the tip of the nose," the OR and 95% CI for subjects who chose "sometimes" were 0.61 (0.39, 0.96). However, keeping the chest more than the width of a fist away from the edge of the table was a risk factor for myopia in female students [usually: 1.89 (1.03, 3.49), always: 2.01 (1.04, 3.88)]. In both male and female students, the more the parents reminded them of their reading and writing postures, the higher the risk of getting myopia.

The associations between reading and writing postures and myopia in different school types were similar (Table 3). After adjusting for gender and age, reading distances more than 33 cm were identified as a protective factor for myopia in both primary [always: 0.55 (0.30, 0.99)] and middle school students [always: 0.37 (0.15, 0.90)]. Compared with middle school students who chose "never" for "the finger is about 3.3 cm away from the tip of the nose," the OR and 95% CI for subjects who chose "sometimes" was 0.41 (0.21, 0.79). Still, keeping the chest more than the width of the fist away from the edge of the table was a risk factor in middle school students, and parents who were reminded of reading and writing postures were considered a risk factor in primary school students.

Discussion

The prevalence of myopia among school students in our study was comparable to figures reported from other provinces and cities in China. A study covering six provinces in China found that the prevalence of myopia among primary and middle school students was 55.7%, of which the prevalence was 35.8% in the age group 6–8 years, 58.9% in the age group 10–12 years, 73.4% in the age group 13–15 years, and 81.2% in the age group 16–18 years (13). Compared with school students in other countries, the prevalence of myopia in our study population was considerably higher. The Ireland Eye Study examined 1,626 participants, and the prevalence of myopia among participants aged 6–7 years and aged 12–13 years was 3.3 and 19.9%, respectively (14). Jorge et al. revealed that the prevalence of myopia in first-year university students in Portugal was only 23.4% (15).

Reading and writing postures can affect the pleasure and effectiveness of reading and writing as well as retinal image quality, convergence and accommodation demands, and binocular comfort during the process (16). Through these factors, some investigators also considered that reading and writing postures may be an important factor in the development of myopia (17). The Myopia Investigation Study in Taipei was a population-based cohort study that followed 9–11-year-old children ($n = 10,743$) for 2 years (18). After adjustment for gender and high parental myopia, students with a near-work distance >30 cm and who discontinued near work every 30 min had significantly less myopic progression. These factors remained significant after adjusting for other behavior, suggesting that they are independent risk factors. The findings are in accordance with those reported by Ip et al. (12), who similarly found that longer reading time for pleasure and a closer reading distance (<30 cm) were associated with the progression of myopia after multivariate adjustment ($p < 0.05$ for both).

In our study, we also identified that keeping the eyes more than 33 cm away from the book and keeping the finger 3.3 cm away from the tip of the nose were protective factors for myopia in school students. Our findings were nearly consistent with previous studies. Bao et al. investigated 120 children with myopia aged 6–13 years and found that working distance decreased significantly across time for the reading and writing tasks ($p < 0.001$), suggesting that close working distance may be a risk factor for myopia progression (19). In the study by Wu et al., 4,677 students aged 16–18 years participated, and multiple

TABLE 1 Characteristics of all subjects included in the study.

Characteristics	Primary School ($N = 1,088$)	Middle School ($N = 1,088$)	High School ($N = 1,080$)
Age	10.66 ± 0.86	13.59 ± 0.92	16.59 ± 0.89
Gender (M/F)	585/503	548/540	499/581
Myopia prevalence	61.49% (669/1,088)	81.43% (886/1,088)	89.72% (969/1,080)
Male	58.63% (343/585)	78.28% (429/548)	87.17% (435/499)
Female	64.81% (326/503)	84.63% (457/540)	91.91% (534/581)
When you're reading and writing			
The chest is more than the width of a fist from the edge of the table			
Never/Sometimes/Usually/Always	135/340/321/290	78/408/322/279	92/434/330/218
The eyes are more than 33 cm (one Chi) away from the book			
Never/Sometimes/Usually/Always	132/373/278/300	92/467/294/228	114/534/309/118
The finger is about 3.3 cm (one Cun) away from the tip of the nose			
Never/Sometimes/Usually/Always	162/218/227/473	142/287/267/386	174/331/261/306
Does your teacher remind you that your reading and writing posture is not correct?			
Never/Sometimes/Usually/Always	181/302/227/372	191/419/231/243	357/488/158/72
Do your parents remind you that your reading and writing posture is not correct?			
Never/Sometimes/Usually/Always	91/272/253/467	97/274/326/387	140/419/357/159

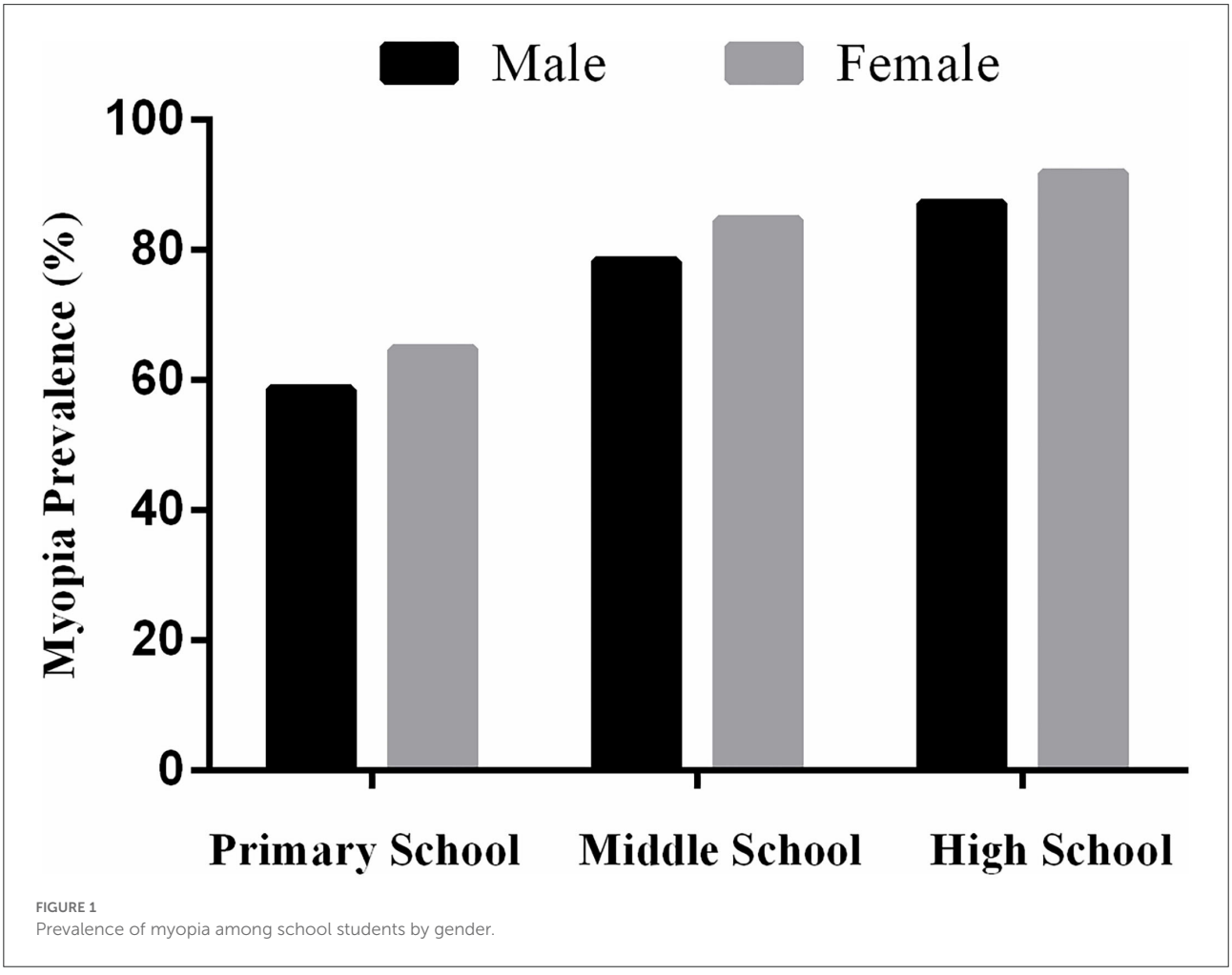

FIGURE 1
Prevalence of myopia among school students by gender.

TABLE 2 Logistic regression of myopia-related factors by gender.

Items	Total		Male		Female	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Age	**1.23 (1.11–1.36)**	**<0.001**	**1.21 (1.06, 1.38)**	**0.006**	**1.27 (1.09, 1.48)**	**0.002**
Grade	1.30 (0.95–1.78)	0.103	1.32 (0.87, 2.01)	0.195	1.24 (0.77, 2.01)	0.373
The chest is more than the width of a fist from the edge of the table						
Never			Reference			
Sometimes	1.33 (0.92–1.91)	0.126	1.27 (0.78, 2.07)	0.334	1.30 (0.73, 2.32)	0.373
Usually	**1.60 (1.09–2.35)**	**0.017**	1.27 (0.76, 2.13)	0.359	**1.89 (1.03, 3.49)**	**0.041**
Always	**1.54 (1.02–2.32)**	**0.041**	1.16 (0.67, 1.99)	0.598	**2.01 (1.04, 3.88)**	**0.039**
The eyes are more than 33 cm (one Chi) away from the book						
Never			Reference			
Sometimes	0.98 (0.67–1.43)	0.924	1.51 (0.92, 2.49)	0.103	**0.52 (0.28, 0.97)**	**0.041**
Usually	0.92 (0.62–1.39)	0.705	1.49 (0.86, 2.58)	0.152	**0.49 (0.25, 0.96)**	**0.036**
Always	**0.57 (0.37–0.87)**	**0.010**	0.93 (0.52, 1.64)	0.790	**0.31 (0.15, 0.64)**	**0.001**
The finger is about 3.3 cm (one Cun) away from the tip of the nose						
Never			Reference			
Sometimes	0.76 (0.55–1.05)	0.093	**0.61 (0.39, 0.96)**	**0.033**	1.01 (0.62, 1.65)	0.967
Usually	0.72 (0.52–1.01)	0.058	0.78 (0.49, 1.25)	0.303	0.67 (0.41, 1.09)	0.110
Always	0.90 (0.65–1.25)	0.539	0.87 (0.55, 1.37)	0.550	0.93 (0.57, 1.49)	0.748
Does your teacher remind you that your reading and writing posture is not correct?						
Never			Reference			
Sometimes	1.00 (0.77–1.31)	0.987	1.03 (0.71, 1.50)	0.882	1.01 (0.68, 1.51)	0.959
Usually	0.78 (0.57–1.08)	0.138	0.81 (0.52, 1.27)	0.353	0.84 (0.52, 1.36)	0.478
Always	0.72 (0.50–1.03)	0.074	0.62 (0.37, 1.03)	0.064	0.92 (0.54, 1.57)	0.757
Do your parents remind you that your reading and writing posture is not correct?						
Never			Reference			
Sometimes	1.25 (0.89–1.77)	0.195	1.11 (0.70, 1.74)	0.666	1.43 (0.84, 2.44)	0.189
Usually	**1.58 (1.09–2.29)**	**0.016**	1.22 (0.74, 2.00)	0.440	**2.03 (1.14, 3.61)**	**0.016**
Always	**2.10 (1.41–3.13)**	**<0.001**	**2.22 (1.28, 3.87)**	**0.005**	**1.90 (1.05, 3.45)**	**0.034**

OR, odds ratio; 95% CI, 95% confidence interval.
Adjusted for age and grade. Bold numbers are statistically significant at $P < 0.05$.

logistic regression analysis showed that a higher prevalence of myopia was associated with a longer time spent for near work (OR = 1.43, 95% CI: 1.06–1.93) and shorter near-work distance (OR = 1.87, 95% CI: 1.55–2.26) (20). However, reading behavior is not a fixed entity but differs in terms of grade level and reading conditions, which also suggests that reading behavior can be altered through better ergonomics and text design that may reduce myopia and help school students to read better (21).

However, keeping the chest more than a fist away from the edge of the table and parents who were reminded of reading and writing postures were identified as risk factors for myopia, which were contrary to our common sense. Considering that once school students become myopic, their parents may pay more attention to their children's reading and writing postures and set more reminders, which may cause the prevalence–incidence bias. As for the chest-to-table distance, the results remained counterintuitive, so we cannot exclude the potential that school students may have misunderstood the question or that maintaining the chest-to-table distance can cause other changes in reading and writing postures, so we will consider further refining the questionnaires and verifying them in a larger population sample.

This study has some limitations. First, we mainly explored the associations between reading and writing postures and myopia, and there were still certain other myopia-related factors that we did not include in our study, like short-distance reading time. Second, there was recall bias and prevalence-incidence bias in our study due to the study design. Third, the feedback and perception in the three categories of students would be highly variable due to the evolved level of understanding of the questionnaire. Fourth, non-cycloplegic measurements of myopia were used, and the prevalence of myopia may have been overestimated. Last but not the least, the sample size is limited

TABLE 3 Logistic regression of myopia-related factors by school type.

Items	Primary School		Middle School		High School	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Gender	**1.32 (1.02, 1.71)**	**0.034**	1.33 (0.96, 1.84)	0.084	1.50 (0.99, 2.28)	0.059
Age	**1.55 (1.33, 1.80)**	**<0.001**	1.15 (0.97, 1.38)	0.111	0.82 (0.65, 1.03)	0.083
The chest is more than the width of a fist from the edge of the table						
Never			Reference			
Sometimes	1.25 (0.76, 2.05)	0.376	1.93 (0.95, 3.94)	0.070	0.50 (0.17, 1.47)	0.206
Usually	1.54 (0.91, 2.60)	0.107	**3.60 (1.66, 7.80)**	**0.001**	0.37 (0.12, 1.09)	0.072
Always	1.70 (0.97, 3.00)	0.065	**2.79 (1.25, 6.26)**	**0.013**	0.33 (0.11, 1.02)	0.054
The eyes are more than 33 cm (one Chi) away from the book						
Never			Reference			
Sometimes	0.78 (0.46, 1.30)	0.339	1.02 (0.47, 2.20)	0.970	1.86 (0.81, 4.26)	0.143
Usually	0.97 (0.55, 1.71)	0.913	0.58 (0.25, 1.31)	0.187	1.80 (0.74, 4.40)	0.198
Always	**0.55 (0.30, 0.99)**	**0.046**	**0.37 (0.15, 0.90)**	**0.028**	1.17 (0.43, 3.22)	0.762
The finger is about 3.3 cm (one Cun) away from the tip of the nose						
Never			Reference			
Sometimes	1.00 (0.63, 1.60)	0.996	**0.41 (0.21, 0.79)**	**0.008**	0.86 (0.42, 1.75)	0.666
Usually	0.72 (0.45, 1.16)	0.181	0.63 (0.32, 1.25)	0.187	0.79 (0.38, 1.67)	0.536
Always	0.96 (0.61, 1.51)	0.858	0.66 (0.34, 1.29)	0.225	1.23 (0.59, 2.58)	0.578
Does your teacher remind you that your reading and writing posture is not correct?						
Never			Reference			
Sometimes	0.93 (0.60, 1.42)	0.731	1.03 (0.62, 1.71)	0.921	1.15 (0.68, 1.94)	0.599
Usually	0.89 (0.54, 1.44)	0.625	0.86 (0.47, 1.58)	0.634	0.55 (0.28, 1.09)	0.085
Always	0.73 (0.44, 1.22)	0.231	0.93 (0.47, 1.82)	0.820	0.65 (0.20, 2.08)	0.464
Do your parents remind you that your reading and writing posture is not correct?						
Never			Reference			
Sometimes	1.31 (0.76, 2.24)	0.328	1.34 (0.71, 2.51)	0.369	0.91 (0.46, 1.76)	0.770
Usually	1.56 (0.87, 2.80)	0.137	1.39 (0.71, 2.72)	0.343	1.52 (0.72, 3.18)	0.271
Always	**1.96 (1.07, 3.57)**	**0.029**	1.91 (0.93, 3.92)	0.077	2.49 (0.88, 7.08)	0.087

OR, odds ratio; 95% CI, 95% confidence interval.
Adjusted for gender and age. Bold numbers are statistically significant at $P < 0.05$.

in our study and the results need to be verified in a larger population in the future.

In conclusion, maintaining an appropriate distance (>33 cm) between the eyes and the book may be good for the prevention and control of myopia.

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 Ningbo Municipal Center for Disease Control and Prevention. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

Study design: DJ and YZ. Data acquisition: HG, YG, and SZ. Statistical analysis: DJ and BS. Manuscript preparation and editing: DJ. Manuscript revision/review: YZ. 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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