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School-based nutrition and physical activity interventions among children and adolescents

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School-based nutrition and physical activity interventions among children and adolescents

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Editorial: School-based nutrition and physical activity interventions among children and adolescents

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Editorial on the Research Topic
School-based nutrition and physical activity interventions among children and adolescents

Schools play a crucial role in shaping children's eating habits by providing access to healthy food options, implementing nutrition education programs, and fostering a culture that encourages healthy eating (1). Effective implementation strategies include integrating nutrition education into the curriculum, collaborating with local food suppliers to provide healthier meals, and promoting awareness through school-wide campaigns. By creating a supportive environment, schools can enhance student wellbeing and reinforce positive dietary habits (1). School-based interventions significantly improve students' food choices, encourage healthier eating patterns, and reduce the prevalence of diet-related health issues. The considerable influence of school environments on students' dietary habits highlights the need for healthy canteen interventions as a strategic approach to improve students' nutritional intake (1–3). Effective School-based interventions should focus on enhancing the availability and affordability of nutritious foods, increasing student participation in physical education (PE), and establishing social support systems to promote physical activity (PA) (4).

The increasing prevalence of obesity, sedentary lifestyles, and unhealthy eating habits among children and adolescents is associated with chronic health issues (5–7). Recent data from the World Health Organization indicate that over 39 million children under the age of five were overweight or obese in 2020, underscoring the urgency of preventive interventions. Therefore, promoting healthy eating and sufficient PA among school-aged children is essential. This Research Topic presents the outcomes of 13 school-based studies designed to enhance dietary quality and PA levels in children and adolescents. Among these, four studies focused on nutrition and dietary patterns in children and adolescents, seven examined PA, and two addressed recruitment and outreach within a school-based pediatric obesity intervention, as well as health behaviors and health-related quality of life.

Jha et al. conducted an interventional study to evaluate the impact of a health promotion initiative on the dietary behaviors of Indian adolescents, utilizing the theory of planned behavior (TPB) as a framework. TPB is particularly relevant in this

context as it helps explain how attitudes, subjective norms, and perceived behavioral control influence dietary decisions and intentions to adopt healthier eating habits. The study found that the intervention successfully fostered a positive shift in adolescents' intentions to adopt healthier dietary practices. The study highlighted the effectiveness of model-based and construct-oriented intervention strategies in enhancing adolescents' commitment to healthier eating habits (Jha et al.). Devine et al. explored the factors influencing food choices in school canteens, identifying barriers such as convenience, food placement, peer influence and food availability. The study proposed practical, cost-effective strategies, including menu planning, labeling and pricing adjustments, to promote healthier eating habits among secondary school students (Devine et al.).

Sezer et al. investigated the effects of socioeconomic status on the diet quality and snack preferences of adolescents from diverse backgrounds. The findings revealed that adolescents attending public schools had a lower tendency to choose healthy snacks than their peers who attended private schools. This disparity underscores socioeconomic status as a critical determinant of eating behaviors among adolescents. In addition, significant income differences between students attending private and public schools likely contributed to the higher frequency of snack consumption among students attending private schools. Thus, financial resources play a vital role in shaping dietary habits and preferences in this age group (Sezer et al.). A systematic review performed by Ahmed et al. evaluated the effects of the coronavirus disease 2019 (COVID-19) pandemic on school food programs in Canada, focusing on their delivery, adaptability, and resilience. These programs implemented various strategies to address the challenges posed by the pandemic, ensuring that vulnerable students continued to receive nutritious meals. Key initiatives included the distribution of prepared meals, food kits, and gift cards, which effectively enhanced food availability for pupils and their families. The study highlighted the importance of increased collaboration among community members, organizations, and stakeholders as a critical factor in maintaining food delivery and developing new methods for food distribution. However, the study also identified significant challenges related to the sustainability of these programs, particularly operating costs and funding (Ahmed et al.).

Moore, Edmondson et al. conducted a qualitative study to examine PE teachers' perceptions on barriers and facilitators of PA and digital exercise interventions for inactive British adolescents in secondary schools. Using the theoretical domain framework (TDF), the capability, opportunity, motivation, and behavior (COM-B) model, and the behavior change wheel (BCW). The study provided insights into policy functions and behavioral change tools that could enhance PA participation (Moore, Edmondson et al.). Their pre-intervention online survey revealed that while universal barriers affect adolescents' PA, tailored support that considers demographic differences is necessary to effectively promote engagement in PA (Moore, Vernon et al.). Liu Y. et al. proposed a protocol for a 12-week school-based high-intensity interval training (HIIT) intervention to assess its effectiveness on various health and academic outcomes among 12- to 13-year-old students in Ningbo, China (Liu Y. et al.). Peiris et al. planned a protocol for a randomized controlled trial (RCT) to develop and evaluate an in-classroom PA breaks (IcPAB) intervention in Sri Lanka (Peiris et al.). Aly et al. analyzed cross-cultural differences in health-related fitness (HRF) among children from five Mediterranean countries (Italy, Spain, Egypt, Portugal, and Lebanon). Significant variations in HRF were observed across different countries and age groups. The study emphasized the need for culturally tailored PE strategies and public health initiatives to promote balanced fitness development across diverse cultural contexts (Aly et al.).

Wu et al. conducted a network meta-analysis of 66 studies to evaluate the effectiveness of six exercise modalities on various physical fitness indicators within a school-based context. The findings indicated that HIIT was the most effective intervention for reducing body mass index (BMI), enhancing VO2 max, and improving 20-meter sprint performance. Aerobic training was the most effective method for reducing waist circumference (WC). In addition, active video games were recognized as promising options for enhancing countermovement jump and shuttle run performance. Strength training was found to be the most effective for improving standing long jump performance, whereas combined training was rated the highest for reducing body fat percentage and increasing push-up repetitions (Wu et al.). Another network meta-analysis by Hassan et al. evaluated the effectiveness of various school-based obesity prevention initiatives on improving BMI among children and adolescents. The findings revealed that the PA-only intervention was the most effective in enhancing BMI, whereas the multiple-component intervention demonstrated the greatest improvement in BMI z-scores (BMIz). Conversely, the diet and nutrition-only intervention was the least effective for improving BMIz. The study indicated that both PA-only and multiple-component interventions are effective strategies for addressing BMI-related outcomes in school settings (Hassan et al.).

Forseth et al. evaluated two recruitment strategies for a pediatric obesity treatment trial targeting rural families, specifically focusing on school recruitment and participant enrollment rates. The opt-in approach, in which caregivers consented to have their child screened for eligibility, and the screen-first approach, in which all children were screened regardless of prior consent. The findings revealed that schools using the opt-in method were more successful in enrolling at least five families and implementing the intervention. In contrast, the screen-first approach resulted in higher overall participation rates (Forseth et al.). A study performed by Liu Z. H. et al. examined the individual and combined effects of breakfast consumption, sedentary behavior, sleep, and PA on health-related quality of life (HRQoL) among Chinese high school students. It was found that students who used computers for two or more hours daily were more likely to report health issues in areas such as mobility, self-care, and daily activities. Additionally, lower PA levels were correlated with increased feelings of worry and sadness, as well as a lower visual analog scale (VAS) score. Inadequate sleep (defined as <7 h) and skipping breakfast were also associated with poorer HRQoL, particularly concerning pain, discomfort, and emotional wellbeing (Liu Z. H. et al.).

In summary, the articles in this Research Topic have provided a foundational framework for developing school-based interventions to improve nutrition and PA among adolescents and children. Further studies should focus on the long-term impact of these interventions, as well as strategies for scaling them up at a national or international level. By addressing key behavioral, environmental, and socioeconomic factors, future interventions can be designed to maximize effectiveness and sustainability. This Research Topic underscores the need for continued public support and policy initiatives to enhance wellbeing and quality of life of school-aged students.

Author contributions

SM: Conceptualization, Writing – original draft, Writing – review & editing. HK: Conceptualization, Writing – review & editing.

Conflict of interest

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

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School-based intervention on behavioral intention of adolescents regarding healthy diet in India

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Introduction: Adolescence is a distinctive period of life when intense physical, psychological, and cognitive development occurs. A healthy diet helps prevent various forms of malnutrition and non-communicable diseases (NCDs) like diabetes, heart disease, stroke, and cancer. The current study aimed to assess the change in behavioral intentions (measured based on the TPB) toward healthy dietary practices through health promotion intervention among adolescents studying in selected schools in an urban area of West Bengal, India

Methods: The current study was a non-randomized controlled interventional study conducted among adolescents in either seventh, eighth, ninth, or tenth grades and aged between 12 and 16 years. Two-step cluster analysis with maximum likelihood estimation identified the intenders of a healthy diet. The intervention effect was measured using Relative Risk (RR) for being in the higher intention cluster through Generalized Linear Model (GLM) with a log-linear link under Poisson distribution assumptions and robust standard errors. A *P*-value of 0.05 or lesser was considered statistically significant.

Results: There was no statistically significant difference in the mean score of "Attitude" in both groups. The mean score of "Subjective Norm" among the intervention group increased after intervention, and the difference was statistically significant. The mean score of "Perceived behavioral control" in the intervention group increased after the intervention, but the difference was statistically not significant. The intervention group's post-intervention proportion of intenders increased, and the difference was statistically significant. The relative risk of becoming an intender for healthy diet consumption in the Intervention group compared to the Control group was 2.07 (1.44–2.97).

Conclusions: The intervention package effectively brought about a positive change in behavioral intention toward healthy dietary practices among adolescents. Model-based and construct-oriented intervention packages can be adopted in school-setting to promote behavioral intention toward a healthy diet.

KEYWORDS

health behavior, healthy diet, health promotion, behavioral intention, Theory of Planned Behavior, adolescents

1. Introduction

World Health Organization (WHO) and the United Nations (UN) defined adolescents as individuals in the 10–19 age group (1). Adolescence is when intense physical, psychological, and cognitive development occurs (2). In this phase of life, people become independent individuals, build up new relationships, develop social skills, and learn behaviors that will last forever

in their life span (3). Adolescence is an age of opportunity for children and a pivotal time to build on their development in the first decade of life, to help them navigate risks and vulnerabilities, and to set them on the path to fulfilling their potential. Dietary Habits are the habitual decisions of individuals, groups, or cultures when choosing what food to eat. A healthy diet helps prevent various forms of malnutrition and non-communicable diseases (NCDs) like diabetes, heart disease, stroke, and cancer (4). The most significant health consequences of childhood overweight and obesity, which become primarily apparent in adulthood, include cardiovascular diseases (mainly heart disease and stroke), diabetes, musculoskeletal disorders, especially osteoarthritis, and certain types of cancer (5). The increasing level of overweight and obesity among children and adolescents is of grave concern, as it links childhood and adolescent obesity with the increased risk of obesity and morbidity in adulthood (6). Faulty dietary habits of skipping meals or eating junk food were associated with more number of participants under the obese or overweight category in a study conducted in India (7). The issue of healthy and unhealthy food consumption among adolescents is crucial, even considering the COVID-19 pandemic. The findings from one systematic review and meta-analysis conducted by Pourghazi et al. (8) stated that the impact of COVID-19 on children and adolescents eating habits was positive and negative, for example, a decrease in fast food, fruits, and vegetable consumption and an increase in snacks and sweet consumption. Both the changes may have a critical short- and long-term impact on adolescents' health.

In general, daily consumption of a diet with recommended proportions of staples like cereals, starchy tubers or roots, legumes, fruits and vegetables, and foods from animal sources is considered a healthy dietary habit (9). In an interventional study conducted by Menor-Rodriguez et al., the educational intervention reduced the levels of overweight and obesity in school children and improved their eating habits (10). Correa et al., in their study among Indian-origin adolescents, reported that all adolescents perceived foods high in vitamins and minerals as healthy (11). In a cross-sectional study, Kumar et al. found that 90% frequently consumed street foods, and 54% reported having overall poor eating habits (12). In a Quasi-experimental study among female students, a significant difference was noted between the two groups regarding the mean scores of attitudes, perceived behavioral control, and behavioral intention. In contrast, no significant difference regarding the mean score of subjective norms was found (13). Families, physicians, teachers, friends, society, and nutrition specialists are critical subjective norms in various studies (14–16).

Health promotion and education are one of several possible intervention strategies to address these various problems (17). It aims to increase awareness, expand knowledge, acquire skills and shape a health-oriented attitude of particular persons who are also perceived as components of society (18). To change behavior, one must first make adolescents aware of the consequences of their behavior. However, knowledge alone is not sufficient to change behavior. There are multiple models of individual health behavior, among which the Theory of Planned Behavior (TPB) identifies behavioral intention as the best predictor of behavior (19). The TPB can assess the behavioral intentions of adolescents toward a healthy diet by measuring the following constructs, i.e., "Attitude," "Subjective norm," and "Perceived behavioral control." In a systematic review conducted by McDermott et al., it was concluded that TPB variables have medium to large associations with both intention and dietary patterns and further provide a guide for designing effective interventions (20).

1.1. The Theory of Planned Behavior

1.1.1. Behavioral intention

The degree to which an individual formulates behavioral plans to attain a behavioral goal. In other words, it is the perceived likelihood of performing the behavior (21, 22).

1.1.2. Attitude

Attitude implies the degree to which a person has a favorable or unfavorable evaluation of the behavior of interest. It entails a consideration of the outcomes of performing the behavior (21, 22).

1.1.3. Subjective norm

The belief about whether most people approve or disapprove of the behavior is a subjective norm. It relates to a person's beliefs about whether peers and people of importance to the person think they should engage in the behavior (21, 22).

1.1.4. Perceived behavioral control

A person's perception of the ease or difficulty of performing the behavior of interest is perceived behavioral control (21, 22). It is the perceived likelihood of occurrence of each facilitating or constraining condition and its perceived effect in making behavioral performance difficult or easy. It varies across situations and actions, which results in a person having varying perceptions of behavioral control depending on the situation.

Cost-effective interventions through clear behavioral intentions should be promoted early in life, especially during adolescence, the most formative stage of life (3). It can be conclusively stated that to prevent the development of risk factors (unhealthy behaviors) in adulthood, the ideal time of intervention is during adolescence, as it is easier to avoid the inculcation of unhealthy habits and facilitate change of practices among young children who are amenable to correction (23). An in-depth study of behavioral intentions and the positive effect of health promotion regarding healthy behavior, like healthy dietary practices among these young populations, may provide valuable insights for health administrators and school health authorities. This study aimed to assess the change in behavioral intentions (determined based on the TPB) toward healthy dietary practices following a school-based health promotion intervention among adolescents in an urban area of West Bengal, India.

2. Methods

2.1. Study design

A school-based non-randomized controlled interventional study with parallel group design was conducted in two co-educational English medium schools in a selected West Bengal municipal area. The data collection was done between March 2019 and January 2020.

2.2. Study participants

Adolescents in seventh to tenth grades aged between 12 and 16 years, studying in the selected schools, whose parents gave consent and who provided assent for participation, were included in the study. Those who were absent at any phase of the study were excluded from the study. Multi-stage sampling was done. In the first stage, two schools were chosen based on enrolment and attendance (one for the intervention group and another for the control group) from the schools in the study area (Uttarpara-Kotrung Municipal area). In the selected schools, sections were chosen based on Probability Proportionate to Size (PPS) method in each grade. Then in the particular section, complete enumeration was done. The sample size was estimated using Fleiss' formula for difference in proportions for parallel group intervention study design (with both groups being equal in size) (24). For sample size calculation, a power of 80% and a confidence level of 95% were assumed. A design effect of 1.5 was used, and an attrition factor of 10% was considered. Based on a school-based study by Kebaili et al. (25), an increase in the proportion of intenders of healthy dietary habits (intention to eat vegetables regularly) among the control group taken as 5%, i.e., $P_{control} = 0.05$, and among intervention group 20%, i.e., $P_{intervention} = 0.2$. Therefore, using the Fleiss formula for difference in proportions, the minimum adequate sample size in each group was 76. With the design effect, the minimum sample size was 114 and using an attrition factor of 10%, the optimum sample size was 125 for each intervention and control group. Thus, the minimum sample size required in each group was 114; accounting for attrition, it was 125. Finally, after completing the post-intervention phase, 133 completed responses in the control group and 118 completed responses in the intervention group were obtained. Figure 1 depicts the selection of study participants.

Among the final 251 responses, a significant proportion of the intervention group (33.05%) belonged to the age group of 15 years, and the control group (37.60%) belonged to the age group of 14 years. Most participants in the intervention group (67.80%) were boys, whereas most participants (50.38%) were girls in the control group. The socio-demographic characteristics of the participants are given in Table 1.

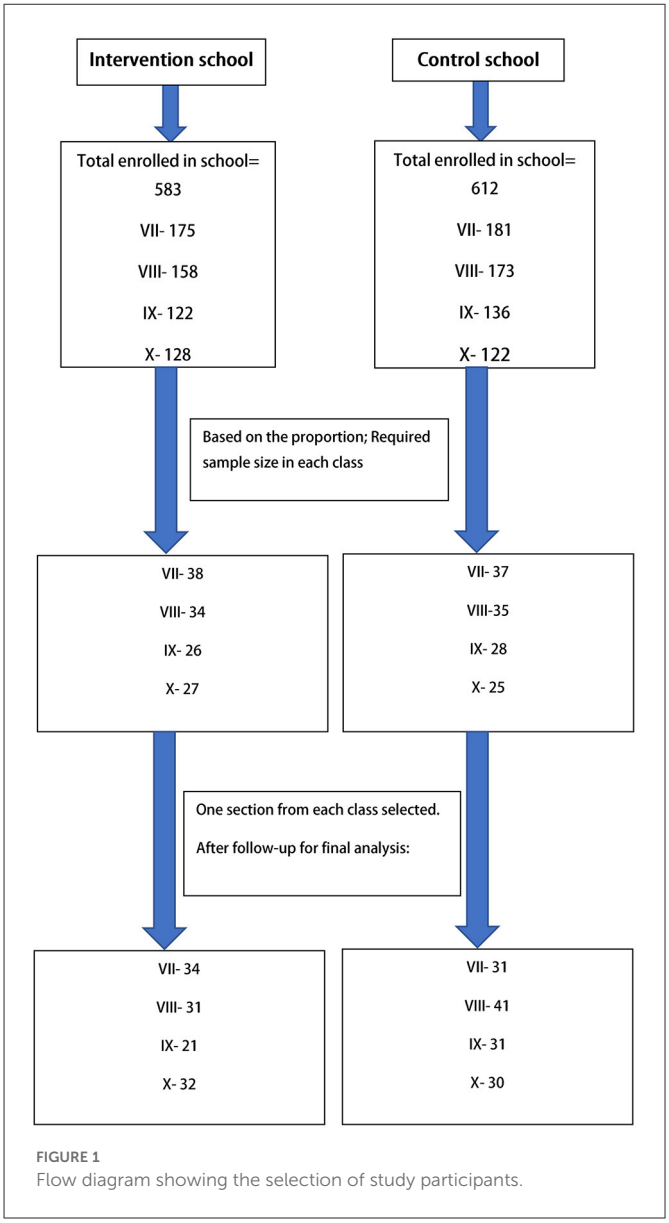

FIGURE 1
Flow diagram showing the selection of study participants.

2.3. Measurements

Behavioral intention toward consumption of a healthy diet was determined utilizing the constructs from the TPB: (i) "Attitude" consisting of domains such as Behavioral belief and Evaluation of behavioral outcome, (ii) "Subjective norm" consisting of Normative beliefs and Motivation to comply, and (iii) "Perceived behavioral control" (PBC) consisting of Control beliefs and Perceived power. Items for intention measurement and identifying intenders were selected through elicitation interviews. These interviews were conducted based on the elicitation interview guide, which focused on the TPB's constructs. Elicitation interviews were done among 20 students of classes VII to X in a separate English medium co-educational school of the study area. The attitude was measured through the items: Sufficiency in consumption of vitamins and minerals, consumption of oily food, Sufficient protein intake, Obesity/overweight, Healthy life span, Taste of Food, and Cost of Food. For Subjective Norms, the items were: Mother, Father, Relatives/other family members, Friends/peers, Teachers, Contents of television, and Contents/discussions in social media. For the PBC construct, the items were as follows: choosing a healthy diet even when hungry, Not choosing unhealthy food even if they are tasteful, choosing to eat a healthy diet even when depressed or sad, opting to eat a healthy diet even when junk food is readily available, choosing to eat a healthy diet even during celebrations or parties, choosing to eat a healthy diet even while visiting any mall/theater, choosing to eat a healthy diet while traveling. Each item was measured on all three constructs through their respective domains using a dichotomous (Agree-Disagree) response. In this study, the intention was not directly computed; instead, the participants with higher intentions (the intenders) were identified in pre- and post-intervention phases through a combination of construct-wise measurements.

2.4. Instruments

A pre-designed, pretested and validated questionnaire was used to assess behavioral intention. After initial preparation, the questionnaire was reviewed by a group of 5 experts who made

TABLE 1 Socio-demographic characteristics of the participants.

Socio-demographic characteristics		Intervention ($n = 118$)		Control (n = 133)		Total (n = 251)		*P*-value
		N	%	*N*	%	*N*	%	
Age (in completed years)	12	9	7.63	10	7.52	19	7.57	0.329
	13	21	17.80	32	24.06	53	21.11	
	14	37	31.35	50	37.60	87	34.66	
	15	39	33.05	30	22.55	69	27.49	
	16	12	10.17	11	8.27	23	9.17	
Gender	Boys	80	67.80	66	49.62	146	58.17	0.004
	Girls	38	32.20	67	50.38	105	41.83	
Religion	Hinduism	111	94.06	126	94.74	237	94.42	0.974
	Islam	4	3.39	4	3.00	8	3.19	
	Others*	3	2.55	3	2.26	6	2.39	
Type of family	Nuclear	70	59.32	94	70.68	164	65.33	0.059
	Joint	48	40.68	39	29.32	87	34.67	

"n" indicates the total participants in respective groups, "N" denotes the numbers in each category, and "%" denotes the respective column percentages. P-values are obtained by Chi-squared tests. *Others include Jainism and Sikhism.

TABLE 2 Description of clusters in Pre-intervention and post-intervention phases as per the defining constructs.

Model constructs	Pre-intervention[a]		Post-intervention[b]	
	Cluster 1: Higher intention [$n = 148$]	Cluster 2: Lower intention [$n = 103$]	Cluster 1: Higher intention [$n = 134$]	Cluster 2: Lower intention [$n = 116$]
Attitude	139.31 (±27.15)	130.64 (±30.83)	154.98 (±18.03)	119.18 (±25.41)
Subjective Norm	166.44 (±19.85)	109.35 (±18.92)	178.18 (±16.80)	128.28 (±25.75)
Perceived Behavioral Control	108.07 (±27.60)	90.23 (±24.41)	112.1 (±31.54)	109.33 (±28.21)

"n" indicates the number of participants in each of the identified clusters, values within parentheses in each of the cells represent the respective standard deviations. [a]No outliers were detected; the average silhouette measure of cluster cohesion and separation was 0.5. [b]One outlier was detected and subsequently excluded from the analysis; the average silhouette measure of cluster cohesion and separation was 0.4.

necessary corrections. Pretesting of the questionnaire was done among 40 students. Cronbach's alpha measured internal consistency reliability construct-wise with values ranging between 0.79 and 0.86. The questionnaire consisted of socio-demographic characteristics and the three constructs of TPB that determined the intention to consume a healthy diet (refer to Supplementary material).

The intervention booklet and demonstration material were designed, developed, and pretested based on the construct-wise findings from elicitation interviews on healthy dietary practices. The conclusions of the pre-intervention survey were utilized in refining the content of the intervention tools. The intervention booklet contained information on different compositions of a healthy diet, accessible and affordable healthy food items, and the importance of developing and maintaining healthy dietary habits. During the interactive sessions, discussions were conducted on common myths and beliefs regarding healthy and unhealthy foods. Thrust was given to facilitating the enablers and overcoming the barriers to healthy dietary practices. Normative influencers and their role in motivating the participants to adopt healthy dietary habits were also discussed. The intervention tools were prepared with subject experts, following standard guidelines on healthy nutritional practices. The intervention materials were also pretested before implementation.

2.5. Procedures

Baseline data were collected from the students of grades VII–X of both the intervention and the control groups with the help of the self-administered questionnaire after obtaining assent. Each participant was allotted an Identification (ID) code, which was further used to associate the data from the same participant upon follow-up. After baseline data collection, the intervention was provided to the intervention group. The intervention was imparted grade-wise, i.e., students from a particular grade were intervened at a time. Booklets were distributed among the participants, and then lectures were conducted based on the booklet's contents. Pre-designed computer-based slides were used as visual aids for pointing out the existing disconnects between their thoughts and action. In between lectures and demonstrations, interactive sessions and discussions were also conducted. After completion of the sessions, queries or doubts were clarified through a question-and-answer session. Follow-up data were collected 3 months after the conclusion of the intervention. Follow-up data were also collected from the control group using the same questionnaire but without intervention. At the end of follow-up data collection, health education interventions were conducted among the control group during the study period in the same manner as in the intervention group.

TABLE 3 Pre- and post-intervention comparison of attitudes regarding consumption of healthy diet among intervention and control groups.

Issues	Domain	Intervention ($n = 118$)			Control ($n = 133$)		
		Pre-intervention	Post-intervention	P-Value[a]	Pre-intervention	Post-intervention	P-value[a]
Sufficiency in consumption of vitamins and minerals	Behavioral belief	88 (74.58)	89 (75.42)	0.881	113 (84.96)	98 (73.68)	0.023
	Evaluation of behavioral outcome	36 (30.51)	54 (45.76)	0.016	102 (76.69)	91 (68.42)	0.131
Consumption of oily food	Behavioral belief	98 (83.05)	99 (83.90)	0.861	129 (96.99)	122 (91.73)	0.063
	Evaluation of behavioral outcome	86 (72.88)	99 (83.90)	0.040	119 (89.47)	117 (87.97)	0.698
Sufficient protein intake	Behavioral belief	85 (72.03)	97 (82.20)	0.063	110 (82.71)	125 (93.98)	0.004
	Evaluation of behavioral outcome	52 (44.07)	49 (41.53)	0.693	102 (76.69)	99 (74.44)	0.669
Obesity/overweight	Behavioral belief	87 (73.73)	86 (72.88)	0.883	112 (84.21)	118 (88.72)	0.282
	Evaluation of behavioral outcome	87 (73.73)	95 (80.51)	0.215	119 (89.47)	118 (88.72)	0.844
Healthy life span	Behavioral belief	91 (77.12)	92 (77.97)	0.876	114 (85.71)	114 (85.71)	1.000
	Evaluation of behavioral outcome	85 (72.03)	96 (81.36)	0.090	102 (76.69)	108 (81.20)	0.367
Taste of Food	Behavioral belief	56 (47.46)	35 (29.66)	0.005	81 (60.90)	73 (54.89)	0.320
	Evaluation of behavioral outcome	42 (35.59)	44 (37.29)	0.787	71 (53.38)	54 (40.60)	0.037
Cost of Food	Behavioral belief	61 (51.69)	44 (37.29)	0.026	66 (49.62)	82 (61.65)	0.048
	Evaluation of behavioral outcome	72 (61.02)	38 (32.20)	0.000	101 (75.94)	99 (74.44)	0.776
Attitude Mean score [SD]		123.68 [±24.54]	123.11 [±27.73]	0.841 [b]	146.47 [±28.46]	146.77 [±24.52]	0.925 [b]

"n" represents the number of completed responses in each group. SD, Standard deviation of Perceived Behavioral Control score. Values within parentheses represent respective column-percentages. Values within square-brackets represent the SD. [a]P-values calculated by chi-squared test except in [b]. [b]P-values were calculated by paired t-test.

2.6. Analysis

Pre-intervention and post-intervention data entered in a spreadsheet were linked through the unique codes. The cleaned dataset was used for statistical analysis using Statistical Package for Social Sciences (SPSS) software version 21 (IBM, Chicago, IL, USA). For computation purposes, items were coded 1 and 2, with 2 indicating a favorable response toward healthier habits. Negatively framed items were reverse-coded while maintaining the directionality of scoring, i.e., a favorable response was coded higher. Construct scores were calculated by multiplying the scores for the contributing domains (21), e.g., "Attitude" was calculated by multiplying the Behavioral belief score and evaluation of behavioral outcome score. A similar calculation was done for "Subjective Norm" and "Perceived Behavioral Control." A linear combination of the responses of the respective item sets computed individual domain-specific scores. Intenders (i.e., those having the latent variable "Behavioral intention") were identified by applying two-step cluster analysis with maximum likelihood estimation based on the calculated Attitude, Subjective norm, and Perceived behavioral control scores, separately for pre-intervention and post-intervention phases. Both intervention and control group measurements were taken for the cluster analysis. Those with a higher mean score in the constructs were considered intenders, and the remaining were non-intenders (refer to Table 2). Using the Silhouette measure, cluster analyses were found to be statistically adequate. The item-specific responses and proportions of intenders were compared between the pre-intervention and post-intervention phases in both the study groups.

The Chi-square test was employed to test for any statistically significant difference in each item in the two study groups before and after the intervention phase. The construct scores were compared (pre- vs. post-intervention) with the help of paired *t*-tests in each study group. The intervention effect was measured using Relative Risk (RR) for being in the higher intention cluster through Generalized Linear Model (GLM) with the log-linear link under Poisson distribution assumptions and robust standard errors. The model was adjusted for the effects of gender, the baseline (pre-intervention) intention cluster, and their interaction with the receipt of intervention (i.e., study groups). The model was statistically significant ($P_{\chi 2}$ <0.001). A two-tailed *P*-value of 0.05 or less was considered statistically significant in all the statistical techniques.

2.7. Ethical consideration

Approval for the study was obtained from the Institutional Ethics Committee of All India Institute of Hygiene and Public Health, Kolkata. Permission from the head of the schools was taken before data collection. Informed written assent was obtained from

TABLE 4 Pre- and post-intervention comparison of subjective norms regarding consumption of healthy diet among intervention and control groups.

Influencers	Domain	Intervention ($n = 118$)			Control ($n = 133$)		
		Pre-intervention	Post-intervention	P-value[a]	Pre-intervention	Post-intervention	P-value[a]
Mother	Normative beliefs	104 (88.14)	111 (94.07)	0.110	126 (94.74)	124 (93.23)	0.606
	Motivation to comply	91 (77.12)	97 (82.20)	0.332	117 (87.97)	123 (92.48)	0.215
Father	Normative beliefs	99 (83.90)	110 (93.22)	0.024	116 (87.22)	116 (87.22)	1.000
	Motivation to comply	92 (77.97)	90 (76.27)	0.757	100 (75.19)	104 (78.20)	0.562
Relatives/other family members	Normative beliefs	79 (66.95)	100 (84.75)	0.001	110 (82.71)	103 (77.44)	0.283
	Motivation to comply	73 (61.86)	92 (77.97)	0.007	99 (74.44)	106 (79.70)	0.307
Friends/peers	Normative beliefs	70 (59.32)	54 (45.76)	0.037	92 (69.17)	87 (65.41)	0.513
	Motivation to comply	64 (54.24)	64 (54.24)	1.000	80 (60.15)	80 (60.15)	1.000
Teachers	Normative beliefs	102 (86.44)	96 (81.36)	0.288	117 (87.97)	118 (88.72)	0.848
	Motivation to comply	81 (68.64)	84 (71.19)	0.670	96 (72.18)	98 (73.68)	0.783
Contents of television	Normative beliefs	75 (63.56)	66 (55.93)	0.232	74 (55.64)	77 (57.89)	0.710
	Motivation to comply	77 (65.25)	75 (63.56)	0.786	73 (54.89)	98 (73.68)	0.001
Contents/discussions in the social media	Normative beliefs	65 (55.08)	76 (64.41)	0.144	67 (50.38)	96 (72.18)	0.000
	Motivation to comply	50 (42.37)	82 (69.49)	0.000	80 (60.15)	103 (77.44)	0.002
Subjective Norm Mean score [SD]		138.88 [±32.72]	146.83 [±29.70]	0.028[b]	146.68 [±35.18]	155.04 [±36.10]	0.060[b]

"n" represents the number of completed responses in each group. SD, Standard deviation of Perceived Behavioral Control score. Values within parentheses represent respective column-percentages. Values within square-brackets represent the SD. [a]P-values calculated by chi-squared test except in [b]. [b]P-values were calculated by paired t-test.

the participants, and informed written consent was obtained from the guardian.

3. Results

3.1. Measurement of intention toward healthy dietary practices

Regarding the choice of food based on its cost, among intervention group participants, there was a significant difference post-intervention in their behavior belief and evaluation of behavioral outcome (Table 3). Relatives/other family members were the important normative influencers among the intervention group participants after the intervention (Table 4). The intervention group participants had greater control belief and perceived power for "opting to eat a healthy diet even when junk food is easily available" after the intervention (Table 5).

3.2. Intenders and non-intenders of healthy dietary practices

In both the intervention and control groups, the Subjective norm and Perceived behavioral control mean scores increased in the post-intervention phase with a broader range of scores (Figure 2). The RR of becoming an intender for healthy diet consumption in the Intervention group compared to the Control group was 2.07 (1.44–2.97). Table 6 represents the generalized linear model showing the effect of intervention in improving intention.

4. Discussion

In the study, the mean score of "Subjective Norm" among the intervention group increased after intervention, and the difference was statistically significant. The intervention group's post-intervention proportion of intenders increased, and the difference was statistically significant. The RR of becoming an intender following intervention was 2.07 (1.44–2.97) compared to the control group.

In the current study, there was an increase in the proportion of respondents in the intervention group who considered "Insufficient intake of vitamins and minerals on health" as bad. This finding was in accordance with a qualitative study conducted by Correa et al. (11) among Indian-origin adolescents. It was reported that all adolescents perceived foods high in vitamins and minerals as healthy. In the present study for the item "Oily food has a harmful effect on health," there was an increased agreement among the intervention group, but it was statistically not significant. Statistically, a significant difference was observed in the increase in the proportion of respondents who considered the "Effects of oily food on health is bad" after the intervention. This finding aligned with the cluster randomized controlled trial conducted by Ochoa-Aviles et al. (26) among 1,430 Ecuadorian adolescents. The intervention group consumed lower quantities of unhealthy snacks like oily food. A cross-sectional study done in India by Kumar et al. (12) reported that 90% of adolescents frequently consumed street foods. In the intervention group, the mean score of "Attitude" decreased slightly following the intervention, although the difference was statistically not significant. In an interventional study from India conducted by Anand et al. (27), it was observed that the participants in the intervention group

TABLE 5 Pre- and post-intervention comparison of perceived behavioral control regarding consumption of healthy diet among intervention and control groups.

Situations	Domain	Intervention ($n = 118$)			Control ($n = 133$)		
		Pre-intervention	Post-intervention	P-value[a]	Pre-intervention	Post-intervention	P-value[a]
Choosing a healthy diet even when hungry	Control belief	83 (70.34)	96 (81.36)	0.048	96 (72.18)	98 (73.68)	0.783
	Perceived power	79 (66.95)	63 (53.39)	0.033	66 (49.62)	78 (58.65)	0.140
Not choosing unhealthy food even if they are tasteful	Control belief	46 (38.98)	66 (55.93)	0.009	45 (33.83)	48 (36.09)	0.700
	Perceived power	50 (42.37)	60 (50.85)	0.192	65 (48.87)	68 (51.13)	0.713
Choosing to eat a healthy diet even when depressed or sad	Control belief	57 (48.31)	50 (42.37)	0.360	67 (50.38)	56 (42.11)	0.176
	Perceived power	61 (51.69)	64 (54.24)	0.696	75 (56.39)	59 (44.36)	0.050
Opting to eat a healthy diet even when junk food is easily available	Control belief	47 (39.83)	69 (58.47)	0.004	57 (42.86)	72 (54.14)	0.066
	Perceived power	47 (39.83)	80 (67.80)	0.000	51 (38.35)	84 (63.16)	0.000
Choosing to eat a healthy diet even during celebrations or parties	Control belief	48 (40.68)	56 (47.46)	0.294	37 (27.82)	64 (48.12)	0.001
	Perceived power	43 (36.44)	52 (44.07)	0.232	44 (33.08)	71 (53.38)	0.001
Choosing to eat a healthy diet even while visiting any mall/multiplex	Control belief	52 (44.07)	62 (52.54)	0.193	33 (24.81)	64 (48.12)	0.000
	Perceived power	60 (50.85)	40 (33.90)	0.008	48 (36.09)	70 (52.63)	0.007
Choosing to eat a healthy diet while traveling	Control belief	51 (43.22)	37 (31.36)	0.059	58 (43.61)	80 (60.15)	0.007
	Perceived power	46 (38.98)	57 (48.31)	0.149	69 (51.88)	75 (56.39)	0.460
Perceived behavioral control Mean Score [SD]		103.37 [±23.10]	108.11 [±26.08]	0.137[b]	98.43 [±31.15]	114.34 [±36.75]	0.000[b]

"n" represents the number of completed responses in each group. SD, Standard deviation of Perceived Behavioral Control score. Values within parentheses represent respective column-percentages. Values within square-brackets represent the SD. [a]P-values calculated by chi-squared test except in [b]. [b]P-values were calculated by paired t-test.

showed significant improvement in "Attitude" after the intervention. Dhauvadel et al. (28), in their interventional study conducted in Nepal, stated that the Education package was reported to be effective in changing the "Attitude" toward healthy eating behavior among adolescents.

Relatives/other family members were critical normative influencers among the intervention group participants. In a study conducted among Danish adolescents by Gronhoj et al. (16), it was observed that the highest "subjective norms" were family members, teachers, and television programs. For the item "Even when junk food is available, I find it easy to opt for a healthy diet," there was an increase in the proportion of participants who agreed in both the intervention and control groups. Still, the difference was statistically significant only for the intervention group. In the intervention group, there was an increase in the proportion of agreement for the item "Can choose to eat a healthy diet even when junk food is easily available" after the intervention, and the difference was statistically significant. These findings in the present study revealed that intervention was adequate for the participants to develop and have more control over healthy eating behavior. This finding was consistent with the conclusions of the study done by Correa et al. (11), where it was mentioned that facilitators to healthy eating were personal preferences for healthy foods. However, a recent study (2021) noted that despite personal preferences and motivations, COVID-19-related lockdown had a menacing effect on practicing healthy dietary behavior (29).

As shown in the results, the intervention significantly improved the intention toward eating a healthy diet. This observation was in consonance with the finding from the study done by Dhauvadel et al. (28), where the Education package was reported to be effective in changing the intention toward healthy eating behavior. In contrast to the current study's finding, Poelman et al. (30), in the inquiry among Australian school children, stated that their intervention did not affect behavioral intentions. However, a systematic review by Bel-Serrat et al. (31) identified the importance of targeted behavioral interventions in improving adolescent dietary behaviors. Thus, designing appropriate school-based health promotion and education interventions relying on the assessment of behavioral intention among school students can lead to healthier children fostering regular healthy dietary practices in their homes and communities. Similarly, Char et al. (32), in their systematic review focused on South Asia, noted that technology-based interventions had a beneficial effect on dietary behavior outcomes. The application of digital technology can aid in the designing and implementation

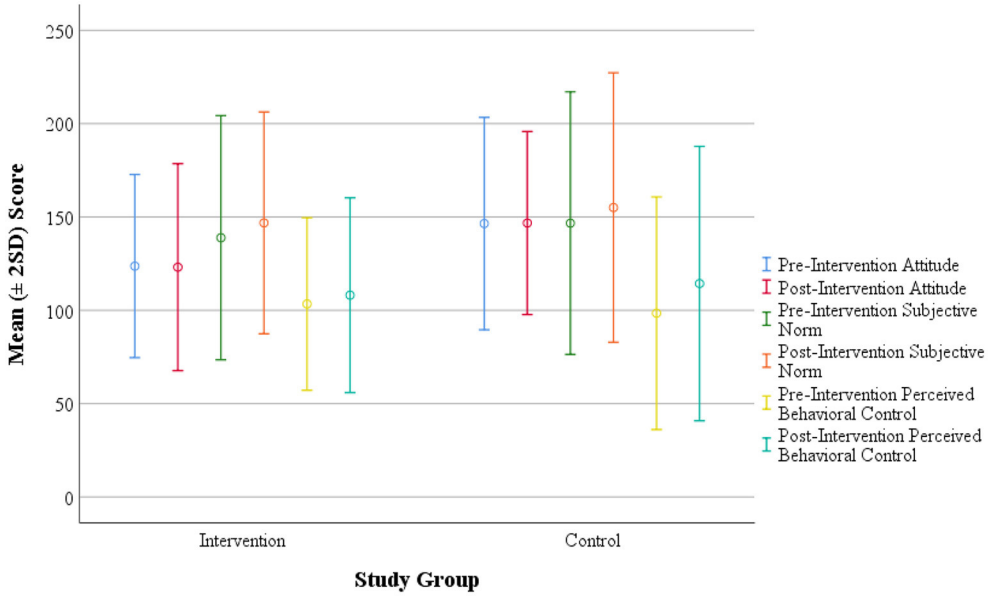

FIGURE 2
Score distribution of intervention and control groups with respect to Attitude, Subjective Norm and Perceived Behavioral Control (constructs) toward healthy dietary practices. The circles indicate the mean value computed, and the bars represent two standard deviation (2SD) around the mean.

TABLE 6 General linear model showing different factors of improved intention for healthy dietary behavior.

Factors for becoming an intender for healthy dietary behavior	aRR (95% CI)	*P*-value
Intervention (Ref.: Control group)		
Intervention group	2.07 (1.44–2.97)	0.000
Pre-Intervention Intention (Ref.: High intention cluster)		
Low Intention Cluster	1.30 (0.97–1.74)	0.076
Gender (Ref.: Girls)		
Boys	1.18 (0.88–1.60)	0.270

aRR, Adjusted Relative Risk; CI, Confidence interval; P-values obtained through Generalized Linear Model (GLM) with the log-linear link under Poisson distribution function and robust standard errors: Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) were 394.646 and 415.774, respectively, with the scale parameter for the model set at 1. The model has been adjusted for the statistically significant two-way interaction sets: gender-study groups and pre-intervention cluster-study groups, with model intercept: 0.47 (95% CI: 0.35–0.62). The model was found to be an appropriate improvement over the intercept-only model (P-value < 0.001).

of cost-effective interventions regarding the dietary behavior of adolescents.

4.1. Limitations

The change in intention status depends upon several external and environmental factors other than the constructs and the items in the TPB. Because of the focused use of the model framework, these exogenous variables were not accounted for in the study. As the participants' self-reported information on the constructs, there is a possibility of social desirability bias, despite the expressed confidentiality protocol.

5. Conclusion

Schools are necessary settings where children should develop behavior and skills for physical, emotional, and social well-being. The behavioral patterns developed during childhood and adolescence are continued, retained, and sustained into adulthood. The best predictor of behavior is behavioral intention which was used in the interventions in this study and demonstrated a statistically significant improvement in "Subjective norm" regarding healthy diet among the intervention group in the post-intervention phase. An expected finding was the improvement in intention following the intervention. Fostering healthy dietary behavior among school students through extra-curricular activities should be promoted. Any junk food stall around school premises should be discouraged by taking necessary steps. Appropriate advocacy with parents and school teachers is also essential; they should be sensitized and trained to understand and identify unhealthy dietary habits and preventive interventions.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Ethics Committee, All India Institute of

Hygiene and Public Health. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

SSJ and MD developed the concept and designed the data collection technique. AL and SSJ contributed to data collection, data validation, formal analysis, and preparation of the first draft. MD and CT provided the necessary supervision. All authors contributed to editing and developing the final version of the article.

Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1094960/full#supplementary-material

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Recruitment and reach in a school-based pediatric obesity intervention trial in rural areas

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Introduction: The purpose of this study is to evaluate two recruitment strategies on schools and participant participation rates and representativeness (reach) within a pediatric obesity treatment trial tailored for families who live in rural areas.

Methods: Recruitment of schools was evaluated based on their progress toward enrolling participants. Recruitment and reach of participants were evaluated using (1) participation rates and (2) representativeness of demographics and weight status of participants compared to eligible participants (who did not consent and enroll) and all students (regardless of eligibility). School recruitment, as well as participant recruitment and reach, were evaluated across recruitment methods comparing opt-in (i.e., caregivers agreed to allow their child to be screened for eligibility) vs. screen-first (i.e., all children screened for eligibility).

Results: Of the 395 schools contacted, 34 schools (8.6%) expressed initial interest; of these, 27 (79%) proceeded to recruit participants, and 18 (53%) ultimately participated in the program. Of schools who initiated recruitment, 75% of schools using the opt-in method and 60% of schools using the screen-first method continued participation and were able to recruit a sufficient number of participants. The average participation rate (number of enrolled individuals divided by those who were eligible) from all 18 schools was 21.6%. This percentage was higher in schools using the screen-first method (average of 29.7%) compared to schools using the opt-in method (13.5%). Study participants were representative of the student population based on sex (female), race (White), and eligibility for free and reduced-price lunch. Study participants had higher body mass index (BMI) metrics (BMI, BMIz, and BMI%) than eligible non-participants.

Conclusions: Schools using the opt-in recruitment were more likely to enroll at least 5 families and administer the intervention. However, the participation rate was higher in screen-first schools. The overall study sample was representative of the school demographics.

KEYWORDS

representativeness, dissemination and implementation, implementation science, RE-AIM evaluation framework, youth, children

1. Introduction

Pediatric obesity contributes to lifelong chronic diseases (e.g., type 2 diabetes) and therefore is a critical concern that needs to be addressed (1). Children who live in rural areas demonstrate a 26% greater risk of obesity compared to their urban counterparts (2, 3). Adding further concern, rural areas lack resources and programs for pediatric obesity treatments (4–6). One option for providing obesity treatments to children living in rural areas is through their local schools which may increase treatment access for a large number of youth (7, 8).

While schools may be an optimal setting for pediatric obesity treatments, many aspects of program uptake by participants are unknown in rural school settings, including best recruitment methods, and representativeness of individuals who are ultimately consented and enrolled. Understanding these facets of program uptake and representativeness is important for future work regarding treatment of pediatric obesity in rural school settings and will aid in bringing evidence-based interventions to families who live in rural areas and are in need of these services. The Reach Effectiveness/Efficacy Adoption Implementation and Maintenance (RE-AIM) framework provides a guide to evaluate both internal and external validity and support the dissemination and implementation of evidence-based interventions into practice (9). Reach specifically supports external validity and generalizability of results by examining the uptake and representativeness of the participants compared to the eligible community or population (in this case, all the children in the school). While previous researchers have applied the RE-AIM framework to a school setting, gaps remain (10–12). First, none of these studies involve an empirically supported pediatric obesity treatment program in accordance with the United States Preventative Services Task Force (USPSTF) guidance (26 contact hours, parents and children participating, etc.) (13). Second, while recruitment strategies have been reported, few studies systematically evaluate which strategies are most effective and provide the most representative study sample in the school setting.

The purpose of the current study was to address these existing gaps in the literature by evaluating recruitment of schools and participants in an 18-site randomized clinical trial. Specifically, we examine success in recruitment of both schools and participants and participant representativeness across select demographics, comparing two common participant recruitment strategies: (1) caregivers were contacted to opt-in to have their child screened for the study (opt-in) and (2) all children within targeted grades underwent body mass index (BMI) screening and eligible participants were invited to the study (screen-first).

2. Methods

2.1. Study design, setting, and participant eligibility

Briefly, iAmHealthy is a two-arm cluster randomized pediatric obesity intervention (14) that follows expert committee guidelines (15), delivered to schools in rural Kansas. Eligible families were those with a child in 2nd−4th grade from a participating school who had a child body mass index (BMI) between the 85th and 99th percentile for age and sex. Exclusion criteria included children with significant limits to physical mobility, significant medical issue (e.g., cancer), cognitive impairments, developmental delays, or did not speak English. Only one child from each family could be enrolled in the study. Randomization occurred at the school-level after baseline data collection; the two interventions were (a) a family-based behavioral intervention where families met for group sessions via telehealth and (b) a control group that received educational newsletters. Within the intervention arm, caregiver/child dyads attended group and individualized health coaching sessions (∼25 contact hours) over the course of 8 months. Caregiver/child dyads in the control group were sent newsletters throughout an 8-month period. The full intervention protocol is described in more detail in Davis et al. (14).

2.2. Recruitment

2.2.1. Recruitment of schools

Schools were recruited between spring 2017—fall 2019. Eligible schools were in cities or counties with a population <20,000 individuals and served students in 2nd, 3rd, and/or 4th grade. Various recruitment methods were utilized to recruit schools including paper flyers to all nurses, gym teachers and principals at all eligible public elementary schools in the state of Kansas, listserv emails, and a partnership with a state level school nursing organization who assisted in contacting schools. Recruitment materials included brief information about the study and contact information for the research team. For a school to be a site, they needed to first respond with a letter of support for participation from a school administrator (e.g., principal or superintendent).

After enrollment, school personnel who supported the study (e.g., school nurses and physical education teachers) underwent a virtual training with the research team on the study protocol, research ethics, and informed consent. Then, school personnel were added to the study Institutional Review Board and were shipped equipment to screen, consent, and enroll students in 2nd−4th grade for the study. School personnel were required to recruit at least 5 families to be randomized as a site; if they were not able to recruit enough families, the school did not move forward to randomization. Throughout the onboarding process, researchers had regular communication with school personnel; therefore, reasons for non-inclusion in the study were gathered from school personnel during these onboarding meetings. School personnel were paid $30 per hour for hours they worked on the study, with a maximum of $2,000 per site.

2.2.2. Participant recruitment strategies

School personnel recruited study participants within their schools. The two strategies to recruit participants were: (1) opt-in or (2) screen-first. School personnel self-selected which recruitment method they preferred based upon their school preference and history of conducting school-wide annual BMI screenings (i.e., they were not randomized to their recruitment method). Participant

recruitment occurred after each school was recruited and occurred between fall 2017—spring 2020.

2.2.2.1. Opt-in

For this recruitment method, school personnel contacted caregivers via personal calls, emails, and flyers, and caregivers opted in for their child to have a BMI screening to participate in a new research program available at their school that was designed to "help rural children in our state to live healthier lives". Researchers did not formally track contact methods or number of contact attempts, but school personnel were encouraged to reach out to caregivers using multiple communication methods. Brief information on what study participation would involve was included as well as the treatment options (i.e., randomization to one of two intervention groups) and a link to the study website. Caregivers who expressed interest gave permission for their child to be assessed for eligibility. Specifically, height and weight data were collected by the school personnel with BMI calculation assistance provided by the study team (if needed). Once BMI eligibility was established, families were screened for other inclusion/exclusion criteria and if eligible, invited to consent and enroll.

2.2.2.2. Screen-first

For this recruitment method, school personnel measured the height and weight of all students in 2nd−4th grade, which they were already doing as part of an annual BMI screening program. The study team offered assistance for BMI calculation (if needed). The number of students screened and the number of students eligible were provided to the research team. Caregivers of children who were eligible based on BMI criteria were then provided information about the study by school personnel via personal calls, emails, and flyers. Once contacted, eligible children were then screened for other inclusion/exclusion criteria and subsequently invited to participate.

2.3. Measures

2.3.1. Participation rates

Regarding participation rate, we report total number of eligible children in the school (based on grade and BMI), total number enrolled, and participation rate (number enrolled divided by the number eligible). For schools using screen-first, the number of children eligible is based on measurements taken on all students in the 2nd−4th grades. For schools using opt-in, we estimated the number of eligible students by taking the total number of children in 2nd−4th grade (from Kansas State Department of Education) and multiplying it by 35.4% (the average percentage of children with overweight/obesity in screen-first schools from this study). We used 35.4% rather than the pediatric rate for overweight and for Kansas (29.5%) (United Health Foundation) (16) because it is more specific to these rural communities participating in the current study. For descriptive purposes, we also report the number eligible from those who opted to be screened at schools using the opt-in method.

2.3.2. Representativeness of sample

For this outcome, we compared participants to non-participants on the following: BMI metrics, sex (female), race (White), and eligibility for free/reduced-priced lunch. Demographic characteristics of the school were collected from the Kansas State Department of Education website, which includes school and classroom-level information (17). In accordance with the Family Educational Rights and Privacy Act (FERPA), the Kansas State Department of Education does not provide data if <10 children fall within a given category; for this reason, grade or classroom level counts of free and reduced-price lunch were limited. When limited, the percentage of students eligible for free/reduced-price lunch from the whole school was applied to the students in 2nd−4th grade. No other race category besides White was selected because there was limited information due to FERPA reporting standards in these communities. Four schools had limited sex or race data and were excluded from these analyses as school-wide data was not available.

With respect to BMI metric comparisons, height and weight data provided by school personnel were utilized to make comparisons on body mass index (BMI), BMI z-score (BMIz), and BMI percentile (BMI%) between children who were enrolled in the study and those who were eligible but did not enroll.

2.4. Statistical analysis

Recruitment of schools is reported at each stage of participation. Frequencies and percentages are reported for child participation rates by school and by recruitment strategy. A Pearson correlation was used to examine the relationship between child participation rate and school size. Paired *t*-test analyses were used to evaluate the representativeness of demographics between all students in the 2nd−4th grade classrooms and study participants at the school level. Additionally, paired *t*-test analyses were used to compare the representativeness of BMI data between eligible individuals (based on BMI screening) and study participants.

3. Results

3.1. Recruitment of schools

The research team invited 395 elementary schools in rural Kansas to participate (Figure 1). Of the schools contacted, 34 expressed interest. Twenty-seven schools began participant recruitment and 18 schools (52.9% of those interested; 4.5% of total contacted schools) enrolled sufficient participants to continue to randomization (Figure 1). Enrolled schools were recruited via flyers ($n = 12$), listserv emails ($n = 1$), direct contact with a state nursing organization ($n = 2$), or referral from a current participant or local nurse ($n = 3$). To increase recruitment, the study team directly called 42 eligible schools, but no schools were enrolled through this method. Schools that were interested but did not participate in the program commonly listed school personnel being too busy and insufficient recruitment as reasons why they were unable to move forward with the study.

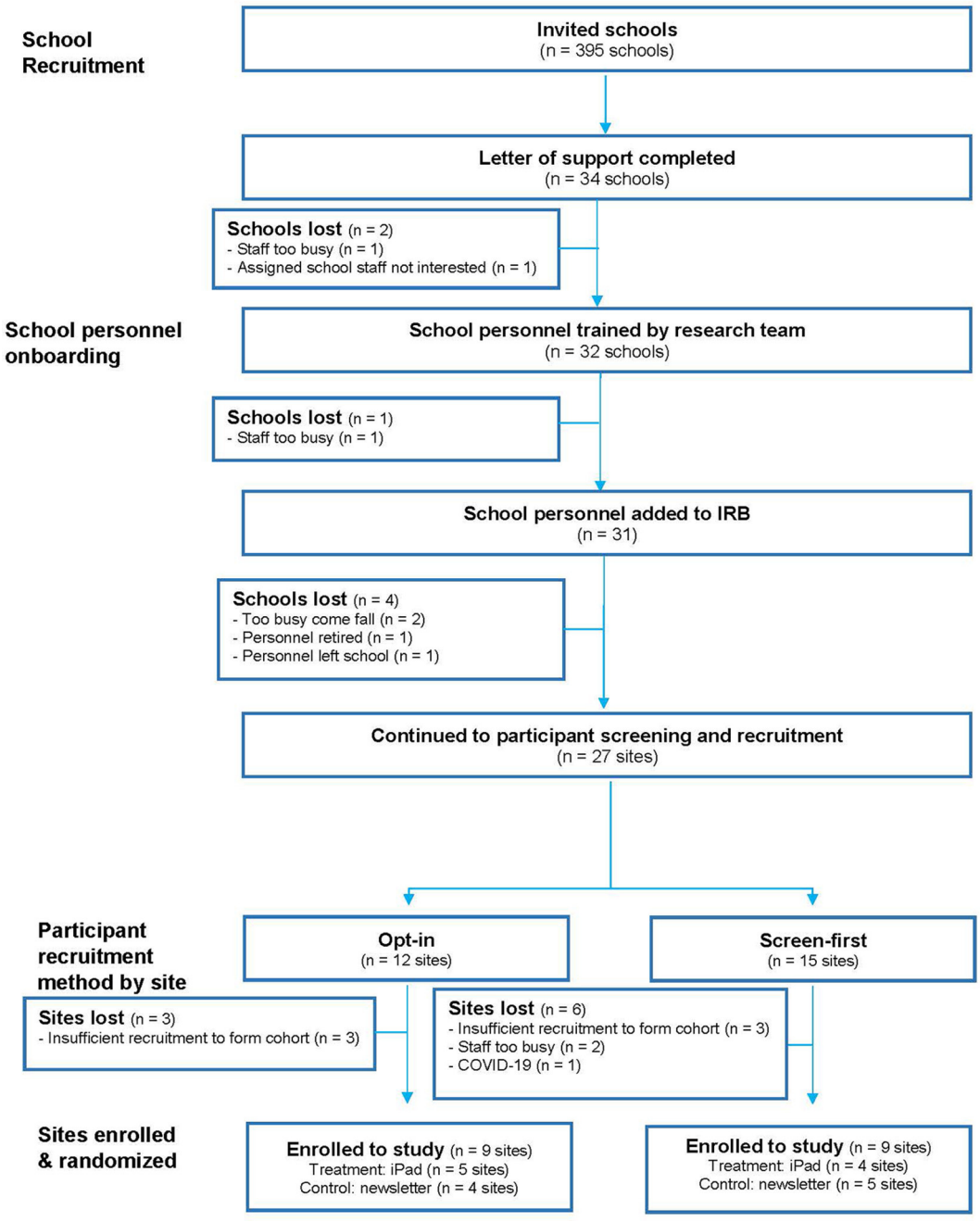

FIGURE 1
Recruitment of schools.

3.2. Participant recruitment strategies

From the 27 schools who initiated recruitment of participants, nine were not able to successfully recruit at least 5 families and discontinued their involvement: this included 3 of 12 (25%) schools using the opt-in method and 6 of 15 (40%) schools using the screen-first method (Figure 1). Two of the twelve schools within the opt-in recruitment strategy that successfully recruited participants reported using additional tactics to increase their response rates. At one school, the school personnel hosted a table at a back-to-school night that allowed them to talk to most caregivers. The second school offered prizes for returning an opt-in form regardless of caregiver response.

3.3. Participation rates

Figure 2 displays participant recruitment, screening, eligibility and enrollment by recruitment method. The participation rate

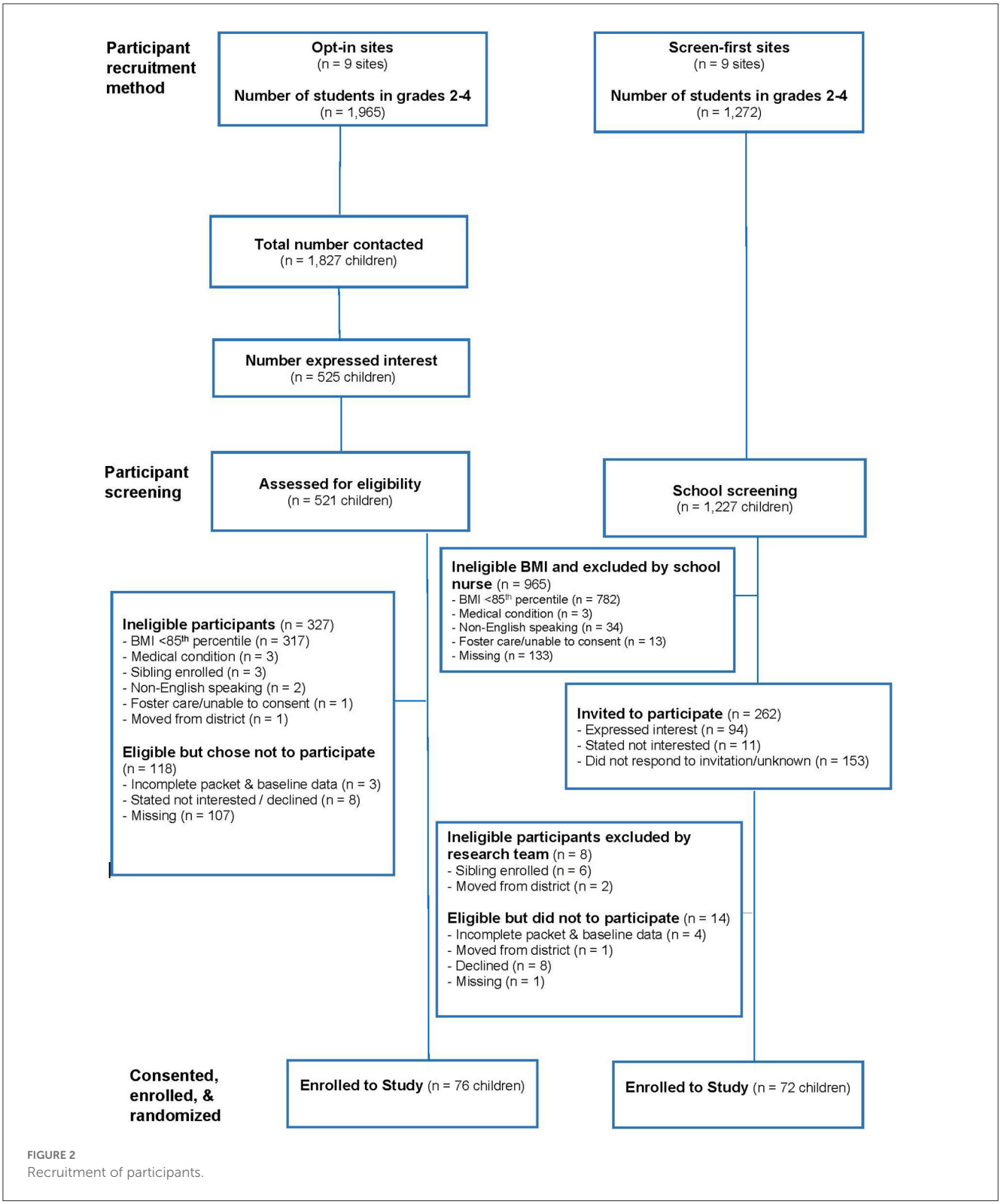

FIGURE 2
Recruitment of participants.

from all 18 schools in the study was 21.6%. Excluding the schools in each recruitment method that were unable to recruit at least 5 families, the participation rate was higher in schools using the screen-first method (average of 29.7% across 9 schools) compared to schools using the opt-in method (average of 13.5% across 9 schools). Table 1 displays participation rates based on recruitment method by school; participation rates ranged from 5.6 to 46.7% across all schools. There was a significant, negative relationship between school size and participation rate ($r = -0.48$, $p = 0.044$), with smaller schools having higher participation rates on average.

TABLE 1 Eligibility and participation rate by recruitment method and by school.

Recruitment method	School ID	Students in grades 2–4	Number screened	Number eligible from screening	Estimate of number eligible	Total number consented and enrolled	Recruitment rate (%)*
Opt-in flier	A	104	50	-	37	7	19.0
	B	80	78	-	28	8	28.2
	D	356	61	-	126	7	5.6
	E	178	46	-	63	7	11.1
	G	172	62	-	61	9	14.8
	H	357	60	-	126	11	8.7
	I	152	18	-	53	6	11.5
	L	145	8	-	51	7	13.6
	N	421	141	-	149	14	9.4
	Opt-in total	**1,965**	**524**	-	**694**	**76**	
Screen-first	F	123	118	50	-	6	12.0
	J	71	73	20	-	7	35.0
	K	120	103	30	-	14	46.7
	M†	176	81	47	-	11	23.4
	O‡	162	160	12	-	9	75.0
	P	192	193	70	-	6	8.6
	Q	33	33	11	-	5	45.5
	R	207	204	94	-	7	7.4
	S	188	123	51	-	7	13.7
	Screen-first total	**1,272**	**1,088**	**385**	-	**72**	

*Recruitment rate = total # enrolled/estimate # eligible (opt-in) or = total # enrolled / # eligible from screening.
†Only screened 3rd and 4th graders.
‡Screened kindergarten–4th grade.

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TABLE 2 Comparison between study participants and students in grades 2–4 at participating schools ($n = 18$ sites).

Demographic characteristic	Overall study			Opt-in schools			Screen-first schools		
	Student population	Participants	*p*-value	Student population	Participants	*p*-value	Student population	Participants	*p*-value
Children	3,237	148		1,965	76		1,272	72	
Females[a]	1,409 (49.3%)	79 (58.7%)	0.059	926 (48.0%)	40 (51.2%)	0.619	**591 (50.9%)**	**39 (68.4%)**	**0.028**
White[b]	2,079 (76.2%)	87 (71.8%)	0.300	1,339 (78.1%)	51 (77.1%)	0.837	680 (73.7%)	37 (64.7%)	0.271
Eligible for FRPL	1,821 (49.5%)	72 (53.9%)	0.411	1,128 (52.8%)	35 (44.5%)	0.251	693 (55.0%)	37 (54.5%)	0.957

Frequency (percentage). FRPL, free-or reduced price lunch.

[a]Overall study n = 16 sites, total participants n = 136 opt-in: participants n = 76 n = 9 sites, screen first: participants n = 60, sites n= 7.

[b]Overall study n = 16 sites, total participants n = 121, opt-in: participants n = 68, sites n = 8, screen first: participants n = 53, sites n = 6; bolded values signify $p < 0.05$.

3.4. Representativeness of sample

Table 2 shows representativeness of the study participants compared to the school student population for sex, race, and free and reduced-price lunch status. Overall, study participants were comparable to the student population regarding these characteristics. When examining sample representativeness within each recruitment method, the screen-first method resulted in a higher percentage of females in the study compared to the school population [68.4 vs. 50.9%; $t_{(6)} = 2.895$, $p = 0.028$].

Sixty percent of the schools sent researchers de-identified height and weight data for the study team to calculate BMI; thus, BMI data were available on all screened individuals for 13 of the 18 participating schools (missing data from 2 schools using opt-in recruitment and 3 schools using screen-first recruitment). Table 3 shows the representativeness of study participants compared to eligible individuals on BMI, BMIz, and BMI percentile (BMI%). Results indicate a significant, but small, difference between eligible individuals and study participants on BMI (23.0 vs. 24.2 kg/m^2), BMIz (1.8 vs. 1.9), and BMI% (94.9 vs. 95.7th%), with the participant group having higher BMI metrics than the eligible individuals. When examining BMI representativeness based on recruitment method, both methods indicate significant differences between eligible individuals and study participants on BMI. Additionally, screen-first schools observed differences for BMIz, with participants having higher BMI metrics than eligible individuals.

4. Discussion

This study examined recruitment of schools, participant recruitment strategies, and representativeness of study participants in a pediatric obesity treatment tailored for families living in rural areas.

The most effective method to recruit schools was by mailing out flyers; however, this study enrolled only 4.5% of the schools contacted. Compared to prior studies evaluating the success rate of school recruitment (18–20), both initial interest and school enrollment for this study was considerably lower, even when compared to a study examining rural school recruitment (21). Notably, each of these prior studies were obesity prevention programs. This may suggest that schools are more likely to participate in school-wide health promotion study rather than treatment programs for children within a certain BMI classification, which was the case in the present study. Further, the method to recruit schools in each of these studies was variable, with the prior studies utilizing partnerships with the U.S. Department of Education (21) and direct phone calls to teachers with pre-established relationships (19). Future studies should continue to evaluate the specific designs that lead to school enrollment to better identify effective methods.

With respect to recruitment of participants, significant variability in the participation rates existed based on schools and recruitment strategy. Schools who utilized the screen-first

TABLE 3 Representativeness of study sample compared to screened non-participants based on body weight measures.

	Overall study				Opt-in schools				Screen-first schools			
	Screened	Eligible individuals	Participants	*p*-value	Screened	Eligible individuals	Participants	*p*-value	Screened	Eligible individuals	Participants	*p*-value
Number of children	1,152	444	111		493	182	63		659	262	48	
Average BMI (kg/m^2)	18.8 (4.3)	**23.0 (4.2)**	**24.2 (4.3)**	**0.002**	18.6 (4.1)	**22.7 (4.0)**	**23.7 (4.3)**	**0.044**	19.0 (4.5)	**23.3 (4.3)**	**24.9 (4.5)**	**0.025**
Average BMIz	0.7 (1.1)	**1.8 (0.5)**	**1.9 (0.5)**	**0.01**	0.6 (1.1)	1.8 (0.5)	1.9 (0.5)	0.200	0.7 (1.1)	**1.8 (0.5)**	**2.0 (0.5)**	**0.027**
Average BMI%	66.9 (28.6)	**94.9 (4.3%)**	**95.7 (4.3)**	**0.044**	66.8 (28.2)	94.7 (4.3)	95.3 (4.7)	0.384	67.1 (28.9)	95.0 (4.2)	96.3 (3.7)	0.079

Mean (standard deviation) or frequency (percentage; %); p-values for t-test comparisons between eligible individuals and study participants' bolded values signify $p < 0.05$.

method were more likely to discontinue participation prior to beginning the intervention, possibly because this method does not consider interest in study participation. However, the screen-first method yielded a higher participation rate. With increasing numbers of school districts including health screening assessments (including BMI) (22) as part of yearly evaluations, this initial screening may be less of a burden on staff for future studies. In contrast, opt-in already takes participation interest into account but not all who are interested may be eligible for the study. Each recruitment method provides information on eligibility or interest, but neither method provides information on both. Therefore, future studies that deem interest is more important should use opt-in methods while studies that deem eligibility is more important should proceed with screen-first.

Overall, participation rates in this study were lower compared to prior pediatric obesity trials (22–72% recruitment rate) (23–26). Previous studies note recruitment challenges (23, 24) and occasionally need to modify recruitment strategies to attain the necessary sample size (24), however few assess best methods for recruitment, especially within school-based studies. Studies within clinics, observe that active recruitment strategies (e.g., physician referral or directed mailings) result in a higher number of enrolled participants compared to passive strategies (posted flyers and media advertisements) (26, 27). Interestingly, in a pediatric obesity treatment through clinics, researchers noted that participants enrolled through passive recruitment strategies had better retention than those enrolled through active recruitment strategies (26). These findings on recruitment strategies within clinics are similar to the present study with more active or targeted recruitment (i.e., screen-first) having a higher recruitment rate compared to the more passive (i.e., opt-in) recruitment strategy (29.7 vs. 13.5%, respectively). Anecdotally, while researchers did not formally track contact methods made by school personnel, it appears that school personnel who made direct phone calls to families seemed to be the most successful at recruiting, consenting, and enrolling participants. Additionally, smaller schools were more successful with recruitment compared to larger schools. This higher recruitment rate may be due to a variety of reasons such as it being easier for school personnel to contact a smaller pool of participants, school personnel having closer relationships with families, or families not being flooded with flyers on other school information (e.g., fewer resources).

Study participants were comparable to the student population in regard to percent female, percent White, and percent eligible for free and reduced-price lunch, and there were limited differences between recruitment methods. The exception is the higher percentage of recruited females from the screen-first recruitment method. This suggests that both recruitment methods are acceptable methods to help ensure that youth from all backgrounds are recruited to participate. With respect to weight status, participants who enrolled in our intervention had a higher weight status compared to all eligible. This may be due to a larger perceived need of the intervention. This provides support and emphasizes a need for prevention and health behavior improvement opportunities at the school level.

4.1. Recommendations and future considerations

Several recommendations can be offered for future school-based intervention research studies based on the current research. First, we recommend discussing pros and cons of each recruitment strategy with school personnel to help them determine the best option for their situation. If a school is not currently screening all youth for other reasons, this may put too much burden on school personnel. Anecdotally, there were many interested families who had children with a BMI within the healthy weight range who were captured within the opt-in method. This interest provides support for school-wide programs focused on obesity prevention rather than obesity treatments. Regardless of method, additional anecdotal information observes that personal contact with eligible families from a trusted contact (e.g., school nurse) appears to have been a very effective, albeit time intensive strategy for recruitment. With respect to recruitment of schools, recruitment efforts need to be flexible and active, especially after the initial wave of interest. Future multi-year studies may want to consider evaluating for differences in school personnel's engagement based on the method in which the school was recruited or how quickly they agreed to participate in the project. Anecdotally, the tenure of school personnel and number of schools they cover appeared to impact recruitment. This may be due to the impact of personal relationships and trust these professionals have with families. Thus, future research may want to more systematically examine the impact of tenure and school personnel workload. Finally, even though our study reports on children enrolled in the study and communication is sent through children, children are governed by their caregivers. Thus, there may be a disconnect in communication or children who are interested but their caregivers are not interested. This is an area to consider for future research.

A strength of this study is this is one of the first studies to examine different child recruitment strategies and representativeness of the study sample compared to the student population in rural schools. Another strength is the collection and reporting of data on BMI screenings for two thirds of the schools in the study. The use of FERPA data from the Kansas State Department of Education to characterize the representativeness of the study sample is both a strength and a weakness. A strength of this data is it provided local, school-specific, FERPA data at the grade level. Unfortunately, due to the privacy policy and small sizes of the grades, we were unable to compare races other than White (e.g., Black and multi-racial) or ethnicity (individuals identifying as Hispanic) between the student population and study participants. An additional limitation of the current project is that it was only provided in English, and many participants who were excluded for being non-English speaking identified as Spanish speakers. Thus, by only offering the program in English, we may have limited participation for some families who were Hispanic. Recruitment of schools took place prior to the COVID-19 pandemic and only one school was recruiting families during the start of the pandemic; findings from this study may not be generalizable to recruitment during a pandemic. Finally, school personnel self-selected their recruitment method, rather than being randomized to a method, and this self-selection may have impacted the schools' ability to recruit enough families and participate in the intervention.

5. Conclusion

This study examined recruitment of schools, participant recruitment strategies, and representativeness of study participants in a pediatric obesity treatment tailored for families living in rural areas. This study was the first to compare school's use of opt-in vs. screen-first recruitment methods for an obesity intervention trial.

Schools using the opt-in method were more likely to enroll at least 5 families and administer the program, but schools using the screen-first method had a higher participation rate. The utilization of a screen-first approach takes substantial effort on the part of school personnel, but ultimately allows for a more targeted approach to recruitment. For schools that already collect BMI data, utilizing the screen-first approach may result in less burden and greater participation rates. However, for those not already screening for BMI, it may be helpful to evaluate the amount of time school personnel is willing and able to dedicate to recruitment. Our findings suggested that both methods recruited a representative sample and thus are acceptable options moving forward.

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

Author contributions

BF led the overall study, conducted the data analysis and interpretation, and wrote and revised the manuscript. BL contributed to data analysis, data interpretation, and initial writing of the manuscript and manuscript edits. MO contributed to the data collection and interpretation and manuscript revisions. CB contributed to study design and manuscript edits. RS and MD contributed to data analysis and interpretation and manuscript edits. KD contributed to the data collection and interpretation and manuscript revisions. E-LN contributed to data collection and manuscript edits. AD contributed to study design, data collection, data analysis interpretation, and manuscript edits. 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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Barriers and facilitators to physical activity and further digital exercise intervention among inactive British adolescents in secondary schools: a qualitative study with physical education teachers

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Background: Previous studies indicated that physical education programs in schools were unsuccessful to ameliorate physical activity (PA) behaviors among adolescents. This study investigated PE teachers' perceptions of barriers and facilitators to PA and further digital exercise interventions among inactive British adolescents in secondary schools based on the Capability, Opportunity, Motivation, and Behavior (COM-B) model, the Behavior Change Wheel (BCW), and Theoretical Domains Framework (TDF).

Method: A qualitative study was conducted among 156 PE teachers in England. deductive thematic analysis approach was applied to analyze data.

Results: A comprehensive perception of PE teachers revealed 21 barriers to PA among inactive adolescents in secondary schools. The study findings show that barriers exist across all categories of the COM-B model in physical opportunity (7), reflective motivation (5), social opportunity (4), psychological capability (4) and physical capability (1). The majority of these barriers were reported in previous studies as being barriers to PA from the perspective of children and adolescents. This shows that the findings are consistent with the views of children and adolescents that participated in these studies. Particular salient barriers for inactive adolescents were reported and greater insight into their experiences was highlighted. The study reported the main sources of behavior, intervention functions, policy functions, and behavior change tools that can be used for future behavior change interventions to support inactive adolescents.

Conclusion: The study recommends using its findings to design interventions for inactive adolescents to achieve recommended levels of physical activity (PA). The study's comprehensive approach and evidence-based solutions provide extensive reference points for future intervention design, informing policy and contributing to enhancing support for inactive adolescents. Further development of digital exercise interventions, including conversational artificial intelligence (AI), is suggested to engage adolescents at scale and provide personalized support to overcome multiple barriers to PA.

KEYWORDS

adolescents, PE teachers, COM-B model, physical activity, digital exercise intervention, United Kingdom, secondary schools

1. Introduction

Secondary schools play a critical role in promoting and guiding adolescents toward health-promoting activities. This includes encouraging and supporting physically inactive adolescents to become physically active through physical education (PE) and extra-curricular activities. Provision of sports and PE opportunities is neccessary to develop the physical literacy of adolescents and promote lifelong physical activity (PA) behaviors. In addition to fostering enjoyment and social interaction, participation in physical activities can lead to enhanced educational attainment and improved health outcomes for students (1–3). However, a worldwide umbrella study has found that efforts to promote PA in schools have mostly been unsuccessful in changing PA behaviors (4). The success of school-based interventions can be hindered by various factors, including poor implementation, which is partly the responsibility of PE teachers (4, 5).

Numerous studies have investigated why some people are more active than others (6). However, there is a limited understanding of the attitudes and behaviors of inactive adolescents who are more susceptible to the negative impacts of physical inactivity. PE teachers play a fundamental role in adolescents' lives, by promoting and encouraging them to be physically active, yet there is inadequate knowledge of their perspectives on inactive adolescents. Several interventions have been implemented worldwide to tackle inactivity yielding mixed results (7). By gaining a deeper understanding of the barriers that PE teachers perceive, it is possible to develop future approaches and identify solutions that would benefit inactive adolescents.

In recent years, there has been a paradigm shift in the design of PA interventions. Rather than focusing solely on individual factors, PA interventions are now being designed to reshape the entire system, encompassing policy, environmental, social, and individual factors. This approach commonly known as a 'whole systems approach', involves applying systems thinking, to identify solutions that may involve multiple stakeholders in addressing the challenges of physical inactivity (8). Thus, multicomponent interventions are now favored over single-component interventions. The World Health Organization (WHO) used a systems framework to develop their Global Action Plan on PA, with four strategic objectives, and twenty policy actions aimed at reducing physical inactivity by 10% globally (9). Two of these objectives include enhancing PE and school-based programs in educational settings and prioritizing programs for the inactive (9). Schools and PE teachers play a fundamental role in this system, as they are responsible for supporting and engaging adolescents in PA every week throughout the school term. Therefore, they have an unrivaled level of understanding of the barriers and facilitators that exist for this population.

According to the PA guidelines set by the Chief Medical Officer of the UK, it is recommend that adolescents engage in moderate to vigorous intensity PA for at least 60 min every day (10). However, in England, around 2.2 million adolescents which accounts for 30% of the population, are considered 'less active' (11) as they engage in less than 30 min of moderate to vigorous PA per day. To combat this, schools play a crucial role in encouraging PA as the UK Government recommends that at least 30 min of daily PA should take place within schools (i.e., PE and extracurricular activity), while the remaining 30 min should be completed outside of school time.

Previous research has shown that school-based physical education can play an important role in promoting daily moderate to vigorous PA and reducing sedentary behavior among adolescents, particularly those who are inactive (12–14). However, in the UK there has been a decline in the number of adolescents who meet the minimum recommended PA target per day, and a decrease in the duration of PE offered to adolescents as they transition through school. An analysis of data from the 2018/19 Active Lives Children and Young People survey revealed that 40% of adolescents engaged in 30 min or more of PA every day at school, while 57% did so outside of school (15). As a result, adolescents are more likely to be less active at school (60%) than they are outside of school (43%). Consequently, many schools are failing to enable adolescents to meet the minimum recommended PA target, thus contributing to their inactivity. Other challenges, such as low-quality PE and a lack of teachers' commitment, have been reported in other countries, which may be contributing to global inactivity levels (4, 16).

It was reported in a systematic review that the main barriers and facilitators to the implementation of PA policies in schools are the 'environmental context and resources' such as the availability of equipment, time, or staff; 'goals' such as the perceived priority of the policy in the school; 'social influences', such as support from school boards; and 'skills' such as teachers' ability to implement the policy. While previous studies have identified PA preferences and barriers (17–19) among adolescents in schools, there is a lack of evidence on the habits and behaviors of inactive adolescents, particularly from the perspective of PE teachers. Although other school staff including headteachers/principals (20) have an impact, PE teachers are the gatekeepers for delivering interventions in schools and have a better understanding of the complex range of needs, attitudes, and preferences of inactive adolescents since they work with them every week.

In order to effectively change behavior, interventions should be based on evidence and informed by theoretical frameworks. One such framework is the Capability, Opportunity, Motivation and Behavior (COM-B) model, which is widely used in the field of health and specifically in some PA interventions (21). The model recognizes that behavior is part of a complex interacting system that is influenced by an individual's capability, opportunity, and 'motivation' to perform a given behavior (22). Therefore, to encourage a new behavior one or more of these components need to be changed. By using the Behavior Change Wheel, which is a synthesis of 19 different frameworks of behavior change, the model can be applied to identify options for suitable interventions designed to change one or more of the components (i.e., capability, opportunity, and motivation). The hub of

the wheel represents the sources of the behavior that could be targeted through interventions and this will be assessed alongside the findings of the study to identify behaviors than can be targeted through intervention to support inactive adolescents. The wheel also includes a layer of nine intervention functions that can be used to modify specific behaviors, as well as seven types of policy that can be employed to deliver the intervention(s).

The Theoretical Domains Framework (TDF) consists of 14 domains (23) and is often used in conjunction with the COM-B model to identify and describe the factors, which may influence a specific behavior. These factors can be mapped onto the COM-B model to identify factors that influence behavior and highlight intervention functions, policy categories and behavior change tools that can inform future intervention design. Finally, to assess the suitability of an intervention for adolescents the APEASE (affordability, practicability, effectiveness, acceptability, safety, and equity) criteria should be applied (22).

The hypothesis for this study is that PE teachers' unique perspective can provide evidence of barriers faced by inactive groups participating in sports and PA in secondary schools and identify sources of behavior contributing to inactivity. The research questions for the study are:

(1). What are the barriers that inactive groups face when participating in sports and PA in secondary schools, according to PE teachers?
(2). How can the COM-B model, Behavior Change Wheel and TDF be used to identify facilitators of change in schools for inactive adolescents to achieve recommended levels of PA?
(3). Based on the APPEASE criteria, how can future intervention support be targeted to improve success in increasing PA levels among inactive groups in secondary schools?

2. Methods

2.1. Design and data collection methods

The study utilized a qualitative approach to examine the perceptions of PE teachers working with inactive adolescents in deprived secondary schools (aged 11–16). The study was conducted on behalf of the Department of Health and Social Care (DHSC) and the definition of 'inactivity' was based on the guidelines set by Sport England. According to Sport England's Active Lives Children and Young People survey, there are three categories of activity: 'active' (i.e., meeting the Chief Medical Officers' guidelines–an average of 60+ daily minutes), 'fairly active' (i.e., an average of 30–59 min per day) and 'inactive' (i.e., an average fewer than 30 min per day).

Five members of the research team conducted structured telephone interviews with 156 Heads of PE in schools and individual telephone interviews lasted on average around 30 min. At the beginning of each interview, a definition of 'inactive' was provided to ensure consistency across schools and to help PE teachers understand the focus of the study. The questions were developed based on the COM-B model of behavior change and piloted with five PE teachers. The following are the questions that were asked during the interviews:

(1). Have you as a school collected information to understand...

(a) What do people like or dislike about PE and school sports?
(b) Why do some adolescents not engage in PE lessons or school sports?

(2). What do adolescents like about PE or school sports?
(3). What do adolescents dislike about PE or school sports?
(4). Why do some adolescents not engage in PE lessons or school sports?
(5). What strategies do you have in place to support inactive adolescents?

(a) What is working well?
(b) What is not working well?

(6). What is the main change required to encourage 'inactive' adolescents to be more active?

2.2. Sample and recruitment

The researchers began by selecting an initial sample of 600 schools from an existing database of schools. To be included in the sample, schools had to have an overall proportion of students equal to or greater than 20% eligibility for free school meals. This criterion was used to identify the most deprived schools in England, where there was a higher likelihood of inactive adolescents. From the initial sample of 600 schools a random sub-sample of 250 schools was selected.

The research team then attempted to contact the PE teachers at each of the schools in the initial sub sample a maximum of five times to arrange interviews. Any schools that were unable to schedule an interview were excluded from the sample. Due to teaching commitments, contacting the Heads of PE was challenging, and many did not respond to the email invite. After approximately 2 weeks, the initial list of schools was exhausted and a further sample of 100 schools was randomly selected from the original database. This process was repeated until all 600 schools had been contacted. Throughout the study, ethical guidelines were strictly followed including providing information sheets, obtaining completed consent forms, and explaining participants rights to withdraw from the study. Anonymity was also assured. The Sheffield Hallam University's Ethics Committee granted approval for the study.

The sample included PE teachers who were 62% male and represented schools from all regions with a higher concentration in the North West and London. It is unclear whether this sample is representative of the gender distribution of PE teachers in England, since there is a lack of data on this matter. As these two regions made up half of the database, it was expected that a higher proportion of schools from these areas would be included in the study. The researchers used Sport England's Active People Survey to map the participating schools and identify the geographic clusters where the physically inactive are most prevalent (15). The results showed that the research sample was broadly representative of these clusters.

2.3. Data analysis (phase 1)—analysis of interviews

Throughout the interviews, the research team used an online survey tool to record the responses of PE teachers. After each interview, the research team checked the data for accuracy and then utilized Quirkos, a qualitative data management and analysis software. The qualitative data that was obtained from the telephone interviews was then deductively coded using thematic analysis (24) and analyzed through the lens of the TDF mapped onto the COM-B model and Behavior Change Wheel. The barriers to PA were then categorized into sub-themes of capability, motivation and/or opportunity. Additionally, preferences were organized into sub-themes and analyzed to understand potential facilitators for students to participate in PA. The aim of Phase 1 was to identify the barriers and to enable the research team to explore diversity in perspective and alternative explanations for the findings, before agreeing on the final list of barriers to be utilized for the next phase of analysis.

2.4. Data analysis (phase 2): COM-B, Behavior Change Wheel and TDF

During Phase 2, the researchers conducted a thorough examination of the barriers and categorized them according to their most relevant domain in the TDF that was mapped to the COM-B, utilizing a seven-step process (19). Afterwards the research team identified target behaviors using the COM-B, specifically focusing on steps 2–3. They then proceeded to specify what changes were necessary for each behavior in order to facilitate increased PA in the context of each domain, which was achieved in step 4. The research team then selected pre-defined intervention functions and policy categories using the COM-B, which were later screened for their relevancy. Finally, the research team used the 'theory and technique tool' to identify suitable behavior change tools relevant to each behavior. Step 8 should be undertaken by intervention designers to design an appropriate mode for the delivery of the intervention. The resulting comprehensive list of behaviors, intervention functions, policy categories and behavior change tools are presented in Table 1.

2.4.1. Stage 1—understand the behavior

(1). Define the problem in behavioral terms through analysis of the study data
(2). Select the target behavior.
(3). Specify the target behavior.
(4). Identify what needs to change.

2.4.2. Stage 2—identify intervention options

(5). Identify intervention functions.
(6). Identify policy categories.

2.4.3. Stage 3—identify content and implementation options

(7). Identify behavior change techniques using the 'theory and technique tool'.
(8). Identify the mode of delivery.

2.5. Rigor

The investigators ensured the reliability and validity of the analysis, by adopting a team-based approach to data analysis. This involved a group of researchers collaboratively reviewing the data using quality criteria such as credibility, dependability, confirmability, and transferability (24). By including multiple researchers, the team addressed potential individual biases and ensured a rigorous and nuanced understanding of the research topic. Through this approach, the team addressed credibility, dependability, and confirmability by identifying patterns in the data and creating themes that were interrogated and confirmed about the research aims and the COM-B model (25). Furthermore, to enhance transferability, the investigators conducted further analysis by combining the TDF mapped onto the COM-B model, which allowed the findings to be useful in several ways and applicable to other studies.

3. Findings and discussion

The study found that various factors impact inactive adolescents' habits and behaviors, which determine levels of engagement in PE lessons and participation in extra-curricular sports and PA. These habits and behaviors are reported according to adolescents' motivations, capabilities, and opportunities toward PA within schools.

3.1. Motivation

3.1.1. Sport and PA preferences

PE teachers reported considerable variation in their descriptions of students' sport and PA preferences within their schools. These preferences differed between schools, across genders and among various demographic groups including different ethnicities and cultural backgrounds. The significant variance in preferences underscores the importance of taking an individualized approach to identifying motivations and overcoming barriers to PA. To this end, some schools implemented 'student voice' activities to identify sporting preferences, which in some cases were targeted specifically at the inactive.

> *Depends on the fad at the time. Particularly interested in cricket due to their cultural background. If you name a sport from A to Z we have tried it at some point. Within this school, they do prefer more traditional sports (PE teacher – 1).*

PE teachers stated that inactive students tended to favor individual sports and/or fitness-based activities, particularly among girls, whereas those who were more active or 'sporty', tended to prefer traditional team sports. PE teachers reported that adolescents appreciated having a range of activities and the opportunity to choose activities in their PE lessons.

> *De-motivated, unsure of activities on offer, not enjoying team sports as much. Lethargic. Bad diet. Don't like team sports (PE teacher – 2).*

> *Depending on the student…students that enjoy PE and are naturally more sporty, like the national things. With the less sporty they like alternative activities / less traditional (PE teacher – 3).*

TABLE 1 COM-B and TDF.

Sources of behavior (COM-B)	Theoretical domains framework	Barrier/construct	What needs to happen for target behavior to occur	Intervention function(s)	Policy functions	Behavior change tool(s)
Physical capability (1) Physical skill, strength, or stamina.	**Physical skills** An ability or proficiency acquired through practice.	Physical ability/competency to participate in PA.	Support adolescents to develop physical competency (i.e., physical literacy) to perform in PE/school sports (particularly in team sports and for adolescents who are obese).	Training Enablement	Guidelines Service provision	Instruction on how to perform the behavior Behavior practice/rehearsal Graded tasks
Psychological capability (4) Knowledge or psychological skills, strength, or stamina to engage in the necessary mental processes.	**Behavioral regulation** Anything aimed at managing or changing objectively observed or measured actions	Body image effects adolescents experience of PA.	Support adolescents to overcome negative feelings due to perceived negative body image which is often amplified in PA setting.	Education Training Enablement	Service provision Communication/marketing	Problem-solving Self-monitoring of behavior Information about antecedents Behavior substitution Reduce negative emotions Conserving mental resources
	Memory, attention, and decision processes.	Previous negative experiences of PA.	Support adolescents and identify coping strategies to address previous negative experiences of sport and PA and consequent negative feelings and emotions.	Education Training	Service provision Communication/marketing	Problem-solving Self-monitoring of behavior Information about antecedents Behavior substitution Reduce negative emotions Conserving mental resources
	Knowledge An awareness of the existence of something.	Adolescents' knowledge of the benefits of PA.	Improve knowledge and promote the importance of PA for mental well-being to balance sedentary activity interests in gaming and social media (i.e., 'screen time').	Education Training Enablement	Communication/Marketing	Instruction on how to perform a behavior Information about health consequences Information about social and environmental consequences
		Parents are not aware of the benefits of PA.	Communicate the benefits of PA to parents/guardians and how they can positively support their child(ren).	Education Environmental restructuring Enablement	Guidelines Communication/marketing	Instruction on how to perform a behavior Information about health consequences Information about social and environmental consequences

(Continued)

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TABLE 1 (Continued)

Sources of behavior (COM-B)	Theoretical domains framework	Barrier/construct	What needs to happen for target behavior to occur	Intervention function(s)	Policy functions	Behavior change tool(s)
Social opportunity (4) The opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way that we think about things, e.g., the words and concepts that make up our language.	**Social influences** Those interpersonal processes can cause individuals to change their thoughts, feelings, or behaviors.	Adolescents feel alienated during PA sessions.	Challenge behaviors that alienate those who do not appear to fit perceived social norms in the PA setting (particularly adolescents who are obese) to create an inclusive environment.	Education Enablement Modeling Restrictions	Guidelines Communication marketing	Social reward Social comparison Information about others' approval Social support (practical)
		Adolescents being bullied.	Address instances of bullying that occur during PA.	Environmental restructuring Modeling Restrictions	Guidelines Communication marketing	Social comparison Social support (practical)
		Parents need support to help adolescents to be active.	Provide opportunities for parents to gain support to overcome economic and environmental barriers (i.e., safety concerns, financial constraints) to PA.	Environmental restructuring Enablement	Guidelines Communication/marketing	Social comparison Information about others' approval Social support (practical)
		Adolescents were worried about their appearance during sport/PA.	Support for adolescents to overcome perceptions of their appearance during PA (e.g., PE kit, excessive sweating).	Education Environmental restructuring Modeling	Guidelines Communication/marketing	Social comparison Information about others' approval Social support (practical)

(Continued)

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TABLE 1 (Continued)

Sources of behavior (COM-B)	Theoretical domains framework	Barrier/construct	What needs to happen for target behavior to occur	Intervention function(s)	Policy functions	Behavior change tool(s)
Physical opportunity (7) Opportunity afforded by the environment involving time, resources, locations, cues, and physical 'affordance.'	**Environmental context and resources** Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior	Lack of inclusive opportunities for adolescents.	Provide an inclusive mix of PA in school which promotes opportunities that caters to a variety of preferences.	Environmental restructuring Enablement Restrictions	Environment/social planning Guidelines	Social support (practical) Restructuring the physical environment Restructuring the social environment
		Adolescents' preferences not informing school sport provision.	'Student voice'–provide and encourage opportunities for adolescents to communicate their preferences around PA.	Environmental restructuring Enablement Restrictions	Environment/social planning Guidelines	Restructuring the physical environment Restructuring the social environment Adding objects to the environment
		Adolescents unable to access facilities outside of school time.	Provide access to school facilities outside of school time.	Environmental restructuring Enablement Restrictions	Environment/social planning Guidelines	Social support (practical) Restructuring the physical environment Restructuring the social environment Adding objects to the environment
		Adolescents are not able to access individual or health promoting activities.	Provide access to opportunities for adolescents to engage in individual activities / health-promoting activities (particularly for girls) while still promoting the benefits of team sports.	Environmental restructuring Enablement	Environment/social planning Guidelines	Social support (practical) Restructuring the physical environment Restructuring the social environment
		Adolescents not able to access PA during busy (i.e., academic) and stressful periods in school.	Provide/maintain access to PA opportunities during busy/ potentially stressful periods (e.g., during exams).	Environmental restructuring Enablement Restrictions	Environment/social planning Guidelines	Social support (practical) Restructuring the social environment
		Adolescents not finding a suitable capability level to participate in PA, particularly in team sports.	Provide opportunities that allow adolescents to participate with others of a similar level of capability (particularly in team sports).	Environmental restructuring Enablement	Environment/social planning Guidelines	Social support (practical) Restructuring the physical environment Restructuring the social environment Avoidance/reducing exposure to cues for the behavior Adding objects to the environment
		Adolescents do not find certain activities to be fun.	Provide opportunities that focus more on fun than competition.	Environmental restructuring Enablement	Environment/social planning Guidelines	Social support (practical) Restructuring the physical environment Restructuring the social environment Avoidance/reducing exposure to cues for the behavior Adding objects to the environment

(Continued)

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TABLE 1 (Continued)

Sources of behavior (COM-B)	Theoretical domains framework	Barrier/construct	What needs to happen for target behavior to occur	Intervention function(s)	Policy functions	Behavior change tool(s)
Reflective motivation (5) Reflective processes involve plans (self-conscious intentions) and evaluations (beliefs about what is good and bad).	**Beliefs about capabilities** Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use.	Adolescents have a lack of confidence in their abilities.	Support adolescents to develop perceived confidence performing sport/PA (particularly in group/team sport environment).	Education Incentivization Persuasion Coercion	Service provision Communication/marketing Environmental/social planning Guidelines	Verbal persuasion about capability Focus on past success Self-talk Graded tasks Behavioral practice/rehearsal Demonstration of the behavior Instruction on how to perform the behavior Problem-solving
		Adolescents believe they are not capable of being physically active.	Support adolescents to identify as being someone capable of being physically active.	Education Incentivization Persuasion Coercion	Service provision Communication/marketing Environmental/social planning Guidelines	Verbal persuasion about capability Focus on past success Self-talk Graded tasks Behavioral practice/rehearsal Demonstration of the behavior Instruction on how to perform the behavior Problem-solving
	Beliefs about consequences	Adolescents have a fear of failure in PA.	Support adolescents to overcome the fear of failure and reduce unwanted feelings.	Education ncentivization Persuasion Coercion	Service provision Communication/marketing Environmental/social planning Guidelines	Information about health consequences Salience of consequences Information about social and environmental consequences Anticipated regret Information about emotional consequences Pros and cons Comparative imagining of future outcomes Material incentive (behavior) Incentive (outcome) Reward (outcome)
		Adolescents feel inferior during competitive sports.	Support adolescents to overcome feelings of inferiority during competition.	Education Incentivization Persuasion Coercion	Service provision Communication/marketing Environmental/social planning Guidelines	
	Intentions A conscious decision to perform a behavior or resolve to act in a certain way.	Adolescents not committing to do 60 min of PA per day.	Encourage daily intentions to do at least moderate PA for 60 min in and out of school.	Education Incentivization Persuasion Coercion	Service provision Communication/marketing Guidelines	Goal setting (behavior) Information about health consequences Incentive (outcome)

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PE teachers described that inactive students tended not to enjoy PA, with variations reported between schools and among different demographic and ethnic groups. According to PE teachers many adolescents disliked large team games or whole-year group activities, including cross-country and were generally not fond of traditional team sports.

> *[They] dislike team traditional sports. Many rather play individual sports, but schools don't have the opportunity to provide these as the curriculum doesn't offer enough time so have to focus on team sports which are on the curriculum (PE teacher – 4).*

> *[The] less active don't like football and the pressure of being involved in team sports as much i.e., picked on for not playing a part in a team game. Girls don't like being in the spotlight once they're a little bit older, they're self-conscious (PE teacher – 5).*

3.1.2. Disengagement

PE teachers' had varying perceptions when describing the characteristics of inactive adolescents. Generally, inactive adolescents were seen as more likely to be female, overweight, or obese and image (i.e., body and appearance) conscious. Over 40% of teachers described inactive adolescents as being disengaged, not motivated or reluctant to participate in sports or PA. For Key Stage 4 students, academic pressures left little time for PA as coursework and exam revision were prioritized. Some PE teachers described pupils' disinterest in PE and PA as being due to them prioritizing time to use digital technology. Generally, boys were more interested in computer games, and/or watching TV, while girls were more interested in social media or communicating with friends either in person or online.

> *Students that prefer computers and social media are quieter individuals and less co-ordinated, so they are challenged when they do something physical (PE teacher – 6).*

> *[The] influence of technology has made a difference to adolescents. 'Why play sport when we can play a game on a computer?'*

PE teachers expressed concern that inactive adolescents often disengage from sports due to negative experiences they experienced in primary school. This may have caused feelings of fear or anxiety, while some students may have been unable to self-regulate during sessions. Teachers described that habits are formed early in life, and that experiences with PE in primary school play a significant role in later participation in secondary school. As the primary school curriculum is heavily focused on team sports, negative experiences with these activities may have contributed to disengagement in secondary school. Such experiences could have had an impact on their physical or psychological capability, affecting their motivation to participate in sports or PA.

> *I asked one child the other day why he didn't like PE. He had a bad experience with PE at primary school which he is still carrying with him (PE teacher – 7).*

3.2. Capability

PE teachers often described that inactive students had lower physical capability, and that this difference in ability was often magnified in a team sport setting. Some PE teachers also reported that some students disliked participating in PE in mixed-ability groups or mixed-gender groups, as they did not want to be seen participating in front of people who were more capable or of the opposite sex. Consequently, their physical capability influenced their motivation to participate in these types of sessions. Conversely, some teachers reported that more capable adolescents became frustrated when grouped with less able or less motivated students, leading to ill feelings among peers. Some students also disliked having to participate with peers from outside of their friendship groups.

PE teachers reported that some schools have made changes in provision to cater to the needs of inactive students. As a result, there has been a shift toward fitness-based activities including circuit training, Zumba, yoga, and aerobics. Many PE teachers highlighted that these activities had proven successful in engaging inactive students in their school as they require a lower skill level and can be performed individually reducing self-consciousness. Furthermore, alternative activities have been used to help the inactive habituate to PA and improve physical capability.

> *Some adolescents prefer team sports as a general rule, and non-mainstream sports become favourite activities i.e., trampolining, learning and improving/progressing quickly whereas they feel miles behind in other sports i.e., football. Non-mainstream sports, are often on a level playing field and that's where their progress and enjoyment come (PE teacher – 8).*

PE teachers reported that many students had lower psychological capability, partly due to their lower physical capability reducing confidence in their abilities to participate effectively. This was more prominent in those students that were either obese or overweight as they might be reluctant to take part due to a fear that they would not be able to perform effectively. This lack of confidence was observed across a range of activities but was more noticeable in team sports because of the competitive nature of such activities, which often required group participation. In team sports, students ability levels could be compared to those of their peers which could further expose their lack of confidence to the whole group.

According to PE teachers some students may find certain PA difficult due to their weight, and not having enough energy, or sufficient mobility. The issue of body image was also a concern raised by PE teachers, which was not exclusive to overweight and obese adolescents. As one PE teacher described, comparing themselves to other more 'sporty' or physically capable students could exacerbate feelings of inadequacy among overweight or obese students.

> *Mental barriers and fear of taking part and fear of failure are related to the lack of belief that they can do well and fear of what class they may be in. That's why targeted interventions work best because students may not feel inadequate. Sometimes you want to be able to straight talk to kids – we are not aware of how we engage and have a conversation with obese people and how do we work with parents? (PE teacher – 9).*

There were reported incidences of bullying of overweight and obese students, and it was suggested that this might be exacerbated in PE activities if students could not perform effectively or were seen as a liability.

> *Peer pressure and bullying is a problem. Can feel isolated if they have a bad experience in a team because they are maybe not as good at certain activities. Problems with body image, different changing rooms help (PE teacher – 10).*

> *Less pressure on them when doing an individual activity rather than team sports which often creates added pressure (PE teacher – 11).*

Motivations and particular insecurities held by adolescents were reported around both the preparation and action of performing PA. These include concerns about becoming sweaty and the physical effects of exercise, wearing the required PE kit, performing, and being judged by others. As adolescents got older they were described as becoming less interested in sport and PA due to an increase in social pressures and concerns around body image. Social media and peer pressure were mentioned as factors that may influence adolescents and consequently make them more concerned with appearance and image.

Adolescents may face physical and psychological challenges that may limit their ability to perform an activity and affect their confidence, enjoyment, and motivation to continue participating. It was universally accepted by PE teachers, that inactive students need support to develop psychological and physical capability but there are constraints on resources, time and capacity to provide the necessary support.

3.3. Opportunity

3.3.1. Curricular and extra-curricular opportunities

PE teachers are eager to expand the range of curricular and extra-curricular opportunities available to students, in order to expose them to a diverse selection of sport and PA. While team sports like dodgeball may be included, they are more likely to include individual, adventure sports and fitness-based activities. PE Teachers have expressed concerns about the current content of both curriculum PE and extra-curricular activity. Some suggested that a lack of choice and/or a focus on team sports in some schools restricts the choices of students that were less engaged and less interested in competitive sports.

> *It's the same core of students that engage with everything. We want to inspire others to get involved. We have tried climbing and trampolining away from traditional / team sports (PE Teacher – 12).*

> *Finding activities that they enjoy doing, a lot of them don't like the traditional team sports of football etc, so it's breaking down some of the barriers that they can enjoy PE because there are lots of different activities that they can do, that's our main focus at the moment (PE teacher – 13).*

Students should also be able to participate with peers of similar ability. However, this is often a challenge for PE teachers, due to limited staff time, which can make it challenging to organize a variety of extra-curricular activities for all students, let alone provide enhanced support to inactive students.

> *Having time to do this as we are quite a small team. Most staff do 4 or 5 times a week after school and we have lots of other whole-school work to do. Difficulty planning sometimes and doing activities outside of school (PE teacher – 14).*

> *Our PE Staff have core teaching responsibility, clubs and coaching sessions, plus other duties within the school that teachers have to do. We have little time to do the smaller more focused activities needed to engage students, giving students individual attention and one-to-one time is difficult (PE – Teacher – 15).*

Parental engagement and support were regarded as a key factor influencing adolescents' participation in PA. According to PE Teachers parents from lower socio-economic groups were also more likely to have low PA levels themselves, and may not fully understand the potential benefits of PA for their children. This lack of understanding can lead to a lack of support or encouragement for their adolescents to engage in PA. Furthermore, the social opportunities presented by parents can influence the motivations of inactive adolescents, which can be affected by negative experiences of PE or sports in the past. Consequently, this may lead to inactive adolescents having less opportunity and interest to participate in PA, outside of school time. Adolescents who have supportive, engaged parents who are willing to both transport and support their child before, during and after sessions are more likely to participate in PA and benefit. Some PE teachers highlighted that however proactive the school was in trying to engage adolescents, if their parents were not supportive of their child, then there was very little that the school could do to support them.

> *Some students come from disadvantaged homes with low income so we provide kits so that isn't a problem. Most students do not engage purely because they don't like it and their parents do not see it as valuable and do not support them (PE Teacher – 16).*

> *When you meet parents, [it is] all 'I hated PE at school'. Their attitude is already affecting their child regarding fitness and health, the inactive and overweight ones all start at home (PE Teacher – 17).*

The social inequalities which exist in deprived areas are also a barrier to participation in PA. PE teachers reported a range of challenges for adolescents to access sports outside of school due to anti-social behavior, cost and poor transport links which represent wider system failures.

> *The area is quite mixed, not a place where parents will want kids out late. There are football clubs/training sessions that run a bit later, but access to them isn't there – too far away and time an issue…but support is needed for the school students to get them to and from (PE Teacher – 18).*

Teachers reported that a key factor that limits engagement and participation in PA is a lack of opportunities available for adolescents to be active within their local communities. PE teachers commented that in the areas around their schools, there is a lack of facilities such as parks and green spaces, sports centers, and gyms, and a lack of specific sessions or activities aimed at adolescents. They noted a need for more sessions targeted at adolescents, including less competitive options and more non-traditional activities to appeal to the inactive.

> *There isn't anything for adolescents in the area. There is no sports centre, no facilities. There is nothing for them, which is why they either go home and watch TV and play on the computer, or turn to antisocial behaviour, out of boredom. The facilities and the culture of the community need to change (PE Teacher – 19).*

Deprived areas may experience additional constraints when it comes to promoting PA including more pronounced financial constraints, difficulties with transport and safety concerns. Furthermore, the local environment and context often reinforces unhealthy behaviors, such as the prevalence of low cost, nutritionally deficient fast food options that limit access to healthier options.

Some PE teachers were adamant that any external investment for opportunities to participate in sports or PA outside of school should be focused on widening participation in the community.

> *Targeted funding to community organisations – needs to be spent on minority sports or groups that don't engage in traditional mainstream sports, so a shift to some non-traditional sports i.e., judo, dodgeball, rock climbing etc (PE Teacher – 20).*

3.3.2. Pupil preferences

Efforts to combat obesity and promote healthy lifestyles has led to a shift in the type of activities being delivered in these schools. As previously stated, PE teachers have described a growing interest among inactive students, particularly girls in fitness-based PA. Increasingly, gym and fitness sessions were also being described as becoming increasingly popular due to their non-competitive nature, and focus on improving body shape, fitness, and health. PE teachers have observed students making progress in their physical health and fitness through these activities and have highlighted their potential for promoting lifelong physical activity beyond school years. T This trend also promotes individual activities which adolescents can do in their own space in their own time.

> *With them being girls, we have to use fitness, gym, and introduce things that we know girls like to do. We recently got a disco ball that we are using with circuit training - turn down the lights, put the disco ball on, and turn up the music. This is the type of stuff we have to do to engage them. And it works! Most of this is for KS4 as they are leaving school soon and we need to get them engaged in these types of fitness so that they have been introduced to this and might join a gym or go to a fitness class as an adult (PE Teacher – 21).*

> *They want to be left alone doing something they are confident in which points to individual sports rather than team sports (PE Teacher – 22).*

A shift has also occurred in schools to promote activities that are deemed to be more fun rather than competitive. PE teachers reported that some inactive students did not like the competitive element of team sports, and as a result, some schools described an increased emphasis on the fun elements of PE, rather than on competition.

> *The lunch clubs work well with the younger age groups, they can come and play and choose what they want to do each day. Relaxed environment focused on fun rather than competition (PE Teacher – 23).*

> *Going with what the students want rather than what we can provide - non-competitive, don't play against other schools, work together as a group, building their confidence…offer what they want and link that in with the curriculum (PE Teacher -24).*

There is no suggestion that competitive sport is not fun, but many factors including how team sports are delivered, and the preferences and personalities of the inactive, may influence how these adolescents perceive or experience such activities. These assumptions could be further fuelled by the perception that team sports are not suitable forms of activity for the inactive.

3.4. Capability, opportunity, motivation, and behavior and TDF analysis

PE teachers identified a total of 21 barriers to adolescents meeting government guidelines for PA. These barriers were classified into categories based on the COM-B model into physical opportunity (7), reflective motivation (5), social opportunity (4), psychological capability (4) and physical capability (1). Table 1 presents these barriers and corresponding facilitators for change with suggested intervention functions, policy functions and behavior change tools that could be incorporated into future behavior change interventions.

Table 2 shows the aggregate total of intervention functions and policy categories defined by the COM-B and Behavior Change Wheel that are required to provide a broad understanding of where behavior change interventions could be targeted in schools. The most recorded intervention functions were 'enablement' (14) and 'environmental restructuring' (12). For policy categories, the most recorded were 'guidelines' (14) and 'communication/marketing' (13).

4. Discussion

This study was conducted following previous studies (5, 16–18) that have identified barriers to PA and contributed to existing knowledge (4, 16) of challenges to promoting PA and enhancing the quality of PE among inactive adolescents in the United Kingdom. A

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TABLE 2 Total number of intervention and policy categories.

Intervention functions	No.	Description	Policy categories	No.	Description
Coercion	5	Creating an expectation of punishment or cost.	Communication/marketing	13	Using print, electronic, telephonic, or broadcast media.
Education	8	Increasing knowledge and understanding.	Environmental/social planning	7	Designing and/or controlling the physical or social environment.
Enablement	14	Increasing means/ reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring).	Guidelines	14	Creating documents that recommend or mandate practice. This includes all changes to service provision.
Environmental restructuring	12	Modifying the physical environment around someone to influence their behavior.	Service provision	7	Delivering a service.
Incentivization	5	Creating an expectation of reward.			
Modeling	3	Providing an example for people to aspire to or imitate.			
Persuasion	4	Using communication to induce positive or negative feelings to stimulate action.			
Training	4	Imparting skills.			
Restrictions	6	Using rules to reduce the opportunity to engage in the target behavior (or to increase the target behavior by reducing the opportunity to engage in competing behaviors).			

comprehensive perception of PE teachers was provided for 21 barriers to PA among inactive adolescents. It applied a novel approach that utilizes the COM-B model, BCW (22), and TDF (23) to present policy categories, intervention functions and behavior change tools to support future PA intervention design. This provides a structured, systematic, and replicable approach for developing an intervention strategy grounded in theory (23). By using this approach, researchers and practitioners can identify target behaviors for inactive individuals, specify what needs to change, and select the appropriate intervention functions and behavior change tools to facilitate behavior change.

The findings from the study report barriers exist across all categories of the COM-B model in physical opportunity (7), reflective motivation (5), social opportunity (4), psychological capability (4) and physical capability (1). The majority of these barriers (90%) were reported in previous studies as being barriers to PA from the perspective of children and adolescents (17, 19). This shows that the findings are consistent with the views of children and adolescents that participated in these studies. However, the study also reveals omissions and nuances in the barriers revealed from the perspective of PE teachers. For example, PE teachers highlighted 'bullying' which is not PA specific but is as an additional barrier that can influence PA behavior. Also, PE teachers noted that inactive adolescents may be more affected by a lack of awareness regarding the benefits of physical activity. This study highlights the barriers that are more significant for inactive adolescents and provides additional context regarding the experiences of the inactive. This offers valuable insights for designing targeted interventions that are tailored to their specific needs. It is important to note that the research team does not recommend a homogenous approach to intervention design, even though inactive adolescents may be more impacted by previous negative experiences of PA, influenced by social media or peers, and inclined toward individual or fitness-based activities. Rather, the findings should serve as a basis for developing multi-component interventions which meet the unique needs of inactive adolescents.

Overall, the study presents evidence of the extensive change required to support inactive adolescents to achieve 60 min of at least moderate intensity PA across the week (10). It details the range of individual and systemic changes necessary for effecting behavior change and identified intervention functions that should inform future public health intervention design. For each barrier, a list of

behavior change tools are reported that were informed by the theory and techniques tool presenting evidence-based solutions to each barrier. Intervention designers can use the findings in this study as an extensive reference point to inform the design and evaluation of multi-component interventions, as recommended by a previous study (4) and WHO (9), to improve the success of future school-based PA interventions. Furthermore, the study's findings could also inform policy which may lead to systemic changes (8) necessary for overcoming the barriers highlighted in this and other studies and contributing to the aims of the WHO Global Action Plan (9) aimed at enhancing support for adolescents.

It is important to prioritize certain intervention functions that have a broad impact on the barriers identified in the study, in order to support behavior change. For example, there is a need for enablement, to enhance the capabilities of students and for environmental restructuring to shift the physical environment in schools to influence pupil behavior. Physical capability was identified as a factor influencing motivation and participation, with some students being reluctant to participle in mixed-ability and mixed-sex groups. Nevertheless, it is essential for the school environment to facilitate development of physical capability, since various social influences (such as bullying and alienation) can exacerbate the challenges that adolescents face in this regard. For instance, negative experiences of sports in primary schools may have contributed to the disengagement of some students in secondary school, with some students developing feelings of fear or anxiety during sessions. Targeted work with inactive adolescents through service providers may help overcome some of the physical and psychological barriers that are more pronounced among this group. Additionally, it is necessary to adjust the physical and social environment in schools to establish guidelines to support positive habits and effectively reach the intended audience. Improved communication and marketing are therefore required to reinforce key messages and promote PA opportunities for adolescents that have a lack of knowledge of the benefits of PA. By adopting such approaches inactive adolescents can gain the same benefits as their more active peers, including improved health outcomes and academic achievement which could enhance their future life chances (1–3).

When exploring the implementation of behavior change techniques it is important to consider the APEASE criteria (22). Usually, this criteria is applied to a specific intervention, but can also be useful in considering the barriers to implementation. When evaluating the practicality and affordability of policy interventions for promoting physical activity, it is important to consider the barriers identified in the literature, such as limited resources, time constraints, and funding limitations (17). In the current environment, particularly in the UK, there is uncertainty as to whether all policy functions can be fully realized. Furthermore, acceptability and effectiveness can pose additional challenges in school settings, where adolescents may resist behavior change, and teachers and school leaders may have competing priorities that make focusing on physical activity a lower priority. Such challenges may contribute to a lack of progress in supporting adolescents and the poor implementation of PA interventions, as previously reported (4). To address these issues, digital exercise interventions have emerged in the past decade as a tool to improve the diet and PA behaviors of adolescents (26). More recently, conversational Artificial Intelligence (AI) driven solutions including conversational agents have emerged, offering personalized support through rule-based or natural language interactions tailored to the needs and requirements of users (27). The use of digital approaches in schools to promote PA was suggested in some studies (4).

To advance future digital exercise interventions, conversational AI may hold promise. By providing personalized and natural language-based interactions, it could offer scalable, multi-component, and individualized support to help overcome the various barriers identified in this study. If properly tested, monitored, and evaluated for effectiveness, conversational AI could offer a low-cost and resource-efficient means to support students. While there have been some studies (26, 27) on digital exercise interventions for adolescents, none have explored how conversational AI can be used to overcome barriers to PA and therefore further research is required to determine how much digital solutions could prove beneficial and how effective evidence-based content can be delivered to young people. Further, these solutions should be co-designed with young people to develop suitable person-centered approaches that provide engaging content for young people that is evidence-based, accessible and ethical.

A limitation of this study is that it is based on the subjective opinions of PE teachers of inactive adolescents during a single interview, which is not informed by demographic characteristics (apart from age), their background, or the context where they work. However, it was important to provide teachers with anonymity, so they were free to share their thoughts and feelings about their pupils openly. Moreover, as schools do not track participation, their perceptions of the activity levels of adolescents may not be entirely accurate. However, they are better placed than most to both identify and provide context on the barriers that exist.

5. Conclusion

The study provides a comprehensive understanding of the barriers to PA in secondary schools. Specifically it explores the habits and behaviors of inactive adolescents, from the unique perspective of PE teachers. The study identified 21 barriers to PA, with the majority consistent with previous studies. However, previous studies have not definitively determined which barriers are most pertinent to either inactive or active students, thus impeding the prioritization of effective interventions. This study highlights the barriers that are particularly salient for inactive adolescents, and it identifies previously unreported barriers that offer greater insight into their experiences in secondary schools.

It is recommended to use the findings of this study to design future PA interventions for inactive adolescents. The study utilized the COM-B model, Behavior Change Wheel and TDF to identify facilitators of change in schools, for inactive adolescents to achieve recommended levels of PA. The study provides a comprehensive approach to developing intervention strategies grounded in theory, offering evidence-based solutions to each barrier. This findings of this study provide extensive reference points for future intervention design, which could inform policy and contribute to the objective of enhancing support for inactive adolescents. The research team recommend multi-component interventions that are personalized to the needs of inactive individuals to support the changes necessary to overcome barriers to PA and achieve recommended PA levels. They also recommend the further development of digital exercise interventions, particularly

conversational AI which may afford a more personalized, natural language experience to engage adolescents at scale and overcome the various individual barriers to PA revealed in this and other studies.

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 Sheffield Hallam University Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RM collected and analyzed data and wrote the final manuscript. LE collected data and wrote the final manuscript. MG collected and analyzed data. KG collected and analyzed data. EF analyzed data and wrote the final manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Comparative effectiveness of school-based exercise interventions on physical fitness in children and adolescents: a systematic review and network meta-analysis

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Background: Schools provide a favorable setting for health education, however, the most effective school-based exercise mode for improving physical fitness remains unclear. This network meta-analysis was designed to assess and rank the comparative efficacy of six exercise modalities on physical fitness indicators in a school-based setting.

Methods: An online search of the Web of Science, PubMed, SPORTDiscus, and Scopus databases was conducted. Randomized and quasi-randomized controlled trials were considered. Outcomes included measures of anthropometry and body composition, muscular fitness, and cardiorespiratory fitness. Data were pooled with a random effects model using the frequentist framework.

Results: A total of 66 studies with 8,578 participants (48% girls) were included. High-intensity interval training was the most effective intervention reducing body mass index (mean difference (MD) = −0.60 kg·m^{-2}, 95% confidence interval (95%CI) = −1.04 to −0.15, p = 0.009), elevating VO_{2max} (MD = 3.59 mL·kg^{-1}·min^{-1}, 95% CI = 2.45 to 4.74, p < 0.001), and 20-meter sprint performance (MD = −0.35 s, 95% CI = −0.55 to −0.14, p = 0.001). Aerobic training had the highest probability of reducing waist circumference (standardized mean difference (SMD) = −0.60, 95% CI = −0.88 to −0.32, p < 0.001). Active video games emerged as a promising modality for improving countermovement jump (MD = 2.43 cm, 95% CI = 0.06 to 4.80, p = 0.041) and shuttle running performance (SMD = 0.86, 95% CI = 0.29 to 1.43, p = 0.003). Strength training was the best exercise mode for improving standing long jump performance (SMD = 1.03, 95% CI = 0.07 to 1.98, p = 0.035) while combined training was rated the first for decreasing body fat percent (MD = −2.56%, 95% CI = −4.73 to −0.40, p = 0.022) and increasing push-up repetitions (SMD = 3.59, 95% CI = 0.81 to 6.37, p = 0.012).

Conclusion: School-based exercise interventions have multiple effects on physical fitness. The findings of this study will help to inform physical education teachers and coaches how best to deliver exercise programs in a school setting. Since the study was limited by the original research, the conclusions will require further verification using high-quality randomized controlled trials.

Systematic Review Registration: PROSPERO, Identifier: CRD42023401963.

KEYWORDS
adolescents, school-based exercise, physical fitness, children, network meta-analysis

Introduction

Physical fitness (PF) is a valuable health marker. Maintaining satisfactory PF status in children and adolescents reduces the risk of obesity (1), cardiovascular disease (2), and diabetes (3) in adulthood. Indeed, approximately 80% of children and adolescents suffer from these health conditions because they are engaged in an insufficient level of physical activity (PA) (4–6). As a result, exercise intervention and PF promotion among children and adolescents have become a major focus of public health research. Schools are favorable setting for PF promotion (7) because they offer this age group a high amount active time during the school day (8). The school environment provides an equitable sociocultural environment for exercise behavior using various PF promotion programs (9). Studies have reported the impact of particular school-based interventions on health-related PF (10, 11). A recent systematic review found that school-based neuromuscular training is effective at increasing strength (12). Two systematic reviews with meta-analyses involving 11 and 35 randomized controlled trials (RCTs) found that high-intensity interval training (HIIT) in school contributes to greater improvement in muscular and aerobic fitness (13, 14). However, these pairwise meta-analyses only compared one type of exercise to regular physical education (PE) lessons. While one meta-analysis attempted to evaluate the impact of school-based PF promotion programs on obesity prevention (15), it still failed to assess the superiority of the diverse exercise types. Overall, the evidence needed to measure the comparative effectiveness of multiple school-based exercise treatments on PF remains limited.

Recently, gamified exercises with higher attractiveness have been embedded in school-based PA programs to enhance students' enjoyment (16). One meta-analysis reported favorable results for active video games (AVGs) on body mass index (BMI) reduction in children and adolescents (17). Likewise, game-based exercise (GB) including small-side ball games in recreational sports and aerobic exercise performed with game patterns, attracts researchers' attention. A previous review found that small-side football ball games had a similar effect as interval running on PF (18). However, whether these novel exercise programs are superior to other modalities remains unclear. Thus, AVGs and GB conducted in school were included in the comparison.

No systematic review has integrated and assessed the effects of various exercise treatments on anthropometry and body composition, muscular fitness (MF), and cardiorespiratory fitness (CRF) outcomes, concentrating exclusively among children and adolescents in school-based settings. This review used network meta-analysis (NMA), a newly recommended analysis tool in the field of PA and health promotion (19), to (1) evaluate the comparative efficacy of six exercise treatments performed in the school environment on anthropometry and body composition, MF and CRF and (2) construct an effectiveness hierarchy. Unlike pairwise meta-analysis, NMA is able to comparative multiple interventions as an intermediary for indirect comparisons even in the absence of direct comparative evidence. NMA also ranks probable success of each intervention.

Methods

The study follows the relevant PRISMA checklist (20). The study protocol was registered prospectively in PROSPERO (registration code: CRD42023401963).

Search strategy

A comprehensive computerized search of the Web of Science, PubMed, SPORTDiscus, and Scopus database was performed from inception until February 2023. The retrieval strategy was conducted using the PICOS tool: (P) Population: children and adolescents; (I) Intervention: active video games (AVGs), game-based exercise (GB), high-intensity interval training (HIIT), aerobic training (AT), strength training (ST), and combined aerobic and strength training (CT; Table 1); (C) Comparator: regular physical activity or physical education; (O) Outcomes: anthropometry and body composition, muscular fitness (MF), and cardiorespiratory fitness (CRF); (S) Study type: randomized controlled trials (RCTs) or quasi-RCTs. The detailed search algorithms are shown in Supplementary Table S1. Reference lists of the included studies and previous reviews were scanned for articles that met the eligibility criteria.

Eligibility criteria

The inclusion criteria for this systematic review and NMA were as follows: (1) peer-reviewed original research with full text in English over the past 20 years (January 2003 to February 2023); (2) study participants were children and adolescents aged 4–18 years of age enrolled in full-time or part-time education; (3) at least one exercise type, including AVGs, GB, HIIT, AT, ST, or CT, was employed in a school setting (intra-PE, or extra-PE during school hours); (4) anthropometry and body composition [body mass index (BMI), body fat percent (BF%), and waist circumference (WC)], MF [standing long jump (SLJ), countermovement jump (CMJ), push-ups, and 20-meter sprint (20-m sprint)], and/or CRF (shuttle running (SR), and VO_{2max}) were used as outcomes; and (5) the intervention lasted at least 4 weeks. Both RCTs and quasi-RCTs were included given the difficulty of implementing RCTs in school settings. The inclusion of only RCTs may have led to the omission of relevant information. Participants with injuries or chronic or acute diseases, participants who were youth athletes, reviews and meta-analyses, studies lacking the required outcomes, or studies that were unable to identify implementation setting were excluded.

TABLE 1 Description of the exercise modes.

Exercise types	Description
AVGs	Frequency: 1–3 times/week, 20–30 min/session
	Intensity: light-to-moderate intensity
	Duration: ≥4 weeks
	Type: various commercial exergames (e.g., Xbox Kinect, Wii sports, Rhythmic Dance Games, and PlayStation)
GB	Frequency: 1–3 times/week, 15–25 min/session
	Intensity: moderate-to-vigorous intensity
	Duration: ≥4 weeks
	Type: small-side ball games in recreational sports and moderate intensive aerobic exercise performed with a game pattern
HIIT	Frequency: 2–3 times/week, 10–15 min/session
	Intensity: >75% VO_{2max} or > 80% HRmax
	Duration: ≥4 weeks
	Type: any type of interval training
ST	Frequency:2–3 times/week, 20–30 min/session
	Intensity: ≥50% 1RM
	Duration: ≥4 weeks
	Type: any form of strength training (e.g., bodyweight, free weights, and functional strength training)
AT	Frequency: 2–3 times/week, 20–30 min/session
	Intensity: >45% VO_{2max} or > 65% HRmax
	Duration: ≥4 weeks
	Type: any continuous aerobic training (e.g., running, walking, and cycling)
CT	A combination of CET and RT and concurrent training
CON	Regular physical activity or physical education course

Study selection and data extraction

Two independent authors (JW and YY) screened the literature based on the inclusion and exclusion criteria and read the full text to assess their eligibility. Any disagreements were handled by adjudications from other team members. The following data were extracted from eligible articles and recorded in EXCEL: (1) first author and publication year; (2) participant demographics (e.g., sample size, sex, and mean age); (3) intervention characteristics (exercise type, duration frequency, time in school); and (4) outcomes. EndNote X9 was used to consolidate and remove duplicates. If the same trial was published more than once, the most recent or more complete study was selected.

Risk of bias assessment

Two authors (JW and YY) independently assessed the risk of bias (ROB) using the following seven dimensions from the Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 tool (21): (1) randomized sequence generation; (2) treatment allocation concealment; (3) blinding of participants; (4) blinding of personnel; (5) incomplete outcome data; (6) selective reporting; and (7) other sources of bias. Eligible studies were divided into high risk (≥4), medium risk (3), and low risk (≤2) of bias based on the frequency of high-risk items. By default, all studies were classified as high ROB in the "blinding of participants" dimension since it is difficult to achieve participant blinding during exercise intervention protocols in school settings. Thus, this domain was not counted toward the overall score.

Data synthesis and statistical analysis

All outcomes involved in this study were continuous variables, so the mean and standard deviations (SDs) were extracted from the included studies. Mean differences (MDs) were obtained by directly extracting or subtracting the mean at the post-training vs. pre-training. The unreported standard deviation difference was imputed according to the formula provided in the Cochrane Handbook (Supplementary Figure S37) (22). Standardized mean differences (SMDs) were applied when different evaluation methods or scales were used to measure the same indicator. When multiple posttests (e.g., multiple follow-ups) occurred, data measured immediately after the intervention were extracted. If multiple variations of the same interventions or different population subgroups were compared in an included study, the respective outcomes were pooled using the formula provided in Supplementary Figure S37 (22).

Statistical analyses were conducted using STATA 16.0 software. Heterogeneity was assessed using I^2 statistic. Values of $I^2 \leq 25$, $25\% < I^2 \leq 50$, $50\% < I^2 \leq 75\%$, and $I^2 > 75\%$ represented no significant heterogeneity, low heterogeneity, medium heterogeneity, and high heterogeneity, respectively. A random-effects frequentist framework-based NMA was used to calculate pooled estimates and 95% confidence intervals (CI) (23). Network plots were created to visually demonstrate the geometry of various treatments. Each node corresponded to a certain treatment, and the node size represented the sample size. The lines linking the nodes indicated the direct head-to-head comparisons between interventions, and the line thickness between nodes represented the number of included studies. The Wald test and node splitting methods were used to evaluate global and local inconsistencies, respectively. The surface under the cumulative ranking curve (SUCRA) shows the ranking probability of each intervention. The larger the SUCRA value, which ranges from 0 to 100%, the more significant the intervention effect. Network funnel plots were generated to identify whether publication bias was caused by any small sample studies. To examine robustness, sensitivity analyses were performed by eliminating individual studies separately to evaluate the impact of each study on the overall heterogeneity.

Results

Literature search and selection

A total of 2,296 studies were obtained by a preliminary search of the databases, and an additional 25 studies were obtained from existing systematic reviews. After removing duplicate studies and screening titles and abstracts, 241 studies were carefully read, of which

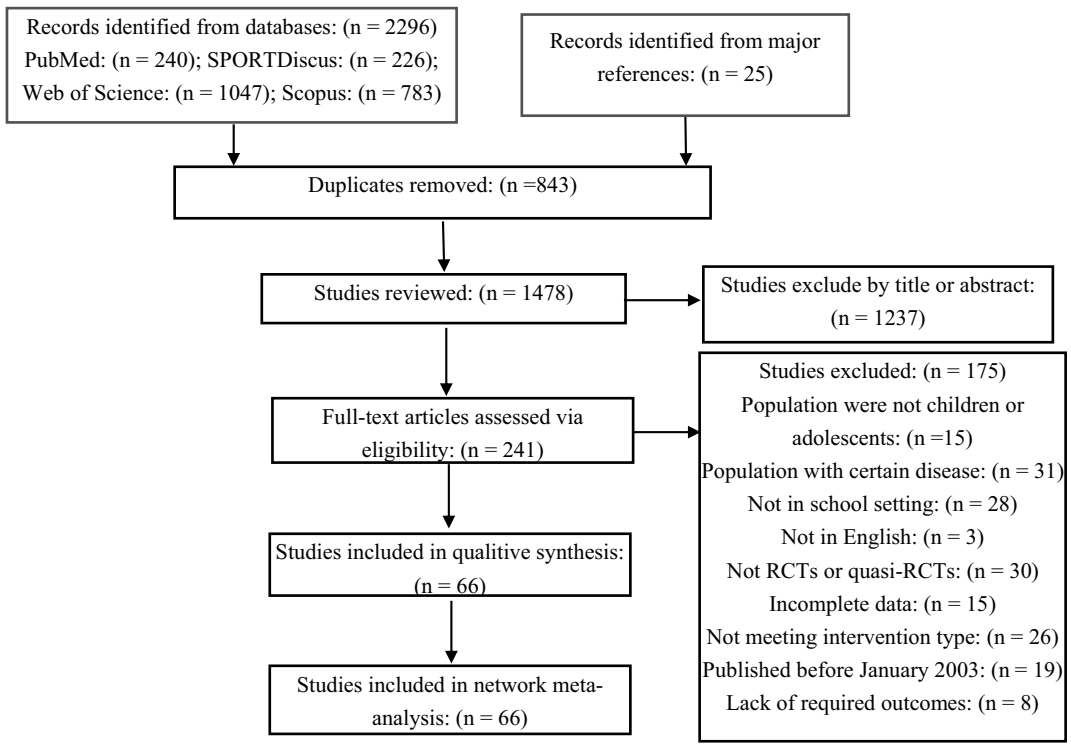

FIGURE 1
Flowchart of study selection.

66 studies were finally included. A flowchart of the selection process is shown in Figure 1.

Description of the included studies

Basic information about the eligible studies is shown in Supplementary Table S3. These included studies were conducted in North America ($n = 3$), South America ($n = 3$), Europe ($n = 38$), Asia ($n = 13$), Oceania ($n = 7$), and Africa ($n = 2$). A total of 8,578 children and adolescents (48% girls) with a mean age of 13.6 ± 4.3 were included in the 66 studies. Nine studies recruited only girls, eight studies recruited only boys, and the remaining 49 recruited both boys and girls. Fourteen studies focused on overweight or obese children and adolescents.

A total of 3,486 participants (1,685 girls) were included in the control group (CON) group that participated in regular physical activity (PA) or physical education (PE), 426 participants (171 girls) were included in the active video games (AVGs) group (24–31), 1,670 participants (803 girls) were included in the game-based exercise (GB) group (32–42), 1,085 participants (522 girls) were included in the high-intensity interval training (HIIT) group (36, 37, 43–65), 1,005 participants (462 girls) were included in the strength training (ST) group (41, 66–82), 599 participants (300 girls) were included in the aerobic training (AT) group (49, 53, 56, 61, 62, 66, 76, 83–87), and 307 participants (197 girls) were included in the combined aerobic and strength training (CT) group (68–71, 76, 88, 89). Interventions lasted on average of 13.9 ± 9.6 weeks and ranged from 4 to 50 weeks, with 73% of studies lasting less than 12 weeks. The average number of sessions per week was 2.7 ± 0.8. Twenty-three interventions were conducted intra-PE, 38 were conducted extra-PE, and five occurred both intra- and extra-PE.

Risk of bias assessment results

A summary of risk of bias (ROB) evaluation results is shown in Supplementary Table S2. Ten studies had high a ROB, 38 had a moderate ROB, and the remaining 18 had a low ROB. For each individual ROB item, 48 studies had a high random sequence generation. Only two studies demonstrated a low ROB in allocation concealment, while four mentioned blinding of research personnel. Seven studies had a high ROB due to incomplete outcome data and 36 studies had unclear ROB from selective reporting. Five studies had a high risk of other bias. Table 2 presents the ROB results in each intervention.

Network meta-analysis

Three anthropometry and body composition [body mass index (BMI; $kg \cdot m^{-2}$), waist circumference (WC), and body fat percent (BF; %) measurements, four muscular fitness (standing long jump (SLJ), countermovement jump (CMJ; cm), push-up, and 20-meter sprint (20-m sprint; s)] measurements, and two cardiorespiratory fitness [shuttle running (SR), VO_{2max}; $mL \cdot kg^{-1} \cdot min^{-1}$)] measurements were included in the network meta-analysis (NMA). The geometry of different interventions for each outcome is shown in Figure 2. Each

TABLE 2 ROB in each intervention.

Exercise types	Low risk	Moderate risk	High risk
AVGs	4	1	3
GB	4	6	1
HIIT	5	17	2
ST	5	10	3
AT	3	8	1
CT	1	4	2

Each cell represents the number of included studies. AT, aerobic training; HIIT, high-intensity interval training; AVGs, active video games; GB, game-based exercise; CT, combined aerobic and strength training; ST, strength training.

node represents one type of exercise treatment, while node size represents the sample size used in the intervention. The lines between two nodes indicate direct comparisons between the exercise types, with thicker lines indicating that more studies were included. Additional information about the contribution plots of comparative evidence is available in Supplementary Figures S1–S9. Global inconsistency testing was not significant (all Wald test statistic p values >0.5). Homoplastically, the results of local inconsistency testing using the node splitting method showed that each direct and indirect comparison among estimates was coincident for all outcomes (all p-values > 0.5; Supplementary Tables S4–S12). Forest plots with 95% CI are displayed in Supplementary Figures S10–S18. The comparative effects of each exercise type is shown in Figures 3A–I. Funnel plots evaluating publication bias are available in Supplementary Figures S19–S27. Supplementary Figures S28–S36 describes the surface under the cumulative ranking curve for all interventions. Larger SUCRA values, represent a higher probability that a treatment will be effective. Using the SUCRA value and mean rank of all exercise types were sorted (Table 3). Besides, due to the limitation of original studies, hand grip strength and sit-ups were not able to form a complete loop in NMA. Therefore, they were excluded.

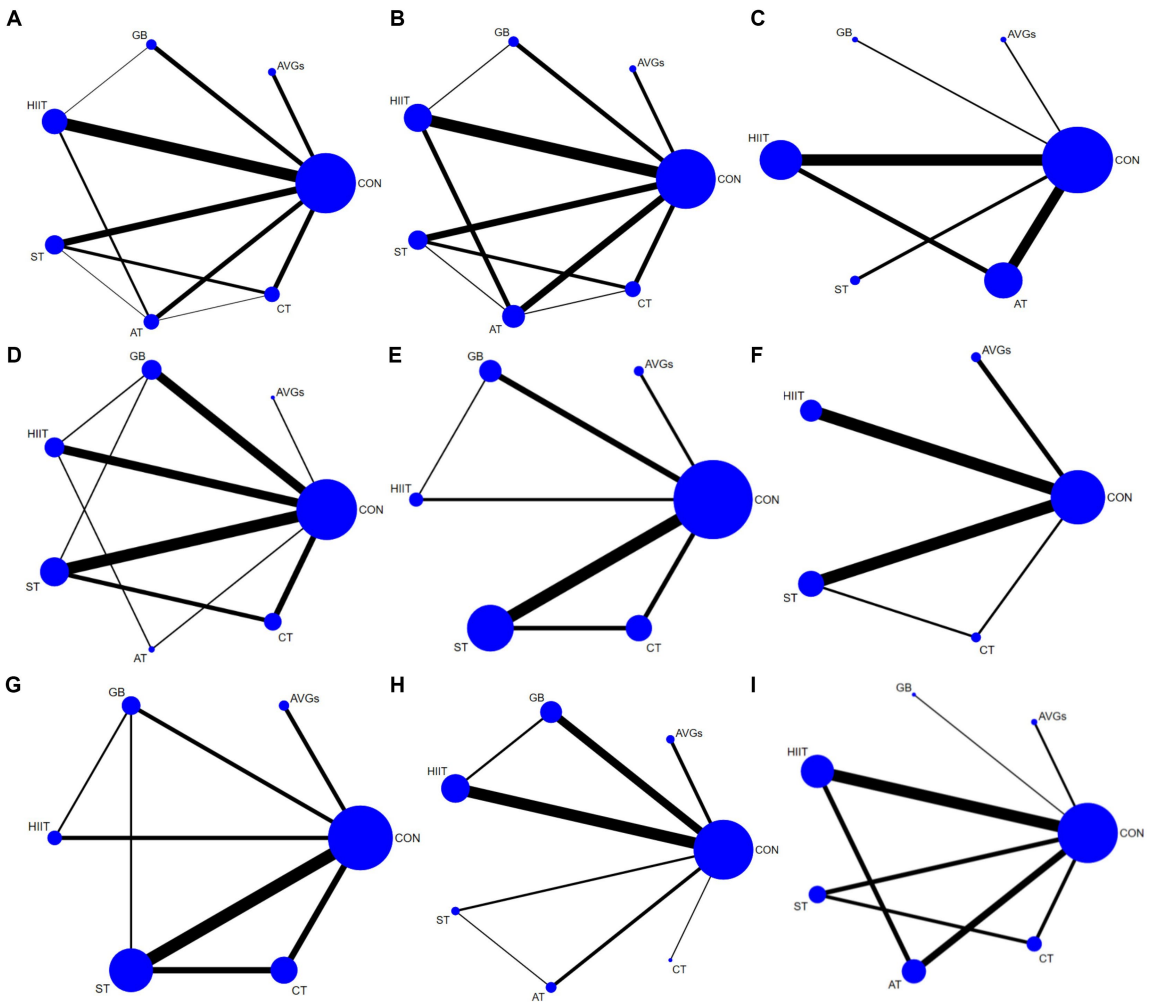

FIGURE 2
Network plots for outcome comparisons. The node size represented the sample size corresponding to the intervention, and the line thickness between nodes represented the number of included studies. **(A)** BMI, **(B)** body fat percent, **(C)** waist circumference, **(D)** standing long jump, **(E)** countermovement jump, **(F)** push-ups, **(G)** 20-m sprint, **(H)** shuttle running, and **(I)** VO_{2max}.

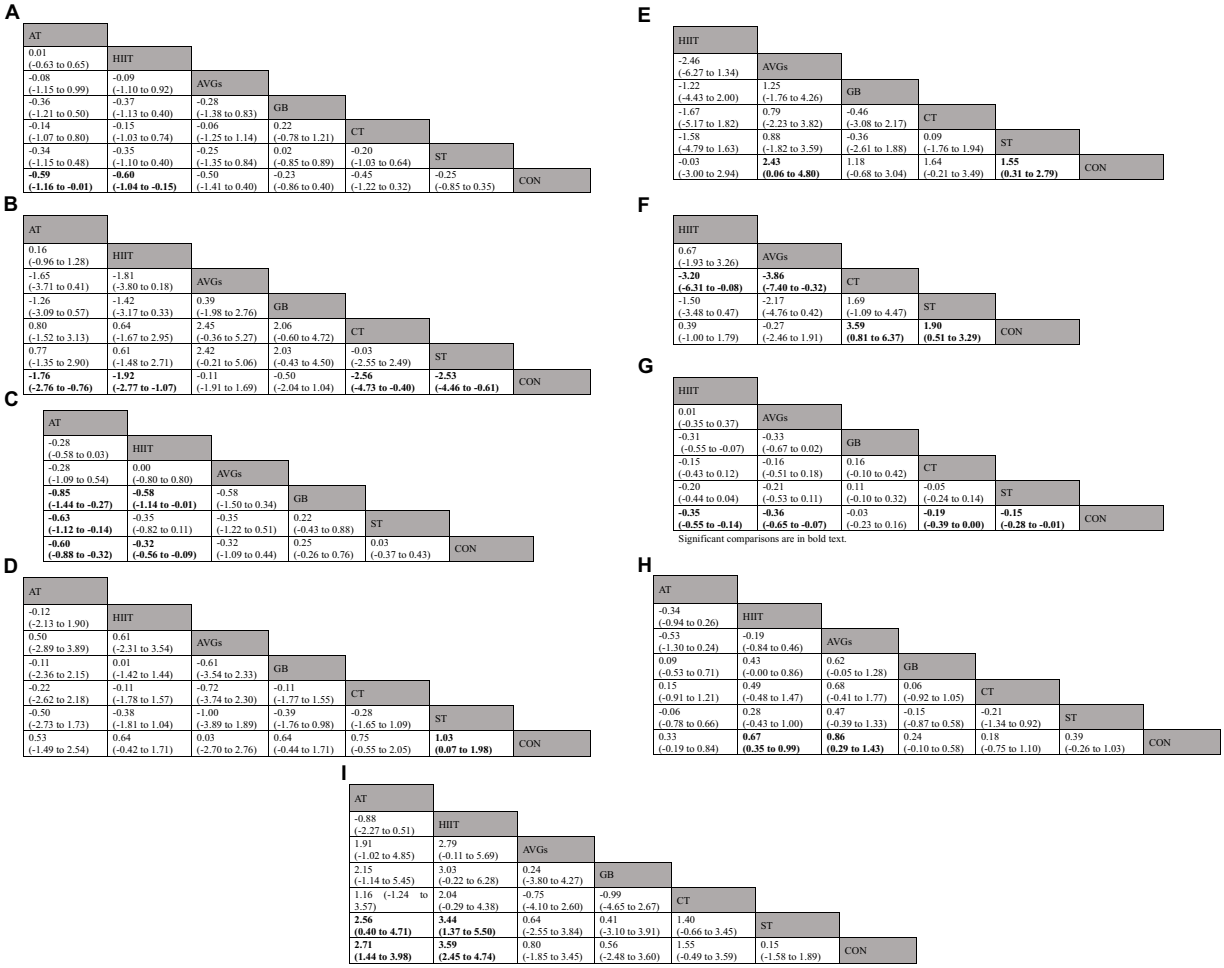

FIGURE 3
League table of comparative effectiveness results for **(A)** BMI [kg·m^{-2}], **(B)** body fat percent [%], **(C)** waist circumference, **(D)** standing long jump, **(E)** countermovement jump [cm], **(F)** push-ups, **(G)** 20-m sprint [s], **(H)** shuttle running, **(I)** VO_{2max} [mL·kg^{-1}·min^{-1}]. Significant comparisons are in bold text. Each cell presents an SMD/MD with a 95%CI. For **A–C,G**, lower negative SMD/MD values indicate positive effects on PF. Thus, a negative SMD/MD supports the upper-left intervention. For **D–F,H,I**, higher positive SMD/MD values indicate positive effects on PF. Thus, a positive SMD/MD supports the upper-left intervention, and a negative SMD/MD supports the lower-right intervention. 95%CI=95%confidence interval; AT, aerobic training; HIIT, high-intensity interval training; AVGs, active video games; GB, game-based exercise; CT, combined aerobic and strength training; ST, strength training; CON, control group; SMD, standardized mean difference; MD, mean difference.

Anthropometry and body composition outcomes

Body mass index

Forty studies involving 4,841 participants and all six exercise types reported BMI. Overall effects indicated that school-based exercise interventions can effectively reduce BMI (MD = −0.39 kg·m^{-2}, 95% CI = −0.62 to −0.15, $p = 0.001$). Compared with CON, AT (MD = −0.59 kg·m^{-2}, 95% CI = −1.16 to −0.01, $p = 0.043$) and HIIT (MD = −0.60 kg·m^{-2}, 95% CI = −1.04 to −0.15, $p = 0.009$) significantly reduced BMI while AVGs (MD = −0.50 kg·m^{-2}, 95% CI = −1.41 to 0.40, $p = 0.275$), GB (MD = −0.23 kg·m^{-2}, 95% CI = −0.86 to 0.40, $p = 0.475$), ST (MD = −0.25 kg·m^{-2}, 95% CI = −0.85 to 0.35, $p = 0.418$), and CT (MD = −0.45 kg·m^{-2}, 95% CI = −1.22 to 0.32, $p = 0.255$) had no significant impact on BMI (Figure 3A; Supplementary Figure S10). HIIT had the highest probability (SUCRA = 72.6%) of being the most treatment for lowering BMI (Table 3; Supplementary Figure S28).

Body fat percentage

Thirty studies involving 3,332 participants and all six exercise types included BF%. Overall effects indicated that school-based exercise interventions can effectively reduce BF% (MD = −1.78%, 95% CI = −2.38 to −1.17, $p < 0.001$). Compared with CON, CT (MD = −2.56%, 95% CI = −4.73 to −0.40, $p = 0.022$), ST (MD = −2.53%, 95% CI = −4.46 to −0.61, $p = 0.011$), HIIT (MD = −1.92%, 95% CI = −2.77 to −1.07, $p < 0.001$), and AT (MD = −1.76%, 95% CI = −2.76 to −0.76, $p < 0.001$) significantly reduced BF% (Figure 3B; Supplementary Figure S11). CT was the most effective intervention for BF% reduction (SUCRA = 81.0%; Table 3; Supplementary Figure S29). Compared with CON, AVGs (MD = −0.11%, 95% CI = −1.91 to 1.69, $p = 0.909$), and GB (MD = −0.50%, 95% CI = −2.04 to 1.04, $p = 0.534$) had no significant impact on BF% (Figure 3B; Supplementary Figure S11).

Waist circumference

Sixteen studies involving 1,073 participants and five exercise modalities in addition to CT explored the effects of exercise on waist

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TABLE 3 Rankings for six exercise types in order of effectiveness.

	SUCRA, %	Mean rank		SUCRA, %	Mean rank		SUCRA, %	Mean rank
Body mass index			Body fat percent			Waist circumstance		
AVGs	60.3	3.4	AVGs	18.0	5.9	AVGs	64.4	2.8
GB	37.8	4.7	GB	27.1	5.4	GB	11.0	5.5
HIIT	72.6	2.6	HIIT	68.6	2.9	HIIT	68.9	2.6
ST	38.8	4.7	ST	80.9	2.1	ST	29.8	4.5
AT	70.4	2.8	AT	62.2	3.3	AT	94.2	1.3
CT	57.5	3.5	CT	81.0	2.1	CON	31.8	4.4
CON	12.5	6.2	CON	12.2	6.3			
Standing long jump			Countermovement jump			Push-ups		
AVGs	35.6	5.6	AVGs	81.9	1.9	AVGs	19.5	4.2
GB	55.1	4.7	GB	52.6	3.4	HIIT	37.5	3.5
HIIT	54.9	3.6	HIIT	23.4	4.8	ST	74.6	2.0
ST	74.6	3.7	ST	63.5	2.8	CT	96.0	1.2
AT	50.3	2.5	CT	65.1	2.7	CON	22.3	4.1
CT	59.6	4.6	CON	13.5	5.3			
CON	19.7	3.4						
20-m sprint			Shuttle running			VO_{2max}		
AVGs	84.0	1.8	AVGs	89.1	1.7	AVGs	40.3	4.6
GB	18.7	5.1	GB	37.8	4.7	GB	35.4	4.9
HIIT	85.6	1.7	HIIT	78.9	2.3	HIIT	96.5	1.2
ST	45.8	3.7	ST	52.1	3.9	ST	23.4	5.6
CT	57.5	3.1	AT	46.4	4.2	AT	78.9	2.3
CON	8.4	5.6	CT	34.5	4.9	CT	56.7	3.6
			CON	11.0	6.3	CON	18.9	5.9

Higher SUCRA and lower mean ranks indicate better-performed interventions. AT, aerobic training; HIIT, high-intensity interval training; AVGs, active video games; GB, game-based exercise; CT, combined aerobic and strength training; ST, strength training; CON, control group; SUCRA, surface under the cumulative ranking curve.

circumference. Overall effects indicated that school-based exercise interventions can effectively reduce WC (SMD = −0.31, 95% CI = −0.52 to −0.10, $p = 0.004$). Compared with CON, HIIT (SMD = −0.32, 95% CI = −0.56 to −0.09, $p = 0.007$) and AT (SMD = −0.60, 95% CI = −0.88 to −0.32, $p < 0.001$) significantly reduced WC (Figure 3C; Supplementary Figure S12). AT had the highest probability (SUCRA = 94.2%) of reducing WC (SUCRA = 94.2%; Table 3; Supplementary Figure S30). Compared with CON, AVGs (SMD = −0.32, 95% CI = −1.09 to 0.44, $p = 0.405$), GB (SMD = 0.25, 95% CI = −0.26 to 0.76, $p = 0.333$), and ST (SMD = 0.03, 95% CI = −0.37 to 0.43, $p = 0.887$) had no significant impact on WC (Figure 3C; Supplementary Figure S12).

Muscular fitness outcomes

Standing long jump

Twenty-two studies involving 4,185 participants and all six interventions reported the effects of multiple exercise modes on SLJ. Overall effects indicated that school-based exercise interventions can effectively improve SLJ (SMD = 0.63, 95% CI = 0.38 to 0.89, $p < 0.001$). Compared with CON, ST (SMD = 1.03, 95% CI = 0.07 to 1.98, $p = 0.035$) significantly improved SLJ while AVGs (SMD = 0.03, 95% CI = −2.70 to 2.76, $p = 0.983$), GB (SMD = 0.64, 95% CI = −0.44 to 1.71, $p = 0.245$), HIIT (SMD = 0.64, 95% CI = −0.42 to 1.71, $p = 0.234$), AT (SMD = 0.53, 95% CI = −1.49 to 2.54, $p = 0.607$), and CT (SMD = 0.75, 95% CI = −0.55 to 2.05, $p = 0.258$) had no significant impact on SLJ (Figure 3D; Supplementary Figure S13). ST had the highest probability of improving SLJ (SUCRA = 74.6%; Table 3; Supplementary Figure S31).

Countermovement jump

Fifteen studies involving 934 participants and five exercise modalities other than AT examined the effects of various exercise treatments on CMJ. Overall effects indicated that school-based exercise interventions can effectively improve CMJ (MD = 1.22 cm, 95% CI = 0.27 to 2.18, $p = 0.012$). Compared with CON, AVGs (MD = 2.43 cm, 95% CI = 0.06 to 4.80, $p = 0.041$) and ST (MD = 1.55 cm, 95% CI = 0.31 to 2.79, $p = 0.014$) significantly improved CMJ while GB (MD = 1.18 cm, 95% CI = −0.68 to 3.04, $p = 0.212$), HIIT (MD = −0.03 cm, 95% CI = −3.00 to 2.94, $p = 0.983$), and CT (MD = 1.64 cm, 95% CI = −0.21 to 3.49, $p = 0.083$) had no significant impact on CMJ (Figure 3E; Supplementary Figure S14). AVGs had the highest probability of improving CMJ (SUCRA = 81.9%; Table 3; Supplementary Figure S32).

Push-ups

Twelve studies involving 1,557 participants and four interventions in addition to AT and GB assessed the effects of diverse exercise regimens on push-up ability. Overall effects indicated that school-based exercise interventions can effectively improve push-up ability (SMD = 1.14, 95% CI = 0.35 to 1.93, $p = 0.005$). Compared with CON, CT (SMD = 3.59, 95% CI = 0.81 to 6.37, $p = 0.012$) and ST (SMD = 1.90, 95% CI = 0.51 to 3.29, $p = 0.007$) significantly improved push-up ability while AVGs (SMD = −0.27, 95% CI = −2.46 to 1.91, $p = 0.806$) and HIIT (SMD = 0.39, 95% CI = −1.00 to 1.79, $p = 0.581$) had no significant impact on SLJ (Figure 3F; Supplementary Figure S15). CT had the highest probability of improving push-up ability (SUCRA = 96.0%; Table 3; Supplementary Figure S33).

20-m sprint

Ten studies involving 1,059 participants reported the effects of five exercise modalities on 20-m sprint performance. Overall effects indicated that school-based exercise interventions can effectively improve 20-m sprint performance (MD = −0.17 s, 95% CI = −0.24 to −0.10, $p < 0.001$). Compared with CON, HIIT (MD = −0.35 s, 95% CI = −0.55 to −0.14, $p = 0.001$), AVGs (MD = −0.36 s, 95% CI = −0.65 to −0.07, $p = 0.016$), ST (MD = −0.15 s, 95% CI = −0.28 to −0.01, $p = 0.035$), and CT (MD = −0.19 s, 95% CI = −0.39 to 0.00, $p = 0.047$) significantly advanced the 20-m sprint performance while GB (MD = −0.03 s, 95% CI = −0.23 to 0.16, $p = 0.729$) had no significant impact on 20-m sprint performance (Figure 3G; Supplementary Figure S16). HIIT had the highest possibility of improving participant 20-m sprint ability (SUCRA = 85.6%; Table 3; Supplementary Figure S34).

Cardiorespiratory fitness outcomes

Shuttle running

Twenty-three studies involving 3,927 participants explored the impact of all six exercise types on SR. Overall effects indicated that school-based exercise interventions can effectively improve SR performance (SMD = 0.44, 95% CI = 0.29 to 0.59, $p < 0.001$). Compared with CON, AVGs (SMD = 0.86, 95% CI = 0.29 to 1.43, $p = 0.003$) and HIIT (SMD = 0.67, 95% CI = 0.35 to 0.99 $p < 0.001$) significantly advanced SR while GB (SMD = 0.24, 95% CI = −0.10 to 0.58, $p = 0.170$), ST (SMD = 0.39, 95% CI = −0.26 to 1.03, $p = 0.238$), AT (SMD = 0.33, 95% CI = −0.19 to 0.84, $p = 0.210$), and CT (SMD = 0.18, 95% CI = −0.75 to 1.10, $p = 0.710$) had no significant impact on (Figure 3H; Supplementary Figure S17). AVGs had the highest probability of improving SR (SUCRA = 89.1%; Table 3; Supplementary Figure S35).

Maximum oxygen uptake (VO_{2max})

Twenty-one studies involving 2,842 participants reported the effects of all six treatments on VO_{2max}. Overall effects indicated that school-based exercise interventions can effectively improve VO_{2max} (MD = 2.50 mL·kg^{-1}·min^{-1}, 95% CI = 1.78 to 3.22, $p < 0.001$). Compared with CON, HIIT (MD = 3.59 mL·kg^{-1}·min^{-1}, 95% CI = 2.45 to 4.74, $p < 0.001$) and AT (MD = 2.71 mL·kg^{-1}·min^{-1}, 95% CI = 1.44 to 3.98, $p < 0.001$) significantly improved VO_{2max} while AVGs (MD = 0.80 mL·kg^{-1}·min^{-1}, 95% CI = −1.85 to 3.45, $p = 0.428$), GB (MD = 0.56 mL·kg^{-1}·min^{-1}, 95% CI = −2.48 to 3.60, $p = 0.669$), ST (MD = 0.15 mL·kg^{-1}·min^{-1}, 95% CI = −1.58 to 1.89, $p = 0.370$), and CT (MD = 1.55 mL·kg^{-1}·min^{-1}, 95% CI = −0.49 to 3.59, $p = 0.054$) had no significant impact on VO_{2max} (Figure 3I; Supplementary Figure S18). Overall, HIIT had the highest probability of increasing VO_{2max} (SUCRA = 96.5%; Table 3; Supplementary Figure S36).

Discussion

To the best of our current knowledge, it is the first network meta-analysis (NMA) to compare the effects of school-based exercise modalities for physical fitness (PF) promotion among young students. High-intensity interval training (HIIT) was the most effective intervention reducing body mass index (BMI), and elevating VO_{2max}, and 20-meter sprint (20-m sprint) performance. Aerobic training (AT) had the highest probability of reducing waist circumference (WC) while active video games (AVGs) emerged as a promising modality for improving countermovement jump (CMJ)and shuttle running (SR). Strength training (ST) was the best exercise for standing long jump (SLJ). Of the six interventions discussed, combined aerobic and strength training (CT) was most effective at lowering body fat percent (BF%) and increasing push-up repetitions.

Anthropometry and body composition

BMI, total body fat, and abdominal adiposity are important predictors of cardiometabolic risk among youth. A recent systematic review used pairwise meta-analysis to assess the effects of HIIT (MD = −1.66 kg·m^{-2}) and moderate-intensity continuous training (MD = −2.37 kg·m^{-2}) on pediatric BMI and found no significant differences between the two exercises (90). While these findings were similar to those reported by the current study, the effects provided by this NMA were smaller, possibly due to differences in participant demographics. While the review focused exclusively on obese children, the current study did not make a strict distinction between overweight and normal weight participants. Exercise tends to have a greater impact on the body composition of obese or overweight children than those of normal weight (91).

One study found that exercise had a greater impact on BF% than BMI (92). This may be because a decrease in BMI can correlate with both weight loss and an increase in height caused by the natural growth of children and adolescents. In addition, because it is the most metabolically hazardous tissue, body fat serves as a valuable health measure of exercise intervention assessments. However, there is limited evidence showing that school-based exercise programs can reduce student BF%. A recent meta-analysis summarized the effect of a school-based HIIT program on BF% and found a pooled effect size of −1.7% (13). The current NMA went one step further by evaluating different exercise types. In addition to HIIT, AT, ST, and CT also lowered BF% of children and adolescents, a finding consistent with a previous NMA that compared the effects of five exercise types on the PF of adults (93). Although the current NMA found that CT was the best exercise mode for reducing body fat, HIIT was more efficient. Additional research is needed to compare the effect of CT and HIIT on fat loss.

In addition to total body fat, abdominal adiposity correlates closely with all-cause mortality (94). WC is often used as an indicator of abdominal adiposity and serves as a warning of potential health risks. For example, the risk of cardiovascular disease increases by 2% for each 1 cm increase in WC (95). While prior studies have suggested that HIIT does not significantly decrease WC in adolescents (96), more recent evidence contradicts these results (97). Similarly, this study found that HIIT and AT were effective at reducing WC in youth.

Surprisingly, while prior studies showed that AVGs significantly reduced BMI and BF% in children and adolescents, the current study found that school-based AVGs did not have a significant impact on participant anthropometry and body composition (98, 99). Differences in environmental factors may explain this inconsistency. While the articles included in this NMA study were exclusively conducted in schools, other reviews incorporated home or laboratory settings that were more beneficial to AVGs programs. Thus, more high-quality RCTs are needed to explore the influences of school-based AVGs on anthropometry and body composition.

Muscular fitness

Maximum muscular strength, muscular power, and endurance are potentially correlated with cardiovascular variables and the future health of children and adolescents (100). One prior review found that school-based interventions have a small-to-moderate effect on muscular fitness (101), which is congruent with the results of the current study. However, distinct from the strength exercise guidelines (102), this NMA suggested that ST had a relatively small impact on muscular fitness (MF). The development of muscle strength involves both neuromuscular adaptation and muscle hypertrophy. Thus, to improve MF through ST, a detailed assessment of training prescription (i.e., frequency, load, volume, and duration) should be conducted. However, it can be difficult to develop in-school exercise programs that strictly following the prescription when there is a high number of students. In addition, there is variation in the efficacy of different ST modes. Compared with bodyweight training, for example, plyometric training has a greater impact on CMJ and SLJ (103). Unfortunately, the use of specialized plyometric training in school settings was not assessed in this review. Some teachers also oppose school-based ST due to their limited experience and qualifications or low confidence in the training plans (104), further limiting the benefits of this intervention.

Of note, the current NMA found that AVGs are an innovative exercise mode with the highest possibility of increasing vertical jump performance. Compared to regular physical activity (PA) or physical education (PE), AVGs led to statistically significant and clinically important changes in CMJ. Since the exercise intensity of most commercial AVGs (e.g., Xbox Kinect, Wii, PlayStation) cannot reach the minimum threshold needed to stimulate growth in muscle strength (27), it is probable that the increase in CMJ performance caused by AVGs may be related to elevated locomotor skills rather than muscle strength. Two previous reviews support this inference, revealing that AVGs had a small but statistically significant effects on the fundamental motor skills of young people (105, 106). However, the disadvantages of AVGs are obvious as well. Since the sensors embedded in exergames are unable to precisely track human movement, skill-specific motor learning cannot be guided. This explains why the effect size reported in these reviews was smaller than that observed in a previous meta-analysis of foundational motor skill (FMS) interventions presented in real-life situations (107).

Push-ups provide a simple and valid muscular endurance test for the upper body. Higher push-up capacity relates to a lower incidence of cardiovascular disease events (108). The current NMA found that CT was the most promising exercise treatment for enhancing push-ups. While this supports the findings of other studies, limited data have been collected in the school environment. One randomized controlled trial (RCT) compared the effects of a 22-week CT to ST and AT alone on obese adolescents, and CT was shown to have a superior impact on muscle endurance (109). The current study also found that HIIT had no effect on push-ups, which is inconsistent with previous reports. For example, Eather et al. reported 4.0 repetition (95% CI: 1.2 to 6.8) push-up changes in favor of a HIIT program in the university setting (110). This discrepancy may stem from differences in the HIIT content. Indeed, push-up capacity only increases when relevant upper body motions are involved in the HIIT prescription.

HIIT had the highest possibility of improving participant 20-m sprint performance. This finding generally coincides with previous studies on the effect of HIIT and ST on sprint running (111, 112). The main factors that contribute to sprint performance are anaerobic power and leg muscle strength. Recent studies suggest that specialized HIIT and ST are the key to modifying these factors (113, 114), with running-based HIIT and velocity-based ST showing relatively higher efficacy. Running-based HIIT employs stretch-shortening cycle (SSC) actions that involve the sequential assortment of eccentric and concentric muscle actions. SSC improves concentric power output, which increases maximal running speed (115). Velocity-based ST tends to improve strength and power via neural mechanisms (116).

Cardiorespiratory fitness

CRF has a positive impact on physical and mental health (117) and academic performance (118) in teenagers, and physical exercise is recommended as a cost-effective tool to sustain CRF (119). The current study found that AVGs and HIIT were most effective at improving shuttle running and VO_{2max} respectively. The impact of AVGs was strongly impacted by the intervention arrangements used in each study. Due to governmental restrictions associated with the COVID-19 pandemic, regular daily PA was reduced for participants in the CON and their performance in shuttle running decreased significantly (26), leading to an unexpected gap between the experimental and CON groups. Without this interference, our calculations suggest that HIIT has a superior impact on shuttle running and VO_{2max}, a result consistent with several pairwise meta-analyses (120–122). These improvements could be related to exercise-induced advantageous mitochondrial adaptations as well as an increase in blood capillarization, oxidative enzyme activity, and oxygen transport to the muscular system (123).

Strengths and limitations

The strengths of this study include the following: (1) a considerable sample size ($n = 8,578$) of children and adolescents that provided enough power to identify statistically significant mean differences; (2)

the incorporation of two emerging exercise interventions (AVGs and game-based exercise) that catered to the latest trends; and (3) the use of strict eligibility criteria to ensure that data were extracted from high-quality literature.

The study limitations are as follows: (1) low methodological quality of the included studies, with only 18 using random sequence generation methods and two mentioning whether allocation concealment was performed. Unclear allocation concealment may exaggerate study results and increase heterogeneity in meta-analysis; (2) the small number of AVGs studies may have reduced the robustness of the results and biased comparisons; (3) the failure to conduct detailed subgroup analysis for intra- and extra-PE interventions, making it difficult to explore the heterogeneity among studies.

Conclusion

This systematic review using NMA suggested that except for GB, school-based exercise interventions were associated with an improvement in PF among children and adolescents. Based on these findings, we recommend integrating HIIT into PE classes and adding AT and ST to extracurricular activities. It is encouraged that exergaming systems be introduced into primary and secondary schools to improve student exercise enjoyment and PF. However, because the school-based exercise interventions evaluated by this study were applied to different populations (e.g., boys, girls, students of normal weight or overweight) and were largely affected by PE teachers, additional high quality RCTs are needed to explore the influence of teacher and student-related factors on the effectiveness of various exercise interventions.

Author contributions

JW and YY contributed to study design, literature research, data extraction, risk of bias assessment, and drafting of the manuscript. HY and LL made substantial contributions to risk of bias assessment and data analysis. YC was a significant manuscript reviser. YS played important role in concept and design. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1194779/full#supplementary-material

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Glossary

PF	Physical fitness
PA	Physical activity
AVGs	Active video games
GB	Game-based exercise
HIIT	High-intensity interval training
ST	Strength training
AT	Aerobic training
CT	Combined aerobic and strength training
CON	Control group
RCTs	Randomized controlled trials
BMI	Body mass index
BF%	Body fat percent
WC	Waist circumference
SLJ	Standing long jump
CMJ	Countermovement jump
SR	Shuttle running
20-m sprint	20-meter sprint
MF	Muscular fitness
CRF	Cardiorespiratory fitness
NMA	Network meta-analysis
PE	Physical education

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Factors that influence food choices in secondary school canteens: a qualitative study of pupil and staff perspectives

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Background: Adolescence is recognised as a period of nutritional vulnerability, with evidence indicating that United Kingdom adolescents have suboptimal dietary intakes with many failing to meet dietary recommendations. Additionally, adolescence is a time of transition when they become more independent in their dietary choices and begin to develop their own sense of autonomy and are less reliant on their parent's guidance, which is reported to lead to less favourable dietary behaviours. Reducing the prevalence of poor dietary intakes and the associated negative health consequences among this population is a public health priority and schools represent an important setting to promote positive dietary behaviours. The aim of this school-based study was to explore the factors and barriers which influence food choices within the school canteen and to identify feasible strategies to promote positive dietary behaviours within this setting.

Methods: Thirteen focus groups with 86 pupils in Year 8 ($n = 37$; aged 11–12 years) and Year 9 ($n = 49$; aged 12–13 years) in six secondary schools across Northern Ireland, United Kingdom were conducted. Additionally, one-to-one virtual interviews were conducted with 29 school staff [principals/vice-principals ($n = 4$); teachers ($n = 17$); and caterers ($n = 7$)] across 17 secondary schools and an Education Authority (EA) senior staff member ($n = 1$). Focus groups and interviews were audio-recorded, transcribed, and analysed following an inductive thematic approach.

Results: Using the ecological framework, multiple factors were identified which influenced pupils' selection of food in the school canteen at the individual (e.g., time/convenience), social (e.g., peer influence), physical (e.g., food/beverage placement), and macro environment (e.g., food provision) level. Suggestions for improvement of food choices were also identified at each ecological level: individual (e.g., rewards), social (e.g., pupil-led initiatives), physical (e.g., labelling), and macro environment (e.g., whole-school approaches).

Conclusion: Low-cost and non-labour intensive practical strategies could be employed, including menu and labelling strategies, placement of foods, reviewing pricing policies and whole-school initiatives in developing future dietary interventions to positively enhance adolescents' food choices in secondary schools.

KEYWORDS

pupil, school staff, food choice, secondary school, canteen, adolescence

Introduction

Globally, adolescent overweight and obesity has increased significantly (1) and is now recognised as one of the most urgent public health challenges (2). This issue is particularly prevalent within the United Kingdom, with >30% of adolescents (aged 11–15 years) impacted by overweight or obesity (3). The negative physical (4, 5) and psychological (4–6) health implications associated with adolescent obesity are well-documented. Additionally, challenges also exist with reversing adolescent obesity, with 80% of obese adolescents likely to remain obese in adulthood (7), increasing the risk of further poor health outcomes in later life (8). Thus, determining effective preventative measures to mitigate the risk of obesity among this population is crucial to improve current and future health and minimise long-term obesity-related medical costs (9).

Less healthful dietary behaviours during adolescence, such as the overconsumption of energy-dense, nutrient-poor foods, can increase short (10) and long-term (11) obesity risk. United Kingdom adolescents' dietary habits are of concern, with The National Diet and Nutrition Survey indicating suboptimal dietary behaviours among this population, including inadequate consumption of fruit and vegetables (12), low fibre intakes (13), excessive fat and sugar intakes (13) and higher energy intake also among those with overweight or obesity (14). As children transition to adolescents, they can become more susceptible to consuming an unbalanced diet (15) and dietary behaviours acquired during this period can persist into adult life (16). Therefore, dietary intervention during adolescence is essential to offset trends of declining dietary quality and establish healthy eating behaviours that can be sustained across the lifespan.

Adolescents are required to spend 190 days each year in school (17). Given the continuous contact time schools provide to this population, this setting represents a promising environment to deliver dietary interventions (18). School-based interventions are cost-effective (19) and offer the opportunity to reach the majority of adolescents, irrespective of socio-economic status or ethnical background (20). Moreover, adolescents' consume a substantial proportion of their daily energy intakes in school (up to 1–2 meals per day) (21, 22). However, despite consistent efforts to determine the most effective school-based interventions to improve adolescents' dietary intakes, outcomes remain short-term (23).

In Northern Ireland (NI), records suggest that more than half of adolescents (54–63%) typically consume school meals (provided by schools) at lunchtime (24) as opposed to a packed lunch (brought from home) or sourcing items from nearby food outlets. Mandatory food-based standards (25) are in place in NI schools to ensure pupils have access to a healthy and balanced school meal (26), which is of particular benefit to those who may have limited access to nutritious food outside school. However, although secondary schools provide healthier options compliant with the school-food standards, many adolescents continue to purchase the less nutritious items from the menu on offer (27), highlighting the need to explore alternate influential factors on adolescents' lunchtime food choices. In addition to improved food provision, nutritional education is also compulsory in NI secondary schools (post-primary) for adolescents in Key Stage 3 (aged 11–14 years) (28), albeit, adolescents' nutritional knowledge often has minimal impact on their food choices (29). Thus, identifying additional opportunities within the school-setting to promote positive dietary change is of importance. As pupils progress from primary to secondary education, parental control over their eating behaviours lessens and their propensity towards their dietary decisions become more independent-based (15). It is therefore pertinent to gain insight into the principal factors influencing adolescents' school-based food choices as they develop increasing nutritional autonomy during this transitional period to optimise engagement and success of future school-based dietary interventions.

Research suggests that adolescents' food choices within the school canteen can be influenced by various food-related factors, including available items, quality, appearance, taste, cost, value for money and peer pressure to opt for specific foods and canteen-related factors such as food hygiene, school menu and price displays, queue length and seating availability (30). More recent work has revealed adolescents' favour take away items in the school canteen and associate 'main meals' as food to be consumed within the home environment (31).

In order to better understand the multiple levels of influence on adolescents' food choices, Story et al. (32) proposed an ecological framework to consider their eating behaviours under four broad levels of influence to include individual (intrapersonal), social environmental (interpersonal), physical environmental, and macro level to aid in the design of appropriate nutrition interventions targeted at this population.

The difficulties associated with changing health behaviours are well recognised (33). When designing interventions, early involvement of stakeholders and the target user is recommended (34). In addition, although often under-utilised, qualitative research methodologies may assist in informing and optimising the design of interventions (35). Gaining further understanding of NI adolescents' perspectives on the factors influencing their food choices within school and their suggestions on how best to address these factors through school-based strategies is needed if effective interventions to enhance positive dietary behaviours in this population are to be achieved. Additionally, a paucity of information exists on United Kingdom school staff's perspectives on adolescents' school-based food choices and their recommendations for improvement, limiting the ability for comparisons between key stakeholder groups to be examined. Furthermore, to aid in successful intervention design, consulting with school staff may provide researchers with a better understanding of any existing implementation practicalities to consider, such as schools' academic priorities, available resources and the need to avoid over-burdening staff (36).

The aim of this study was to explore the primary factors influencing adolescents' food choices within the school canteen environment from the pupil and school staff perspective. Additionally, a secondary aim was to identify feasible strategies to encourage healthful food choices amongst adolescents within the school-setting.

Methods

Study design

Qualitative research methods were selected to provide insight into the complexity of individuals' food-related behaviours (37), in addition to their interactive nature to facilitate in-depth exploration of topics raised that is less possible with quantitative surveys (38, 39). Focus groups with pupils and one-to-one interviews with school staff were conducted to capture participants' perspectives, attitudes, and

experiences (40, 41). The reporting of this study is aligned with the consolidated criteria for reporting qualitative research (COREQ; Supplementary Table S1) (42). This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by Ulster University's Research Ethics Committee (FCBMS-20-016-A; REC/20/0031). Written informed consent was obtained from all participants and their parents/ guardians.

Sample selection and recruitment

School pupils

Year 8 (aged 11–12 years) and Year 9 (aged 12–13 years) pupils in seven purposively sampled (43) mixed-gender secondary schools in NI were invited to take part in this study. Year 8 (aged 11–12 years) and year 9 (aged 12–13 years) pupils were the focus as they had recently transitioned to secondary school and had become exposed to making independent food choices in the school canteen. Pupils who purchased food in the school canteen regularly (at least once each week) were eligible to participate. Schools were contacted via email or telephone and following agreement from the school principal, information sheets, assent and consent forms were distributed by a senior teacher to eligible pupils and asked to discuss with their parents/guardians. Participants who returned completed assent and consent forms were selected by a senior teacher to participate in the focus group.

School staff

A purposive sample (43) of school staff from a range of socio-economic (assessed using number of free school meals) and geographically diverse mixed-gender secondary schools ($n = 17$) across NI were invited to participate in this study. All grades of staff were eligible to participate including principals/vice principals and teaching staff from a range of subject disciplines. School catering staff included supervisors and caterers. Additionally, as the EA has responsibility for school meal provision in a large proportion of NI secondary schools, one senior EA staff member was invited to participate. School staff were contacted via email or telephone, and following agreement, information sheets and consent forms were distributed.

Data collection

Pupils participated in mixed-gender focus groups and staff in one-to-one interviews, which were conducted independently by a researcher trained in qualitative research (L.D.D, PhD researcher, not affiliated with schools). Similar semi-structured discussion guides were used for the focus groups and interviews (Table 1) to ensure consistency and facilitate comparability between the pupils' and staff's perspectives. All focus groups and interview discussions were facilitated by the researcher using the topic guide to explore key issues. To enhance interaction and active listening during the discussions, notes were made directly after each session to enrich the data collected (40). Focus groups and interviews were undertaken until data saturation had been reached (44).

Pupils

Mixed-gender focus groups of 5–8 pupils were conducted between May and June 2021 within the school (classroom or hall) and during

TABLE 1 Semi-structured discussion guide for pupils focus groups and school staff interviews.

Pupils focus group topic guide	School staff interview topic guide
Approximately, how many times a week would you eat school meals as opposed to taking a school lunch?	What is your opinion of the school meals provided in your school?
What is your opinion of the school meals provided in your school?	Do you feel any improvements could be made to the school meals provided in your school?
Do you feel any improvements could be made to the school meals provided in your school?	What is your opinion of the school canteen environment?
What is your opinion of the school canteen environment?	Do you feel any improvements could be made to your school canteen environment?
Do you feel any improvements could be made to your school canteen environment?	What do you perceive to be the most popular food options on your school lunch menu?
What are your favourite foods on the school lunch menu?	What do you perceive to be the least popular food options on your school lunch menu?
What are your least favourite foods on the school lunch menu?	What factors do you perceive to influence pupil's food choice in the canteen at lunchtime?
What factors influence your food choice in the school canteen at lunchtime?	Are there any barriers that you perceive to prevent adolescents selecting the healthier food items in your canteen at lunch?
Are there any barriers that you perceive to prevent adolescents selecting the healthier food items in your canteen at lunch?	Are there any facilitators you perceive to encourage adolescents to select the healthier food items in your canteen at lunch?
Are there any facilitators you perceive to encourage adolescents to select the healthier food items in your canteen at lunch?	What changes, if any, to the school canteen environment do you perceive would encourage pupils to select healthier items at lunchtime that could be used as part of an intervention in school canteens?
What changes, if any, to the school canteen environment would encourage you to select healthier options at lunchtime?	Have you any additional thoughts, ideas or comments you would like to share that have not already been addressed in today's discussion?
Have you any additional thoughts, ideas or comments you would like to share that have not already been addressed in today's discussion?	

school hours under observation from a senior teacher. All pupils were reminded prior to commencing the focus groups that the information they provided would remain anonymous and would not be shared with their parents or school staff. The topic guide (Table 1) was designed and developed based on a review of the area and pilot tested on a small group of Year 8 pupils in different schools to test the questions for level of comprehension to optimise clarity of questions (45). Focus group sessions were on average 30 min duration (range 12–43 min).

Staff

One-to-one interviews were conducted remotely with school staff via Microsoft Teams or by telephone call at a suitable time for each participant between October and December 2020. Interview questions were pilot tested with one teacher in a different school to test suitability of questions. Interviews took on average 30 min (range 9–57 min).

Data analysis

Focus groups and interviews were audio-recorded and transcribed verbatim. Transcripts were uploaded to NVivo 12 Pro Software (QSR International) for data management and analysed following the six phases of reflexive thematic analysis using an inductive approach (46). Codes were independently applied to quotes throughout each transcript by a member of the research team (L.D.D). To minimise the risk of bias and ensure correct interpretation of quotes, transcripts and codes were critically reviewed, discussed and confirmed by the research team (A.J.H and A.M.G). Quotes representing similar views were then clustered together and assigned initial sub-themes (L.D.D), which were reviewed by the research team (A.J.H and A.M.G) and refined before reaching consensus on the potential sub-themes. Each sub-theme was then mapped to each level of the ecological model, namely: individual (intrapersonal), social environment (interpersonal), physical environment, and macro environment (32). Quotes that were most reflective of the sub-themes were selected for inclusion.

Results

Participant and school characteristics

Pupils

Of the seven purposively sampled schools, six schools expressed an interest in participating and one did not respond to the study invitation. 86 pupils participated in 13 focus groups across the six schools ($n = 4$ urban; $n = 2$ rural) throughout three different district council areas in NI, with six focus groups undertaken with Year 8 pupils ($n = 24$ female; $n = 13$ males) and seven with Year 9 pupils ($n = 28$ female; $n = 21$ males). All six schools were co-educational and mixed-gender. Free school meal entitlement across the schools ranged from 21 to 53%.

School staff

Of the 35 participants who received initial invitations, 29 participated in this study (four did not respond to the study invitation; one did not return the consent form; one was excluded as they did not have recent experience in a secondary school). The final sample of 29 (24 females, 5 males) comprised principals ($n = 2$), vice-principals ($n = 2$), teachers ($n = 17$), catering staff ($n = 7$) sampled across 17 secondary schools, and a senior staff member ($n = 1$) in the EA. The schools were in urban ($n = 14$) and rural ($n = 3$) environments located within eight of 11 district council areas in NI. 16 schools were co-educational (mixed-gender) with one school being female only. Free school meal entitlement in these schools ranged from 7 to 54%.

The key sub-themes identified from the pupils' and staff's responses and exemplar quotes are reported in Tables 2, 3 using under the four levels of the ecological framework: individual (intrapersonal), social environment (interpersonal), physical environment, and macro environment (32).

Influences on pupils' food choices in the school canteen

Individual (intrapersonal)

Exemplar quotes to illustrate the following sub-themes are shown in Table 2.

Internal motivations

Pupils' personal preferences, in addition to taste, appearance and habitual intakes, were important factors that influence their food choices in the school canteen. These factors often took precedence over the healthiness of the food items on offer, with many pupils commenting that options which were perceived to be less healthy were more tasteful. Pupils' also commented that if they did not like the choices available, they may have not have lunch in the canteen that day.

> *'I just pick what I like'* (P14, FG2, F)

School staff had similar perceptions regarding personal preferences and reinforced that pupils were more likely to select items which were less healthy. School staff also reported that the appearance, familiarity and taste of the food were important when selecting items in the canteen and that these factors may act as barriers to pupils choosing alternate food options.

Time and convenience

Many pupils identified time restrictions as being a major barrier when making food choices as they have limited time for lunch break and many preferred convenient, 'grab-and-go' options as they preferred to maximise their free time with peers and participate in lunchtime activities. Additionally, the length of queue in the canteen was also commonly cited, with pupils' opting for meals which had shorter queues, which may influence choice and possibly discourage pupils from eating in the canteen or skipping their lunchtime meal.

> *'If there's big long queues, I just say forget it and not eat'* (P79, FG11, M)

This was similar to school staff's views, who suggested that the queues were a factor which influenced food choices in the canteen and this issue was identified to be of greater importance for male pupils who prioritised socialising outside at lunchtime and were less likely to

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be waiting in queues. School staff also described how in more recent years, pupils' choices have gradually changed over the years from selecting more traditional sit-down meals in the canteen to more convenient, portable and on-the-go options.

Financial motivations

Both pupils and staff commonly reported that price, value for money and portion size influenced food choice. For example, fruit options were reported to be of a small portion size and lower satiety value, thus, not good value for money, and therefore limited the selection of these items. Additionally, pupils reported that food items were expensive, with one pupil noting that on occasions, money allocated from 'free school meal entitlement' was insufficient to cover the cost of lunch. Financial motivations were identified as a key theme reported by five out of six schools regardless of whether the school was located in an area deemed to be rural or urban.

> *'Not everyone can afford spending like £3 a day on lunch'* (P62, FG9, M)

School staff also commented that they believed that pupils had a budget to purchase lunch and that the cost of food items and value for money was an important factor in their choice of food. It was noted by staff that dissatisfaction with food choice for value for money was perceived to increase the number of pupils opting for a packed lunch. School staff also commented that male pupils prioritise purchasing food which seemed to have larger portion sizes.

Nutritional knowledge

Pupils' reported different views on the importance of understanding the nutritional value and composition of foods and whether the food was a healthy choice. Some pupils stated that they were unaware of which foods and meals were healthier, whereas, others were very aware of the healthier options. Both groups stated that this would not be a primary factor to influence their food choices.

> *'I do not mind if its healthy or not, it does not influence me'* (P17, FG3, M)

School staff agreed that they did not believe that nutritional knowledge was a key factor in influencing food choices of most pupils and reported that other factors, such as taste preferences, familiarity and convenience were more of a priority whilst in school. Nutrition education forms part of the curriculum for all secondary (post-primary) school pupils in NI for Year 8–10 (aged 11–14 years), however, staff reported that this knowledge was not considered to be sufficient to change their behaviour and translate into more positive health behaviours in the canteen.

Social environmental (interpersonal)

Exemplar quotes to illustrate the following sub-themes are shown in Table 2.

Peer influence

Peers were consistently identified as a major influence on pupils' food choices. Pupils reported feeling pressurised to select similar items in the canteen to those of their peer group to avoid negative comments. Both male and female pupils expressed concerns about how their peers viewed them when making their individual food choices and that selecting certain food items in the canteen may not be considered socially acceptable.

> *'Like today, one person got pizza and then everyone else just got the pizza, it's just what everyone else gets, you have to get'* (P22, FG4, F)

Peer influence was also the most dominant, reoccurring sub-theme within this level (social environmental) among school staff. School staff shared the view that pupils' want to emulate their peers and aim to conform to what is perceived to be acceptable eating behaviours in an attempt to avoid standing out and to preserve a positive social status. In addition, catering staff reported viewing peer-induced choices in the canteen, with pupils selecting similar items to their friends.

Home influence

No pupils made reference to the influence of eating habits at home impacting on food choice in the school canteen. However, school staff expressed that eating habits established at home are reflective of pupils' food behaviours in school and that both schools and parents need to promote positive eating behaviours to pupils simultaneously for the message to be impactful, as schools alone were considered to be insufficient to achieve sustainable positive dietary change.

Physical environmental

Exemplar quotes to illustrate the following sub-themes are shown in Table 2.

Placement of food and beverages

The location and ease of access to food and beverage items in the canteen was noted as being influential on food choice. Pupils' acknowledged that healthier options were usually in a less prominent position in the canteen and often placed out of sight, having a direct influence on their purchasing decisions.

> *'The apples are sort of out of the way, so you would not pick an apple because the biscuits are there, so you would just pick a biscuit'* (P14, FG2, F)

School staff also recognised the impact of product placement on pupils' food choice and cited that they are likely to opt for the food items which they observe first in the canteen.

Menu options and pricing information

Pupils indicated that they were often unaware of what foods were available on the menu in the canteen daily. This uncertainty of the menu was reported to impact on purchasing decisions, for example, pupils opting for a packed lunch or skipping their school meal. Pupils also noted dissatisfaction with clarity of pricing information and thus difficulties arose when choosing meals.

> *'You do not really know how much something is going to cost until you go to pay for it so you do not [buy it]'* (P84, FG13, M)

The majority of school staff members did not comment on school menus and pricing information in influencing adolescents' food choice. A few school staff reported that lunchtime menus were

TABLE 2 Pupils' and school staff's perceptions on the influences of adolescents' dietary choices in the school canteen.

	Participant quotations	
	Pupil	School staff
Individual (intrapersonal)		
Internal motivations		
Personal preference	'*I just pick what I like*' (P14, FG2, F) '*It would be my choice for what I want to eat*' (P25, FG4, M)	'*It's down to personal preference for what they like and what they do not like*' (P9, T, F) '*9 times out of 10, that age group are always going to go for what they prefer, and unfortunately what they prefer tends to be the less healthy options*' (P14, T, F)
Taste	'*Because always unhealthy stuff tastes better, like yeah you want to get skinny or whatever, but oh well, it tastes nice so*' (P30, FG5, F)	'*I think they are driven by what they like the taste of*' (P26, T, F)
Appearance	'*It's really all about appearance, appearance is a really big factor*' (P59, FG9, F)	'*Quite often they do not want to try something because of the look of it perhaps*' (P17, T, F) '*I truly believe kids keep with their eyes*' (P27, C, F)
Habitual intake	'*I would just get the same thing every week because you know it's nice*' (P78, FG12, M)	'*A lot of them take the same thing nearly every day, they do not alternate at all*' (P1, T, F)
Time and convenience		
Time restrictions and convenience	'*We just get panini's and that's it because it's quicker…so then you have more time outside*' (P47, FG8, F) '*It's just really short, the lunches, you kind of just want to make the most of being outside before you go back to class*' (P14, FG2, F)	'*I would say a huge factor is time and wanting to get outside rather than um actually sitting down to enjoy their meal*' (P22, T, F) '*I think it's things they can eat in their hands…they can carry outside with them*' (P8, T, F)
Lunchtime activities	'*I sometimes just want to go outside to play*' (P63, FG10, M) '*I would prefer to just grab and go, so I can go out and play football for longer with my friends*' (P10, FG2, M)	'*Well, I do think particularly the boys like to get out to play football, so they will grab a panini and a juice carton and try to eat it quickly in the dining hall or slip out and eat it outside*' (P18, P, M)
Queues	'*Sometimes if the queue is long, then I'd just get a drink and leave*' (P39, FG6, F) '*If there's big long queues, I just say forget about it and not eat*' (P79, FG11, M)	'*They do not want to queue; they want to have their time*' (P20, C, F) '*One factor I suppose would be the speed at which the dinner queue is moving. So, if there's a short queue at the snack bar, they will go there just cause it's quick and handy and they do not want to have to wait*' (P24, T, F)
Financial motivations		
Price	'*The price can be a bit dear*' (P85, FG13, M) '*Not everyone can afford spending like £3 a day on lunch*' (P62, FG9, M)	'*The pupils only have a certain amount of money to spend, that is a big thing with the students, it really is*' (P13, C, F)
Value for money	'*Sometimes the money because for a little tiny pot, it could be like £2.20*' (P14, FG2, F)	'*I think value for money is very important for them*' (P2, VP, F)
Portion size	'*They have wee bowls of fruit, but like nobody ever takes them or the fruit pots because they are like, they do not fill you up*' (P20, FG4, F)	'*Whenever they would go down to the canteen, it was sort of like the portion size that they would be looking at…so say if there was curry or something on, they'd be more inclined to go for that, not because they like the taste of it but because they'd think they were gonna get more food*' (P7, T, M)
Nutritional knowledge	'*I do not mind if it's healthy or not, it does not influence me*' (P17, FG3, M) '*Do not really know if it's healthy or not, I would just eat it*' (P32, FG5, M)	'*Awareness does not correlate with the decisions they make*' (P8, T, F) '*They have the knowledge because they are taught it in class, so I know they do get it, they know what they should be taking, but knowledge is not enough to change behaviour*' (P14, T, F).
Social environment (interpersonal)		
Peer influence	'*Like today, one person got pizza and then everyone else just got the pizza, it's just whatever everyone else gets, you have to get*' (P22, FG 4, F) '*They usually just slag you and stuff for it, like they give you a bad name or something for like eating healthier*' (P10, FG2, M). '*It's not normal to eat healthy*' (P7, FG2, F)	'*I would say it's a lot to do with what their peers are eating. I do think a lot of them would just follow on from what others have chosen, maybe would not want to eat something different, just to be seen as different*' (P6, T, F) '*I also feel if one child lifts something to eat, a line of children want to eat the same thing, they go by what other pupils are eating you know*' (P13, C, F).
Home influence	N/A	'*If they are not eating the food at home, they are not going to eat it in school*' (P2, VP, F) '*If you are used to eating a certain diet at home, whether healthy or not, that will probably be mirrored in your choices that you make in the canteen*' (P12, T, M). '*I think it very much, um, needs to be come from home as well. We can only do so much*' (P16, P, F)

(Continued)

TABLE 2 (Continued)

	Participant quotations	
	Pupil	School staff
Physical environmental		
Placement of food and beverages	*'They keep all the fruit up in the corner, so you do not really see them, but like all the unhealthy foods, like the biscuits, are right beside the tills. The apples are sort of out of the way, so you would not pick an apple because the biscuits are there, so you would just pick a biscuit'* (P14, FG2, F).	'W*hen a pupil comes in, it's the first thing that they see is what they want'* (P13, C, F). *'But there's not enough of those [salads] sitting visually would be one fault'* (P10, T, M)
Menu options and pricing information	*'You do not really know how much something is going to cost until you go to pay for it so you do not'* (P84, FG13, M) *'Sometimes like, since you do not know what you are getting, if you like have not ate in the last couple of days or have only taken a bread roll, I do not want to have to do that again…cause you do not know what you are getting, you just take lunch instead'* (P2, FG1, F).	*'They do not seem to read the menu to see what's* on' (P13, C, F) *'I'd say most days pupils just walk past and then just decide whenever they get up to, up to the canteen'* (P6, T, F)
Macro environmental		
Food provision	*'Whatever's there, I'd just ate it'* (P83, FG13, M) *'You just pick whatever is there like you do not really think about it'* (P14, FG2, F)	'*First and foremost would be what is actually on offer will determine what they are eating'* (P21, T, F) *'The variety of food on offer'* (P2, VP, F)

P, participant; FG, focus group; Y8, Year 8; Y9, Year 9; M, male; F, female; P, principal; VP, vice principal; T, teacher; C, caterer; and NA, not applicable.

displayed in their schools, however, considered them to be ineffective or overlooked by pupils.

Macro environment

Exemplar quotes to illustrate the following sub-theme are provided in Table 2.

Food provision

Pupils and school staff both cited food availability in the canteen as having a direct influence on the item's pupils were consuming daily. Pupils also perceived there to be a lack of variety served in the canteen and that the options provided can often be repetitive. According to school staff, the canteen offered a good range of food options.

Strategies to encourage selecting healthier options in the school canteen setting

Individual (intrapersonal)

Exemplar quotes to illustrate the following sub-themes are provided in Table 3.

Taster opportunities

To encourage the selection of healthier items in the school canteen, pupils' and school staff recommended providing pupils with the option to sample certain food items prior to purchasing them to minimise financial risk.

Autonomy in food choice

Some pupils reported that combined food items in the canteen were off-putting, for example, mixed vegetable dishes and pre-made fruit salads. To counteract this barrier of improved food choices and to facilitate a higher uptake of these items in the canteen, pupils suggested that options be served separately to allow independent, self-selection of these items.

School staff did not directly comment on pupil's autonomy to promote positive food decisions in the school canteen.

Rewards and incentives

The opportunity to receive rewards as a strategy to engage pupils in healthy eating practises in the canteen was a common, reoccurring sub-theme. Social rewards (e.g., trips, queue skips, extended lunchbreaks, sports activities, non-uniform day, and homework exemption pass), financial rewards (e.g., vouchers, discounted/free canteen items), and recognition rewards (e.g., certificates, awards/credit points) were reported as suitable incentives by pupils to encourage healthier choices in the school canteen. It was clear from the discussions that the concept of tracking their progress could stimulate further interaction with a reward scheme and incorporating in a competitive element at both individual and class group level.

> *'A VIP pass to the front of the line'* (P32, FG5, M)

School staff's views reflected pupils' in that they also recommended the use of social, financial, and recognition rewards to incentivise pupils to select healthier choices and considered that this would encourage pupils, in particular younger pupils, to be more proactive in their food-based decision making.

Social environmental (interpersonal)

Exemplar quotes to illustrate the following sub-theme are provided in Table 3.

Pupil-led initiatives

Pupils did not make suggestions on how their friends (e.g., pupil-led initiatives) could be a strategy for encouraging the selection of healthier items in the school canteen.

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TABLE 3 Pupils' and school staff's views on strategies to encourage selecting healthier options in the school canteen.

	Participant quotations	
	Pupil	School staff
Individual (intrapersonal)		
Taster opportunities	*'Like if they gave us a wee taster'* (P6, FG1, F) *'They could give samples at the start of the day for new foods that would come in'* (FG11, P69, M)	'*Maybe some kind of tasting type things where they get the opportunity to taste these vegetables without costing them money'* (P11, C, F)
Autonomy in food choice	*'Even if there was a place where you can make up your own fruit box and add your own fruit because people might not like the grapes or the watermelon in it, so you could make your own fruit box'* (P72, FG11, F) '*I just like doing it myself'* (P21, FG4, F).	N/A
Rewards and incentives	*'Maybe if you eat healthy, you could get 50% of your food'* (P8, FG3, M) *'You could get like a reward card, like every time the dinner lady sees you get something healthy, they stamp it or something and then once you use up 5 [stamps], you get a free lunch or something like that'* (P68, FG8, F) *'A VIP pass to the front of the line'* (P32, FG5, M)	*'Even some sort of a rewards scheme that if you choose these meals, then you are put into a draw or something at the end of the month and you can win vouchers or something'* (P2, T, F) *'Even if they had Like a loyalty card system, you know, like stamps'* (P26, T, F) *'Pupils, especially Key Stage 3 pupils, really respond to rewards and achievement points'* (P5, T, F)
Social environment (interpersonal)		
Pupil-led activities	N/A	*'I certainly think the younger pupils would be looking up to you know the older ones as role models and that could have a positive influence on them'* (P24, T, F) '*If you had those older ones maybe acting as healthy eating role models or prefects, that probably might encourage them'* (P3, T, F).
Physical environmental		
Labelling	'*Colours would help because if you say put the unhealthy options in maybe red, it would maybe drive us towards the green'* (P59, FG9, F) '*It would be nice if they could put like a green tick or something beside it to let you know what's healthy'* (P20, FG4, F)	*'The labelling of the food maybe could be better'* (P17, T, F) '*I think the traffic light system would be excellent'* (P1, T, F) *'There could be more signage around the food and encourage them that way'* (P18, P, M) *'I would maybe worry about focusing on the calorie content just for pupils who are maybe a little conscious of their weight'* (P5, T, F)
Improved information accessibility	*'You're kinda just guessing whether the food will be good or not that day… but if there was a menu, you could go 'oh I do not like it that day', so I could take a lunch and actually eat something instead of just taking a bread roll'* (P22, FG4, F)	*'I do think maybe making their parents more aware of what kinda is available in the canteen would be something that would perhaps encourage them to choose healthier options…maybe putting on Facebook or giving them [pupils] a menu out to take home every week so that the parents knew what they were eating'* (P3, T, F)
Placement manipulations	*'I would say show them more [healthier items] because they are hidden away in the fridge, like nobody ever sees them, we thought they were for the teachers, like nobody actually realised they are for us'* (P58, FG9, M) *'Like the healthy stuff is way over there, but if they seen healthy stuff's on offer, they'd be like, 'oh yeah I will go get that, I forgot about that'…it could remind them that it is there'* (P54, FG9, M)	*'The counter could be divided up into healthier options, you know, even start with the more healthier options and finish with less healthy options'* (P10, T, M) '*Try and change the positioning of it cause they have already chosen their foods before they get to the healthy options…so trying to have the first foods that they come to being the healthy ones'* (P6, T, F).
Special offers	*'If the healthy foods were just really cheap that would drive people towards them because people go for the cheap'* (P59, FG9, F)	*'Having some sort of special offers or something to sort of catch their eye on the healthier options…like a meal deal where they could get like a sandwich, the fruit and the drink, all for a better price'* (P6, T, F). *'Possibly the healthier options a bit cheaper and advertised as that'* (P10, T, M)
Macro environment		
Food provision	*'Not necessarily everything healthy, but a bit more healthy options'* (P16, FG2, M)	*'Maybe take away the unhealthier options which is what we have tried to do, but the problem with that is then you will always get those who just walk past which is bad on two accounts. Because one, they are not getting anything to eat and 2, we are not getting the income'* (P11, C, F)

(Continued)

TABLE 3 (Continued)

	Participant quotations	
	Pupil	School staff
Whole-school approach and educational practices	N/A	'*Maybe within certain subjects you know they could do activities on healthy eating. For example, for English, you could bring in like a healthy eating focus; maybe they could do a piece of persuasive writing to focus on the importance of choosing healthy foods*' (P5, T, F). *'It would be a good idea to have at least one initiative, whole school, a year and try and drive that message home because in that way you are targeting the whole school population rather than just those in Home Economics*' (P8, T, F)

P, participant; FG, focus group; Y8, Year 8 pupil; Y9, Year 9 pupil; M, male; F, female; P, principal; VP, vice principal; T, teacher; C, caterer; and NA, not applicable.

School staff recommended utilising peer networks as an effective means of facilitating positive food choices among adolescents and felt pupils were more likely to resonate with information provided by their peers than those delivered by staff. More specifically, school staff advocated for schools to implement specific roles for senior pupils to act as healthy eating ambassadors within the school to promote healthy eating.

Physical environmental

Exemplar quotes to illustrate the following sub-themes are provided in Table 3.

Labelling

When pupils were asked how best to promote selecting healthier options in the canteen, displaying nutritional labels was highlighted as a means of facilitating their ability to make informed decisions about food choices. Both male and female pupils recommended visual labelling schemes, for example, symbols or icons. Pupils also suggested that schools applying the traffic-light colour-coding system to food items in the canteen and to the school menus would be useful. In addition to nutritional labelling, pupils stated the importance of general food labelling, such as the food item name and ingredients.

> *'Colours would help because if you say put the unhealthy options maybe in red, it would maybe drive us towards the green'* (P59, FG9, F)

School staff also proposed labelling of foods and menus as an efficient strategy to facilitate positive food behaviours in the canteen. They suggested colour-coding and visual labelling, but urged the need for caution on calorie/energy labelling, stating concerns of the impact this may have on pupils who may already be weight conscious. School staff suggested that traffic-light labelling in particular would be applicable in the canteen setting and commented that pupils would be familiar with this scheme as it is covered early in the compulsory Home Economics Key Stage 3 (pupils aged 11–14 years) school curriculum. However, it was also noted that labelling schemes may be onerous on the canteen staff and adversely impact on their daily duties and should be considered.

Improved information accessibility

Another recommendation raised by the pupils was making menu and pricing information accessible in the canteen to enable them to make informed choices. Pupils suggested placing visual, eye-catching menu and pricing displays on the canteen walls that they could read readily whilst queueing. Additional menu and pricing information around the school, in classrooms, on school apps, websites and social media was also cited. Some pupils also advocated for healthy eating posters to be displayed in school, whilst others felt they would not be impactful. In addition, they expressed their desire to pre-order their meals, and to have knowledge in advance of what food items were going to be available daily.

School staff suggested further promotion of the school menus, for example, sending them to parents and uploading them on to the school apps, websites and social media platforms. School staff also recommended placing posters in different locations throughout the school.

Placement manipulations

Pupils and staff both commented on making improvements to where healthier food items were situated in the canteen. Pupils advocated for the healthier food items to be clearly visible in the canteen, whilst school staff advised ensuring that the healthier items were positioned more prominently and first in line in the serving area, as pupils can have their foods selected before having the opportunity to view the healthier options available.

Special offers

Applying special offers and reducing the price of the healthier items in the canteen was a view shared by both pupils and school staff. The concept of a healthy meal deal was reported amongst both pupils and school staff to allow pupils the opportunity to afford, for example, a healthy main meal, snack item and beverage.

> *'If the healthy foods were just really cheap that would drive people towards them because people go for the cheap'* (P59, FG9, F)

Macro environment

Exemplar quotes to illustrate the following sub-theme are provided in Table 3.

Food provision

Increasing the variety of foods on offer in the canteen was noted among pupils, with some pupils advocating for more healthy options, such as additional fruit and salad items.

School staff discussed restricting the sale of the less healthy options. However, it was also acknowledged that although the

provision of healthy food items was a priority, it was important to recognise that the canteen was a business and there was a need to find a balance between serving the healthier options and those in demand by pupils in order to maintain pupil uptake and preserve the overall financial viability of the canteen.

Whole-school approach and educational practices

Pupils did not advocate for further input from school staff to encourage healthy eating or their nutrition-based education as strategies to promote improved food choices in the school canteen.

As Home Economics is a non-compulsory subject for pupils beyond Key Stage 3 education (pupils aged 11–14 years), principals and teachers suggested a whole-school, cross-curricular approach to delivering nutrition education to pupils which should involve other departments incorporating the promotion of healthy eating into their subjects. Some examples included the English department assigning pupils written tasks on the topic of healthy eating and the art department incorporating healthy eating poster campaigns as part of the curriculum. It was noted that as a start to have even one stand-alone lesson across a number of taught subjects would facilitate pupils thinking more about their food choices and could prove beneficial. School staff also acknowledged that healthy eating promotion should not be limited to the Home Economics department and suggested additional whole-school, educational strategies to promote healthy eating such as delivering talks during assemblies and educating parents.

> *'It would be a good idea to have at least one initiative, whole-school, a year and try and drive that message home, because in that way you're targeting the whole-school population rather than those just in Home Economics'* (P8, T, F)

Discussion

This study explored pupils' (aged 11–13 years) and school staff's perspectives on the main factors influencing adolescents' canteen-based food choices and how best to encourage this population to select healthier food items within this environment. This qualitative research has identified several influential factors on food choices and recommended strategies for improvement to consider when designing future school-based interventions aiming to facilitate positive dietary behaviours among adolescents that are both acceptable to the target population and viewed as feasible for implementation by key school staff members.

In this present study, both pupils' and school staff cited habitual intakes and personal preferences as important determinants of adolescents' food choices within the school canteen. Food appearance and perceived taste were also identified as particularly salient factors, which can act as deterrents to selecting the healthier items available in the canteen. These findings support recent research by Glabska et al. (47) whereby adolescents considered sensory appeal of higher importance than health when determining food choices. Moreover, taste has consistently been identified in the literature to motivate adolescents' school-based food choices irrespective of gender or location (30, 48–52). Opportunities to sample items served in the school canteen free of charge was a strategy proposed by participants in the present study, which aligns with previous United Kingdom research (53) reporting that 9–10-year-old advocated for exposure to new foods through school 'taster sessions'.

The influence of queues on United Kingdom adolescents' food choices in the school canteen has been reported from the early 2000s (38, 54). Results from the present study confirm that queue length remains a prominent factor when making dietary decisions in the school canteen. Data from the present study also identified that long queues can negatively influence adolescents' food choices, and in line with previous studies in the United Kingdom (55) and further afield (56), can act as a barrier to school meal uptake, with pupils' often sacrificing their school lunch due to long waiting times. Thus, efforts to alleviate the impact of queue length at lunchtime, such as implementing staggered breaks for different year groups or, as suggested in the present study, providing queue skips as a reward for healthy eating, may be measures for schools to consider to both encourage the uptake of school meals and establish healthier dietary habits within this environment. Findings from the current study also correspond with past research (57) that adolescents' can be more inclined to opt for the grab-and-go options available in the canteen. As grab-and-go foods tend to be ultra-processed with typically high fat, sugar and salt contents (58), it is important that schools provide alternate nutritious, readily available grab-and-go options to support healthy school-based food choices.

In accordance with previous literature, highlighting the influential role of peer social conformity in influencing adolescents' dietary intakes (59), the present study further evidences that peer acceptance is also fundamental when considering food options in the school-setting, which can impede the selection of healthier items. Recent work has highlighted gender differences among this age group, with females having larger concern for peer perceptions than males in relation to their dietary behaviours in school (60, 61). Interestingly, these gender disparities were not apparent in the present study, with both male and female pupils reporting feeling conscious and subject to disapproval from their peers if they opted for the healthier options, directly impacting their food choices in the school canteen. Given the perceived impact peers pose on purchasing decisions, school staff in the present study proposed involving peers in school-based strategies to promote positive dietary behaviours and particularly emphasised the opportunity to utilise senior peers in healthy eating school-based initiatives. In Australia, senior pupils have proven effective in role modelling healthful behaviours among the younger pupils in secondary school (62). Additionally, in America, a peer-led, school-based nutrition education intervention among adolescents was positively viewed and reported as feasible and acceptable among pupils, peer-leaders and teaching staff, with peer-leaders also citing improved dietary practices and awareness of healthy eating as a result of their role (63). However, the feasibility and acceptability of delivering a peer-led, school-based dietary intervention in secondary schools across NI is unknown, and thus, further investigation is warranted.

Whilst peers appear to have a significant role in influencing adolescents' school-based dietary behaviours, school staff in the present study also cited the importance of home and parental influences in helping school's shape adolescents' dietary practices and were of the opinion that '*we can only do so much*'. This is comparable to an English study where secondary school headteachers and chairs of governors viewed parents as key influencers on adolescents' lifestyle habits and that any measures taken by schools to improve these behaviours can either

be supported or impaired by the home environment (64). Contrary to previous research (65), pupils' in the present study did not acknowledge their parents or their home environment as an influential factor on their food choices in school, which may reflect how this population group place greater importance on expressing their own individual autonomy at this life stage. Future work to determine NI parents'/guardians' perspectives on both their own and the school's responsibilities in influencing adolescents' food choices within the school-setting may be worthwhile.

Ultimately, participants in this study cited that adolescents' food choices are influenced by what is available to them. In NI, assisted by a checklist, individual schools are required to self-monitor their compliance with the school food standards (66). In a recent study, NI stakeholders' commented that adherence to the school-based standards may be negatively impacted due to a lack of monitoring (15), thus, implementation of a systematic monitoring process or procedure may be beneficial to enhance the provision of nutritious foods across NI schools.

Based on findings from the present study, pupils would welcome more frequent information on school meal choices on the menu and food prices, which would assist with pre-planning their meals. In addition to suggesting improvements to menu and pricing information, some pupils advocated for a pre-order lunch system, which has been previously shown to increase the selection of fruit, vegetable and low-fat milk items among youth in US school canteens, however, more research is required with larger sample sizes and in alternate locations to generalise these findings (67).

Incorporating labelling schemes for items served in the canteen was a leading strategy recommended from both pupils and school staff to improve food choices. Pupils and staff suggested visual labels, with pupils placing emphasis on the usage of icons and symbols. This suggestion supports previous research (68) which showed subtle messaging around foods was more impactful than explicit messaging, with adults more likely to select healthier items labelled with a heart logo than those with labels stating 'a healthy choice'. Discussions with pupils and school staff also indicated the potential usage of colour-coded labels including traffic-light labels. A study conducted in secondary schools in Belgium found that increasing the number of healthier beverages available and applying a traffic-light labelling scheme to all items, effectively reduced adolescents' consumption of sugar-sweetened beverages (SSB's; labelled red) in both the school canteen and vending machine (69). Nonetheless, the importance of consultation with catering staff in individual schools prior to the design and implementation of labelling schemes was acknowledged in the present study to ensure feasibility with caterer's daily routines, which aligns with previous research (70) reporting that school staff's time constraints acts as one of the most dominant challenges to the implementation of school-based healthy lifestyle programmes.

Both pupil and school staff participants had a level of awareness of how adolescents' food choices can be dependent on the location of items in the canteen, hence, manipulating the placement of the healthier options to more visible and accessible locations was a desirable concept among both stakeholder groups. Placement manipulations are a form of 'nudge intervention' which are generally minimal cost to implement (71). Implementing placement manipulations has resulted in increased and decreased purchases of fruit pots and SSB's/sweet-baked goods, respectively, within United Kingdom secondary school canteens, albeit the evidence was limited (71). Further, school staff perceived items positioned first in the canteen serving area can directly impact adolescents' food choices, and therefore, proposed serving the healthier items first as an effective strategy to improve food selection. This strategy has proven effective in breakfast buffet lines, with >75% of individuals opting for the first items they encountered (72), which could be easily transferred for implementation within school canteens.

The concept of receiving rewards to engage adolescents' in healthy food-related behaviours in the school canteen has been positively viewed as a suitable strategy among socially deprived NI adolescents (aged 11–12 years) (30). Our findings in this study address a gap in the literature by further confirming the acceptability and feasibility of reward schemes (social, financial and recognition rewards) as incentives to promote positive food choices in school from the perspectives of both adolescents and school staff from a range of socio-economically diverse schools located in numerous district locations across NI. Tangible and praise rewards have previously proven effective in achieving positive food choice change by increasing fruit and vegetable consumption among elementary school children, although tangible rewards were more effective in the short and longer-term (73).

Overall, in line with a recent review (74), this qualitative study has identified various influential factors impacting adolescents' food choices in secondary school canteens, with many also acting as barriers to the selection of the healthier food items in this setting. Moreover, similar to previous research with key school stakeholders outside the United Kingdom (75, 76). Participants in the present study perceived schools to be a viable setting to nurture healthy eating habits in adolescents and had clear ideas on practical and acceptable solutions, which could be implemented to better support adolescents making improved food choices in the school environment.

Strengths and limitations

A strength of this study is that we successfully recruited a relatively large sample of mixed-gender pupils and staff in schools with socio-economically diverse profiles across a wide range of geographical locations in NI, including both urban and rural areas, increasing the generalisability of these findings. Given the complexity of adolescents' dietary behaviours, the recruitment of adolescents, principals, vice-principals, teachers, caterers and EA staff enabled a holistic view of the primary factors influencing adolescents' food choices within the school-setting and novel suggestions for improvement within this environment to be obtained, whilst also facilitating comparisons between a range of key stakeholder groups to be investigated. To our knowledge, this is the first study to explore NI school staff's perspectives on adolescents' school-based food choices and their recommendations for feasible intervention components to facilitate improvements in their dietary behaviours within this setting and to also compare these with the views of adolescents across NI. Moreover, schoolteachers in this study were recruited across a variety of subject disciplines, reducing the risk of selection bias of individuals particularly interested in the promotion of healthy eating within their school.

When interpreting the results, several limitations should be considered. It must be acknowledged that although a large sample

of pupils of mixed-gender ($n = 52$ female; $n = 34$ male) were recruited to this study across 2-year groups, selection bias cannot be overlooked as only pupils who returned their study forms were eligible to be selected by a teacher for participation as the researcher (not affiliated with schools) was not involved in the selection process. Additionally, it is possible that pupils may have felt the need to provide desirable responses regarding their school's food practises and their dietary behaviours, however, all pupils were informed by the researcher at the beginning of the focus groups that their responses would remain anonymous. Within the sample of pupils, 60% were female and 40% male, which is unlikely to introduce gender bias, however, it is important to note, that the participating school staff were predominantly female. Therefore, future work should consider achieving a gender-balanced sample by targeting male teachers within schools to encourage participation to determine if any gender differences may be present among school staff on this topic.

Conclusion

Collectively, this research highlights the complexity of the multilevel factors which influence adolescents' food choices within the school canteen and identifies barriers to achieving healthier dietary behaviours. Involving pupils and school staff to explore these barriers has highlighted a number of possible practical solutions to improve food choice in school, in particular those that are low-cost and non-labour intensive. Using the ecological framework, suggestions for improvement of food choices were identified at the individual (e.g., rewards), social (e.g., pupil-led initiatives), physical (e.g., labelling) and macro environment (e.g., whole-school approaches) level. At macro level, it is recommended that schools may wish to review the pricing policy to consider offering for example meal deals or special offers, with clear menu and labelling strategies to improve information for pupils at the point of purchase and also consider the location and placement of foods on sale. Additionally, it may be beneficial to implement a whole-school initiative, for example, healthy eating days/themes in the canteen to encourage all pupils to make healthier choices. This study highlights the importance of early consultation with school stakeholders to identify the existing influential factors on adolescents' school-based food choices and which strategies are viewed as both acceptable to the target population and suitable for implementation within the school-setting by key school staff members which should be considered in future intervention design. Further research is needed to determine the feasibility of implementing these intervention strategies within the school-setting and to test their effectiveness in practice.

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 Ulster University Research Ethics committee FCBMS-20-016-A; REC/20/0031. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

LD, AH, and AG: conceptualisation, data coding, data analysis, and interpretation of findings. LD, AH, SB, and AG: methodology. LD and SB: recruitment. LD conducted the interviews and focus groups and drafted the manuscript. AH, SB, and AG critically reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1227075/full#supplementary-material

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Facilitators and barriers to physical activity among English adolescents in secondary schools: a mixed method study

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Background: It is evident that physical activity (PA) programmes implemented in schools were not effective in improving PA behaviours among adolescents. This study investigated students' perceptions of barriers to PA among inactive English adolescents in secondary schools based on the Capability, Opportunity, Motivation, and Behaviour (COM-B) model, the Behaviour Change Wheel (BCW), and Theoretical Domains Framework (TDF). The study compared barriers faced by inactive and active groups participating in sports and PA in secondary schools to identify sources of behaviour contributing to inactivity.

Methods: A pre-intervention online survey was distributed to affiliated schools by 233 Teaching Schools Alliances (TSAs) as part of the monitoring and evaluation of the Secondary Teacher Training study. Data were cross-tabulated to analyse activity levels and behavioural barriers for active and inactive groups, using the COM-B domains. The research team followed a seven-step process to categorise barriers based on their relevant domain in the TDF mapped to the COM-B.

Results: The findings were derived from one of the most extensive surveys of adolescents ever undertaken involving 200,623 active and 8,231 inactive respondents. The study identified 52 barriers and 68 behaviours that prevent adolescents from participating in PA. Psychological and social barriers were found to affect all activity levels, genders, and ethnic groups, with a lack of confidence and self-consciousness being the most prevalent. Certain demographic groups, such as those from minority ethnic groups and disabled individuals, were found to be overrepresented among inactive populations. The finding of the study indicated that there were common barriers that affected both inactive and active groups, with further similarity when examining barriers between active and inactive girls. The study also found that girls were more likely to experience the main barriers compared to boys, while inactive boys were more likely to encounter these barriers compared to active boys. The findings suggest that common barriers could be addressed across the population, while recognising some differences in demographics, and the need to provide personalised support. Targeted interventions are also suggested for all girls and inactive boys.

Conclusion: This study highlights the range of barriers that impact adolescents and provides insight into potential mechanisms for behaviour change, including intervention functions, policy categories, and evidence-based behaviour change tools. The study highlights the need for further research to address the barriers to PA among adolescents, particularly those who are inactive. Utilising the findings of this study, future research should investigate the effectiveness of novel digital

exercise interventions and policies in increasing PA levels among children and adolescents. Complex digital exercise interventions, including conversational AI solutions, could provide personalised tools to identify and revolutionise support around the multitude of barriers that impact adolescents globally.

KEYWORDS

adolescents, COM-B model, physical activity, digital exercise intervention, inactivity, secondary schools, conversational AI

1. Introduction

There is a growing body of evidence advocating the benefits of physical activity (PA) in enhancing physical and emotional health (1), cognitive health (2) and academic attainment (3, 4) among adolescents. Engaging in sustained PA during adolescence can lead to lifelong PA behaviours (5–7) reducing the likelihood of inactivity in adulthood. Unfortunately, approximately 80% of adolescents globally are 'insufficiently active' highlighting the need to prevent rises in the health consequences associated with physical inactivity (8–10). Schools play a crucial role in promoting healthy behaviours (8) as they provide equal opportunities for all students from all backgrounds to engage in regular PA, regardless of parental behaviour, social or economic status (10).

School-based physical education (PE) plays a significant role in promoting daily moderate to vigorous PA as well as reducing sedentary time among adolescents (11–13). However, there is growing concern that sport and PE provision, particularly in secondary schools, has decreased in recent years (14) and this trend is continuing. This decline can be attributed to a range of factors, and although there is consensus regarding the need to improve adolescents PA behaviours, this goal is often encumbered by a lack of time, resources and capacity required to achieve progress (15, 16).

A Cochrane systematic review, encompassing 89 studies with 22 involving adolescents, compared various interventions, and unveiled limited evidence regarding the effectiveness of school-based PA interventions (10). This evidence was reinforced by a worldwide umbrella study published in the Lancet (8). The study found that the poor implementation of PA interventions was a major barrier to the success of school-based interventions and highlighted the importance of supportive social and built environments in driving adolescent activity. It concluded that innovative approaches, informed by the input of children and adolescents, are necessary to develop novel interventions in educational settings. Interventions should be targeted at older inactive adolescents who have been neglected because of competing factors in the education system (e.g., exams) and beyond (8, 15). However, there is a lack of knowledge about the specific barriers to PA for inactive groups and whether these differ from their more active counterparts. Gathering such evidence becomes imperative to prioritise support for inactive groups and pinpoint the barriers that warrant priority consideration during the development of PA interventions.

Inactive adolescents are more likely to be from lower socio-economic groups, be female or be from ethnically diverse groups (17–20). Although there is substantial evidence supporting the profile of inactive adolescents, the specific barriers affecting them are relatively less explored. However, studies have shown that barriers to PA may be exacerbated by network effects and associated with those of their friends (21). There is also evidence of a correlation between being overweight or obese (22) and differences in barriers to PA participation based on gender (23).

A systematic review of adolescent barriers and facilitators to PA, found common barriers experienced by both United Kingdom and non-United Kingdom adolescents (17, 20). These included attitude towards PA, motivations and perceptions of competence, femininity, friends and family influence, physical and motor skills, time, and competing activities (17, 20). Individual factors such as lack of time, changes in workload, and interest in other leisure activities were also identified as barriers for adolescents whose participation in PA decreased over time. Other factors influencing PA participation included negative feelings when active, extrinsic motivation and poor social support. Overall, the evidence base is limited by small sample sizes, and there remains an inadequate amount of data on inactive adolescents and differences between active and inactive groups. Furthermore, there is a lack of evidence on approaches that could be used to target specific behaviours that may prevent PA. A lack of knowledge of evidence-based tools to target the wide range of adolescent behaviours that influence PA levels is also evident.

PA interventions must draw upon established theories to gain deeper insights into adolescents' habits and behaviours, thereby enabling the development of more impactful interventions. One theoretical framework that can be useful in this regard is the Capability, Opportunity, Motivation and Behaviour model (COM-B) (24). The Behaviour Change Wheel (BCW) and Theoretical Domains Framework (TDF) can also be used in conjunction with the COM-B to support intervention design (24, 25). The BCW is a theoretical framework used extensively to support intervention design and evaluation in public health, including PA interventions (26, 27).

To improve the design of behaviour change interventions, the TDF is often used in conjunction with the COM-B model (25). The TDF consists of 14 domains that provide insight into the determinants of behaviour across the domains of capability, opportunity, and motivation (25). In this study, the TDF is employed to categorise specific factors that may impact PA behaviour. Simultaneously, it is integrated with the BCW to categorise intervention functions, and the behaviour change taxonomy (28) to identify relevant behaviour change tools. This approach informs the design of future interventions

and used as a foundation for exploring perceived barriers and facilitators to PA in the adolescent population.

Schools have the potential to play a pivotal role in enhancing PA levels among adolescents. However, numerous challenges within the system often lead to missed opportunities. Both national and international agencies recognise the importance of evidence-based multi-component approaches that necessitate minimal resources and can be tailored for inactive groups. To develop effective interventions that cater to the needs of adolescents, particularly those who are inactive, utilising existing evidence and understanding the barriers and facilitators to PA are pivotal in creating innovative approaches. This study aims to provide a comprehensive evidence base of barriers and facilitators to PA, with a focus on inactive adolescents. It applies the BCW and TDF to detail the intervention functions, policy categories and behaviour change tools that could be used to design successful interventions in schools and extend their application across the public and private sectors. The study compares inactive and more active groups to explore potential differences in reported barriers. Finally, the study discusses the feasibility of implementing the identified intervention functions in schools, considering the challenges in the education sector and considers the use of novel digital approaches to deliver interventions.

The hypothesis and research questions for this study are:

Adolescents can provide evidence of barriers faced by inactive and more active groups participating in PA in secondary schools to identify sources of behaviour contributing to inactivity.

1. What are the barriers and facilitators to PA among inactive adolescents in schools?
2. What are the differences in barriers reported between inactive and more active groups of adolescents?
3. What are the intervention functions, policy categories, and behaviour change tools that can be used to design effective interventions to increase PA levels among inactive adolescents in schools?
4. How can the identified intervention functions be feasibly implemented in schools, considering the challenges in the education sector?

2. Methods

In 2019, Sport England invested £13.5million of National Lottery funding into a Secondary Teacher Training programme, in partnership with the Association for Physical Education, the Youth Sport Trust, Activity Alliance and the Teaching Schools Council. The aim of the programme was to support teachers with resources and training to engage all students in sport and PA. As part of the monitoring and evaluation of the programme, a pre-and post-online survey was distributed by 233 Teaching Schools Alliances (TSAs) to affiliated schools. The results for this study are based on the pre-intervention online survey results from September 12th, 2019, to October 7th, 2021.

Due to the unprecedented impact of the COVID-19 pandemic, secondary schools were compelled to close their doors to all but vulnerable students, from March to July 2020. Consequently, the online survey was temporarily paused during this period, which lasted from March 2020 to September 2020. Although a partial resumption of the program occurred during the autumn term, it was subject to various restrictions, such as implementing 'bubbles' and adhering to safety protocols. However, the program's continuity was once again disrupted as a second wave of school closures took place from January to March 2021, following a brief return to school for 1 day in January. The COVID-19 pandemic did impact on certain individuals, as some respondents mentioned 'COVID' as a barrier. Assessing the overall impact of COVID-19 on the results proved challenging, as similar barriers were reported before, during, and after the pandemic. Some of these barriers were exacerbated during this period and other studies provide evidence of this (29).

2.1. Question design

To obtain a comprehensive understanding of students' perceptions, habits, and behaviours regarding PE, school sports and PA, a range of self-report questions was included in the design of an online survey:

- PA habits.
- Perceptions of PA and sport lessons at school.
- PE, sport, and PA preferences.
- Perceptions of the wider benefits of sport and PA.
- Self-reported physical and mental well-being.
- Barriers to PA.

The following data collected as part of the evaluation of the Secondary Teacher Training project was analysed:

- Gender.
- Ethnicity.
- Number of days participating in PA per week.
- Perceived barriers to PA.

To elicit a comprehensive range of barriers to PA from the respondents, the survey included a multiple-choice question specifically addressing perceived barriers to PA, while also providing another option to encourage open-ended responses. Respondents that selected 'other' as a response, input either single word text or full sentences to explain the barriers they experienced to PA.

2.2. Online survey distribution

A convenience sample of adolescents was selected to pilot the survey, thus allowing for an expedient data collection process, and providing initial insights into the questionnaire's suitability and comprehension among the target population. Once the survey was finalised an online survey link was embedded into an email distributed to TSAs. This was cascaded to their associated schools who subsequently arranged completion by their students. The survey was administered at various time points, which captured the influence of potential barriers that may vary across different temporal contexts. Guidance was given to teachers as to how and when to administer the survey to students.

Considering the large sample size, it was not feasible to eliminate the potential influence of teachers or school staff on students during the administration of the survey. However, given the diverse range of

barriers reported, often pertaining to personal and sensitive factors, it is improbable that such influence would have significantly affected the results of this study. A further limitation of the study is that the quantitative research only allowed for the selection of ten barriers in the survey completed by respondents, which may have excluded potential barriers not included in the quantitative analysis. This is a common limitation of survey methodologies used in PA research. A mixed-method approach to the research, allowed for further barriers to be identified through qualitative research.

2.3. Coding and analysis of barriers

Out of 23,550 respondents that selected 'other' (1,650 inactive and 21,899 active), 6,725 responses were coded using a combination of deductive and inductive methods in chronological order. The remaining 16,825 responses were deemed irrelevant, unintelligible, or had "fuzzy" boundaries and were thus excluded from the analysis.

The coding of responses involved a combination of deductive and inductive methods to create a comprehensive list of barriers to PA (30). Responses that aligned with the pre-defined codes were deductively coded, while those that did not were inductively coded. A total of 958 responses were added to the deductive codes and 6,297 responses were inductively coded into 42 new codes, resulting in a total of 52 codes or barriers to PA. A discrepancy of 530 responses occurred due to some respondents citing multiple barriers in their responses. All codes and responses were checked for accuracy by members of the research team and subsequently given a numeric value to aid quantitative analysis. Intra-coder reliability was employed in this study to enhance the coding process of qualitative data (31). A subset of the data was coded at different time points, allowing for the assessment of agreement between the coder's coding decisions. This approach ensured the evaluation of consistency in coding decisions made by the same coder over time, thereby enhancing the reliability and accuracy of the identified codes.

2.4. Analysis

Data were cross-tabulated to analyse the activity levels of adolescents and to compare if there were any statistical differences in behavioural barriers (i.e., COM-B domains) for those who are inactive (i.e., less than 30 min a day across the week) compared to those who are more active (i.e., more than 30 min a day, 1 day or more per week). The data were analysed by gender, ethnicity, and disability to determine if there were any significant statistical differences. A two-tailed t-test was employed to analyse the two groups and determine if there was a significant difference between the means of the inactive and active groups (32). The data were organised into two groups, and the t-statistic was calculated using the means, standard deviations, and sample sizes of the two groups. By using a well-established statistical procedure like the two-tailed t-test, which considers both directions of difference, the study aimed to ensure robustness in evaluating and comparing the means of the two groups. Furthermore, organising the data into the respective groups and calculating the t-statistic using the means, standard deviations, and sample sizes of each group allowed for a comprehensive assessment of the significance of any observed differences. The research team also checked the accuracy and validity of the data at all stages.

2.5. Analytical framework

The research team applied the COM-B model as a framework to categorise the barriers according to the three main sources of behaviour - capability, opportunity, and motivation (24). Subsequently, the TDF was then applied to the COM-B model to reveal fourteen domains. Afterwards, the research team discussed and checked each barrier and mapped it accordingly to the most relevant domain in the combined COM-B and TDF table. A source of behaviour was identified for each barrier, alongside facilitators (i.e., intervention functions, policy categories and behaviour change tools) of change for each behaviour. During this stage of the research, it was apparent that some of the barriers belonged in multiple domains. For example, a 'lack of confidence in my ability' may have a physical and a psychological component. The qualitative data was subsequently reviewed to determine whether the 'other' responses provided by the respondents pertained to multiple domains. If this was evident, then the barrier was added to the relevant domain. This process increased the number of behaviours to 68 from 52. Utilising the COM-B and TDF provides construct validity allowing for direct alignment with existing theories and concepts related to the barriers being examined.

2.6. COM-B and TDF, behaviour change wheel and TDF

The research team followed a seven-step process to examine the barriers and categorise them according to the most relevant domain in the TDF mapped to the COM-B (24). To identify target behaviours, the team utilised steps 2–3 of the COM-B framework. Next, the necessary changes were specified for each behaviour to facilitate increased PA within each domain, as outlined in step 4. Pre-defined intervention functions and policy categories were selected using the COM-B, which were later screened for their relevancy. The team then utilised the behaviour change taxonomy (28) to identify suitable behaviour change tools that were relevant to each behaviour. Step 8 considers the mode of delivery to utilise behaviour change tools and does not form part of this study. However, the study affords a contribution to knowledge that will inform decision-making for future modes of delivery and discusses potential modes to consider in future.

Stage 1 – Understand the behaviour:

1. Define the barrier in behavioural terms through analysis of the study data.
2. Select the target behaviour.
3. Specify the target behaviour.
4. Identify what needs to change.

Stage 2 – Identify intervention options:

5. Identify intervention functions.
6. Identify policy categories.

Stage 3 – Identify content and implementation options:

7. Identify behaviour change techniques.
8. Identify the mode of delivery.

2.7. Ethics statement

Institutional ethics approval (ER15365244) was granted for the study, participants provided informed consent and all responses were anonymous. An 'opt out' option was provided for all demographic questions should respondents prefer not to disclose this information.

3. Results

In this section, a comparison is made between the demographic characteristics of inactive and active adolescents, to identify any differences between the two groups. Next, the main barriers to PA for each group are reported to identify the 'priority' barriers that could be targeted by future interventions. Finally, all the reported barriers are presented in Table 1, which provides a comprehensive overview of the barriers as well as potential facilitators of behaviour change, including intervention functions, policy categories and behaviour change tools.

The survey was completed by a total of 208,854 adolescents between the ages of 11 and 18, with the majority identifying as being either male (52%) or female (43%). The majority of respondents ($n = 200{,}623$) were classified as active, indicating their engagement in an average of at least 30 min of moderate to vigorous PA (MVPA) on at least 1 day per week. In contrast, the inactive group ($n = 8{,}231$), engaged in PA for less than 30 min per day of MVPA, on average, across the week. While the inactive group represents just under 4% of the sample, it should be noted that the total number of inactive adolescent respondents is the largest ever reported in the United Kingdom. The overall survey response is also the largest in the United Kingdom compared with the national Sport England Active Lives survey, which achieved 120,000 students and parents' responses during the 2021/22 academic year (18).

While the study utilises a representative sample, caution should be exercised in generalising the findings to all adolescents in the United Kingdom, as regional differences and school-level variations may influence the identified barriers and facilitators. The study also relies on self-reported data, which introduces the potential for recall bias and social desirability bias. This may result in underreported barriers to PA or socially desirable responses, potentially distorting the representation of factors influencing activity levels (Figure 1).

This table illustrates the frequency of participation in moderate to vigorous PA among adolescents. It displays the number of days on which the participants engaged in at least 30 min or more of MVPA over the course of an average week. The data provide insights into the distribution and extent of PA levels among the adolescent population.

3.1. Demographics

3.1.1. Gender

Table 2 displays the profile of the active and inactive groups. The proportion of girls and boys in both groups was found to be similar, however, a significantly higher percentage of participants in the inactive groups identified as "other" or preferred not to disclose their gender ($p < 0.01$).

Further analysis of the data by gender resulted in a statistically significant ($p < 0.001$) difference between the inactive (47% girls and 40% boys) and active groups (52% girls, 44% boys). Proportionally the difference between the 'inactive' and 'active' groups was similar to the overall average (51% girls, 44% boys). However, the lower percentages in the 'inactive' group were due to a greater number of participants identifying as an 'other gender' (5% in active group and 2% in active group) or having a preference not to disclose their gender (7% in inactive group and 3% in active group). This indicates a slightly higher level of gender diversity and/or a reluctance to share or identify in gender terms within the inactive group.

3.1.2. Ethnicity

The majority (71%) of survey respondents identified as 'White British or English'. National data is not collected on the population of adolescents. However, the proportion of 'White British' adolescents is lower than the national average (81%) for adults in England and Wales (33). The findings support previous research that found a higher proportion of individuals from ethnically diverse backgrounds in the inactive population. Specifically, the inactive group had 14% fewer 'White British' respondents and a greater proportion of 'Black or Black British' (>66%) and 'Asian or British Asian' (>17%) respondents compared to the active group.

3.1.3. Disability

Just under 10% of all respondents were disabled. Among these respondents, a higher proportion of disabled adolescents were found to be in the inactive group (16%) compared to the active group (9%) with this difference being statistically significant ($p < 0.001$). Out of the total number of disabled respondents surveyed, only 1% required support to participate in PA, compared with 4% of the inactive group.

The results indicated that the inactive group were more likely to be from ethnically diverse backgrounds or be disabled and require additional support to participate in PA. Inactive groups were more likely to identify their gender as "other" or preferred not to disclose their gender, compared to the active group. Girls were not more likely to be inactive, which is contrary to the evidence presented in the literature.

3.2. Barriers to PA

The barriers to PA reported most frequently for both active and inactive groups were 'feeling self-conscious' ($m = 42\%$) and a 'lack of confidence' ($m = 41\%$) when participating in PA (Figure 2). Other notable barriers included 'lack of time' ($m = 31\%$) and 'no one to take part with' ($m = 25\%$). These barriers are largely social and psychological factors that impact on an individual's habits and behaviours related to PA.

There were statistically significant differences ($p < 0.001$) in the reporting of certain barriers between the active and inactive groups. The inactive group was more likely to report 'lack of confidence' (>12%), 'feeling self-conscious' (>10%) and 'have not found something I enjoy' (>59%) as prominent barriers. Furthermore, 'lack of time' was more frequently stated as a barrier by the active group, providing evidence that the more active cohort had limited time for further activity. A higher percentage of students in the inactive group (35%) expressed not having found a sport or PA that they enjoy, in contrast to the active group (21%). This finding highlights a potential requirement for assistance in discovering an activity that aligns with their needs and preferences.

TABLE 1 Analysis of barriers and facilitators.

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
Physical capability Physical skill, strength, or stamina.	**Physical skills** An ability or proficiency acquired through practice.	Health problem or injury.	Support to overcome physical limitations.	•Training •Enablement	•Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Graded tasks •Behavioural rehearsal/practice
		Disability.	Support to overcome physical limitations.	•Training •Enablement	•Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Graded tasks •Behavioural rehearsal/practice
		Lack of fitness, stamina or strength.	Support to improve physical fitness and strength.	•Training •Enablement	•Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Graded tasks •Behavioural rehearsal/practice
		Overweight/underweight.	Support to reduce weight.	•Training •Enablement	•Guidelines •Service provision	•Instruction on how to perform behaviour •Graded tasks •Behavioural rehearsal/practice
		Lack of confidence in their ability.	Support to improve physical skills.	•Training •Enablement	•Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Graded tasks •Behavioural rehearsal/practice
Psychological capability Knowledge or psychological skills, strength, or stamina to engage in the necessary mental processes.	**Behavioural regulation** Anything aimed at managing or changing objectively observed or measured actions.	Overweight/underweight.	Support to manage weight effectively.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Mental health, anxiety, depression.	Support to overcome mental health problems.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions •Conserving mental resources
		Tiredness/lack of energy/ lack of sleep.	Support to improve sleep and develop good habits to improve energy levels.	•Education •Training	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Food prevents me from being physically active.	Support to overcome mental obstacles and improve relationship with food.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Laziness/cannot be bothered to be physically active.	Support to develop a habit and reward of doing PA.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Judgement (others or self) of adolescent body image during sport/PA.	Support to improve person's perception of their own body.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Judgement (others or self) of adolescent's appearance during sport/PA.	Support to improve their perception of their appearance.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Health problem or injury.	Support to overcome psychological barriers due to health problem or injury.	•Education •Training •Enablement	•Communication/marketing •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Feeling self-conscious or shy during PA.	Support to overcome mental obstacles - reduce unwanted feelings.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Previous negative experiences of PA.	Provide support to have empathy and reassurance.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Fear of the unknown when being physically active.	Support to overcome fears of what may happen during PA.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Lack of time to participate in PA.	Support to develop daily habit of PA (e.g., 5 min, active breaks etc.).	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Perceived to be too old or too young to do a PA or sport.	Support to overcome psychological barriers about age.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Too much computing/tv devices/screen time.	Support to overcome psychological dependency on screen time/tv/devices.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Emotional isolation.	Support to overcome emotional isolation.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Being bullied before, during or after PA.	Support to help deal with instances of bullying.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Negative reaction from others (i.e., people being unkind) before, during or after PA.	Support to help deal with instances of people reacting negatively.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
		Weather.	Support to deal with psychological barriers caused due to the weather.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines Service provision	•Problem solving •Self-monitoring of behaviour •Information about antecedents •Behaviour substitution •Reduce negative emotions
	Knowledge An awareness of the existence of something.	Lack of information to be aware of PA opportunities.	Know more about how/ where to do PA.	•Education •Training •Enablement	•Communication/marketing •Guidelines •Service provision	•Instruction on how to perform behaviour •Information about health consequences •Biofeedback •Information about antecedents •Information about social and environmental consequences
		Mental health, anxiety, depression.	Information about the benefits of PA to mental health.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Information about health consequences •Biofeedback •Information about antecedents •Information about social and environmental consequences
		Too much computing/tv devices/screen time.	Information about the importance of achieving a balance of screen time etc. and PA during the week.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Information about health consequences •Biofeedback •Information about antecedents •Information about social and environmental consequences
		Prioritise education/ homework.	Information about achieving a healthy balance including education/homework and PA.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Information about health consequences •Biofeedback •Information about antecedents •Information about social and environmental consequences

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		No one to take part with (i.e., friends).	Support to understand how PA can be performed alone.	•Education •Training •Enablement	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Information about health consequences •Information about antecedents •Information about social and environmental consequences
		Weather.	Information about how to do PA when weather conditions are not ideal.	•Education	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Instruction on how to perform behaviour •Information about health consequences •Information about antecedents •Information about social and environmental consequences
Social opportunity Opportunity afforded by interpersonal influences, social cues, and cultural norms that influence the way that we think about things, e.g., the words and concepts that make up our language.	**Social influences** Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviours.	No one to take part with (i.e., friends).	Support to identify people to take part with.	•Environmental restructuring •Enablement •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Lack of time to participate in PA.	Support to develop a daily habit of PA.	•Environmental restructuring •Enablement •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Restrict PA participation due to age.	Overcome age limitations.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Loneliness.	Develop social connections through PA.	•Environmental restructuring •Enablement •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Prioritise education/ homework.	Prioritise time to be active (active breaks etc.).	•Environmental restructuring •Enablement •Modelling •Restrictions •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Being bullied before, during or after PA.	Support to find alternative PA option, talking to someone.	•Environmental restructuring •Enablement •Modelling •Restrictions •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Too much computing/tv devices/screen time.	Prioritising time to be active, healthy routine.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Negative reaction from others (i.e., people being unkind) before, during or after PA.	Support to find alternative PA option, talking to someone.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Family and/or friend influences which prevent participation in PA.	Support to overcome barriers to PA presented by friends and family.	•Environmental restructuring •Enablement •Modelling •Restrictions •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Lack of support to be physically active.	Try and identify support from others, develop agency so can take control of what they want to do.	•Environmental restructuring •Enablement •Modelling •Restrictions •Modelling	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Religion restricts time to participate in PA.	Develop routine for PA, discuss how to incorporate PA with family/friends, adapt to something more achievable.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Gender prevents participation in PA.	Support to overcome gender barriers to sport and PA.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Judgement (others or self) of adolescent body image during sport/PA.	Support to overcome other people's perception of appearance during sport/PA.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulations •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Judgement (others or self) of adolescent's appearance during sport/PA.	Support to overcome other people's perception of appearance during sport/PA.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Other people, peers, teachers have an influence on people's reason to participate.	Support to overcome barriers presented by other people including teachers and peers.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Lack of diversity and equality prevent opportunities to be physically active.	Support to provide equal opportunities for all to participate in PA.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward
		Not finding suitable ability level to participate in PA/ Sport.	Support to find opportunities at a similar level.	•Environmental restructuring •Enablement •Modelling •Restrictions	•Communication/marketing •Environmental/social planning •Guidelines •Regulation •Service provision	•Social support (practical) •Social support (general) •Social comparison •Information about others approval •Social reward

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
Physical opportunity Opportunity afforded by the environment involving time, resources, locations, cues, physical 'affordance.'	**Environmental context and resources** Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour.	Lack of transport.	Support to find alternative local opportunities to be physically active.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment
		Lack of local provision/ opportunities.	Support to identify opportunities or create new ones.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment
		PA provision is not accessible.	Identify alternative provision or adapt to independent provision.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment
		Weather.	Support to overcome physical limitations caused due to the weather.	•Environmental restructuring •Enablement •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		COVID-19.	Rest, do PA at home/ online (social) if feel well.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Adding objects to the environment
		Distractions take attention away from PA.	Develop better routine/a habit of doing PA.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment
		Lack of equipment to participate in PA.	Support to find alternative provision, low/no equipment workouts.	•Environmental restructuring •Enablement •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Restructuring the physical environment •Restructuring the social environment •Adding objects to the environment
		Not feeling safe in environments where PA takes place.	Support to find safe space to do PA.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment
		Isolation.	Be active at home or online or at school.	•Environmental restructuring •Enablement •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Lack of money to fund PA participation.	Support to be given or earn money or find cheaper/free activities.	•Environmental restructuring •Enablement •Restrictions •Training	•Guidelines •Environment/social planning •Service provision	•Social support (practical) •Prompts/cues •Remove aversive stimuli •Restructuring the physical environment •Restructuring the social environment •Avoidance/reducing exposure to cues for the behaviour •Adding objects to the environment
Reflective motivation Reflective processes involving plans (self-conscious intentions) and evaluations (beliefs about what is good and bad).	**Beliefs about capabilities** Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use.	Lack of confidence in their ability.	Support to improve confidence.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Problem solving •Instruction on how to perform behaviour •Demonstration of the behaviour •Behavioural practice/rehearsal •Graded tasks •Verbal persuasion about capability •Focus on past success •Self-talk
	Intentions A conscious decision to perform a behaviour or resolve to act in a certain way.	Procrastination particularly negative thoughts about being physically active.	Support to improve mental strength and learn how to reason more effectively.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Goal setting •Information about health consequences •Incentive
		Do not like or do not want to be physically active.	Support to understand that PA would be a good thing to do.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Goal setting •Information about health consequences •Incentive
		Lack of motivation to be physically active.	Support to improve motivation to do PA and find purpose or meaning.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Goal setting •Information about health consequences •Incentive
		Other interests.	Support to understand that PA would be a good thing to do.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Goal setting •Information about health consequences •Incentive
		Do not like socialising with others during physical activity.	Overcome social obstacles to PA.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Goal setting •Information about health consequences •Incentive

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
	Social/professional role and identity A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting.	PA is not part of my identity.	Believe that it would be a good thing to do for health reasons.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•No evidence of successful behaviour change tools in this domain
	Beliefs about Consequences Acceptance of the truth, reality, or validity about outcomes of a behaviour in each situation.	Fear of getting hurt while being physically active.	Support to overcome thoughts about being injured.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Information about health consequences •Salience of consequences •Information about social and environmental consequences •Anticipated regret •Information about emotional consequences •Pros and cons •Comparative imaging of future outcomes •Material incentive (behaviour) •Incentive (outcome) •Reward (outcome)
		Competition (competitive sports etc.) or competitive behaviours.	Find alternative type of PA or believe that it would be a good thing to do, do not think about what other people think.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Information about health consequences •Salience of consequences •Information about social and environmental consequences •Anticipated regret •Information about emotional consequences •Pros and cons •Comparative imaging of future outcomes •Material incentive (behaviour) •Incentive (outcome) •Reward (outcome)

(Continued)

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TABLE 1 (Continued)

Sources of behaviour (COM-B)	Domain (TDF)	Barrier/construct	What needs to happen for target behaviour to occur	Intervention function(s)	Policy categories	Behaviour change tool
		Fear of failing in front of peers during PA.	Overcome mental obstacles - reduce unwanted feelings.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•Information about health consequences •Salience of consequences •Information about social and environmental consequences •Anticipated regret •Information about emotional consequences •Pros and cons •Comparative imaging of future outcomes •Material incentive (behaviour) •Incentive (outcome) •Reward (outcome)
	Optimism The confidence that things will happen for the best or that desired goals will be attained.	Adolescents have not found PA they enjoy.	Empathy and reassure that they will find something they will enjoy, identify new opportunities.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•No evidence of successful behaviour change tools in this domain
		Find PA boring or not fun.	Believe that PA would be a good thing to do and find a reward for doing it.	•Education •Persuasion •Incentivisation •Coercion	•Communication/marketing •Environmental/social planning •Guidelines •Service provision	•No evidence of successful behaviour change tools in this domain

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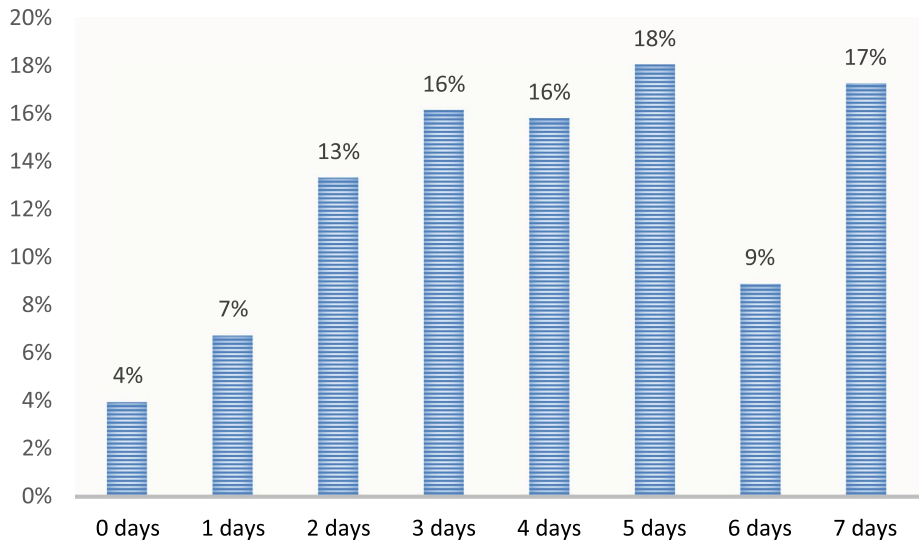

FIGURE 1
Number of days participating in 30 min or more of PA.

TABLE 2 Value of *p*.

Measure	Active (*n* = 200,623)	Inactive (*n* = 8,231)	value of *p*
Gender	• Male 44% (87,444) • Female 52% (103,509) • Other 2% (3,328).	• Male 40% (3,343) • Female 47% (3,885) • Other 5% (418).	$p < 0.001$
Ethnicity	• White (British or English) 71% (142,979) • White (Not British or English) 5% (10,295) • Mixed Ethnic Background 5% (9,443) • Asian or British Asian 9% (18,218) • Black or black British 4% (8,798).	• White (British or English) 61% (5,038) • White (Not British or English) 5% (444) • Mixed Ethnic Background 5% (437) • Asian or British Asian 11% (882) • Black or Black British 7% (600).	$p < 0.001$
Disability	• 9% (18,504)	• 16% (1,336)	$p < 0.001$

Even among the 'most active' adolescents who participate in PA for 5, 6 and 7 days per week, the main barriers remained the same, though slightly less prominent. This was evident in the responses of those who cited 'lack of confidence,' 'feeling self-conscious,' and 'no one to take part with' as barriers, which were reported by less than 5% of respondents.

This table compares the reported barriers to participating in PA among three groups of adolescents: active, inactive, and the overall sample. The table highlights the most cited barriers by each group, providing insights into the factors that may prevent adolescents from engaging in regular PA.

In relation to the quantity of reported barriers, the inactive group exhibited a slightly higher average of 2.4 barriers per individual, in contrast to the active group's average of 2.3 reported barriers. These findings indicate that while support should be prioritised for the inactive, most adolescents require assistance in overcoming barriers, to either increase or maintain PA habits. This notion is further supported by the fact that only 20% of the active group claimed that 'nothing stops them from participating in PA'.

3.2.1. Gender

Figure 3 highlights that a 'lack of confidence' and 'feeling self-conscious' are the primary barriers reported by girls, especially those who are inactive. For instance, 51% of inactive girls reported a 'lack of confidence' as a barrier, which is a 9-percentage point difference compared to inactive boys. Similarly, 55% of inactive girls reported 'feeling self-conscious', which is a 20-percentage point increase compared to inactive boys. A similar trend was found for boys, with a 'lack of confidence' (active = 32%, inactive = 42%) and 'feeling self-conscious' (active = 28%, inactive = 35%) being more prominent barriers for inactive boys. Notably, the most significant difference for inactive boys was a 15-percentage point increase in 'not found something I enjoy' (active = 20%, inactive = 35%), which suggests that future discovery of enjoyable activities might promote PA among inactive boys. A comparable trend was observed for girls (active = 23% inactive = 36%), although, unlike boys, no other significant differences were reported between the two groups.

This table compares the reported barriers to participating in PA between boys and girls from online survey data. It highlights the most

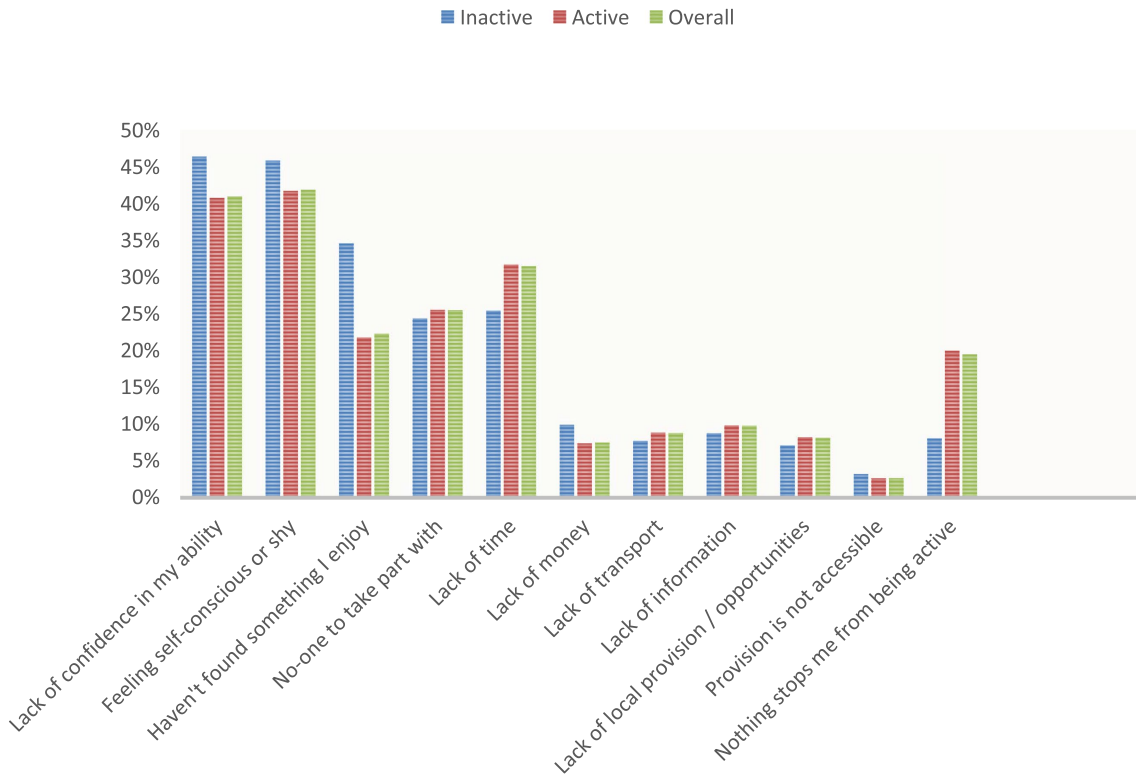

FIGURE 2
Barriers to participation in PA (%).

reported barriers for each gender, that may prevent boys and girls from engaging in regular PA.

3.2.2. Ethnicity

No significant differences were observed in the barriers reported by adolescents from different ethnic backgrounds, except for a marginal increase in students from minority ethnic groups reporting 'lack of time' (over 7%) as a barrier. Among minority ethnic girls, no disparities were identified in the barriers selected between the inactive and active groups, except for 'have not found something I enjoy,' which exceeded the overall average by 7 percentage points.

3.2.3. Disability

No notable differences were reported in the barriers reported by disabled and non-disabled students, between inactive and active groups. Disabled respondents were slightly less likely to report a 'lack of time' or 'have not found something I enjoy as a barrier,' compared to the overall sample.

3.3. Qualitative analysis

While online surveys are an efficient means of collecting data at scale from a diverse population, there are acknowledged limitations when it comes to the number of pre-defined responses that can be included, without making the survey completion complex or overly time-consuming. In this study, the coding and analysis of 'other' qualitative online survey responses have broadened the understanding of the range of barriers influencing PA participation. The most frequently cited barriers that were coded from 'other' responses for both the active and inactive groups were 'health or injury,' 'lack of motivation' and 'laziness or cannot be bothered.' Although these terms may be perceived as barriers impacting inactive groups, they were equally a factor for preventing/limiting PA across both groups.

3.4. COM-B and TDF behaviour change wheel

In total, 52 barriers and 68 behaviours were identified from the quantitative and qualitative research, by applying the BCW and TDF, as shown in Table 1. Facilitators for each barrier are provided, encompassing intervention functions, actionable categories for behaviour change that can be utilised to modify behaviour, policy categories that can aid in facilitating behaviour change, and behaviour change tools that can be employed to support adolescents.

Table 3 presents the total number of intervention functions and policy categories, that could facilitate change for each of the barriers and associated behaviours related to PA. This information indicates the type of interventions that could be implemented in schools to increase MVPA for both active and inactive groups and policy categories which could be used to drive change. The analysis revealed that the most identified intervention function was enablement, which aims to increase opportunities and reduce barriers to PA. Additionally, the most frequent policy categories identified were service provision, to design services that address barriers to PA, and guidelines that provide information to control the social or physical environment.

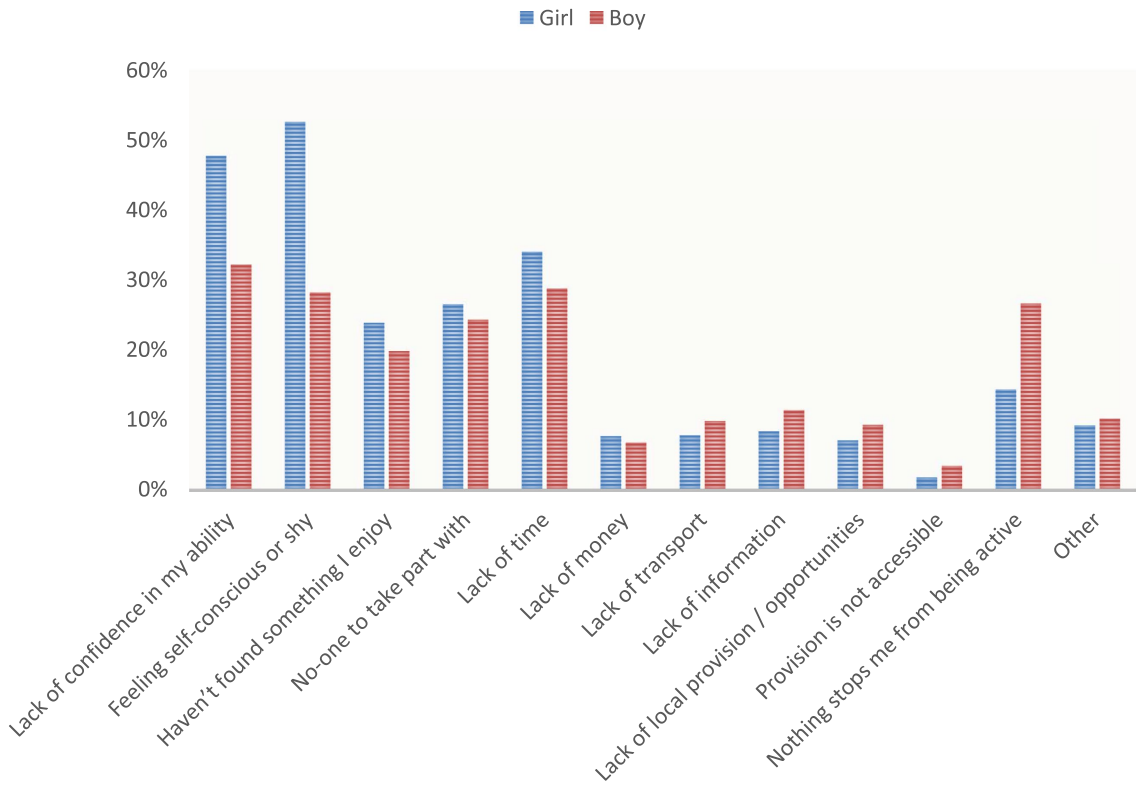

FIGURE 3
A comparison of barriers to participation between boys and girls (%).

TABLE 3 Total number of intervention functions and policy categories.

Intervention functions	No.	Description	Policy categories	No.	Description
Coercion	12	Creating an expectation of punishment or cost.	Communication/ marketing	53	Using print, electronic, telephonic, or broadcast media.
Education	37	Increasing knowledge and understanding.	Environmental/ social planning	55	Designing and/ or controlling the physical or social environment.
Enablement	54	Increasing means/reducing barriers to increase capability (beyond education and training) or opportunity (beyond environmental restructuring).	Guidelines	68	Creating documents that recommend or mandate practice. This includes all changes to service provision.
Environmental restructuring	27	Modifying the physical environment around someone to influence their behaviour.	Service provision	69	Delivering a service.
Incentivisation	12	Creating an expectation of reward.			
Modelling	21	Providing an example for people to aspire to or imitate.			
Persuasion	12	Using communication to induce positive or negative feelings to stimulate action.			
Training	41	Imparting skills.			
Restrictions/using rules	21	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours).			

4. Discussion

This study aimed to identify barriers to PA, explore demographic differences and compare reported barriers between inactive and active adolescents. These results were drawn from one of the largest surveys of adolescents ever conducted, which included a robust sample of respondents from both active (n = 200,623) and inactive (n = 8,231) groups. The rich quantitative and qualitative data enabled the

identification of 52 barriers and 68 behaviours which prevent adolescents from participating in PA. Even though the sample is heavily weighted towards the active group, the study's large sample size is sufficient to provide a comprehensive understanding of barriers from the perspective of inactive adolescents (over 8,000) who are often underrepresented in PA research. Utilising existing models and frameworks including the COM-B, BCW and TDF enhanced the validity of the research and potential for the findings to be applied in a real-world setting.

The study's findings offer valuable insights into the under-researched inactive group and underscore the necessity for further investigation to address the barriers to PA among inactive adolescents. It introduces an original comprehensive guide for schools, PA agencies, and PA intervention designers to gain a comprehensive understanding of the array of barriers that affect adolescents. It presents potential mechanisms for behaviour change, encompassing intervention functions, policy categories, and evidence-based behaviour change tools, which can be applied to future modes of delivery. This comprehensive analysis will provide valuable insights for the implementation of PA strategies that effectively address each identified barrier. By utilising evidence-based behaviour change tools, these strategies have the potential to benefit schools, public health policies, and intervention designers alike.

Demographic characteristics were compared between the inactive and active groups, revealing that certain inequalities are more prevalent in the inactive group. This includes a higher proportion of children and adolescents from minority ethnic groups, those with disabilities, and those requiring additional support to participate in PA. This is consistent with previous research which has also found that certain demographic groups, such as minority ethnic groups and disabled individuals, are overrepresented among inactive populations (17–19). Notably, there was no difference in gender distribution between the inactive and active groups, but the inactive group was more likely to select "other" or "prefer not to say" when specifying gender. Further investigation is needed to explore the relationship between gender identity and PA participation, particularly among inactive adolescents.

The survey results showed that the main barriers to PA were similar for both inactive and active groups. The most prevalent barriers were psychological (e.g., confidence and self-consciousness) and social (e.g., lack of a partner) barriers, which affected all activity levels, genders, and ethnic groups to varying degrees. 'Lack of time' and 'having no one to take part with' were also significant barriers, with the former being more prevalent for active groups. Girls were more likely than boys to experience the main barriers, as were inactive boys when compared to active boys. In comparison barriers were more consistent between active and inactive girls. These findings suggest that common barriers could be addressed across the population, and interventions could be developed and targeted at all adolescents in the future while recognising some differences. For instance, targeted interventions on how to maintain PA amidst a busy schedule for active groups and helping inactive boys find a suitable activity could be considered. However, considering the number of adolescents impacted by these main barriers, there is still a need for whole-school PA approaches to behaviour change in schools, in consideration of whole systems approaches considering The World Health Organisation's (WHO) Global Action Plan on PA (34, 35). As only 20% of active adolescents stated that nothing stops them from being physically active, active groups also require support to increase or maintain participation.

Generally, this study's findings are consistent with prior systematic reviews of barriers to PA (17, 20). The most recent study employed a thematic analysis to examine the viewpoints of approximately 1,250 adolescents aged 13–18 years, across 13 countries representing various continents. Its primary focus was on identifying barriers and facilitators of PA within five overarching themes.

One notable finding of the study was that most of the reviewed studies lacked a theoretical foundation, which influenced the approach taken in this study. The systematic review identified broad categories framed using the socio-ecological model (36) that overlap with the current study's findings. These categories were: Physical and Motor Skills (29, 37); PA Attitude, Knowledge, and Understanding (38, 39); Motivation (40, 41); Perception of Competence and Self-Efficacy (42, 43); Perceptions of Body Image, Femininity, and Sociocultural Norms (44, 45); Youth Agency (46, 47); Influence of Friends and Peers (29, 42); Influence of Family (38, 48); Influence of Significant Others (38, 39); Fun (46, 49); School-Based PA and PE (37, 50); Time and Competing Activities to PA (47, 51); Life-Course and PA-Related Factors (40, 42); Sociocultural and Environmental Factors (52, 53).

Both studies (17, 29) have similarities with this study in the range of barriers reported. However, the current study identified additional physical and psychological barriers that may have been overlooked as significant influences on adolescent behaviour towards PA. For instance, 'health problems', 'injury,' and 'disability' were identified as physical barriers to PA. In the psychological capability category, 'mental health, anxiety, and depression' were also additional barriers reported affecting participants' psychological skills and stamina for PA. These findings may indicate a greater willingness among adolescents to report psychological suffering due to the anonymous nature of reporting, which might not have been evident in earlier qualitative studies. Other psychological barriers not previously reported in these studies include 'negative food habits,' 'laziness,' and 'fear of getting hurt while doing PA'. Additionally, adolescents reported feeling 'isolated,' 'lonely,' or being 'bullied' before, during, or after engaging in PA, and expressed a 'lack of desire to socialise with others during PA'. While previous studies have focused on the emotional benefits of PA, there is a dearth of research on interventions to overcome emotional or psychological barriers to help adolescents develop the mental skills, stamina, and resilience necessary for PA. Therefore, it is crucial to provide support and prepare adolescents to overcome these barriers and enable them to engage in PA.

The findings in both systematic reviews (17, 29) also revealed other nuanced findings not included in this study. For instance, working part-time, physically inactive family members, and high levels of PA intensity were not identified as barriers in this study. Since many of the studies included in both reviews were qualitative (17, 29) and involved interviews and focus groups, they may have provided a more in-depth understanding of specific barriers than reported in the current study. For example, in these studies, there is more context around the association of 'fun' (38, 47, 48) on PA and the influence of family (47, 48, 52), friends (40, 43, 47), and others (38, 39) as well as the adolescent life course (43, 48, 49) being significant barriers. However, the present study discussed these barriers in a general context, without considering the specific influence of the adolescent life course or the impact of others etc. This emphasises the significance of developing future interventions that are tailored to the specific

contexts they address, to create effective strategies that aim to promote adherence.

This study also focuses primarily on individual-level factors, with limited exploration of environmental or contextual influences on PA or from the perspective of other key stakeholders like PE teachers which are reported in other studies (15, 54, 55). Factors such as school policies, access to recreational facilities, or social support systems are not extensively examined, despite their potential impact on adolescent PA levels. Moreover, the study lacks longitudinal data, offering only a snapshot of the identified barriers and facilitators. Longitudinal data would provide a more comprehensive understanding of how these factors evolve and interact as adolescents progress through secondary school.

It is evident that individual factors are numerous, and the complexity of addressing these barriers is further compounded by evidence in the literature of the challenges schools encounter in allocating time and resources to support adolescents (15). As the literature highlights (8, 34), innovative approaches and modes of delivery are required which are scalable and personalised to adolescents needs, addressing the complex mix of barriers that adolescents face. Considering the lack of capacity and time in schools, digital self-help tools might prove to be a valuable approach to support adolescents in the future, as some studies have previously advocated (8).

Digital exercise interventions have received much publicity in recent years as being able to solve many of society's problems, with physical inactivity being no exception. They may not be a panacea but offer hope in the current environment because they are relatively low-cost and can provide scalable population level interventions in schools that are personalised and easily accessible for adolescents. Whilst they have received much attention, digital interventions to improve PA behaviours have initially achieved mixed results (56). More recently, study authors have reported emerging evidence of digital interventions targeting emotions, attitudes, and motivations towards PA (57) with some evidence that they are more effective for adolescents than younger children (58).

Recently, conversational Artificial Intelligence (AI) solutions have gained popularity due to their ability to offer personalised conversational-driven support for individuals. Chatbots, in particular, have emerged as a promising self-help tool in this domain, supported by a notable increase in PA from studies, including four randomized control trials (59–61). The strength of these solutions lies in an ability to engage in humanlike automated natural language interactions, that are personalised and available at any time (62–64). This feature makes them an appealing option for schools facing time, resource, and capacity constraints, while also presenting an innovative and engaging tool for adolescents to access personalised assistance in overcoming barriers. Such AI solutions hold potential for broader application, being adaptable for use in healthcare and community organisations across both public (i.e., social prescribing) and private sector. Despite their promise, there remains a need for consistent measurement and evidence of efficacy to establish their effectiveness conclusively (65).

The outcomes from this study may help to accelerate the development of digital PA interventions targeted at adolescents who need to overcome multiple barriers around psychological capability and motivation. For example, when considering the COM-B there are 24 sources of behaviour in the Psychological Capability domain and 12 in the Reflective Motivation domain which could be initially targeted and inform the design of digital health interventions for adolescents. Such digital health interventions could also provide more practical support and guidance to overcome barriers in the Social Opportunity domain (17 behaviours) and Physical Capability domain (5 behaviours). The findings could also be used to build knowledge bases and Natural Language Models (NLP) so that machines can understand barriers and provide relevant solutions. It could lead to the creation of algorithms designed to provide personalised support understanding the complexity of barriers, and identifying suitable interventions tailored to the individual. This has the potential to revolutionise support to adolescents and be adapted to support other populations including older adults, people with disabilities or long-term health conditions to address health inequalities.

Further studies are required to develop appropriate modes of delivery which should be co-designed with adolescents using the findings of this study, and others (17) as a basis for understanding adolescent behaviour. Behaviours in the Physical Opportunity domain will be more challenging to overcome as they require systemic changes, achieved through a multi-agency approach including schools. However, it is important to note that Physical Opportunity behaviours account for only 15% of all behaviours highlighted in this study. Therefore, in the short and medium term, prioritising an adolescent-centered approach to behaviour change, focusing on enhancing Physical Skills, Psychological Capabilities, Social Influences, and Reflective Motivation, would be advisable.

5. Conclusion

In conclusion, this study identified 52 barriers and 68 behaviours that prevent adolescents from participating in PA. It revealed that psychological and social barriers affect all activity levels, genders, and ethnic groups to varying degrees, with the most prevalent being a lack of confidence and self-consciousness. The study also highlighted that there are certain demographic groups, such as those from minority ethnic groups and disabled individuals, who are overrepresented among inactive populations. It indicated that there are common barriers that impact both inactive and active groups, with more overlap observed when examining barriers between active and inactive girls. Girls were more prone to experiencing the main barriers compared to boys, while inactive boys were more likely to encounter these barriers compared to active boys. These findings suggest that common barriers could be addressed across the population while recognising some differences in demographics, and the need to provide personalised support. It reveals important insights into this under-researched group and highlights the need for further research to address the barriers to PA among adolescents, particularly those who are inactive. Targeted interventions are also suggested including all girls and inactive boys. This study offers an original guide for schools, public health policy, and intervention designers by identifying diverse barriers impacting adolescents. It highlights potential behaviour change mechanisms through intervention functions, policy categories, and behaviour change tools. Digital/mobile health interventions and conversational AI solutions hold promise in addressing adolescents' varied behaviours, utilising this research and supporting them in overcoming barriers. Further investigation is needed to explore their efficacy and implementation strategies.

Data availability statement

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

Ethics statement

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

Author contributions

RM collected and analysed data and wrote the final manuscript. TV managed STT (secondary teacher training) project and collected data. MG managed STT project and collected data. EF analysed data and wrote the final manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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The individual and combined associations of health behaviours with health-related quality of life amongst junior high school students in China

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Objectives: This study aimed to investigate the individual and joint associations of sedentary behaviour, physical activity (PA), sleep and breakfast eating on health-related quality of life (HRQoL) amongst Chinese junior high school students.

Methods: Data were from 783 junior high school students who participated in a health behaviour and health survey in Jining city of Shandong province of China. HRQoL was measured by the EuroQol five-dimensional questionnaire, youth version (EQ-5D-Y). Multivariable logistic and linear regressions were applied to examine the associations between health behaviours and HRQoL.

Results: Multivariable regression analyses showed that using a computer ≥ 2 h a day (vs. < 2 h/day) is associated with increased likelihood of having health problems in the three EQ-D-Y dimensions, including walking, looking after self and doing usual activities. Lower PA is associated with more problems in feeling worried, sad or unhappy, and with a lower visual analogue scale (VAS) score. Students who had insufficient sleep time (e.g., <7 h/day), and skipped eating breakfast were more likely to experience lower HRQoL in the dimensions of having pain or discomfort, and feeling worried, sad or unhappy, and a lower VAS score than those students who had longer sleep time and no breakfast skipping. Students who reported having the combined ≥ 2 unhealthy behaviours relative to the peers with 0–1 unhealthy behaviours were more likely to have lower HRQoL.

Conclusion: The findings in the present study underline the importance of promoting healthy behaviours in order to improve HRQoL amongst Chinese junior high school students.

KEYWORDS

sedentary behaviour, sleep, physical activity, breakfast, health-related quality of life, junior high school students

1. Introduction

Health-related quality of life (HRQoL) is a subjective evaluation of an individual's overall health status and its underlying sub-dimensions, including physical, psychological and social functioning and well-being (1). Evaluations of HRQoL amongst children and adolescents is critical in order to develop effective and targeted interventions to enhance their health status.

Previous studies have shown that health-related behaviours such as sedentary behaviours, physical activity (PA), sleep and diet are associated with HRQoL amongst children and adolescents (2–4). Research evidence suggests that high physical activity is associated with better HRQoL, and sedentary behaviour is related to lower HRQoL amongst children and adolescents (2). A lack of sleep and skipping breakfast are related to lower HRQoL amongst children and youth (3–6). However, the relationships between the health behaviours and HRQoL have been mostly investigated in developed countries (2, 3). Very few studies have examined the influence of PA, sedentary behaviour, breakfast skipping and/or sleep on HRQoL in adolescents in China (7). Besides, some studies documented that health behaviours may not act in isolation in their associations with health outcomes, and that the co-occurrence of multiple health behaviours may cause greater effects than their individual effect (8, 9). Few studies have yet investigated the influence of combined or joint associations of PA, sedentary behaviours, sleep duration and diet behaviours with HRQoL in school-aged children and youth (8, 10). To our knowledge, no study has been found to examine the combined effect of multiple health behaviours, including PA, sedentary behaviours, sleep and breakfast eating habit simultaneously on HRQoL in China. Understanding the combined impact of multiple health behaviours on HRQoL will help address synergistic effects between the health behaviours and health outcomes, and thus provide scientific information for public health policy makers in prioritising school-based health intervention programmes in order to promote healthy lifestyle behaviours and health amongst adolescents. Given prior studies have mainly examined the impact of single health behaviour on health, further interventions of the joint association between multi-dimensional health behaviours and HRQoL will help address cumulative benefits of health behaviours for adolescents' health and wellbeing.

This study aimed to investigate associations between physical activity, sedentary behaviour, sleep time, breakfast eating and HRQoL; and to examine combined associations of the health-related behaviours on HRQoL amongst junior high school students in Jining city, Shandong province of China.

2. Materials and methods

2.1. Participants

This study surveyed students from four junior high schools in Jining city, Shandong province of China in June and July in 2020. Jining city is one of the historical and large cities located in the southwest region in the province with a population in urban area of approximately five millions in 2022.[1] The survey aimed to evaluate health-related behaviours and health amongst school students to promote their healthy lifestyle behaviours and health status. Four junior high schools were selected in the city. Classes were then randomly selected within each of the chosen schools. In total, 800 students aged 11–16 years from 16 classes in the four schools were invited to participate, and 783 students (98%) completed the survey with complete information on lifestyle behaviours and HRQoL. The survey included the EuroQol five-dimensional questionnaire, youth version (EQ-5D-Y) with a five-dimensional descriptive system and a visual analogue scale (VAS) (11), questions on sedentary behaviours (using a computer, using a cellphone), physical activity, sleep and dietary behaviours (e.g., frequency of eating breakfast), and socio-demographic characteristics of students.

2.2. Measures of health-related quality of life

HRQoL was measured by the EQ-5D-Y designed for use amongst children and youth aged between 8 and 18 years. The EQ-5D-Y instrument has questions on five-dimensions: walking; looking after myself; doing usual activities; having pain or discomfort; and feeling worried, sad or unhappy (11). Each dimension has three response options asking whether children have 'no problems, some problems or a lot of problems'. The instrument also includes VAS which is anchored at 100 (best imaginable health) and 0 (worst imaginable health) to capture self-rated values of overall health status. The EQ-5D-Y has been validated in a number of languages and countries (12, 13). The Chinese version of the EQ-5D-Y used in this study has also been validated and showed feasible and valid for assessing HRQoL amongst children and adolescents in China (14, 15). In this study, the reliability coefficient (Cronbach's alpha) is 0.70.

2.3. Assessments of lifestyle behaviours

Students were asked to report frequencies of their engagements in moderate and vigorous physical activity (MVPA) outside of schools in the past 7 days with the response levels: never or once a month, Once a week, 2–3 times a week and ≥4 times a week. In the analysis, the last two levels were combined into one group: ≥2 times a week. The sedentary behaviours were reported as daily hours spent on using a computer and playing a cellphone with response categories: less than 1 h a day, 1–2 h a day, and ≥2 h a day. Sedentary behaviours were dichotomized as <2 h/day and ≥2 h/day according to the physical activity guidelines for children and adolescents in China (16). Questions on physical activity have been previously validated, and showed a good validity and reliability amongst Chinese children and adolescents (17).

Sleep time was reported as habitual number of hours a day spent on sleep, and it was categorised to two levels: ≥7 h/day and <7 h/day. Eating behaviour was measured as frequencies of eating breakfast with 3 options: eating breakfast every day, eating breakfast often, and never or almost never eating breakfast.

2.4. Socio-demographic characteristics

Students' socio-demographic characteristics included gender, grade, highest level of parental education. Grade was categorised as junior (grade 1 and 2 in junior high school) and senior (grade 3 and 4 in junior high school) levels. Parental educational attainment was categorised as junior high school or less; high school; and university/college or higher.

1 https://www.jining.gov.cn/col/col2598/index.html

2.5. Statistical analyses

Descriptive analyses were used to describe the frequency distribution for categorical variables and the mean score with its standard deviation (SD) for VAS score. We used a chi-square test to examine differences in the prevalence of health problems for each of the five EQ-5D-Y dimensions by the health behaviour and socio-demographic variables, respectively. As very few students reported 'a lot of problems' in the EQ-5D-Y dimensions, we combined this with the response level 'some problems' into one group. A dichotomous outcome (Having any problems vs. no problems) was used in the analysis for the five EQ-5D-Y dimensions. We applied t-test (for two groups) or analysis of variance (ANOVA; for more than two groups) to examine differences in the mean VAS score by the health behaviour and socio-demographic variables.

The present study used univariate and multivariable logistic regressions, respectively, to examine the associations between the health behaviours and HRQoL measured by each of the five EQ-5D-Y dimensions. Univariate and multivariable linear regressions were applied to assess the association of the health behaviours with the VAS score. The multivariable regression analyses adjusted the confounding influence of gender, grade level and parental education.

To analyse the combined associations of health behaviours with HRQoL in regression analyses, the three-category MVPA and breakfast eating variables were dichotomized, respectively. MVPA was dichotomized as high PA (≥2 times a week) and low PA (combined 'never or once a month' and 'once a week'). Breakfast eating was dichotomized as eating every day and often (healthy eating) and never or almost never eating (unhealthy eating). Using all the five dichotomous health behaviour variables (recoded as 0 = healthy, 1 = unhealthy), the total number of variables that met the unhealthy or poor level of the behaviours (from zero, one up to five) was calculated for each student observation. Next, a new health behaviour variable representing the number of combined unhealthy behaviours was generated, and categorised into three levels: 0–1, 2 and ≥3 unhealthy behaviours. The observations with zero and one unhealthy behaviour were combined since the number of students who responded to zero level was low (16.6%). Subsequently, using the combined HB variable as an exposure and HRQoL as an outcome, univariate and multivariable regressions were fitted to examine the combined effect of the health behaviours on the HRQoL outcomes.

2.6. Ethical approval

The present study, including the data collection was approved the Human Research Ethics Boards of the Weifang Medical University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin, and students themselves. All methods were performed in accordance with the relevant guidelines and regulations.

3. Results

Table 1 shows the frequency distribution of socio-demographic characteristics, and health behaviours of the junior high school students. Amongst 783 students, 54.5% were girls, 61.0% were in junior grade level. Approximately half of students (47.1%) engaged in MVPA ≥ 2 times a week and had sleep time less than 7 h a day (47.3%), respectively. Students who reported spending 2 h or more a day on using a cellphone and a computer accounted for 33.6% and 17.6%, respectively. Never or almost never eating breakfast was reported amongst 14.8% of students.

The prevalence of students who reported having 'some or a lot of problems' on the EQ-5D-Y dimensions was 5.9%, 5.2%, 12.4%, 26.4%, and 37.7% for 'walking', 'looking after self', 'doing usual activities', 'having pain or discomfort', and 'feeling worried, sad or unhappy'. The mean VAS score was 82.0 (standard deviation, SD:18.6).

TABLE 1 Frequency distributions of socio-demographic characteristics, health behaviours of the junior high school students.

Variable	Frequency	Percentage, %
Using a computer		
<2 h/day	645	82.4
≥2 h/day	138	17.6
Using a cellphone		
<2 h/day	520	66.4
≥2 h/day	263	33.6
MVPA		
≥2 times a /week	369	47.1
Once a week	179	22.9
Never or once a month	235	30.0
Eating breakfast		
Eating everyday	441	56.3
Eating often	226	28.9
Never or almost never eating	116	14.8
Sleep time		
≥7 h/day	404	52.7
<7 h/day	362	47.3
Number of health behaviours with the unhealthy level response		
0–1	380	49.6
2	218	28.5
≥3	168	21.9
Gender		
Girls	427	54.5
Boys	356	45.5
Grade level		
Junior (grade 1 and 2)	478	61.0
Senior (grade 3 and 4)	305	39.0
Parents' education		
Junior high school or less	158	20.2
High school	398	50.8
University/college or higher	227	29.0

MVPA, moderate and vigorous physical activity.

Table 2 presents the prevalence of problems in the EQ-5D-Y dimensions and the mean VAS score by the health behaviour and socio-demographic characteristics. Students who spent more time on using a computer or a cellphone (≥2 h/day) had a higher prevalence of health problems on 'walking', 'looking after self', and 'doing usual activities' in the EQ-5D-Y than students who spent less time on the sedentary behaviours (<2 h/day). In addition, using a cellphone is significantly associated with a higher prevalence of poor health problems on 'having pain or discomfort'. Students who engaged in lower level of physical activity (MVPA <

TABLE 2 Prevalence of problems in the EQ-5D-Y dimensions and mean VAS score by health behaviours and socio-demographic characteristics amongst junior high school students.

Variable	The EQ-5D-Y dimensions (percentage of students reporting some or a lot of problems)					VAS score
	Walking	Looking after self	Doing usual activities	Having pain or discomfort	Feeling worried, sad or unhappy	Mean (95% CI)
Using a computer	**P < 0.001**	**P < 0.001**	**P < 0.001**	*P* = 0.337	*P* = 0.339	*P* = 0.250
<2 h/day	4.0	3.7	10.2	25.7	37.0	82.4 (81.0, 83.9)
≥2 h/day	14.5	12.3	22.5	29.7	41.3	80.4 (77.2, 83.7)
Using a cellphone	**P < 0.001**	**P < 0.001**	**P = 0.002**	**P = 0.005**	*P* = 0.170	**P = 0.042**
<2 h/day	3.7	3.1	9.8	23.3	36.0	83.0 (81.5, 84.6)
≥2 h/day	10.3	9.5	17.5	32.7	41.1	80.2 (77.8, 82.6)
MVPA	*P* = 0.058	**P = 0.025**	*P* = 0.065	**P = 0.016**	**P < 0.001**	**P < 0.001**
≥2 times a week	3.8	3.0	9.5	22.8	31.0	85.2 (83.6, 86.9)
Once a week	8.4	7.8	14.5	25.1	39.1	80.8 (78.1, 83.4)
Never or once a month	7.2	6.1	15.3	33.2	47.2	78.1 (75.4, 80.8)
Sleep time	*P* = 0.078	*P* = 0.740	*P* = 0.321	**P < 0.001**	**P < 0.001**	**P < 0.001**
≥7 h/day	3.0	3.4	9.4	18.3	27.3	86.6 (85.2, 88.0)
<7 h/day	5.5	3.0	11.6	32.0	46.4	78.2 (76.0, 80.3)
Eating breakfast	*P* = 0.815	*P* = 0.792	*P* = 0.980	**P = 0.001**	**P < 0.001**	**P < 0.001**
Eating every day	5.4	5.7	12.2	22.2	32.9	84.7 (83.1, 86.3)
Eating often	6.2	4.4	12.4	27.9	39.4	80.8 (78.4, 83.2)
Never or almost never eating	6.9	5.2	12.9	39.7	53.0	74.4 (70.5, 78.4)
Number of combined unhealthy level of behaviours	**P < 0.001**	**P = 0.017**	**P = 0.002**	**P < 0.001**	**P < 0.001**	**P < 0.001**
0–1	1.3	1.8	6.6	18.2	28.2	86.9 (85.4, 88.3)
2	5.1	3.2	13.8	27.5	38.5	80.3 (77.6, 83.0)
≥ 3	9.5	6.6	14.9	36.3	51.8	76.0 (72.8, 79.2)
Gender	*P* = 0.134	*P* = 0.069	*P* = 0.372	*P* = 0.076	**P = 0.001**	**P = 0.029**
Girls	4.5	3.7	11.2	29.5	44.2	80.5 (78.4, 82.6)
Boys	7.0	6.6	13.4	23.9	32.3	83.4 (81.7, 85.1)
Grade level	**P = 0.031**	**P = 0.009**	*P* = 0.400	**P = 0.011**	*P* = 0.656	*P* = 0.694
Junior (grade 1 and 2)	7.3	6.9	13.2	23.2	37.1	81.9 (80.1, 83.7)
Senior (grade 3 and 4)	3.6	2.6	11.2	31.5	38.7	82.4 (80.6, 84.2)
Parents' education	*P* = 0.201	**P = 0.042**	*P* = 0.076	*P* = 0.795	*P* = 0.318	*P* = 0.528
Junior high school or less	8.9	8.9	16.5	24.7	34.8	80.6 (77.2, 83.9)
High school	5.0	5.0	12.8	27.4	40.3	82.4 (80.6, 84.2)
University/College or higher	5.3	3.1	8.8	26.0	35.2	82.5 (80.4, 84.7)

A bold *p*-value indicates a statistical significance ($p < 0.05$) between groups of the variables. MVPA, moderate and vigorous physical activity.

2 times a week) had more poor health problems in three EQ-5D-Y dimensions: looking after self, having pain or discomfort and feeling worried, sad or unhappy than students who were physically active. Students who had shorter sleep time (<7 h/day) or a breakfast skipping reported more health problems in the EQ-5D-Y dimensions of 'having pain or discomfort' and 'feeling worried, sad or unhappy' than students who had longer sleep time (≥7 h/day) and ate breakfast every day. The prevalence of having some or a lot of problems in the 'feeling worried, sad or unhappy' dimension by the health behaviours is displayed in Figure 1.

Students who were inactive, used a cellphone more often, spent less time on sleep and skipped a breakfast had a lower VAS score ($p < 0.05$) relative to their reference peers. Students who had combined unhealthy behaviours on two, three and more behaviours (compared with 0-1unhealthy behaviour) had a higher prevalence of poor health problems on all five dimensions of the EQ-5D-Y, and a lower VAS score. Female students had a higher prevalence of health problems in the 'feeling worried, sad or unhappy', and a lower VAS score than male peers. Students in the senior grade level were affected by more health problems in 'having pain or discomfort' relative to students in the junior grade level. However, senior grade level students had a lower prevalence of health problems in 'walking' and 'looking after self' than junior grade level students. Higher level of parental education was associated with a lower prevalence of health problems in 'looking after self' amongst students. The mean VAS scores by the health behaviour variables are presented in Figure 2.

Table 3 shows the multivariable regression results for the association between health behaviours and HRQoL. Of 783 students, 17 students had missing responses to sleep time, resulting in 766 observations available in the multivariable regression analysis. After adjusting for the effect of sociodemographic and other health behaviour variables in the table, using a computer significantly affected three of the EQ-5D-Y dimensions: walking, looking after self and doing usual activities. Low MVPA was significantly associated with problems in 'feeling worried, sad or unhappy' (OR = 1.51, 95% CI 1.05, 2.17). Students who had sleep time < 7 h/day and skipped a breakfast were more likely to report some or a lot of problems in 'having pain or discomfort' and 'feeling worried, sad or unhappy'. Regarding VAS score, low MVPA level, shorter sleep time and skipping a breakfast, respectively, correlates with a lower VAS score. Girls were more likely to feel worried, sad or unhappy than boys (OR = 1.44, 95% CI 1.04, 1.98). Students in higher grade level were more likely to experience pain or discomfort (OR = 1.65, 95% CI 1.15, 2.38).

Table 4 presents the multivariable regression results for the combined effects of multiple health behaviours (combination of MVPA, using a computer and a cellphone, sleep time and breakfast eating) and HRQoL. Compared to the reference group with relatively healthy level for the combined behaviours, students who reported the unhealthy level on three or more behaviours had a higher likelihood of experiencing lower HRQoL on all the five dimensions and the VAS score of the EQ-5D-Y. Students who responded to the poor health level on two behaviours were more likely to have lower HRQoL on all the dimensions and the VAS score except for the dimension looking after self. A dose–response relationship between the exposure level of the combined HBs and HRQoL outcomes was observed on all the EQ-5D-Y dimensions and the VAS score. For example, the VAS score of students with unhealthy behaviours of three and more was 6.34 points lower than students with two unhealthy behaviours, and 10.7 points lower than students with healthier behaviours (Table 4).

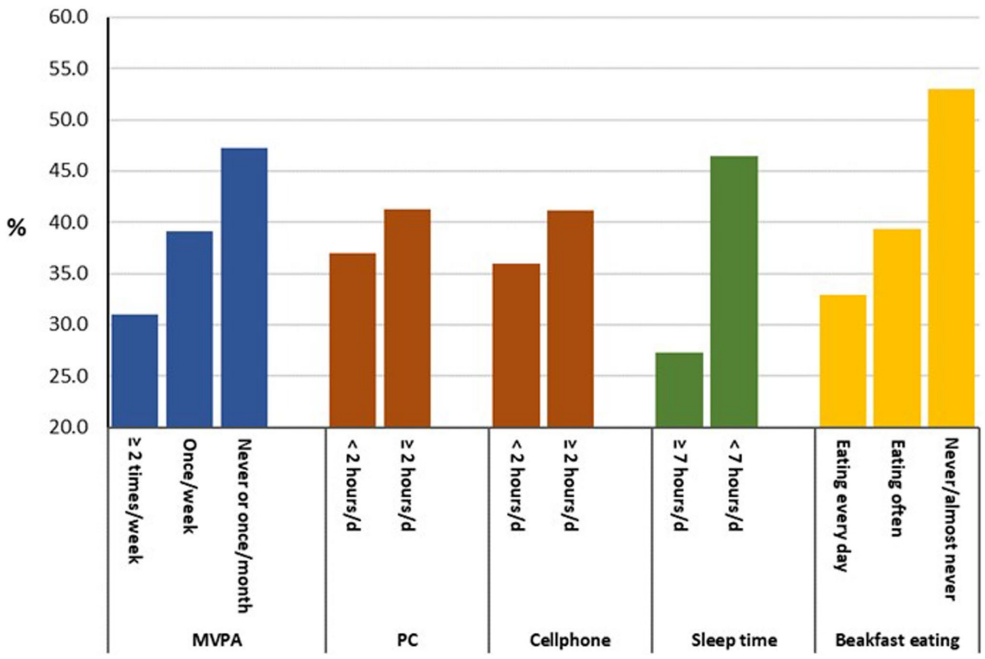

FIGURE 1
Prevalence of having some and a lot of problems in the EQ-5D-Y dimension of feeling worried, sad or unhappy by the health behaviours. MVPA, moderate and vigorous physical activity; PC, using a computer; d, day.

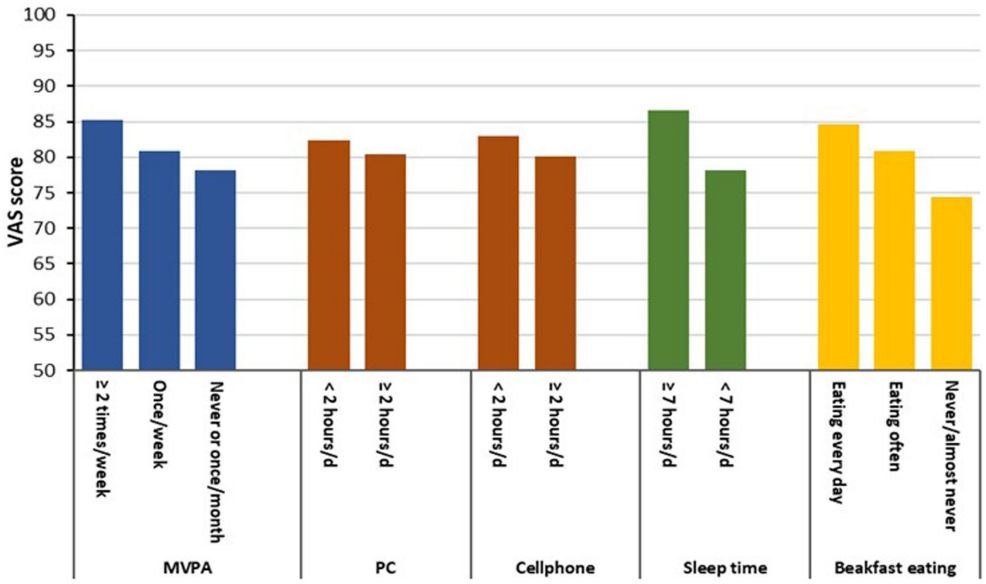

FIGURE 2
Mean VAS scores by the health behaviours. MVPA, moderate and vigorous physical activity; PC, using a computer; d, day.

4. Discussion

The present study reveals that using a computer or a cellphone, physical activity, sleep duration and breakfast eating are associated with HRQoL in junior high school students. Students who were physically inactive, engaged in a higher level of sedentary behaviour, had shorter sleep time, and/or a higher frequency of skipping breakfast had a lower HRQoL. The associations are independent of the effect of students' gender, grade level and parental education. This study also finds that the combined unhealthy levels of the health behaviours are associated with lower HRQoL. The dose–response relationship observed between the joint health behaviours and HRQoL suggests that a synergistic effect of multiple behaviours on HRQoL may exist amongst students.

Adolescence is an important period to establish healthy lifestyle behaviours, and it is also a period to be affected by various health problems such as poor mental health and well-being (18). Considering that adolescents' health behaviours can persist into adulthood (19), investigations of the impact of health behaviours on HRQoL is crucial in informing public health intervention programmes amongst the young population. This study found that junior high school students who were physically active had significantly better HRQoL (VAS) scores, and a lower likelihood of feeling worried, sad or unhappy than those students who were physically inactive. This is consistent with other studies in other countries (20–23) showing that PA is related to mental health aspect of HRQoL. Similarly, the associations between increased screen time behaviours (using a computer or a cellphone) and poorer HRQoL observed in the present study are in line with other studies amongst school-age children and adolescents (20, 22, 24, 25).

To the best of our knowledge, the present study is the first to reveal the associations of sedentary behaviour, physical activity, eating breakfast and sleep time simultaneously with HRQoL amongst junior high school students in China. The study observed that students with skipping breakfast, and shorter sleep time were more likely to have poor HRQoL, including VAS score and two major domains (having pain or discomfort, and feeling worried, sad or unhappy) of the EQ-5D-Y. The finding for skipping breakfast is consistent with few other studies in Japan showing that children and adolescents who ate breakfast seldom or never had a higher odds of experiencing poor HRQoL than their peers who ate breakfast often or every day (6, 26). The association of skipping breakfast with poor HRQoL in the mental health domain, 'feeling worried, sad or unhappy' is in accordance with some previous studies reporting that breakfast skipping correlated with increased mental and psychological health problems (27–30). In line with previous literature (5, 7, 31–33), the results in this study showed that insufficient sleep time was related to lower HRQoL compared to longer sleep time (≥7 h/day), further highlighting the importance of better sleep duration for HRQoL in students. Notably, our observation that a lack of sleep is related to 'feeling worried, sad or unhappy' in the EQ-5D-Y amongst students coincides with other studies showing that poor sleep is associated with more mental health problems (24, 34, 35).

The present study contributes to the related research by revealing the correlations of a combination of certain health behaviours with HRQoL amongst junior high school students. Whilst an increasing studies have emerged over the past decade to examine the combination effect of multiple types of health behaviours such as physical activity, sedentary behaviour, sleep and/or diet on other health indicators (e.g., obesity, adiposity, cardiometabolic disorders, school academic performance, and mental health) amongst children and youth (8, 9, 34, 36), very few studies have investigated the effect of adhering to several modifiable health behaviours on HRQoL in the general populations

TABLE 3 Multivariable logistic and linear regression results for the association between health behaviours and the EQ-5D-Y dimensions and VAS score amongst junior high school students.

Variable	Walking	Looking after self	Doing usual activities	Having pain or discomfort	Feeling worried, sad or unhappy	VAS score
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	Coefficient (95% CI)
Using a computer						
≥2 h/day	**7.31 (2.72, 19.65)**	**8.08 (2.70, 24.20)**	**3.17 (1.66, 6.08)**	1.08 (0.65, 1.79)	1.26 (0.79, 2.02)	−1.28 (−5.11, 2.56)
Using a cellphone						
≥2 h/day	0.57 (0.20, 1.57)	0.44 (0.14, 1.37)	0.80 (0.43, 1.48)	1.33 (0.88, 2.02)	0.92 (0.63, 1.36)	0.23 (−2.90, 3.36)
MVPA						
Once a week	1.61 (0.62, 4.20)	1.43 (0.48, 4.21)	1.13 (0.60, 2.12)	0.90 (0.56, 1.42)	1.15 (0.77, 1.72)	−3.02 (−6.26, 0.23)
Never or once a month	1.45 (0.60, 3.49)	1.79 (0.67, 4.75)	1.39 (0.80, 2.42)	1.30 (0.87, 1.93)	**1.51 (1.05, 2.17)**	**−4.79 (−7.79, −1.79)**
Sleep time						
<7 h/day	1.91 (0.86, 4.25)	0.88 (0.37, 2.14)	1.19 (0.73, 1.96)	**1.67 (1.18, 2.38)**	**1.99 (1.45, 2.74)**	**−6.74 (−9.34, −4.14)**
Eating breakfast						
Eating often	1.68 (0.72, 3.94)	1.25 (0.48, 3.23)	1.19 (0.69, 2.04)	**1.50 (1.01, 2.23)**	1.29 (0.91, 1.83)	**−3.63 (−6.53, −0.74)**
Never or almost never eating	1.77 (0.63, 5.03)	1.72 (0.53, 5.61)	1.17 (0.59, 2.32)	**2.16 (1.35, 3.44)**	**1.95 (1.25, 3.04)**	**−8.60 (−12.33, −4.87)**
Gender						
Girls vs. boys	0.48 (0.21, 1.12)	0.40 (0.15, 1.08)	0.83 (0.50, 1.38)	1.19 (0.83, 1.69)	**1.44 (1.04, 1.98)**	−0.93 (−3.55, 1.70)
Grade level						
Senior (grade 3 and 4)	0.49 (0.19, 1.24)	0.39 (0.12, 1.23)	1.08 (0.64, 1.83)	**1.65 (1.15, 2.38)**	1.03 (0.74, 1.43)	1.00 (−1.70, 3.70)
Parents' education						
High school	0.61 (0.25, 1.53)	0.59 (0.23, 1.55)	0.82 (0.46, 1.46)	1.31 (0.82, 2.08)	1.41 (0.93, 2.12)	0.67 (−2.63, 3.97)
University/College or higher	1.10 (0.40, 3.04)	0.58 (0.17, 1.96)	0.60 (0.30, 1.20)	1.20 (0.71, 2.00)	1.21 (0.76, 1.93)	−0.57 (−4.26, 3.13)
Constant	NA	NA	NA	NA	NA	90.28 (86.59, 93.97)

Bold numbers indicate a statistically significance ($p < 0.05$). The reference group for the variables: MVPA: ≥ 2 times a week; using a computer/cellphone: < 2 h/day; sleep time: ≥ 7 h/day; eating breakfast: eating every day; grade level: junior (grade 1 and 2); parental education: junior high school or less. NA, not applicable.

of children and adolescents. We have found only two studies that evaluated the combined effect of these behaviours (physical activity, sedentary behaviour, sleep and diet) on HRQoL amongst adolescents (4, 31). A study in Spain found that adolescents adhering to two or more healthy levels of the behaviours (physical activity, Mediterranean diet, sleep quality, sleep duration and screen time) had higher HRQoL compared with adolescents with unhealthy levels of the behaviours (i.e., healthy lifestyle index score = 0) (31). Another study observed that Portuguese adolescents who achieved more healthy lifestyle behaviours (i.e., healthy lifestyle composite score = 6) amongst six health-related behaviours (physical activity, screen time, sleep duration, daily fruit and vegetable consumption, drinking alcohol, and smoking) had higher HRQoL relative to those who achieved less than six healthy behaviours (4). The observation in this study that adolescents who had the unhealthy level of behaviours ≥2 showed lower HRQoL compared to those with no or only one of the poor behaviours is consistent with the previous studies (4, 31). This study supports the prior research finding that the combined health-related behaviours may pose a greater impact on HRQoL than single behaviour (4, 10, 31). The present study filled the gap in the literature by investigating a cumulative effect of multiple health behaviours on HRQoL amongst junior high school students in China. It is also worth to mention that the present study analysed HRQoL outcomes, including both the overall QoL (VAS score) and HRQoL in the EQ-5D-Y dimensions, and examined the effects of both single and multifaceted health-related behaviours. Therefore, the findings in this study contributes to the literature by providing relatively a comprehensive view of the relationships between health behaviours and HRQoL amongst adolescents.

Regarding the effects of socio-demographic factors on HRQoL, the present study found a significant association between gender, grade level and HRQoL in students. The findings that girls were more likely than boys to feel worry, sad or unhappy, and senior students were more likely than junior students to show pain and discomfort problems are consistent with previous studies (37, 38) showing that

TABLE 4 Multivariable logistic and linear regression results for the association between the combined health behaviours and the EQ-5D-Y dimension and VAS score amongst junior high school students.

Variable	Walking	Looking after self	Doing usual activities	Having pain or discomfort	Feeling worried, sad or unhappy	VAS score
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	Coefficient (95% CI)
Number of health behaviours with the unhealthy level response						
2	**4.25 (1.45, 12.51)**	1.83 (0.63, 5.35)	**2.27 (1.29, 3.99)**	**1.73 (1.16, 2.59)**	**1.55 (1.09, 2.22)**	**−6.34 (−9.33, −3.36)**
≥3	**8.57 (3.05, 24.08)**	**3.88 (1.46, 10.35)**	**2.51 (1.39, 4.55)**	**2.60 (1.72, 3.94)**	**2.63 (1.80, 3.85)**	**−10.70 (−13.95, −7.44)**
Gender						
Girls vs. boys	**0.42 (0.19, 0.94)**	**0.36 (0.14, 0.93)**	0.76 (0.47, 1.23)	1.24 (0.88, 1.74)	**1.60 (1.18, 2.17)**	−2.38 (−4.94, 0.17)
Grade level						
Senior (grade 3 and 4)	0.43 (0.18, 1.06)	0.34 (0.11, 1.04)	0.99 (0.60, 1.64)	**1.69 (1.19, 2.39)**	1.13 (0.82, 1.55)	−0.08 (−2.60, 2.76)
Parents' education						
High school	0.57 (0.23, 1.39)	0.59 (0.23, 1.51)	0.83 (0.46, 1.47)	1.25 (0.79, 1.97)	1.32 (0.88, 1.99)	1.10 (−2.25, 4.45)
University/college or higher	1.04 (0.39, 2.77)	0.57 (0.18, 1.86)	0.62 (0.31, 1.24)	1.13 (0.68, 1.88)	1.13 (0.71, 1.78)	0.15 (−3.59, 3.90)
Constant	NA	NA	NA	NA	NA	**87.23 (83.84, 90.62)**

Bold numbers indicate a statistically significance ($p < 0.05$). The reference group for the variables: 0–1 for number of health behaviours with the unhealthy level response; grade level: junior (grade 1 and 2); parental education: junior high school or less. NA, not applicable.

girls and older students tend to have lower HRQoL relative to boys and younger students. The association between parental education and HRQoL in children and appears more inconsistent. Some studies found a significant association between parental education and HRQoL in adolescents (38), whilst other studies did not observe a significant association (31). Our finding is consistent with the later in that we did not find a significant association between parental education and HRQoL amongst students in the adjusted regression model. Future research is needed to better elucidate the relationship between parents' educational attainment and HRQoL amongst junior high school students. Particularly, future studies that expand investigations amongst junior high school students in other regions of China and other countries with various socio-economic and cultural background will help provide better insights on the relationship of socio-economic factors with HRQoL.

The feasibility, reliability and validity of the EQ-5D-Y have been tested amongst children and youth in more than 15 countries (12). However, as the EQ-5D-Y is relatively a new HRQoL measure, very few studies have applied the EQ-5D-Y in HRQoL assessment amongst children and adolescents in China (12). The present study supports the feasibility, reliability and validity of the EQ-5D-Y amongst Chinese junior high school students. Of the 783 students, there is only one student with missing value in the dimension of 'feeling worried, sad or unhappy', confirming its feasibility. The Cronbach's alpha is 0.70 in this study, showing a good reliability. The pattern of prevalence of problems in the five dimensions (e.g., higher prevalence of problems in the last two dimensions and lower prevalence of problems in the first, second and third dimensions) is similar to other studies in China and other countries like European countries (i.e., Germany, Spain, Sweden), Canada, South Africa, etc. (12–15, 39), and within the expectation, suggesting the validity of the EQ-5D-Y. The differences in the HRQoL across groups by the health behaviour and socio-demographic variables also support the discriminant validity of the EQ-5D-Y in Chinese adolescents.

One strength of the present study is that we analysed the associations between health behaviours and HRQoL with respect of both individual and combined behaviours. Another strength is that the current study used validated questionnaires to assess health behaviours and HRQoL. HRQoL was measured by the EQ-5D-Y, hence, facilitating the comparison of the present study findings with other prior studies using the same HRQoL measure. Additionally, multivariable regression analyses were used to adjust the potential confounding effects of socio-demographic factors of students, thus the association between health behaviours and HRQoL can be considered independent of the effect of students' gender, grade level and parental education.

Limitations of the study should also be clarified. The observed associations of health behaviours with HRQoL could not be inferred as causality due to the cross-sectional study design. Future research is needed to conduct prospective studies that will help address a prospective relationship between the health behaviour and HRQoL in children and youth. Measurements of health behaviours relied on students' self-report although questions have been previously validated, hence the findings may be prone to error or bias. The use of objective measures of physical activity (e.g., pedometers) and screen time behaviour (e.g., screen use monitor) would help to make more accurate assessments of these behaviours. However, the use of objective measures may present challenges in financial and human resources' allocation in large-sample studies. Although the present study analysed five important health behaviours, there may be other health behaviours (e.g., eating fast food) that could impact HRQoL of students. Future research is needed to examine the associations of

unmeasured health behaviours in this study with HRQoL. Additionally, the survey was conducted amongst junior high school students in one city in the province, thus the findings in this study are limited to generalise to junior high school students in other areas in China.

The findings in the present study have important implications in public health policy and population health research for improving health behaviours and health amongst children and youth. Public health policymakers, school educators, parents and caregivers of students are encouraged to understand the importance of promoting healthy lifestyle behaviours amongst children and adolescents, and do their best to improve health behaviours of the younger population. Public health strategies should place a priority on those subgroups with poor health behaviours, and target promoting these behaviours together rather than consider them separately. Previous studies suggest that school-health intervention programmes that adopt a comprehensive school health promotion approach incorporating promoting nutrition and diet quality, physical activity and sleep quality, and reducing sedentary behaviours simultaneously may produce more positive effects on health outcomes of children and adolescents (40, 41). According to World Health Organization's (WHO's) Health Promoting Schools (HPS) framework (42), school health programmes are needed to implement both at schools and at communities and homes, and target students, their parents and school teachers for the purpose of enhancing HRQoL amongst students. For public health researchers, future research is required to conduct more longitudinal and experimental studies in various socio-economic and cultural contexts to better inform a causal role of the health behaviours for HRQoL of students.

5. Conclusion

The present study reveals that sleep time, breakfast eating, physical activity and sedentary behaviour are related to HRQoL amongst junior high school students. Both individual behaviour and their joint behaviours are significantly related to HRQoL amongst students. A dose–response relationship was found in the associations between the health behaviours and HRQoL. The findings suggest that school-based programmes that target promoting these health behaviours amongst adolescents may help to enhance their health and HRQoL. School health programmes that focus on multiple health behaviours simultaneously may be more effective in the improvement of students' physical and mental health, psycho-social functioning and well-being than targeting single behaviour. Further research using prospective designs, such as cohort studies and school health intervention studies amongst children and adolescents in different cultural, socio-demographic and socio-economic settings, is needed to better understand the relationship between health behaviours and HRQoL amongst children and adolescents.

Data availability statement

The datasets presented in this article are not readily available because of privacy policies however are available from the corresponding author on reasonable request. Requests to access the datasets should be directed to XYW, wxy196163@163.com.

Ethics statement

The present study, including the data collection, was approved by Human Research Ethics Boards of the Weifang Medical University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin, and students themselves.

Author contributions

XYW conceptualized the study, analyzed data, drafted and revised the manuscript. HQL reviewed the statistical analysis and revised the manuscript. ZHL reviewed the analysis results, drafted and revised the manuscript. TZH conducted data collection, data management and revised the manuscript. YLW, YSY, YR reviewed and revised the manuscript. All authors participated in the critical revisions of the manuscript, and read and approved the final 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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Impact of the COVID-19 pandemic on the adaptability and resiliency of school food programs across Canada

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Introduction: Following the sudden closure of schools due to the pandemic in 2020, many school food program (SFP) operators lost their operating venues and had to innovate to continue distributing meals to children. Our objective was to assess the impact of the COVID-19 pandemic on the delivery, adaptability, and resiliency of school food programs across Canada by conducting a systematic rapid review.

Materials and methods: Systematic literature searches identified newspaper articles and social media sources related to the adaptations and challenges faced by school food programs across Canada in response to the COVID-19 pandemic. Included sources were assessed and thematically categorized according to the dimensions of the Analysis Grid for Environments Linked to Obesity (ANGELO) and Getting To Equity (GTE) frameworks to identify factors impacting the delivery, adaptability, and resiliency of school food programs in Canada.

Results: School food programs in Canada made various efforts to meet existing and new challenges associated with the delivery of these programs to keep feeding school children, particularly those most vulnerable, during the pandemic. Distribution of food kits, prepared meals and gift cards/coupons were successful pathways in ensuring support for food accessibility to students and their families. Increased collaborations between community members and organizations/stakeholders to help maintain food delivery or collectively offer new modes to deliver foods were most frequently cited as key to facilitating school food programming. However, maintenance and sustainability related to operating costs and funding were identified as key challenges to successful school food programming.

Conclusion: Our study highlights the swift and substantial transformation school food programs,, underwent in response to the pandemic, driven by the urgent need to ensure that students still had access to nutritious meals and the importance of policy and resource support to bolster the adaptability and resiliency of these programs. Findings on facilitators and challenges to school food programs during the early months of the COVID-19 pandemic can inform development of guidelines to design a robust national Canadian school food program and help make existing programs more sustainable, adaptable, and resilient.

KEYWORDS

Canada, COVID-19, challenges, children, school food programs, nutrition programs

1 Introduction

On March 2020, the COVID-19 outbreak was declared a pandemic by the World Health Organization (WHO) (1), resulting in stresses on economies and food supply chains around the world, and disproportionately impacting the world's most vulnerable populations, including children. The number of food insecure children nearly doubled due to the COVID-19 pandemic (2). Lockdown measures and school closures during the pandemic are key factors in driving increased food insecurity, by cutting off children's access to the food sources they once relied on during the school week, especially for children already living in poverty or those with lower socioeconomic status (3).

In Canada, the food retail landscape rapidly evolved during the COVID-19 pandemic through consumer panic buying, increased operating costs of grocery stores (due to new enhanced safety precautions) and potential food shortages as a result of closed manufacturing plants, which led to increases in food prices, particularly for certain core food (i.e., recommended) categories (4). Many Canadians were and are currently faced with reduced work hours or unemployment, lower incomes, and decreased food budgets as a result of the pandemic (5) thereby increasing their risk of food insecurity and poor diet quality. In Canada, as across the world, fractured school operating schedules or long-term school closures mean that many students may no longer have access to meals through voluntary school programs that they may have relied on under normal circumstances to meet their nutritional needs (6). As COVID-19 continues to disrupt the food retail environment and create growing economic uncertainty, children and their families are at increased risk of poor nutrition (6).

School environments that reinforce positive habits and practices are critical in shaping the well-being of children and adolescents, who spend a considerable portion of their day at school. In Canada, children and adolescents reportedly consume about one-third of their daily energy at school, with most of it coming from foods low in nutritional quality (7). While schools could be a channel for nutritious foods through national school food programs, Canada remains one of the few industrialized countries without one (8). Instead, municipal, and provincial/territorial governments and non-governmental organizations support a patchwork of school food programming across Canada (9, 10). Recent evidence suggests that the participation rates of these mixed efforts in school food programming ranges from approximately 5% in Alberta to 83% in Yukon (11). Despite varying participation, school food programs offer a source of quality nutrition for children who may come to school hungry for various reasons (e.g., food insecurity).

School food programs serve nutritious meals and snacks, ensuring consistent access to healthy foods for children. With abrupt school closures due to lockdown measures, many programs faced challenges finding new ways to distribute meals. While news articles captured the adaptation and resilience of school food programs in Canada during the pandemic, there is a lack of systematic evidence synthesis on their emergency adaptations. Therefore, the objective of this study was to conduct a rapid review to systematically explore the impact of the COVID-19 pandemic on the delivery, resiliency, and adaptability of school food programs across Canada, offering insights to strengthen future policies, especially food food-insecure and marginalized communities, particularly during periods of school closures (e.g., during the summer holidays).

2 Materials and methods

2.1 Information sources and literature search

Recognizing the rapidly evolving nature of the COVID-19 pandemic and its influence on school closures, this study was designed as a systematic rapid review of newspaper articles, social media and grey literature covering information on the delivery, adaptability, and resiliency of school food programs as emergency response feeding strategies across Canada. The research question addressed by this rapid review was: For school-going children and adolescents, how did school food programs adapt during the pandemic in terms of delivery and infrastructure compared with 'pre-pandemic' operations, and what lessons were learned from school food programs that were sustained during the pandemic to ensure provision of nutritious meals to students. This study employed a multiple case study approach to guide our data collection, analysis, and interpretation, given the rapidly evolving nature of school food program modalities during the COVID-19 pandemic. Relevant studies were included if there were sufficient access to pertinent data in relation to the research question.

Data extraction was organized using the PICOTS framework as follows: (a) Population – school food programs provided to school-aged children and adolescents; (b) Intervention – various adaptations to school food program modalities; (c) Comparison – "pre-pandemic" school food program modalities; (d) Outcomes – The various items covered under the delivery, adaptability, and resiliency of SFP were adapted from other studies, guided by the RE-AIM framework: Reach and Effectiveness (Delivery) e.g., SFP modalities, food type and variety, method of delivery/food distribution, food procurement, participation/scope. Adoption and Implementation (Adaptability) e.g., infrastructure, changes to content (e.g., menu items, food type/variety/food distribution and procurement) of SFPs. Maintenance and Sustainability (Resiliency) e.g., concerns, challenges and successes encountered, support/beneficiaries, funding and costs and impact; (e) Time – adaptations to school food programs during the COVID-19 pandemic lockdown and (f) Study design/characteristics – case studies, relevant news/webinar articles and inclusion of necessary information with respect to delivery, adaptability and resiliency. This research was guided by two frameworks: the Analysis Grid for Environments Linked to Obesity (ANGELO) (12) and the Getting to Equity (GTE) (13), selected for their complementarity towards capturing the factors impacting the delivery, adaptability, and resiliency of school food programs in Canada.

To identify potentially relevant articles for inclusion, the following electronic databases was searched: ProQuest Canadian NewStream for news articles and Social Search for social media articles. The search was supplemented by grey literature captured

through targeted internet searches for news articles, as well as attendance and participation in webinars, that provided additional links to strategies addressing the adaptations of school food programs. A concept map was created to identify relevant keywords (Table 1), and the keywords were further refined with the research team and University librarian in terms of redundancy and ability to capture the relevant articles. The inclusion criteria were any case studies, news articles or webinars that were assessing school food programs (lunch, breakfast, snakes, before/after school) for school-aged children/adolescents and mentioned the delivery, adaptability, or resiliency of these programs during the COVID-19 pandemic in comparison to the regular operating schedule from the time of the public health emergency declaration and school closure announcements in Canada. Studies were excluded if they were looking at day care or early child education center food programs.

2.2 Screening

Articles were eligible if they included keywords related to school food program during the COVID-19 pandemic. Potential sources obtained from literature searches were extracted, organized, and reviewed by two team members (J.R and A.R). The first team member began by screening all potential sources for relevance. Non-relevant sources were excluded (e.g., focusing on school food program adaptations outside Canada), as were any sources that were duplicated. The second team member then reviewed the remaining eligible articles for their inclusion in the study.

2.3 Source content analysis and synthesis

The ANGELO framework was designed to assess the environmental factors impacting eating behavior or physical activity and allows for identifying which factors can be readily modified (12). It is designed for communities to identify these factors, however, can be used both at the population (e.g., Canada) and settings/sector level (e.g., schools or fast-food retails). The framework assesses macro and microenvironments, with respect to the physical, economic, political, and sociocultural aspects. Macroenvironments operate at a regional/state level and may include media, food distribution programs, food transport, and food catering services while microenvironments relate to the household/institutional level and may include settings such as the home, school, church, grocery store, and food service outlets (12). In this study, the ANGELO framework was used as a conceptual model to evaluate and assess the balance of the societal and environmental factors impacting adaptability of school food programs during the COVID-19 pandemic (Supplementary Table 1). In reviewing each article, assessors thematically categorized mention of various societal and environmental factors according to the domains of the ANGELO framework.

The Getting to Equity (GTE) framework focuses on equity-oriented obesity prevention action through four types of approaches and was used to assess the gaps in school food programs, specifically for food insecure and marginalized communities during the COVID-19 pandemic (13). The four approaches are: increasing healthy options; reducing deterrents to healthy behaviors; improving social and economic resources; and building community capacity. Increasing healthy options and reducing deterrents focus on potential policy and system interventions that could lead to improved equity, while improving social and economic resources and building on community capacity focus on individual and community resources and capacity developments (13). Specifically, this framework was used to assess the adaptability of school food programs as emergency feeding strategies with a 'people-oriented perspective' according to how they affect school-aged children, families, insecure/marginalized communities, other population subgroups and communities. In reviewing each article, assessors thematically categorized the adaptability of school food programs according to the various approaches of the GTE framework (Supplementary Table 2).

Both the ANGELO and GTE frameworks were used to synthesize common themes related to successes and challenges emerging across the adaptability of school food programs in Canada during the COVID-19 pandemic.

2.4 Data analysis

In reviewing each article, we thematically categorized mention of various societal and environmental factors according to the domains of the ANGELO and GTE frameworks. The components of each framework were used to synthesize the themes after we thematically

TABLE 1 Text used in literature searches.

Literature Search								
School*		Lunch		Program*		COVID-19		Marginalized
Elementary		Breakfast		Policy		COVID*		Insecure
Secondary		Meal*		Environment		Coronavirus*		Vulnerable
High School	**AND**	Nutrient*	**AND**	Arrangement	**AND**		**AND**	At risk
Children*		Snack*		Project				Susceptible
Youth*				Strategy				
Adolescent*				Protocol				
Young Adult*				Supplemental				
Student*								

*Variation each of the text were searched (e.g., school, schools, nutrient, nutrients, snack, snacks, children, child, children's, kids, youth, adolescents, adolescence, young adults, students etc).

analyzed the data using NVivo, guided by the RE-AIM framework. This involved (1) becoming familiar with the literature review/similar studies (14–16), (2) creating initial codes based on these similar studies and using the RE-AIM framework to guide the selection of themes, as relevant to the research question, designed using PICOTS, and (3) Thematically organizing the data.

Data obtained from the search results were extracted and organized into the following categories by each city and province: Reach and Effectiveness (Delivery): SFP modalities (e.g., food kits, gift cards and type of foods), food type and variety, method of delivery/food distribution (e.g., delivery/pickup time), food procurement, participation/scope (e.g., students, families, insecure/marginalized populations). Adoption and Implementation (Adaptability): infrastructure, changes to content/modifications (e.g., menu items, food type/variety/food distribution and procurement) of SFPs (e.g., electronic messages, fund raisers etc.). Maintenance and Sustainability (Resiliency): concerns, challenges and successes encountered, support/beneficiaries, funding and costs and impact. Information was collected and thematically categorized and compiled by the two team members. In case of discrepancy, information was reviewed by a third team member for thematic categorization.

3 Results

A total of 166 citations were initially retrieved. Of these, 165 were obtained from ProQuest Canadian Newsstream. The 1 remaining source was obtained from a webinar *Nourishing students: How Ontario SNP's are adapting in a time of COVID* hosted by Student Nutrition Ontario and sustain Ontario on June 1st 2021.Upon review of the 166 collected citations, 81 duplicated sources and 50 sources deemed to be ineligible for the purposes of this review were excluded from further analysis.

A total of 35 unique sources were validated and included in this review. The 35 sources consisted of different source types such as newspapers ($n = 24$), seminars ($n = 1$), and social media sources comprised of blogs, podcasts, and websites ($n = 3$) and wire feeds ($n = 7$). Source type was determined using the classifications obtained from ProQuest (excluding the seminar as ProQuest was not used to find this source) (Figure 1).

3.1 Captured dimensions of the ANGELO and GTE frameworks

The main dimensions of the ANGELO framework captured by the 35 sources were related to sociocultural ($n = 29$), physical ($n = 26$), or economic ($n = 20$) environments. There was a notable lack of school food program adaptations which incorporated the political environment (n = 3). (Figure 2).

When examined using a basis of the GTE framework, the 35 included sources predominantly focused on improving social and economic resources ($n = 28$) and building community capacity ($n = 26$). Reducing deterrents was also a focus of the included articles ($n = 20$), with the least number of articles focusing on increasing healthy options ($n = 15$) (Figure 3).

3.2 Modality of SFP during the pandemic

In terms of modality, novel approaches to the delivery of school food programs included new initiatives or adjustments to old approaches, community initiatives and increased financial support. Programs in several provinces implemented the provision of food kits and gift cards to students, with some even offering home delivery. Community initiatives included setting up shelters or other public locations to provide meals and food kits to students and their families, as well as organizing local events to increase awareness on food insecurity of local families and raise funds. Additionally, with the support of non-governmental organizations (NGOs) and school food program-allocated funds from governments (federal, provincial/territorial), there was greater capacity to maintain emergency food distribution in certain regions (e.g., Nunavut) (Table 2).

3.3 Adaptations to school food program coverage

During the pandemic, several school food programs focused on vulnerable students and families, particularly those identified as high-risk of facing food insecurity and/or belonging to marginalized communities (e.g., those with language barriers, minority groups). Most programs adapted to provide meals on a weekly basis, with some in the provinces of New Brunswick and Ontario giving daily options (Table 2).

3.4 Types of food kits/prepared meals

For the programs that adapted to provide food kits, the majority of the food kits included some form of fruit, vegetables, dairy and grain products. A few also incorporated granola bars or savory snacks such as crackers. There was none or very limited provision of legumes and pulses, animal protein, sweets and desserts and sugar-sweetened beverages. Only two articles indicated following nutritional guidelines established for the SFP (Table 3).

For the programs that indicated provision of prepared meals, the majority incorporated dairy and grain products as components of meals, while only few indicated the inclusion of animal products other than dairy, fruits, and vegetables (Table 3).

3.5 Lessons learned and challenges in implementing modifications to school food programs

One of the factors that was repeatedly mentioned as facilitating the continuation of school food programs during the pandemic was leveraging existing community partnerships and distribution channels. For example, several articles highlighted the collaborative approach that was helpful in swiftly altering the mode of distribution and provision of nutritious meals and snacks, particularly to those families and children in need. This approach was further facilitated by the development of new partnerships with local businesses, which allowed for the purchase

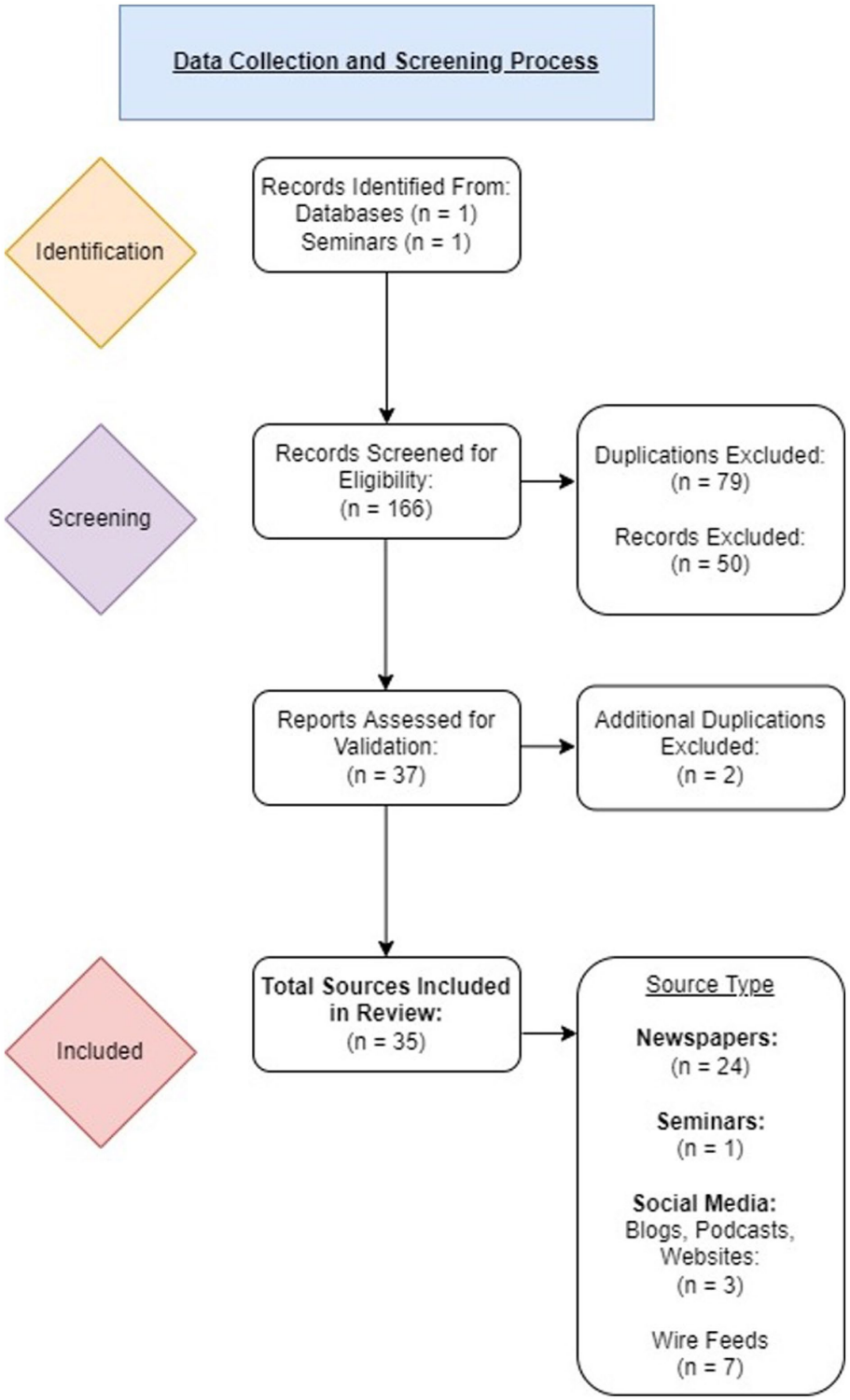

FIGURE 1
Flowchart of data collection and screening process: A total of 166 citations were retrieved. Thirty five articles from 7 provinces and territories across Canada fulfilled the eligibility criteria and were included in this review. Ten of the included articles were from social media sources.

of food from local farmers whose distribution chains had been disrupted and local restaurants taking on the responsibility to provide fresh meals to students after losing regular business. Additionally, the flexibility of certain school food programs led to modifications like expansion in food provision range to reach a larger number of children and families, including extra food in meal kits to help support families over the weekend, and transforming restaurants which supplied lunches to one school pre-pandemic into distribution hubs to reach a larger group of families in the area (Table 4).

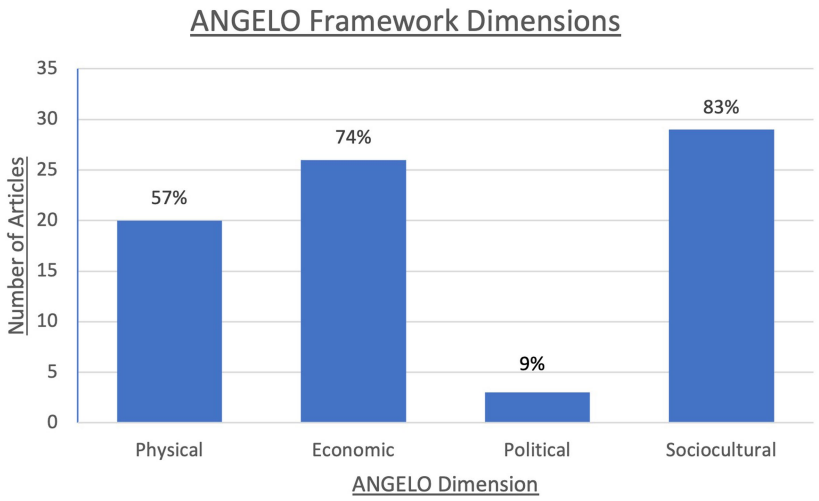

FIGURE 2
Analysis Grid for Environments Linked to Obesity (ANGELO) framework dimensions captured in included sources: Number of sources (out of total $n = 35$) which captured each respective dimension of the ANGELO framework (12). Examples of physical environment components include food availability, accessibility, and distribution. The economic environment covers aspects such as food costs, price gouging, and available financial resources (e.g., monetary donations, fundraisers) for both SFPs and families in need. The political environment includes governmental interventions such as the creation of new laws, regulations, and funding changes. The sociocultural environment focuses on the attitudes, values, and collaborations of the community and society at large. Abbreviations: ANGELO, Analysis Grid for Environments Linked to Obesity; SFP, School Food Program.

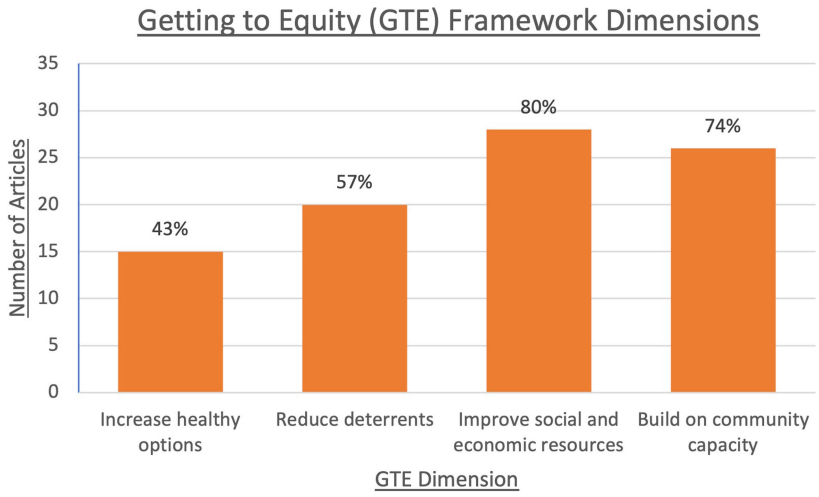

FIGURE 3
Getting to Equity (GTE) framework dimensions captured in included sources: Number of sources (out of total $n = 35$) which captured each respective dimension of the GTE framework (13). Examples of increasing healthy options includes the distribution of free meal kits and prepared meals which follow existing SFP guidelines, as well as meal kit delivery. Reducing deterrents involves mechanisms such as providing food at accessible locations, following COVID-19 guidelines, and non-discriminatory outreach to all students and families. Improving social and economic resources can occur through the creation of new SFPs during COVID-19, along with increased amounts of funding and donations (e.g., monetary, food, other supplies) to SFPs or directly towards vulnerable students and their families. Building on community capacity can be achieved through collaborations between community members to help those in need, using community resources in beneficial ways, and creating new partnerships to provide greater aid to those in need (e.g., working with larger organizations and companies). Abbreviations: GTE, Getting To Equity, SFP, school food program.

A shared barrier among the school food programs were the increased expenses involved with the procurement of food and meals, and additional operating costs related to adhering to COVID-19 protocols. Challenges faced when adapting school food programs also included a heavy reliance on community donations and volunteers, as well as the use of electronic devices and social media to reach families and children in need, although not all families had internet access. Several school food programs continued providing healthy meals during the pandemic without the provision of additional resources. In addition, they faced issues such as limited food supplies and interruptions to food transportation (Table 5).

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TABLE 2 Summary of changes to School Food Programs in response to the COVID-19 pandemic.

Province/ Territory *(and Cities)*	Number of Articles Reviewed	Target Demographic(s)	Modalities of COVID-19 Response	Distribution Schedule(s) [for meals/food kits]
New Brunswick - *Moncton* (2) - *Saint John* (2)	4	• Families in need, including families with language barriers	• Volunteers partnered with local food banks and other facilities to help continue SFP for 13 weeks in school districts following school closures • Creation of emergency food program formed and funded by a collection of local organizations to create and deliver food boxes to food-insecure households	• Daily • Weekly deliveries
Ontario - *Mississauga* - *Toronto* (2) - *Windsor* - *Ottawa* (4) - *Clinton* - *Thunder Bay*	10	• Families in need • Fully online learners	• Volunteers formed small teams to deliver groceries to families in need during school closures • Local restaurants partnered with Ontario School Nutrition Program to become meal kit distribution hub for the areas following school closures • Local businesses started making meals for students in need to help provide relief to struggling families following school closures; Local restaurant owner providing meals to children in need in the community • Food hamper distribution to aid fully virtual students in need • Changing format of in-person fundraising events to virtual in order to continue to raise money for SFPs and local food bank • Teachers and volunteers starting new programs to deliver fresh fruits and vegetables to vulnerable students and their families • Transition to delivering breakfast meals directly to food agencies to accommodate for school closures and still be able to provide food for families in need • Increased funding by the Government of Canada to help initiatives which help combat food insecurity for students and their families • Food donations and support by private sectors to partners and distribution of private sector's products and coupons to most vulnerable families throughout Canada	• Daily • Weekly
Québec - *Montréal*	1	• High-risk students	• Redistributing funding normally allocated for schools towards students at high-risk for food insecurity/low-income and partners equipped to serve students in need	• N/A
Saskatchewan - *Maple Creek*	1	• School students and staff	• Serving fresh meals	• Weekly
Alberta - *Edmonton* - *Edson* - *Rycroft* - *Sylvan Lake*	4	• School students • Families struggling with food security	• New food distribution program to communities • Monetary donations from community to help run SFPs and local food banks during closures • Additional government funding to expand SFP into new areas to help more families struggling with food security	• Weekly

(Continued)

TABLE 2 (Continued)

Province/ Territory *(and Cities)*	Number of Articles Reviewed	Target Demographic(s)	Modalities of COVID-19 Response	Distribution Schedule(s) [for meals/food kits]
British Columbia - *Vancouver* (3) - *Clearwater* - *Revelstoke* - *Richmond* - *Victoria* (4) - *New Westminster* - *Smithers* - *Houston*	13	• Families in need of help • Students most vulnerable to food insecurity	• Community fundraiser to help schools support families in need • Creation and funding towards local community project which aims to keep school breakfast programs running • Money raised by local groups towards purchasing groceries for families in the community in need of help • School district offering free meals to families which normally rely on SFPs for help • School staff creating meal kit program for most vulnerable students during closures • Principals continuing SFP by personally shopping for food and clothes for students in need and their families • Creation of new SFP that provides warm breakfast and meal kit to help struggling families during school closures • Local grocery wholesaler donating frozen meat for families in need in absence of SFPs • School district setting up distribution hubs at schools to provide weekly meals to vulnerable families • Food distribution partnered with new agencies to expand outreach, helping to serve more under-privileged communities during school closures	• Twice every week • Weekly • Every 18 days
Nunavut - *Iqaluit*	2	• Food-insecure households	• Members of Legislative Assembly direct increased amounts of funding towards SFPs to operate during closures • Volunteers modified existing breakfast SFP and school food bank to create pre-packaged breakfast kits students could pick up to take home during closures	• Daily

SFP, school food program.

4 Discussion

The findings from this study illustrate how voluntary school food programs across Canada modified and adapted feeding strategies during school closures and the facilitators and challenges they faced in delivering essential provisions to school-aged children, particularly those who were the most vulnerable, which resulted from the COVID-19 pandemic (Figure 4). There was an increased emphasis on community engagement, identified as a key component in facilitating provision of foods to children. However, despite the strengthened efforts among community members, a lack of or limited funds allocated for emergency feeding made delivery of foods challenging, as related to maintenance and sustainability.

As shown from the results of this study, these programs devised and implemented new modalities, which included a mixture of meal provision strategies such as meal pick up at a central location or direct delivery of food kits/prepared meals or gift cards to use in grocery stores. Results from other countries such as the US, Europe or Latin America assessing emergency feeding response indicated similar adaptations (e.g., food kits/ food vouchers) to feeding modalities (14, 17, 18). The results from this study on types of modalities are in alignment with another Canadian study examining the breadth of school food programming; indicating the provision of meals (e.g., breakfast), food boxes and gift cards to sustain school food programming during school closures (16). Direct delivery of food kits/ prepared meals or specified pick-up locations ensured student food accessibility, particularly for those who may have limitations accessing these locations via public/personal transport methods. These adaptations to program accessibility can also benefit students with food provision during the 'summer' months or when schools are not in session, particularly for students receiving free or reduced-priced meals during the school year. Recent studies have incorporated spatial

TABLE 3 Summary of components included in food kits and prepared meals following School Food Programs modifications in response to the COVID-19 pandemic.

Food Kits											
Location	*Continued to follow established SFP Nutrition Guidelines?**	Fruits and Vegetables	Legumes and Pulses	Animal Protein (meat/ non-dairy)	Dairy	Grains†	Savory Snacks†	Sweets and Desserts	Sugar-sweetened beverages	Condiments	Other
Mississauga, ON				√	√	√					
Ottawa, ON		√			√	√	√				Granola bars, applesauce
Thunder Bay, ON	√	√			√	√	√				Granola bars
Toronto, ON		√									
Windsor, ON		√				√					Granola bars
Smithers, BC	√					√					Canned soup, snacks‡
Vancouver, BC		√		√		√	√			√	
Iqaluit, NV		√			√	√					

Prepared meals§											
Location	*Continued to follow established SFP Nutrition Guidelines?**	Examples of Meals Served	Fruits and Vegetables	Legumes and Pulses	Animal Protein (meat/ non-dairy)	Dairy	Grains	Savory Snacks†	Sweets and Desserts	Sugar-sweetened beverages	Other
Moncton, NB		*Sandwiches‡*					√				
Clinton, ON		*Peanut butter + jelly sandwiches, cereal with milk*				√	√				Peanut butter, jelly
Maple Creek, SK		*Hamburgers, breakfast burritos, chicken, pizza pockets, grilled ham, meatball sandwiches, side of fresh vegetables*	√		√	√	√				
Houston, BC	√	*Sandwiches‡, wraps‡, side of fruits and vegetables, oatmeal (packaged)*	√				√				

SFP, school food program.

*Criteria met based on article's explicit mention of following previously established SFP guidelines and/or consulting higher authority (ex. regional health care provider) about which foods to include in meal kits.†Examples of grains would be rice or bread. Examples of savory snacks include crackers, tortilla chips and salsa, hummus, and pita, etc.

‡Relevant articles did not specify the types of snacks, sandwiches, or wraps included/prepared.

§Meals were either prepared fresh on-site and provided to students or prepared prior, packaged, and distributed.

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TABLE 4 Overall summary of positive adaptions made to the School Food Programs in response to the COVID-19 pandemic.

Themes	Ways which positive adaptations emerged across Canada
Collaborations supporting modified SFPs (ex. within community, partnering with organizations)	• Donations from community members and local businesses to support preparation of fresh meals/meal kits • Volunteers using their own resources and money to continue supporting small group of families who relied on SFPs pre-pandemic • Support from local food banks to help keep SFPs supplied during pandemic • Formation of new food programs comprised of a collection of organizations to support those struggling with food insecurity • Local business owners providing food to children in need by accepting food donations from the community and preparing fresh meals • Teachers delivering groceries to families in need, accepting donations from the community to fund grocery purchases • Local fire department assisting with meal kit deliveries • Private sector donating foods and funding to partners/organizations providing foods
Use of meal kits	• Implemented to compensate for lack of fresh meals being served to students during school closures • Variety of distribution methods (ex. Delivery to students directly, pick-up at school, pick-up at set distribution points in community) • Variable distribution schedules (ex. Bi-weekly, weekly, monthly)
Food types included in meal kits and prepared meals	• Meal kits most often contained fresh fruits and vegetables, grain products, dairy products, savory snacks, and products classified as "other" (ex. Granola bars, canned goods) • Meal kits lacked sweets and desserts, as well as SSBs • Most common prepared meals were sandwiches and wraps (type not usually specified)
Coupon distribution	• Private sector working with the Grocery Foundation of Canada to provide private sector's product coupons to families in need across the country
Price gouging and food affordability	• Meal kits and fresh meals provided free of charge by school/organizations to students in need and their families
Flexibility of SFPs	• Extra food provided in meal kits to help support families over the weekend (and beyond) • Local restaurant which normally supplied lunches to one school becoming a distribution hub for meal kits to help larger group of families in the area • Changing normal school meal distribution format to meal kit delivery to still provide food to families in need despite school closures • Expansion of SFP into new areas to reach larger number of students and families in need • Some SFPs accounted for the food preferences and dietary needs of students
Financial resources used to support continuation of SFPs during the pandemic	• Donations from organizations supporting delivery of groceries to most vulnerable students and their families • Community fundraisers normally held in-person moved to an online format in order to raise money for local food initiatives • Members of legislative assembly (MLAs) allocating increased amounts of spending towards SFPs using emergency budget • Individual members of community starting fundraisers towards helping local SFPs (ex. woman climbing mountains to raise money) • Fundraisers through grocery stores used to help local schools purchase appliances, cutlery, food gift cards, etc. for cafeteria and SFP • Grocery gift cards provided to vulnerable families who relied on SFPs pre-COVID 19 • Government of Canada allocating immediate funding towards supporting SFPs
COVID-19 guideline adherence	• Volunteer staff wearing proper PPE (ex. Face mask, gloves) when preparing and distributing prepared meals/meal kits • Meal kits prepared with precautions for easy disposal and minimal contact (ex. wrappings, paper bag) • Physical distancing procedures followed (ex. one person picks up meal kit from distribution location)
Novel ideas	• Focusing on decentralized practices to recover economic and socialized institution practices (ex. using experiential education settings such as a farm to offer alternative teaching methods to small groups of students and provide fresh food to students and the community)

SFP, school food program.

analyses to assess school meal accessibility related to geographic opportunity, finding that meal distribution sites were often located in larger high poverty areas and areas with a higher proportion of visible minorities (19–21).

Increased outreach (e.g., through local events) and expansion of existing programs (to those outside the community via internet/social media campaigns) also helped improve student food access, as captured by the ANGELO framework of sociocultural factors and GTE framework of building community capacity. Considering the associated risks to student health and well-being due to disruptions in food access, particularly students from vulnerable groups who may lack other nutritious options, future research in Canada can benefit from examining proximity to food access points in relation to factors such as race/ethnicity and socioeconomic status.

The development and effectiveness of these new modalities depended on resource availability and logistical navigation for acquiring and distributing foods with an emphasis on securing funds for sustainability. Support from NGOs, private organizations and/or governmental support was identified as contributing to the maintenance of these emergency food distributions, particularly in regions that are difficult to access (e.g., Nunavut). The modifications in school food programs reflected an increased emphasis on improving social and economic resources as captured by GTE and physical/economic environments aspects as captured by ANGELO. The emphasis on adequate and sustained resources has also been echoed by school-level program volunteers to ensure program feasibility and fidelity (22). These resources not only indicate a need for more staff and enhanced funding but also for resources to train and support staff

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TABLE 5 Challenges faced by modified School Food Programs during the COVID-19 pandemic.

Themes	Ways which challenges emerged across Canada
Use of meal kits	• Certain methods of meal-kit delivery (ex. by local fire department) were only available during certain days/weeks – uncertainty faced when trying to co-ordinate other modes of delivery
Food types included in meal kits and prepared meals	• Meal kits commonly lacked animal protein, legumes and pulses • Prepared meals were usually low in fruits and vegetables and/or animal protein (or did not specify if these foods were included) • Very few meal kits/prepared meals followed established SFP guidelines on foods to include and serve
Price gouging and food affordability	• Increased difficulties faced when trying to access food due to increased prices, lack of donations from usual community donors
Flexibility of SFPs	• Changes to SFPs (ex. changing provider) led to loss of food choice, increased negative attitudes of students towards the SFP, and loss of personal relationships between students and SFP staff (ex. changing to externally prepared and catered format) • Some modified SFPs relied solely on electronic communication and social media announcements which served as a barrier to students and families without internet access
Financial resources used to support continuation of SFPs during the pandemic	• Expenses of modified SFPs hard to maintain, especially when run by small team of volunteers – rely on community donations to continue and have strict budget • School district having to cover costs to maintain SFP instead of relying on donations • Funding uncertainties make it unclear as to how long the modified SFPs will last since it is not sustainable to be run by volunteers alone

SFP, school food program.

(e.g., educational workshops to handle food waste or food for large numbers of children) (22).

Considering the patchwork of programming and multi-modality strategies as adaptations in various regions across Canada, it is unclear whether one method of modality is preferred, feasible or functional over another and how they might be associated with contextual factors such as stigma. A 2017 study investigating using food vouchers or free daily lunch (to reduce food insecurity) found the daily lunch method was preferred by many families, with less stigma associated with this method in comparison to food vouchers (23). However, use of a particular modality is likely community specific as factors identified in this study, such as accessibility and reach, are likely to play a role in their success.

Similar to the response by other countries (14, 17, 18), many organizations considered alternative innovative strategies to continue meal delivery. For example, distribution sites such as local community centers, places of worship and other public institutions were used to maximize access. Home delivery was another innovative approach with a high uptake in neighborhoods and for hard-to-reach areas. This suggests the potential to expand the school food programs beyond the traditional modes of delivery, for school-aged children in remote/hard-to-access areas and for when schools are not in session. Similar benefits have been shown in other studies indicating that relaxing restrictions or expanding locations of free meal sites can increase child access to meals during expected and unexpected disruptions to programs and continue to ensure access to nutritious food (24). In many areas, school meals were extended beyond school-aged children to unhoused individuals/families, those relying on food banks, food insecure families and other vulnerable population groups.

Collectively, this suggests that cross-sectoral collaborations to serve children and families can help strengthen community engagement and local partnerships to resourcefully deploy feeding strategies across various population groups, reaching the most at-risk populations. The results from this study are similar to a case study showing that student nutrition programs rich in partnerships enables the staff to pivot and respond efficiently and quickly to the lockdown restrictions (25). Additional studies have also demonstrated the importance of community/multisectoral partnerships in the provision of local, healthy, and traditional foods for schools (26, 27). Importantly, such partnerships have potential for long-term sustainability and maintenance of school food programs.

Despite logistical challenges, some of the programs identified aimed to provide foods as recommended by 2007 Canada's Food Guide, e.g., including some form of vegetables, fruits, dairy and grain products. However, the challenges of a decreased food supply, price gouging, and changes to normal program delivery impacted the provision of fresh foods and led to increased provision of processed shelf-stable foods that are typically high in discretionary nutrients. Difficulties related to following recommended school food program guidelines were likely related to challenges obtaining fresh food and desire to limit food perishing as much as possible. This is also made evident through the lack of articles which reflected the GTE framework dimension of increasing healthy options. Additionally, food accessibility for children with allergies and/or certain dietary restrictions was more difficult due to the decreased variety of foods available in meal kits and limited options of prepared meals due to indicated challenges. Other countries also reported similar challenges in the provision of healthy foods (14, 17, 18). For example, in UK, media reports showed that many food parcels/kits were inadequate and did not meet school food standards with parents criticizing a lack of fruits and vegetables and inadequate portion sizes (28).

Several studies have indicated that meals offered through school food programs can make substantial contributions in helping children meet their dietary recommendations (29–31), with research indicating consumption of school meals positively relating to child intake of key food groups (e.g., school food participants were more likely than nonparticipants to consume milk, fruit, vegetables and less likely to consume desserts and snack items) (32, 33). Canada's Food Guide stresses the importance of consuming products with healthy fats and limiting highly processed foods (34), thus continued efforts are needed to ensure school meals offered in Canadian schools meet nutrition standards. In addition, beyond food accessibility and availability, children may also benefit from nutrition education programs to

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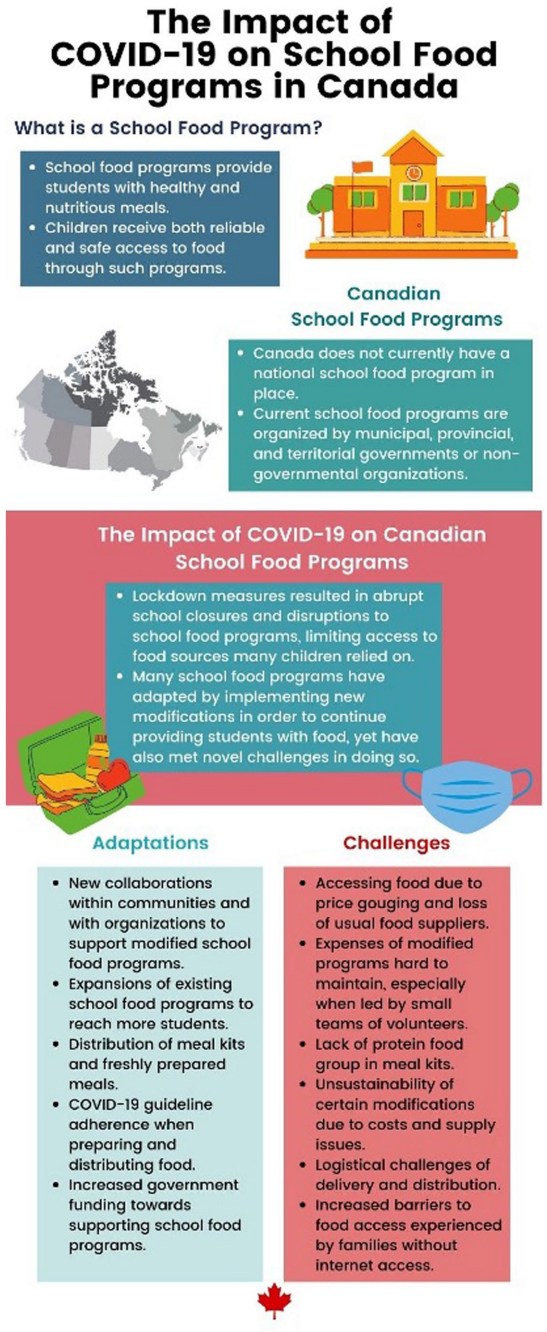

FIGURE 4
Summary on Canadian school food programs and examples of different adaptations and challenges: Summary of the main adaptations and challenges faced by school food programs across Canada in response to the COVID-19 pandemic as evident through this systematic rapid review.

facilitate adoption of better food choices and encourage healthy food-related behaviors (35).

In addition to challenges associated with the quality of foods, other barriers that were commonly mentioned included difficulties in reaching vulnerable families, financial constraints/available funds and limited government fund allocation and involvement in emergency feeding. Students without internet access may have faced limitations in participating in programs relying on online communication. Limited funding raised uncertainties about the sustainability of volunteer-run food programs, impacting the number of families assisted weekly. There was a notable lack of political intervention (e.g., few instances of increased government funding) as captured by the ANGELO framework (the 'political' environment factor was only captured by 3 sources). This highlights a critical need for increased government support of school food programs and feeding strategies during emergencies/school closures; this increased support would also help decrease uncertainties/unknowns associated with school food program reliance on donations and volunteers and would also help ensure that students/families, particularly those in need, have reliable access to healthy food for defined or prolonged periods, mitigating stress associated with food and nutrition insecurity (15).

Canada is the only Organization for Economic Co-operation and Development (OECD) country without a school food program. In the UK, for example, which has a national school food program,, schools were required to adapt their approach to school meals due to COVID-19 to ensure support for eligible children (15, 17) and in the US, which also has a national school food program, United States Department of Agriculture waivers were authorized for provision of school meals (18, 24). Despite not having a national school feeding strategy, various approaches were adapted across Canada to reach school-aged children, particularly those in greatest need. These findings highlight key adaptations to school food programs that played a vital role in responding to student and family food needs and underscore the challenges of feeding children during emergency situations or when schools are closed for prolonged periods.

Unhealthy dietary behaviors are a major preventable risk factor for obesity. Canadian children have poor diet quality (36, 37), consuming diets that are high in sodium, sugar and saturated fat ((36)). Considering that schools are an important setting to address childhood obesity and support healthy eating behaviors (30, 38), implementation of school-based nutrition interventions to create healthy school food environments can benefit student health and well-being. School food programs in Canada continue to be provided by a patchwork of programming and could benefit from a comprehensive and standardized approach that addresses nutritional standards, accessibility and equitable distribution to ensure all students have access to healthy and balanced meals (39).

Considering the national and global momentum on the importance of school food programs for meeting nutritional needs and ensuring access to healthy foods for children (40, 41), the results from this study can be contextualized to highlight lessons learned for future considerations for school food program implementation in Canada and during future emergencies and/or during school closures, as follows: (1) establishment of national school food guidelines to guide the nutritional quality of foods, (2) allocation of funds/resources dedicated to provision of school feeding strategies, and (3) capacity building for strengthening community engagement and local partnerships.

4.1 Establishment of national school food guidelines

Recommendations to reduce intake of foods with nutrients-of-concern (sodium, sugar and saturated fat) and processed foods are recommended by health organizations worldwide, given the increase in overweight, obesity and diet-related non-communicable diseases (42).

The current study indicated, that although there were attempts made at provision of foods from various food groups including fruits and vegetables, limited articles mentioned following nutritional guidelines when determining the types of food provided to children (also given the constraints with resourcing, price increase of foods, and distribution/delivery etc.). Nutritional guidelines are critical to avoid providing less healthful, nutrient-poor foods in emergency programs. Previous studies have indicated prevalence of high-calorie, low nutritional quality foods in such assistance efforts (14, 43). Additionally, self-stable ultra-processed foods, easily pre-packaged for individual consumption, may be provided without assessing their nutritional adequacy in emergency responses (14, 43). Considering the limited literature on the nutritional quality of foods provided during emergencies in high-income countries, there is a critical need for national nutritional guidelines for school feeding programs that also address provision during, school closures, and future emergencies.

4.2 Allocation of funds/resources dedicated to provision of feeding strategies

Limited funds and resources hindered schools from sustaining food provision during COVID-19 related school closures, despite innovative strategies, community engagement and donations. The patchwork of funding coming from various sources and uncertainty surrounding the continuation of funds led to cessation of many feeding adaptations shortly after being initiated, emphasizing the need for a sustainable funding structure for school food programs (44). This challenge extends beyond Canada, as budget constraints were observed globally and noted as a significant barrier to the operability of feeding strategies during the pandemic in other countries (14, 17), highlighting the political aspects of the ANGELO domain with inconsistent funding allocation.

4.3 Capacity building for strengthening community engagement and local partnerships

Adapting school feeding strategies successfully involved community engagement and forming local partnerships for food resourcing and access. Collaborations, such as volunteers working with local food banks and/or community organizations, played a vital role in the adaptability, sustainability, and resiliency of school feeding strategies. Future design of school feeding strategies should prioritize partnerships between local community organizations and government support to enhance community capacity. Previous studies from the US and Latin American emphasize the importance of local partnerships as key to the success for the adaptability of school feeding strategies (14, 18). Strengthening community engagement may also contribute to the success of complementary community food security responses to reach the most vulnerable.

4.4 Strengths and limitations

This study is limited by using case selection and non-traditional literature sources for information on adaptability of school feeding strategies during the COVID-19 pandemic school closures, particularly, as many organizations diverted to use of social media to raise awareness and information about feeding strategies. Data from news articles, gathered through rapid assessment, may not capture specific challenges faced by organizations and/or communities. This study may also be limited in identifying the full breadth of feeding strategies reaching marginalized communities. Nonetheless, the findings highlight challenges and facilitators, informing future considerations. Comparisons with school food programs in other countries such as the US or UK is limited due to Canada lacking a national school feeding strategy. As such, certain aspects of this research, e.g., whether the grocery store gift cards were used for food only is beyond the scope of this study.

This study is the first of its kind in Canada to capture the adaptability and resiliency of various school food programs by province and city during an emergency and provides an overview of the challenges and facilitators faced in adapting school food programs. Furthermore, considering the rapid assessment approach, this study applied validated frameworks (ANGELO AND GTE) that assessed food environments, to give a snapshot of where future considerations could focus for emergency and/or out-of-school feeding strategies.

5 Conclusion

The findings highlight key recommendations that can help inform government and civil society to more readily face the challenges associated with school feeding during similar emergency periods and/or during sustained periods of school closure (i.e., during summertime). Drawing from the lessons learned, the findings underscore the importance of establishing national nutrition guidelines to meet nutritional needs of children, allocation of immediate/emergency funds to sustain the provision of school food programs and supporting strengthening of community efforts to increase the accessibility and affordability of healthy foods within communities.

Data availability statement

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

Author contributions

MA: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. AR: Methodology, Visualization, Writing – original draft, Writing – review & editing. JR: Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. CM: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing. DS: Conceptualization, Funding acquisition, Investigation, Project administration, Supervision, Writing – review & editing. VM: Investigation, Methodology, Project administration, Supervision, Validation, Writing – review & editing.

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Conflict of interest

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Supplementary material

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Diet quality and snack preferences of Turkish adolescents in private and public schools

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Introduction: Socioeconomic level is one of the important factors determining diet quality. Snack preferences are affected by socioeconomic level. The objective of this research was to determine the effect of socioeconomic levels on diet quality and snack preferences among adolescents from different socioeconomic backgrounds.

Methods: The study involved 118 adolescents aged between 10-18 years residing in Istanbul. A questionnaire prepared by the researchers was used to obtain information on the adolescents' dietary habits, consumption of main meals and snacks, habits, and food consumption records. The participants' food consumption was assessed using the retrospective 24-hour recall method, and diet quality was evaluated using the calculated nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR).

Results: The mean age of the adolescents was 16.42±0.89 years. The number of snacks consumed in private schools was found to be higher than in public schools ($p < 0.05$). The NAR score for vitamin C consumption was significantly higher in private schools compared to public schools ($p < 0.05$). Although the MAR scores of adolescents in private schools were higher than those in public schools, this difference was not statistically significant. The majority of adolescents in private schools regularly consumed fresh fruit (67.2%), milk (60.3%), yogurt (60.3%), and nuts (56.9%) as snacks. In contrast, 45% of adolescents in public schools regularly consumed pastries ($p < 0.05$).

Discussion: It was observed that adolescents studying in public schools had a lower tendency to prefer healthy foods for snacks compared to those in private schools. Socioeconomic level was identified as an important factor influencing eating habits during adolescence. Considering that the level of income is significantly different between the adolescents studying at private and public schools, the higher consumption of snacks by the adolescents studying at private school may be associated with higher income.

KEYWORDS

adolescent, diet quality, mean adequacy ratio, nutrient adequacy ratio, snack consumption, socioeconomic level

1 Introduction

Nutrition is an important determinant in maintaining vital functions, supporting the immune system, ensuring growth and development, and maintaining a healthy life (1). It is important to adopt healthy lifestyle behaviors and a balanced diet to achieve a healthy and quality life throughout the life cycle. In order to achieve the desired quality of life, it is necessary to transform the healthy diet model into a lifestyle by increasing the awareness of nutrition throughout society (2).

In adolescence, a transition period from childhood to adulthood, growth and development accelerate, and cognitive and psychosocial development occur. Changes that occur during this period, affect the individual's physical appearance, cognitive, and emotional development. A rapid increase in growth during adolescence results in an increase in the need for nutrients and energy, and nutrition is critically important in adolescence (3).

It is seen that adolescents who eat with their peers frequently prefer fast-food products that are high in energy, saturated fatty acids, sugar, and salt. Fast-food products are unhealthy options for adolescents who are in the growth and development period, as they are insufficient in many nutrients such as dietary fiber, vitamins A and C, and calcium. A diet pattern that is rich in energy and fat increases the risk of obesity in adolescents (4). When the diets of adolescents are examined in a study, it has been indicated that fat, saturated fat and sugar intakes were high, dairy products, fruit, and vegetable consumption were insufficient, and their diet quality was low (5). In a study, it has been observed that the measures of snacking were directly associated with higher energy, lower fruit/vegetable, higher sugar-sweetened beverages, and more frequent fast-food intakes (6). Poor diet quality may lead to several chronic diseases including diabetes, heart disease, stroke, cancer, and obesity and also negatively affects growth and development and school success (7). Regular meal consumption, healthy food choices in meals and energy, and macro and micronutrient intake in the diet as recommended amounts affect the health of adolescents positively. For healthy adulthood, it is of great importance to acquire healthy eating habits in childhood and adolescence (3).

Psychosocial, environmental, and sociodemographic factors also play an important role in the food choices of adolescents. The food choices of parents, which vary depending on sociodemographic characteristics, are also reported as an important factor that determines the nutritional habits of individuals at this age (8). In addition, it is emphasized that nutritional problems seen in childhood and adolescence are closely related to many sectors such as the economy and education (9). Researchers have found that socioeconomic factors, such as living in smaller houses, having a low socioeconomic level, having many family members, and having a low monthly income, are significantly associated with the food choices and diet quality of adolescents (10). In a study conducted with university students, the researchers found that students with low socioeconomic status consumed unhealthy foods significantly more than their peers with higher socioeconomic status (11). In another study conducted with 1,000 adolescents, it has been observed that adolescents living in regions with low socioeconomic status showed higher fast food consumption (12). In studies conducted in different countries, it has been shown that especially adolescents and young adults with low socioeconomic level consume excessive calories, and the researchers emphasized that socioeconomic level can directly affect eating behavior (13, 14).

There are studies investigating the nutritional status of adolescents in Turkey, but studies on snack patterns, snack preferences, and diet quality are limited (15–18). Scarce research exists that contrasts the snacking habits and diet quality of students enrolled in private and public schools. To the best of our knowledge, this research constitutes the first comprehensive examination of adolescent snack preferences within the context of socioeconomic standing in Turkey. This study aims to determine the effects of socioeconomic status on adolescents' snack patterns, snack preferences, and diet quality.

2 Materials and methods

2.1 Research location, time, and sample selection

The research was conducted on randomly selected adolescents aged 10–18 years who applied to the Nutrition and Diet Polyclinic at Istanbul Medipol University between January and June 2020. The study was conducted with a total of 118 high school students enrolled in public schools ($n = 60$) and private schools ($n = 58$) living in Istanbul (Figure 1). Parental consent was obtained for all children and adolescents included in this study.

The G*Power 3.1 software was used to calculate the sample size, and it was determined that 51 participants needed to be included in each group with an effect size of 0.5 and a power of 0.8. In this study, a significance level of $p < 0.05$ was accepted.

In this cross-sectional study, "Ethics Committee Approval" was obtained from Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee with the number E-10840098-772.02-6957 and dated November 15, 2022. Voluntary information and consent forms were obtained from the adolescents who agreed to participate in the study. This study was conducted in accordance with the principles of the Declaration of Helsinki ("World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects," 2014).

2.2 Data collection and evaluation

To collect the research data, a questionnaire form created by the researcher was used, and all data were collected using a face-to-face interview method. The questionnaire form has 4 parts and sociodemographic data, anthropometric measurements, nutritional behaviors, and snack and food consumption of participants were collected.

The minimum wage levels in the year the research was conducted were 2000 TL. Therefore, income grouping is planned as >2000 TL and its multiples. Income levels are categorized as very low, low, medium, high, and very high, according to minimum wage (19).

During the anthropometric measurements of the participants, their height was measured using a wall-mounted height measuring tape, and their body weight was measured using a digital scale. Body mass index (BMI) was calculated by dividing the body weight by the height squared (kg/m^2). An evaluation was made according to percentile curves suitable for the age and gender of the adolescents.

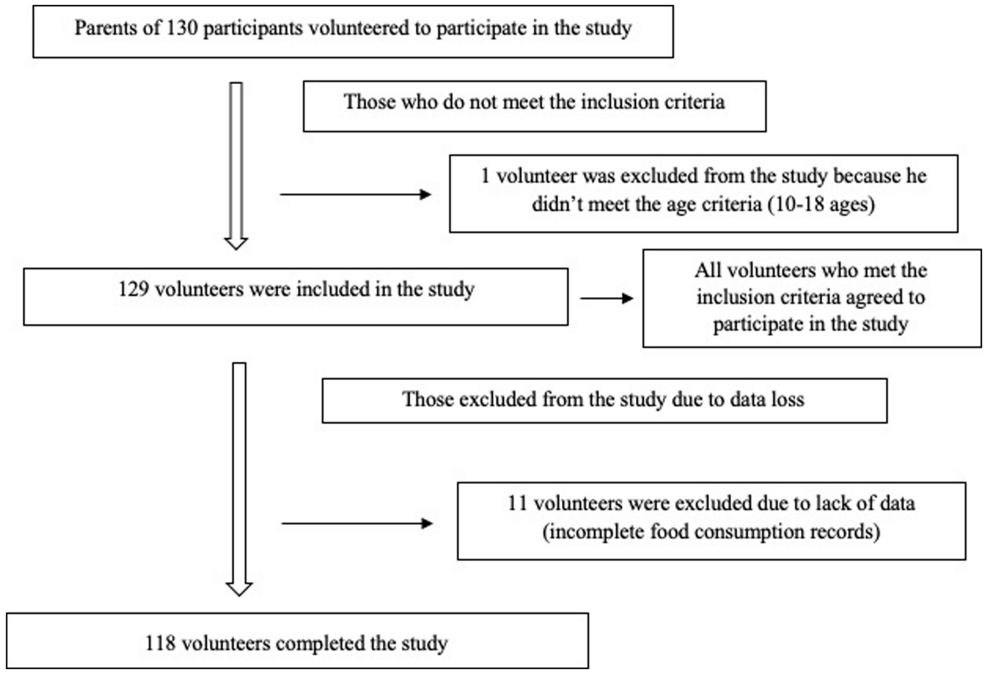

FIGURE 1
Participants recruitment flow chart.

Percentile values and curves developed for Turkish children by Neyzi et al. (20) were used, and percentile values were classified as thin (<5), normal (5–85), overweight (85–95), and obese (≥95).

The number of daily meals, whether they skip meals, where they eat their meals, the opportunity of snacks during the time spent at school, the type of foods they prefer for snacks, and the frequency of snack consumption were questioned. Food and beverages are grouped as milk, yogurt, ayran, kefir, cheese, fresh fruit, dried fruit, salad, nuts, pastries, rusk, biscuits, crackers, chips, tea, coffee, fruit juice, and soft drinks. Adolescents were classified as regular consumers, if they consumed these snacks 4 or more times a week, and as occasional consumers if they consumed less than 4 times a week (21).

In the final part of the questionnaire, the participant's 24-h food consumption was assessed using the retrospective recall method. Participants were asked to specify all the foods and beverages they consumed over the previous 24 h, along with the amounts they consumed, using measures such as tablespoons, glasses, bowls, slices, or weight. Dietary recall data were collected by the researcher guiding the participants to accurately describe their food consumption, using the "Food and Food Photo Catalog" (22). The researcher evaluated the data obtained from the food consumption record, using the Nutrition Information Systems Package Program (BeBiS), which is a software program that analyzes the nutrient content of foods.

The nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR) were calculated using the data from the food consumption records that were analyzed using BeBiS to determine the diet quality of the participants and to evaluate their adequate intake of some nutrients. The nutrients used in the calculation are carbohydrates, protein, calcium, iron, magnesium, phosphorus, folate, vitamin B12, riboflavin, and niacin. If the NAR score is above 1, it is considered to meet the recommended intake. NAR was calculated using the following formula (23).

NAR = Daily intake of the nutrient/Recommended daily intake of the nutrient.

The dietary reference intakes (DRI) specified by the National Institutes of Health (NIH) were used to determine the DRIs for the nutrients used in the NAR calculation (24). After the NAR was calculated, the MAR calculation was made using the following formula (23).

MAR = Sum of all NAR rates/Total number of nutrients.

2.3 Statistical analysis

IBM SPSS Statistics 21.0 was used to analyze the data (25). The acceptable error rate was 5% with a confidence level of 95%. Percentages were used for qualitative variables and mean and standard deviations were used for quantitative parametric variables. The normality of distribution was tested with the Kolmogorov–Smirnov test. The significance of the intergroup distribution of descriptive statistics was tested by Fisher's Chi-square test. Kruskal–Wallis test and Mann–Whitney *U*-test were applied to data that was not normally distributed.

3 Results

This study was conducted with a total of 118 adolescents (48.3% boys and 51.7% girls) with a mean age of 16.4 ± 0.89 years. The demographic characteristics and anthropometric measurements of adolescents are given in Table 1. The income level of the majority of

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TABLE 1 Demographic characteristics and anthropometric measurements of adolescents.

	Private school ($n = 58$)		Public school ($n = 60$)		Total ($n = 118$)		p
	n	%	n	%	n	%	
Gender							
Male	25	43.1	32	53.3	57	48.3	
Female	33	56.9	28	46.7	61	51.7	
Age (years) (Mean ± SD)	16.0 ± 0.91		16.8 ± 0.68		16.4 ± 0.89		
Level of income							
Very low	–	–	3	5.0	3	2.5	
Low	1	1.7	11	18.3	12	10.2	
Medium	8	13.8	24	40.0	32	27.1	**<0.001***
High	20	34.5	14	23.4	34	28.8	
Very high	29	50.0	8	13.3	37	31.4	
Mother's education level							
Primary school or lower	3	5.2	19	31.7	22	18.6	**<0.001***
Middle school, high school	26	44.8	26	43.3	52	44.1	
College or higher	29	50.0	15	25.0	44	37.3	
Father's education level							
Primary school or lower	–	–	15	25.0	15	12.7	
Middle school, high school	22	37.9	29	48.3	51	43.2	**<0.001***
College or higher	36	62.1	16	26.7	52	44.1	
Number of people living in the family (Mean ± SD)	3.5 ± 0.77		4.2 ± 0.99		3.9 ± 0.94		**<0.001***
Anthropometric measurements							
Height (cm) ($\bar{X}$ ±SD)	171.4 ± 7.76		172.4 ± 9.62		171.9 ± 8.73		0.543
Body weight (kg) ($\bar{X}$ ±SD)	65.3 ± 13.63		64.6 ± 13.89		65.0 ± 13.70		0.792
BMI (kg/m^2) ($\bar{X}$ ±SD)	22.2 ± 3.80		21.5 ± 3.40		21.9 ± 3.61		0.288
Categorization of BMI	n	%	n	%	n	%	
Underweight	9	15.5	11	18.3	20	16.9	0.605
Normal weight	34	58.7	38	63.4	72	61.0	
Overweight	14	24.1	8	13.3	22	18.6	
Obese	1	1.7	3	5.0	4	3.5	

*Fisher's Chi-square test, $p < 0.05$.

the adolescents studying in the private school was good (34.5%) and very good (50.0%), while those studying in the public school were medium or worse (63.3%). The educational status of the parents of adolescents in the private school was significantly higher than those in the public school ($p > 0.05$).

Table 2 shows the frequency of consumption of meals and snacks and the places where adolescents consume these meals. It was observed that the majority of adolescents studying at private schools (81.0%) and public schools (81.7%) consumed 3 or more main meals a day ($p > 0.05$). Considering their snack consumption, 74.1% of the adolescents studying at private schools consume 2 or more snacks a day, while 80% of those in public schools have 1 or 2 snacks, and this difference is statistically significant ($p < 0.05$). While the majority of the adolescents studying in private school consume breakfast and dinner at home (84.5 and 91.4%, respectively), approximately half of them consume their lunch in the school cafeteria (48.3%), the adolescents in public school consume all three main meals (breakfast 73.3%, lunch 81.7% and dinner 75.0%) in the school cafeteria ($p < 0.05$).

The factors that affect the snack preferences of adolescents in the study are given in Table 3. While the most important factors that affect snack preferences are hygiene (58.9%) and food being healthy (66.1%) for students in private school, easy access (58.4%) and price (64.9%) were more important for students in public school ($p < 0.05$).

Data on the diet quality of adolescents are shown in Table 4. Adolescents in private school had higher NAR scores for vitamin B2 (0.85 ± 0.43), folate (0.47 ± 0.29), potassium (0.62 ± 0.30), calcium (0.39 ± 0.20) and magnesium (0.49 ± 0.21) than adolescents in public school. However, this difference was not statistically significant ($p > 0.05$). The NAR score for vitamin C was statistically significantly higher in adolescents in private school (0.93 ± 0.89) than in adolescents in public school (0.44 ± 0.34) ($p > 0.05$).

TABLE 2 Meal frequency of adolescents and places they consume their meals.

	Private school (n = 58)		Public school (n = 60)		
	n	%	n	%	p
Number of meals per day					
1	–	–	1	1.6	0.905
2	11	19.0	10	16.7	
3 or more	47	81.0	49	81.7	
Number of snacks per day					
1	15	25.9	30	50.0	**0.02***
2	22	37.9	18	30.0	
3 or more	21	36.2	12	20.0	
Places adolescents consume their meals					
Breakfast					
Home	49	84.5	15	25.0	**0.000***
School cafeteria	–	–	44	73.3	
School canteen	9	15.5	1	1.7	
Lunch					
Home	10	17.2	6	10.0	**0.001***
School cafeteria	28	48.3	49	81.7	
School canteen	3	5.2	2	3.3	
Restaurant/cafe/peddler	17	29.3	3	5.0	
Dinner					
Home	53	91.4	14	23.3	**<0.001***
School cafeteria	–	–	45	75.0	
Restaurant/cafe	5	8.6	1	1.7	
Snack					
Home	27	46.6	3	5.0	**<0.001***
School canteen, market	31	53.4	47	78.4	
School provides snacks	–	–	2	3.3	
Dormitory cafeteria	–	–	8	13.3	

*Fisher's Chi-square test, $p < 0.05$.

The distribution of the frequency of consumption of the foods that adolescents prefer for snacks is given in Table 5. It has been determined that the majority of adolescents studying in private school regularly consume fresh fruit (67.2%), milk (60.3%), yoğurt (60.3%), and nuts (56.9%) as a snack, whereas most of the adolescents studying in public school do not consume milk (41.7%), yogurt (60.0%), ayran (55.0%), and cheese (68.3%) at all. While 45% of the adolescents studying in public school stated that they regularly consume pastries, this rate is 17.2% in private school ($p < 0.05$). A statistically significant difference was found between adolescents studying in private and public schools in terms of consumption of milk and dairy products, fresh and dried fruits, nuts, and pastries in snacks ($p < 0.05$).

4 Discussion

In this study, it was aimed to evaluate the diet quality and nutritional status of adolescents studying in private and public schools, and to compare their snack preferences and consumption frequencies in a sample reflecting different socioeconomic levels.

Studies conducted in different provinces of Turkey indicate that families with high monthly incomes more often prefer private schools. Additionally, as the total income of the family and the education level of the parents increase, so do education expenditures (26). In different studies conducted with adolescents, it has been reported that the type of school (public or private) that adolescents attend is accepted as a factor representing their socioeconomic status (27). Supporting the results in the literature, this study determined that the income status and parental education levels of the adolescents who are educated in public schools were statistically significantly lower than their peers who are educated in private schools.

The average height, body weight, and BMI of the adolescents included in this study are similar to the anthropometric measurements found in studies, conducted with adolescents in different provinces of Turkey (28, 29). When the BMI value specified by the Turkish Dietary Guidelines (TUBER) for the age of 16 is taken as a reference, the mean BMI of the adolescents included in the current study, whose mean age

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TABLE 3 Distribution of factors affecting adolescents' snack preferences.

		Private school		Public school		
		n	%	*n*	%	*p*
Healthy	Yes	41	66.1	21	33.9	**<0.001***
	No	17	30.4	39	69.6	
Easily accessible	Yes	37	41.6	52	58.4	**0.004***
	No	21	72.4	8	27.6	
Price	Yes	26	35.1	48	64.9	**<0.001***
	No	32	72.7	12	27.3	
Hygiene	Yes	43	58.9	30	41.1	**0.007***
	No	15	33.3	30	66.7	
Habits	Yes	46	52.3	42	47.7	0.246
	No	12	40.0	18	60.0	
Taste	Yes	54	51.4	51	48.6	0.160
	No	4	30.8	9	69.2	

*Chi-square test, $p < 0.05$.

TABLE 4 Evaluation of diet quality of adolescents.

	Private school	Public school	
	Mean ± SS	Mean ± SS	*p*
NAR			
Protein	0.99 ± 0.34	1.01 ± 0.34	0.751
Dietary fiber	0.47 ± 0.26	0.48 ± 0.19	0.541
Vitamin B_2	0.85 ± 0.43	0.77 ± 0.38	0.379
Folate	0.47 ± 0.29	0.43 ± 0.17	0.910
Vitamin C	0.93 ± 0.89	0.44 ± 0.34	**<0.001***
Potassium	0.62 ± 0.30	0.60 ± 0.24	0.884
Calcium	0.39 ± 0.20	0.35 ± 0.17	0.392
Magnesium	0.49 ± 0.21	0.48 ± 0.16	0.822
Iron	0.57 ± 0.31	0.59 ± 0.21	0.230
Zinc	0.69 ± 0.28	0.75 ± 0.31	0.245
Niacin	0.59 ± 0.29	0.59 ± 0.20	0.962
MAR	0.64 ± 0.28	0.59 ± 0.20	0.256

*Mann–Whitney *U*-test, $p < 0.05$.

is 16.4 ± 0.89 years, is seen to be in the normal range (1). In a study conducted by Coşkun and Karagöz (29) with 220 adolescents, it was reported that 6.6% of adolescents were overweight and 4.2% were obese. Of the adolescents included in this study, 18.6% were overweight and 3.4% were obese. Although obesity rates are similar to those in other studies, the rate of obese adolescents is higher in this study. During the transition period between childhood and adolescence, a change in diet composition is observed, including higher consumption of snacks and soft drinks and lower intake of fruits and vegetables. This is thought to increase the rate of obesity and overweight (30).

Socioeconomic status is a strong determinant of body weight, obesity risk, and eating behaviors. The probability of developing obesity is higher in children from low-income families than in children from high-income families (30). However, this study found no statistically significant difference in anthropometric measurements between private school and public school adolescents. Supporting the findings of this study, a study reported that the prevalence of obesity was similar among adolescents from low and middle socioeconomic status and among adolescents from low and high socioeconomic status (31). It is not possible to draw a clear conclusion since obesity reflects the complex interactions between genetic, metabolic, behavioral, cultural, and environmental factors (32). More research is needed to help understand the underlying causes of obesity.

The number of meals per day varies according to the socioeconomic status of the family. In a study conducted with adolescents ($n = 891$), it was determined that adolescents with high socioeconomic status (72.3%) consumed 3 or more main meals at a higher rate compared to their peers with medium (61.8%) and low (54.8%) socioeconomic status (33). Another study reported that adolescents with higher socioeconomic status consumed more snacks than adolescents with lower socioeconomic status (34). In this study, it was found that the majority of adolescents consumed 3 or more main meals a day, and there was no statistically significant difference in terms of socioeconomic level. However, the number of snacks consumed daily was found to be significantly higher in adolescents studying at private schools. Considering that the level of income is significantly different between the adolescents studying at private and public schools, the higher consumption of snacks by the adolescents studying at private school may be associated with higher income.

It was observed that the rate of consuming breakfast and lunch at school was higher in adolescents who were educated in public schools and were offered free or affordable breakfast and lunch in their school (35). In a study conducted with adolescents aged 14–19 years studying in a public school in Brazil, it was found that the majority of adolescents (92.2%) ate lunch at home and only 4.9% ate at school (36). In the present study, it was observed that the majority of adolescents in public school consumed breakfast, lunch, and dinner in the school cafeteria. The fact that meals are usually consumed at school, especially in public schools, may be associated with a lower socioeconomic level. It is thought that food practices in schools aim to support the development of children and to give them healthy eating habits, especially children from low-income families.

In a study conducted with 166 adolescents aged 11–13 years in the United States, the factors that affect snack preferences were examined. The most important factor was found to be price, followed by nutritiveness, taste, and easy accessibility (37). In another study of children aged between 7 and 12, it was found that availability and price influenced children's food choices and purchasing decisions. The most commonly purchased foods (42% salty packaged snacks) were the most common and least expensive ones in grocery stores around public schools (38). In this study, the most important factors that affected the preference of snacks for private school students were hygiene and health, and easy accessibility and price for students in public school. Given that the majority of students in public school are from middle- and lower-income families, pocket money is likely to be limited. For this reason, the price factor was found to be statistically significantly more important in snack preferences according to socioeconomic level. This result is similar to the findings of other studies (37, 39, 40).

Diet quality indices, such as NAR and MAR scores, compare an individual's nutrient intake with age- and gender-specific

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TABLE 5 Snack preferences of adolescents.

	Private school			Public school			
	Regular consumer	Occasional consumer	Never consumer	Regular consumer	Occasional consumer	Never consumer	
Besinler	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*p*
Milk	35 (60.3)	15 (25.9)	8 (13.8)	13 (21.7)	22 (36.6)	25 (41.7)	**<0.001***
Yogurt	35 (60.3)	16 (27.6)	7 (12.1)	5 (8.3)	19 (31.7)	36 (60.0)	**<0.001***
Ayran	23 (39.7)	26 (44.8)	9 (15.5)	18 (30.0)	9 (15.0)	33 (55.0)	**<0.001***
Kefir	7 (12.1)	10 (17.2)	41 (70.7)	2 (3.3)	3 (5.0)	55 (91.7)	**0.014***
Cheese	22 (37.9)	15 (25.9)	21 (36.2)	9 (15.0)	10 (16.7)	41 (68.3)	**0.002***
Fresh fruit	39 (67.2)	14 (24.1)	5 (8.7)	15 (25.0)	24 (40.0)	21 (35.0)	**<0.001***
Dried fruit	19 (32.8)	31 (53.4)	8 (13.8)	4 (67)	22 (36.6)	34 (56.7)	**<0.001***
Salad	29 (50.0)	16 (27.6)	13 (22.4)	5 (8.3)	18 (30.0)	37 (61.7)	**<0.001***
Nuts	33 (56.9)	22 (37.9)	3 (5.2)	13 (21.7)	22 (36.6)	25 (41.7)	**<0.001***
Pastries	10 (17.2)	32 (55.2)	16 (27.6)	27 (45.0)	26 (43.3)	7 (11.7)	**0.003***
Breadsticks	7 (12.1)	23 (39.6)	28 (48.3)	3 (5.0)	8 (13.3)	49 (81.7)	**0.001***
Biscuit	18 (31.0)	28 (48.3)	12 (20.7)	26 (43.3)	26 (43.3)	8 (13.3)	0.317
Crackers	14 (24.1)	28 (48.3)	16 (27.6)	20 (33.3)	22 (36.7)	18 (30.0)	0.394
Chips	6 (10.3)	24 (41.4)	28 (48.3)	9 (15.0)	24 (40.0)	27 (45.0)	0.747
Tea	44 (75.8)	7 (12.1)	7 (12.1)	48 (80.0)	4 (6.7)	8 (13.3)	0.599
Coffee	39 (67.2)	13 (22.4)	6 (10.4)	31 (51.7)	20 (33.3)	9 (15.0)	0.227
Fruit juice	9 (15.5)	27 (46.6)	22 (37.9)	5 (8.3)	32 (53.4)	23 (38.3)	0.459
Soft drinks	10 (17.2)	21 (36.2)	27 (46.6)	8 (13.3)	24 (40.0)	28 (46.7)	0.816

*Fisher's Chi-square test, $p < 0.05$.

recommended intake levels to assess the quality of the diet (40). In the Study of Cardiovascular Risks in Adolescents (ERICA), in which the diet quality of 71,553 adolescents was evaluated by Ronca et al., adolescents were found to have poor diet quality (41). In middle school children, considering that NAR scores of vitamin C (boys and girls 0.4 ± 0.3), calcium (boys 0.4 ± 0.3 and girls 0.4 ± 0.2), iron (boys 0.8 ± 0.3, girls 0.7 ± 0.3), vitamin A (boys 0.8 ± 0.4, girls 0.9 ± 0.4), and folic acid (boys 0.9 ± 0.5, girls 0.8 ± 0.4) were low, it is observed that there was insufficient intake of these nutrients. It was observed that the greatest deficiency in both genders was calcium and vitamin C intake, followed by vitamin A, iron, and folic acid. Mean MAR scores were reported to be low (0.9 ± 0.3) in both genders (42). Higher socioeconomic status is associated with better diet quality. Studies indicate that adolescents with high family income have a relatively higher intake of vitamins and minerals, which indicates better diet quality (43). In this study, diet quality was evaluated, and it was found that the MAR scores of the adolescents in the private school were higher than the students in the public school, but this difference was not statistically significant. Only vitamin C has a statistically significantly higher NAR score. It is thought that this may be due to the higher rate of regular consumption of fresh fruit and salad in private school adolescents (44, 45).

In a study, it was found that weekly consumption of soft drinks (51.7%) and sweets (44.1%) in children from families with low socioeconomic status was higher than that of children from families with high socioeconomic status (soft drinks 21.6%, sweets 24.9%), and it was stated that high socioeconomic status was associated with less consumption of energy-dense foods in children (46). In the study conducted by Moitra and Madan (2021) with adolescents ($n = 712$), it was reported that adolescents studying in private school (1.4 days/week) consumed cake and pastry as snacks more than adolescents in public school (0.7 days/week), and the consumption of biscuits and cookies was higher in adolescents studying in public school (6.9 days/week and 4.5 days/week, respectively) (47). According to the results of the Brazilian National Survey of School Health (PeNSE)-2015, the consumption of vegetables in adolescents aged 11–19 was higher in private school students (42.8%) than in public school students (36.8%), in the other hand, it has been reported that ultra-processed salty foods such as processed meats, packaged salty snacks, and crackers, which are expressed as unhealthy diet indicators, are consumed more in private school students (44). Schools should be prohibited from selling deep-fried foods and sugar-rich soft drinks. Instead, the canteens should be encouraged to sell healthy food and drinks, such as fruits and vegetables (48).

In this study, similar to Moitra and Madan's study, consumption of pastries as snacks was found to be higher in adolescents with low socioeconomic status, and similar to the PeNSE-2015 report, salad and vegetable consumption was found to be higher in adolescents studying in private schools. However, unlike the PeNSE-2015 report, this study reported that the consumption of healthy snacks such as milk, fresh and dried fruits, and nuts, instead of highly processed and packaged snacks, was higher in adolescents studying in private schools.

4.1 Limitations of the study

The present study is important in terms of showing the snack preferences of adolescents in Turkey and the factors that affect their snack preferences. Personal awareness of appropriate nutrition is important in reducing the consumption of fast food and snack-type foods and in adopting healthy diets, and individuals could get away from overnutrition or malnutrition in accordance with their level of knowledge and socioeconomic level. Many factors influence dietary choices, but the environment and socioeconomic level are crucial components pointing these decisions. Unless individuals, and especially children, learn how to make appropriate food choices according to socioeconomic levels, they cannot avoid the negative influence of their social environment.

However, this study also has some limitations. The sample size of current study was small, and physical activity, regional differences, and other environmental factors could not be investigated. It should be kept in mind that the food consumption record covers only a single day retrospectively, and this may be insufficient to reflect the overall eating habits of that person.

4.2 Areas for further research

This study can be rescheduled to include a larger sample size and other environmental factors. The quality of the meals offered to students at private and public schools may be examined to determine the dietary quality of students. Adolescents should be educated about adequate and balanced nutrition so that they can make healthy choices from the food available in school canteens, and healthy foods that meet the daily energy and nutritional needs of students should be made available in school canteens and cafeterias. The age group, region, sample, and results of the present study can not be generalized to the rest of Turkey. Therefore, future research should involve a larger geographic region and sample size.

5 Conclusion

Since the nutritional habits acquired during adolescence lay the foundation for adult eating habits, it is of great importance to choose healthy foods and gain healthy eating habits during adolescence. Level of income can affect students' snack preferences. In this study, the diet quality of adolescents was found to be similar, but socioeconomic status affects the factors that influence their snack preferences and the foods they prefer. The majority of children from high-income families who attend private schools, consider factors such as whether the food is healthy, hygienic, and delicious. However, it has been observed that children in public schools from low-income families prefer snacks based on their price and accessibility. Furthermore, it has been shown that children in private schools consume more healthy foods on a regular basis such as milk, yogurt, ayran, kefir, cheese and its varieties, dried fruit, salad, and nuts compared to children in public schools. These findings offer a deeper understanding of the role of socioeconomic level on snack preferences and diet quality of 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 humans were approved by Istanbul Medipol University Non-Interventional Clinical Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

FS: Writing – original draft, Writing – review & editing. İY: Writing – original draft, Writing – review & editing. NS: Writing – review & editing. HB: Writing – review & editing. MP: Writing – review & editing.

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Conflict of interest

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

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In-classroom physical activity breaks program among school children in Sri Lanka: study protocol for a randomized controlled trial

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Background: The problem of sedentary behavior among primary school children is alarming, with numbers gradually increasing worldwide, including Sri Lanka. Physical activity interventions within classroom settings have been acknowledged as a critical strategy to increase students' movement behaviors while enhancing their academic achievement and health. Yet, the busy curriculum and challenging educational demands encourage more sedentary classroom behavior. Hence, this study aims to develop and evaluate an in-classroom physical activity breaks (IcPAB) intervention among fifth graders in Sri Lanka.

Methods: The study will adopt a randomized controlled trial (RCT), comprising an in-classroom physical activity breaks program group and a control group to evaluate the effects of IcPAB on academic achievement, movement behaviors and health outcomes. The intervention design is based on the capability (C), opportunity (O) and motivation (M) behavior (B) (COM-B) model. A least 198 fifth graders will be recruited from two schools in Uva province, Sri Lanka. The recruitment process will start in late 2022. Class teachers of the intervention group will implement 5-min activity breaks at least three times a day after completing a training session. The primary variables include mathematics and reading achievement. The secondary variables include physical activity levels, steps count, sedentary behavior, body mass index, aerobic fitness, and perceived stress. Data collection will be implemented at pre-test and post-test, respectively. Intervention fidelity and the process will also be evaluated.

Discussion: The IcPAB is designed to prevent pure educational time loss by introducing curriculum-integrated short bouts of physical active breaks into the classroom routine. If the IcPAB is effective, it can (1) improve the mathematics and reading achievement of fifth-grade girls and boys, which is a significant factor determining the performance at the Grade Five National Scholarship Examination in Sri Lanka; (2) improve movement behaviors as well as physical and mental health outcomes among primary school students. Sequentially, the IcPAB will enrich school-based physical activity intervention approaches which can in turn bring academic and health benefits to primary school children in Sri Lanka.

Trial registration: The first version of the trial was registered with the ISRCTN registry (Ref: ISRCTN52180050) on 20/07/2022.

KEYWORDS

in-classroom physical activity breaks, behavior change wheel, academic achievement, health outcomes, fifth graders

1 Introduction

The effects of physical activity (PA) on academic achievement (1, 2), movement behaviors (3, 4) and health outcomes such as body mass index [BMI; (5, 6)], aerobic fitness (7, 8), and psychological health such as stress/ test anxiety levels (9, 10) among school children have been long established. However, reports including the elementary education sector highlighted that children should meet the recommended daily PA behavior levels, such as engaging in at least 60 min of moderate-to-vigorous physical activity [MVPA; (11)]. One primary factor influencing this figure is that children have long seated learning time in the classroom due to high academic curriculum demands in primary school (12, 13). As a result, sedentary behavior among primary school children has become alarming, with figures steadily increasing worldwide (14, 15).

A situation analysis conducted in 2016 showed that the learning time is less activity-based (16) in Sri Lanka. National surveillance data also indicated that 63 to 72% of students (age range = 6–12 years old) engaged in sedentary activities (17). Among the five grades in primary schools in Sri Lanka, the grade five curriculum is one of the most loaded and competitive in teaching and learning (18–20). The underlying reason is that grade five students are expected to sit for a national-level competitive scholarship examination in addition to their curriculum-related reviews at the term tests (18, 19, 21, 22). Therefore, the teachers and students are tense in preparing for the scholarship examination and surpassing the cutout marks while achieving the required competency levels for fifth graders (16, 19, 23, 24). This has increased the sedentary behavior with more traditional seated learning as the main objective of the teachers is to improve the students' academic achievement. As a consequence, most of the fifth graders are identified to be physically inactive (17, 25–27), below recommended body mass index (BMI) percentiles (17, 25), aerobically unfit (18), and stressful (16, 19, 20, 23, 24, 28). Therefore, there is a need to target fifth graders in primary schools in Sri Lanka to prevent grade-related sedentary behavior and obtain health benefits and maximum academic performance.

It has been observed previously that PA breaks can improve the number of steps by 18% and minutes of MVPA by 26% during the school day (29, 30). Hence, there needs to be enablement to help manage the increased academic curriculum, and classroom settings are recommended as the best setting to achieve the benefits of PA (31–34). In the recent decade, few countries introduced the concept of in-classroom physical activity breaks (IcPAB) as a means of enhancing academic achievement (12), physical behaviors (35), and health outcomes (10, 36) by changing traditional seated learning into active learning among elementary school students. Still, more IcPAB initiatives are needed due to several limitations emphasized by a recent review based on the data from 1,538 primary school students (from 7 to 12 years old) in 10 studies (37):

(1) Not enough studies focused on introducing integrated PA into academic content through classroom-based interventions (37–40). (2) Most of those studies are introduced for populations from high-income Western countries (37, 39, 41) such as the USA, Australia, the Netherlands and Switzerland. The intervention effects based on gender are understudied. (3) Different durations were used in previous IcPAB initiatives, ranging from 10 min to 4,800 min (37), even though teachers prefer activity breaks that will take no more than 5 minutes (37), and the effectiveness of five-minute IcPAB interventions are understudied (37). (4) Previous studies demonstrated average methodological quality, with concerns around the randomization procedure, handling of missing data, outcome and process evaluation (37). This calls for future study protocols with a more robust methodological quality to avoid potential risks of bias in the IcPAB interventions, in addition to the well-explained outcome and process evaluation and fidelity methods. (5) Few studies used theoretical frameworks and evidence from related stakeholders such as teachers in designing IcPAB interventions. The review suggests (37) that robust PA interventions should be backed by well-established theories such as the capability (C), opportunity (O) and motivation (M) behavior (B) (COM-B) model (42) while considering the evidence-based opinions of the beneficiaries of the IcPAB in implementing an IcPAB program.

Therefore, there is a need for more IcPAB initiatives integrated into the curriculum across different geographic locations/ cultures (37) that require shorter bouts of time [i.e., around 5 minutes (12, 43)] with strong methodological quality (39, 44), outcome and process evaluation procedures and theoretical underpinnings (37, 39, 44). Also, the moderating effects of gender on the intervention should be further examined. Thus, by addressing the research limitations, this study aims to develop, implement, and evaluate a 12-week IcPAB program among grade five primary school children in Sri Lanka.

Depending on the aforementioned rationale, the specific research questions of this study include: (1) What is the impact of the IcPAB intervention on the primary outcome, academic achievement (mathematics and reading achievement) during the school day? (2) What is the impact of the IcPAB intervention on the secondary outcomes, movement behaviors (PA levels, steps count and sedentary behavior) and health outcomes (BMI, aerobic fitness, and perceived stress) during the school day? It is hypothesized that the IcPAB group will show improvement in all measures compared to the control group.

2 Methods

This study received ethical approval from the Ethics Review Committee of the University of Kelaniya, Sri Lanka (Ref: UOK/ERC/SS/2022/009) and Hong Kong Baptist University (Ref: SOSC-SPEH-2022-23_113). The trial was retrospectively registered with the ISRCTN registry (Ref: ISRCTN52180050). Methods are reported by adhering to the Consolidation Standards of Reporting Trials (CONSORT) guidelines and the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) Statement throughout the study. The completed SPIRIT Checklist is added as a Supplementary material S1.

2.1 Study design and selection of subjects

A single-blinded parallel randomized controlled trial (RCT) will evaluate the intervention effects of IcPAB compared to a control group. Target participants will be the fifth graders in government primary schools. Based on the data shared by the Ministry of Health, Sri Lanka, the COVID-19 pandemic severity was slight in the Bandarawela Education Zone (city) in Badulla District. Therefore, the government schools of Bandarawela Education Zone were contacted to initiate the recruitment process in late 2022. The age range of the grade five students is 9 to 10 years old. The targeted population is exposed to 6 hours of regular classroom time (7.30 a.m. to 1.30 p.m.), including a 20-min lunch break according to the government primary school norms in Sri Lanka. Within the government primary school setting, the teacher in charge of a class should teach all subjects in the syllabus for the class, such as mother tongue, mathematics, religion, environment and English. Depending on the interests of the schools, the teachers will conduct additional classes after regular school time to prepare the students for the year-end national scholarship examination. Therefore, the study was designed to be implemented only during the standard classroom time for 12 weeks.

Based on GPower 3.1 software, through *a priori* power analysis, it was estimated to obtain at least 198 participants for both the intervention and control groups to expect an effect size of 0.21 [Cohen's *f*, converted from *d*, (45, 46)] on academic achievement (mathematics) by providing a power of 0.8 (1-β) with an alpha of 0.05 to test the primary hypotheses of the study with an estimated 10% dropout rate [dropout rates were less than 10% in previous studies (10, 33, 47)] at the post-test/ follow-upstage.

Therefore, it is anticipated to recruit five to six classes (30 to 40 students per class) from two government schools to conduct the study to reach the required minimum sample size. Block randomization technique via MS Excel, will be used to randomize the sample classes by an assessor who is blinded to the intervention content and outcome assessment.

Permission was obtained first from the Bandarawela zonal education director to contact eligible government schools. For two schools to be eligible, grade five education must be offered, the students should not be exposed to similar interventions, and the principals must consent to join the research project. Once the principals grant the permission, the research team will contact the teachers in charge of the fifth-grade classes.

Teachers in charge of classes, parents/ guardians, and children at participating schools will be distributed with an informed consent form (Supplementary material S2) in plain language during the parents' meeting days organized by the teachers. After obtaining the permissions, the principal investigator and the research assistants will visit the schools to collect data by giving prior notice to the teachers in charge of classes. The teachers will deliver the IcPAB. Therefore, all the students in the intervention classes will be exposed to IcPAB.

However, data will be collected only from the students meeting the consent requirements. The study will not include data from students with special health conditions and special education needs. An overview of the participant flow diagram (Figure 1) and the intervention schedule for enrolment and assessments [SPIRIT Figure (Figure 2)] are provided below.

2.2 Intervention

2.2.1 Development of the intervention

Development of the intervention is facilitated through six steps. The conceptual design of mapping COM-B onto the suggested research work and the specification of each target behavior in developing and implementing the intervention is provided in Supplementary material S3.

Step 1: Systematically reviewed RCT-based IcPAB interventions for primary school students to identify the current practices at the global level. The review findings have been published elsewhere (37) by recommending the use of COM-B model as the theoretical basis for designing IcPAB interventions.

Step 2: Conducted semi-structured interviews with 21 primary school government teachers in Sri Lanka to analyse their perceptions on implementing IcPAB among Grade five students. The interview findings, which was thematically analyzed based on the COM-B model have been published elsewhere (20).

Based on the review (37) and the interview findings (20), the intervention was developed by embedding the Capability, Opportunity, Motivation-behavior (COM-B) model (20, 42, 48–50). The underlying theory of the COM-B model mentions that outcome behaviors must be understood in their context with consideration given to the individuals' existing capability, opportunity and motivation to achieve these target behaviors (38, 42, 48, 51, 52). For example, it should be mentioned that the COM-B factors have been considered in IcPAB intervention and how they are addressed through the behavior change techniques (BCTs) (38, 53–55), which are defined as the active, observable, replicable, and irreducible components (42, 54) of the COM-B model.

Step 3: Identify the related COM-B that must be addressed to develop and implement the IcPAB. For example, as explicated in Table 1, it was identified that the class teachers' dress code as a physical capability-related factor that should be concerned of when designing the IcPAB activities. Because teachers highlighted that they would have physiological limitations to demonstrate IcPAB as they are not wearing sports friendly wear at the classroom.

Step 4: Applied the BCTs from the BCTv1 taxonomy to mitigate the identified behavioral issue (Table 1) to enhance academic achievement, movement behaviors and the health outcomes of the target group. For example, it was identified that the teachers' doubts on physical capability factors such as dress code-related physiological limits can be mitigated by providing credible written materials and videos of how previous IcPAB practices are conducted despite teacher

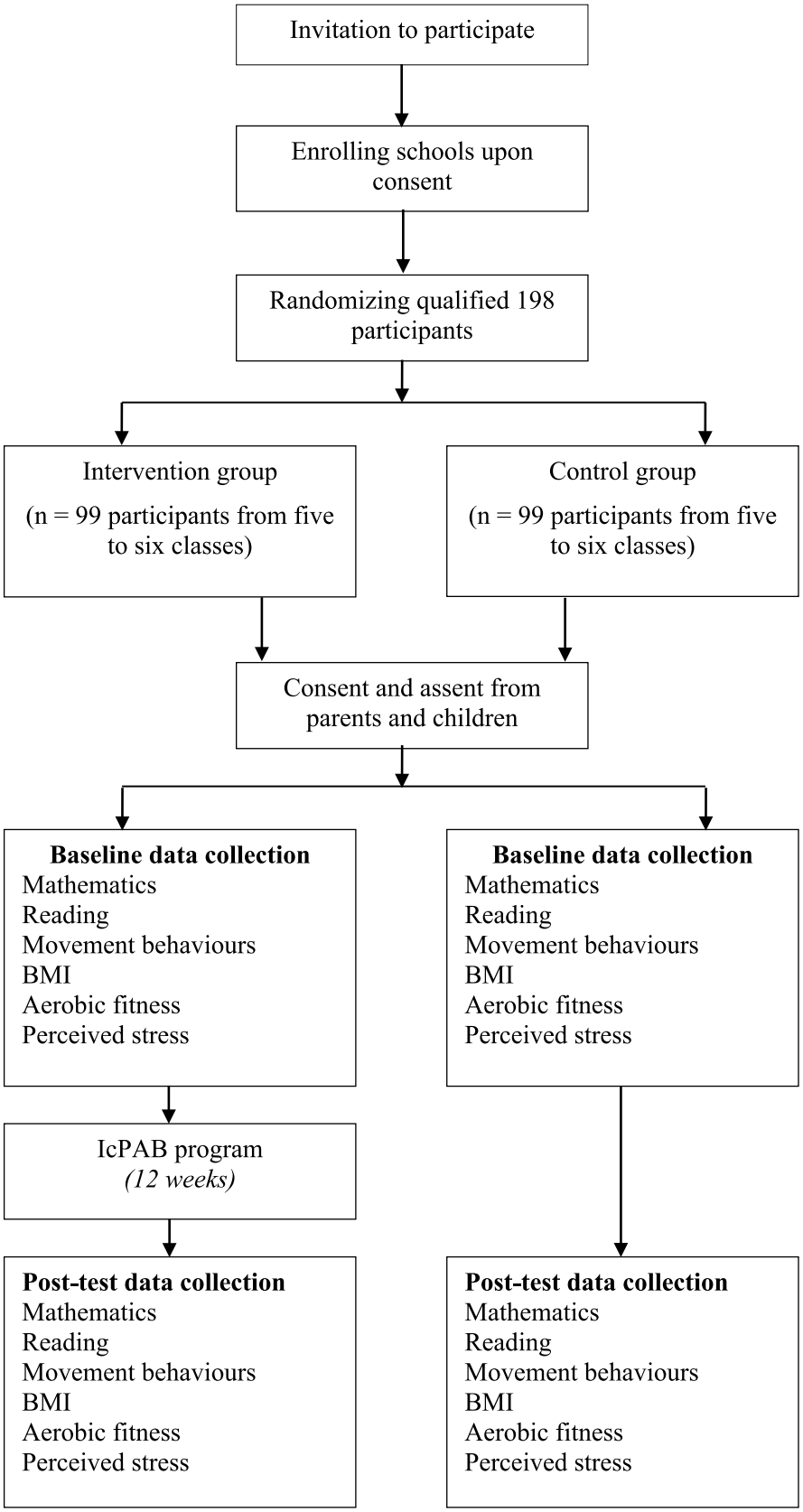

FIGURE 1
Flowchart of participants through the IcPAB program.

	STUDY PERIOD			
	Enrolment	Allocation	Baseline	Close-out
TIMEPOINT**	$-t_1$	0	t_1	t_2
ENROLMENT:	X			
Eligibility screen	X			
Informed consent and assent	X			
Allocation		X		
Teacher training			X	
INTERVENTION:				
In-Classroom Physical Activity Breaks			←	→
ASSESSMENTS:				
Mathematics			X	X
Reading			X	X
Physical Activity Levels			X	X
Steps Count			X	X
Sedentary Behaviour			X	X
BMI			X	X
Aerobic Fitness			X	X
Perceived Stress			X	X

FIGURE 2
Intervention schedule for enrolment and assessments (SPIRIT Figure).

age and dress (BCT 9.1) and telling teachers individually that they can successfully conduct IcPAB frequently (BCT 15.1). Further details are provided in 2.2.2 below.

Step 5: Designed IcPAB activities and facilitator packs with local educators based on the evidence collected from the review and the interviews. For example, a manual, logbooks, timers, WhatsApp messaging group and 20 IcPAB cards were prepared as intervention materials. The details of IcPAB cards will be illustrated in 2.2.2 below.

Step 6: Tested the IcPAB cards in a pilot test with two teachers from two classes in one school. This school will not be involved in the main intervention. The aim of this pilot is to test the ability of the teachers to follow the instructions provided on IcPAB cards and to observe the students' reaction toward the activity breaks.

Step 7: As elaborated in 2.2.2, conduct a training for the intervention class teachers to be familiar with the IcPAB program.

The first six steps were completed, and the Step 7 will be facilitated in future.

2.2.2 Delivery of the IcPAB in the intervention group

The IcPAB program will introduce 20 cards among all intervention classes. The interviews (20) conducted during the intervention development stage (Step 2 in section 2.2.1) explored that activities which take around 5 minutes would be feasible to implement in class due to high density of teaching content in each regular class. Also, the previous evidence assured IcPAB, which requires less than 5 min to provide positive intervention effects (12, 56). Therefore, the teachers will be requested to implement at least five-minute PA breaks three times daily. Each activity should be implemented for at least 5 minutes.

The IcPAB cards can be incorporated into the mathematics and language reading lessons. All the cards are designed for teachers to teach mathematics and language lessons using physically active teaching methods while reducing the fifth graders' school day seated learning time without interrupting academic teaching time. The nature of the activities will also assist students to improve their aerobic fitness and enjoy learning by forgetting any stressors. Each card has a picture resembling a particular IcPAB. The back of the card has written instructions on performing the activities in addition to the instructions provided in the IcPAB manual. The manual was designed for Sri Lankan teachers with pictures by merging the activities with the fifth-grade curriculum with PA.

The first card is designed to implement a breathing exercise as students require stress relief. Hence, the teachers can choose either the first IcPAB card with another card as the first activity of each day or another activity card. Even if the teachers decide not to use the IcPAB card one, they are given instructions on each card to do a little breathing before starting any activity if deemed necessary. Teachers are reminded on each card to use encouraging words (such as very good) to finish the activity and refer to the lesson.

For example, as provided in Supplementary material S4, the first card (IcPAB card ID: IcPAB 3) is designed to help the students with arithmetic skills. If a teacher wants the students to relax by doing a breathing exercise, the students will be instructed to stand comfortably and inhale- exhale three times by raising up and down on the toes while moving the hands up and down in the same rhythm. Then, the students will solve a multiplication problem given by the teacher (if the problem is more complicated, ask students to use a piece of paper while standing) and jump on the spot equal to the obtained answer. Next, the teacher will repeatedly solve the question with the students and jump on the place. The students will be given a verbal appreciation with or without a clap.

The teacher training (BCT 6.1) will be the primary enablement of the teachers to engage in the intervention. Teachers involved in the intervention will receive one-hour training 1 week before the commencement of the IcPAB intervention. The principal investigator will conduct the training session in a classroom after the regular school time upon the teachers' availability. Teachers will receive intervention materials such as the IcPAB manual, IcPAB cards, timers,

TABLE 1 Utilizing COM-B and BCTV1 taxonomy to develop and implement the intervention based on interview findings.

Based on interview findings: What encourages seated learning OR hinders implementing physically active teaching inside the classroom?	Which model of behavior sources (COM-B) is related to the interview finding?	What should be done to introduce IcPAB intervention by improving the identified behavior source model?	What behavior change techniques from BCTTv1 should be applied to activate the intervention functions and policy categories?
Physiological limits due to the age and dress code	Physical Capabilities	Provide examples from the field of education of how IcPAB can be used regardless of the physiological barriers.	4.2 Information about antecedents 5.3. Information about social and environmental consequences 9.1 Credible source 15.1 Verbal persuasion about capability, i.e., *Provide credible written materials and videos of how previous IcPAB practices are conducted despite teacher age and dress; tell teachers individually that they can successfully conduct IcPAB frequently*
		Convince the teachers that the IcPAB can be implemented without changing into a sporty dress.	6.1 Demonstration of the behavior 15.1 Verbal persuasion about capability, i.e., *Show the teachers in a real class situation how IcPAB can be done with the dress code for lady teachers (Saree); tell teachers individually that they can successfully conduct IcPAB frequently.*
Lack of psychological confidence to implement physical activities other than the specified activities in the teachers' guide.	Psychological Capabilities	Provide easy-to-understand written and visual manuals on conducting IcPAB.	4.2 Information about antecedents 9.1 Credible source, i.e., *Provide a manual specifically designed for Sri Lankan teachers with pictures and videos.*
		Provision of regular training and feedback on IcPAB implementation.	4.1 Shaping knowledge 6.1 Demonstration of the behavior 15.1 Verbal persuasion about capability, i.e., *Hold special training sessions for teachers, advise and agree on how to perform IcPAB; Implement IcPAB with teachers/ provide assisted delivery; provide weekly feedback to the teacher and tell them they can successfully conduct IcPAB frequently.*
Not receiving external enablement to conduct classroom-based physical activities.	Social Opportunities	Request school-level policy decisions to implement IcPAB.	1.2 Problem-solving, i.e., *Hold meetings and request permission from section heads to implement IcPAB as a novel teaching strategy and to test its effectiveness on academic achievement.*
		Set goals to achieve a minimum number of IcPAB daily.	1.1 Goal setting (behavior) i.e., *Set a goal to implement 5-min IcPAB at least thrice daily.*
		Regular follow-up and monitoring of the fidelity.	7.1. Prompts/ cues 2.2 Feedback on behavior, i.e., *Send daily WhatsApp messages to teachers to implement IcPAB at least three times; monitor the way the teachers conduct IcPAB and provide informative, evaluative feedback.*

(Continued)

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TABLE 1 (Continued)

Based on interview findings: What encourages seated learning OR hinders implementing physically active teaching inside the classroom?	Which model of behavior sources (COM-B) is related to the interview finding?	What should be done to introduce IcPAB intervention by improving the identified behavior source model?	What behavior change techniques from BCTTv1 should be applied to activate the intervention functions and policy categories?
Most classrooms are crowded and need more space to conduct physical activities.	Physical Opportunities	Convince the teachers that the IcPAB can be implemented in a small space just by standing in front of the desk.	6.1 Demonstration of the behavior 15.1 Verbal persuasion about capability, i.e., *Show the teachers in a real class situation how IcPAB can be done just by standing behind the desk; tell teachers individually that they can successfully conduct IcPAB frequently.*
Not receiving updated information on the risks of prolonged sitting	Automatic Motivation	Provide examples of the risks of prolonged sitting and the benefits of doing IcPAB.	5.1 Information about health consequences 5.3. Information about social and environmental consequences 9.1 Credible source, i.e., *Provide credible written materials and videos on the risks of prolonged seating and how such risks can be minimized.*
Lack of strong will to break sitting time and belief in the benefits of engaging in PA inside a classroom	Reflective Motivation	Convince the teachers with evidence that the IcPAB are integrated into the curriculum and that the activities help enhance academic performance.	4.2 Information about antecedents 5.3. Information about social and environmental consequences 9.1 Credible source, i.e., *Provide credible evidence from previous research findings on how IcPAB helped enhance student performance in various subjects.*

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and the logbook. Intervention materials are written in the local language (Sinhala). However, English terms are used in the materials when deemed necessary.

By addressing the findings from the interviews (20), the training session with the application of the BCT taxonomy (i.e., BCT 4.1; 4.2; 5.1; 5.3; 9.1) will cover (1) the importance and benefits of IcPAB by referring to previous research findings, (2) rationale of introducing the current IcPAB activities, (3) recording of the logbooks (4) demonstration of IcPAB and (5) questions and answer round. i.e., at training, teachers will be given credible written materials and videos of how previous IcPAB practices are conducted despite teachers' age and dress (BCT 4.2; BCT 5.3 and BCT 9.1). The teachers will be convinced that the IcPAB can be implemented without changing into a sporty dress by demonstrating some activities during training in addition to the assisted delivery in the classroom (BCT 6.1). Also, teachers will be convinced about the risks of prolonged seating and how such risks can be minimized through IcPAB can be used (BCT 5.1; BCT 5.3 with research evidence (BCT 9.1) in addition to how IcPAB helped enhance student performance in various subjects (BCT 4.2 and 5.3) in other countries.

The principal investigator will deliver and observe the IcPAB program during the first two weeks of intervention to ensure adherence to the intervention protocol by following a previous practice (12). Therefore, extensive demonstrations of the active break activities will not be provided during the training. i.e., Following a previous intervention practice called assisted delivery (12), the principal investigator will deliver the intervention activities together with classroom teachers during the first week of the intervention. During the second week, the principal investigator will observe teachers doing the activities and provide support if needed. This assisted delivery method (BCT 6.1, BCT 4.1) during the first week of the intervention and the IcPAB manual (BCT 9.1) will enable the teacher to engage in the intervention activities continuously. Teachers are given the opportunity to replicate/ modify the PA breaks. If this is done, the teachers will record their actions in the logbook while noting the detailed information on the last pages of the IcPAB manual. Replicated/ modified activities will be given feedback by the principal investigator.

Additionally, prompts (BCT 7.1) such as WhatsApp messages and interactive discussions (BCT 15.1) with the teachers will be used as techniques to implement the intervention to remind and persuade them to carry out the IcPAB each week at least to meet the minimum required dose (BCT 1.1). Furthermore, should the teachers face any difficulty, they will be assisted by the principal investigator or the research assistants to manage the issues (BCT 1.1) while providing informative, evaluative feedback (BCT 2.2) about their progress with the intervention activities. The feedback will also include the satisfaction of students.

However, should the children or the classroom teachers not want to implement intervention activities, they can do so without any reason. No participants will be advantaged or disadvantaged in any way by doing so. Parents, children, and teachers will be reassured that they can withdraw their permission anytime during this project without penalty. No foreseeable added risk was identified above the risks of everyday life. In addition, implementing IcPAB would not harm the students' physical and emotional health or the pure educational time as the teachers will be given complete autonomy to choose the most appropriate time to carry on IcPAB.

2.2.3 Control group

The classes that will be randomized in relation to the control group will not receive the IcPAB within 12 weeks of the intervention. However, those schools will be given all the resources to implement IcPAB activities once the post-test data collection is fulfilled. During the intervention period, the control group's teachers will be contacted once weekly through WhatsApp phone calls by the principal investigator and twice a week physically by the principal investigator/ research assistants. Correspondence will be maintained to obtain information about their lesson delivery patterns to ensure that the control group did not receive interventions to change their normal study modes.

2.3 Measurements

Synthesis of primary (academic achievement) and secondary outcomes (movement behaviors and health outcomes) measurements in this study are shown in Supplementary material S5. All measurement outcomes will be compared among the control group. Data collection for measuring outcomes will be conducted by adhering to the Helsinki Declaration, national and school-level safety protocols and COVID-19 prevention guidelines.

2.3.1 Primary outcomes

Based on the interviews conducted with 21 teachers from the nine provinces of Sri Lanka (interview findings were published elsewhere; (20)), mathematics and reading performance were identified as the most important subjects for the students to perform well at the Grade Five national level scholarship examination. In the Sri Lankan and international contexts, it is evident that mathematics and reading performance are the key pillars of elementary education's academic achievement (10, 12, 32, 33, 57).

2.3.1.1 Mathematics achievement

Mathematics achievement will be evaluated through a curriculum-based standardized test designed by the teaching officers experienced in Grade five mathematics performance-related evaluation. This test will consist of 60 questions to assess the expected performance of a given term. Students will complete the test within 45 min. The principal investigator and the classroom teacher will collaboratively administer the test.

2.3.1.2 Reading achievement

Reading achievement will be evaluated through a standardized reading test specific to the Sri Lankan Grade Five curriculum. Three grade five teachers have chosen two paragraphs to be used at the baseline and at the end of the intervention to evaluate the students' reading achievement. The paragraphs include around 200 to 250 words; each student will read the sections for 2 minutes. Reading performance will be evaluated by a teacher who is not the student's classroom teacher (yet a classroom teacher of the same school's parallel grade) under the principal investigator's distant observation.

2.3.2 Secondary outcomes

Movement behaviors such as PA levels, steps count, and sedentary behavior within regular school hours will be evaluated. Health

outcomes such as BMI, aerobic fitness, and perceived stress will be assessed as other secondary outcomes.

2.3.2.1 Movement behaviors

Objective data for the light physical activity (LPA), moderate physical activity (MPA), vigorous physical activity (VPA), MVPA, steps count, and sedentary behavior will be measured during regular school hours using waist-worn accelerometers (GT3-X triaxial model, ActiGraph LLC, Pensacola, Fla., USA). Accelerometer data will be collected for a week at baseline and the post-test (week 13).

The accelerometers will be distributed by the teachers to the students randomly on the first school day and collected back on the fifth school day of the week. The research team will demonstrate to the teachers and the students how the accelerometers should be worn on the first day. However, due to the limited number of accelerometers, this study will use a randomly selected subsample (n = 47) to collect data to measure all the movement behaviors following previous research practice (12, 34, 58, 59). After accelerometers are randomly distributed to the students on the first day, the teachers will prepare a list assigning each student to a specific numbered accelerometer to ensure that the same child wears the same device every day during all the data collection stages. Then, the research team will receive another version of the same list where the students' anonymous identification number is related to the accelerometer. The classroom teacher will also record absent students assigned with an accelerometer, and a researcher assistant will verify the data during the school visits.

Based on previous research practices (12, 60), only the accelerometer data, which will be identified for wearing more than five school hours on at least one school day, will be included in the analysis for intervention effects (12, 60). Following the standard practices in the studies involving children, non-wear time will be defined as 20 min of consecutive zeros (12, 31, 61). Freedson cut points will be used to classify movement behavior intensities based on the data collected in 15-s epochs (12, 62). Due to the focus on in-school PA, a longer wear time is not deemed necessary for the current study, as recommended by recent scholars (63). To confirm in-school wear-time for valid days, a further visual check of each accelerometer profile will be undertaken (63). Therefore, research assistants will randomly visit the schools during the data collection week to ensure that the students wear the same device accurately during school hours.

2.3.2.2 Health outcomes (BMI, aerobic fitness, perceived stress)

Students' weight in kilograms to the nearest 0.1 kg (27, 63, 64) and height in centimeters to the nearest 0.1 cm (27, 63, 64) will be recorded using a standard stadiometer and a weighing scale. Body weight in kilograms will be divided by height in meters squared to measure the BMI (27, 63, 64). Students' age and gender-specified BMI categories will be identified using the calculator introduced by the Ministry of Health in Sri Lanka (65).

The multistage shuttle run/ beep test [66] will be used to measure aerobic fitness, proven highly reliable and valid among school children (32, 66). Results from the test will be used to calculate VO_2 max using the equation proposed by previous studies (67, 68). Students will be asked to run back and forth on a 20 m course as instructed by a sound signal emitted from a pre-recorded tape, ensuring they touch the 20 m line with their foot (32). The sound signal frequency increases by 0.5 km/h every minute, indicating the next stage (level), starting with a speed of 8.5 km/h. The test ends when participants fail to reach the line before the signal.

Perceived stress will be measured using a translated Sinhala version of the Perceived Stress Questionnaire 8–11 (PSQ8-11 (67)). PSQ8-11 will measure two subscales: perceived psychological stress (nine questions) and physiological stress (10 questions). This 19-item questionnaire requires the students to recall their feelings from the previous week. The students will self-rate their responses on a four-point Likert scale (1 = never, 2 = sometimes, 3 = often, 4 = very often). A higher score on the questionnaire will indicate greater perceived stress (67).

2.4 Fidelity of the intervention

The primary source for assessing the fidelity will be the logbooks of the teachers. An example of a log sheet can be found in Supplementary material S6. Teachers will indicate how many IcPAB they implemented daily throughout the intervention period. Teachers will be reminded every day via WhatsApp messages to carry out IcPAB, and a research team member will visit the schools once a week to check if the logbooks are duly filled. The personal visits to the intervention schools will also minimize issues with time management and PA breaks implementation from the teachers' side. In addition, accelerometer data from the post-test will be compared with the responses obtained through teacher and student interviews at the post-test.

2.5 Process evaluation

During the intervention, the principal investigator will receive teacher feedback and give subjective evaluations on how the teachers implement the IcPAB. At the same time, the research team will obtain verbal feedback once a week from the students on IcPAB's ability to provide fun and engagement using two close-ended questions: (1) Did you enjoy the activities today? (2) Was it easy for you to follow the instructions and do the activities today? This ongoing feedback-receiving process will be used to overcome any identified or foreseen challenges to implement the IcPAB program (31, 43).

In addition, after the 12-week RCT intervention program, a five-point Likert-scale questionnaire will be distributed among the intervention group's teachers and students to analyse process evaluation outcomes (Supplementary material S7). The teachers' questionnaire consists of eight items, while the students' questionnaire consists of nine items. Both the questionnaires were adopted from previous research work (56, 69).

2.5.1 Sustainability evaluation

As a sustainability strategy to track the program for future adoptions all the teacher facilitators and randomly selected student groups will be contacted. The aim is to explore the perceptions of teachers and students in attending and implementing in-classroom PA breaks program through a semi structured interview study based on the capability, opportunity, and motivation behaviors model. The interview guide is available in Supplementary material S8.

2.6 Data analysis

Data will be statistically analyzed using IBM SPSS software version 28. A randomization check will be performed using independent t-tests (for continuous outcomes) and chi-square (for categorical variables) tests (70). Descriptive statistics such as mean, standard deviation, and percentages will be used to describe the baseline characteristics of the sample and the attrition rates. Primary analysis will be handled with an intention-to-treat modified (m-ITT) approach (71). Missing values analysis will be conducted to observe whether the data are missing completely at random (MCAR). Missing data values will be handled using the multiple imputation method with chained equations.

To test the effectiveness of the IcPAB, generalized linear mixed models (GLMM) will be used by linking to the dependent variables at the individual level (students) and group level (intervention vs. control) with time (pre to post-test) (12, 72, 73). A random intercept will be used to account for the repeated measures of the subjects (35). To test the moderation effects by gender, an interaction test will be conducted via GLMM by setting group-by-time-by-gender as the moderator (35). A 5% level (two-tailed) will be used as the statistical significance cut-off point (74). All the intervention effects will be reported based on the type III tests of fixed effects of GLMM. The estimates of the impact sizes will be written based on the estimated coefficients (β) with the 95% confidence intervals/ odds ratio for those estimates based on previous intervention effect report practices for IcPAB (31, 63) in addition to the mean changes in the intervention and control groups. The odds ratio (OR), where OR = 1.68, 3.47, and 6.71 are equivalent to Cohen's $d = 0.2$ (small), 0.5 (medium), and 0.8 (large), will be used for the interpretations, respectively, (75). Furthermore, a sensitivity analysis to the m-ITT results will be facilitated by considering all the subjects who complete all the baseline and post-test measurements for all the primary and secondary outcomes to ensure the robustness of the primary data assessment and strengthen the conclusions and credibility of the study's findings.

3 Discussion

The primary aim of this RCT is to investigate the effects of the IcPAB program on the mathematics and reading achievement of fifth graders in Sri Lanka. Secondarily, the intervention effects of the LPA, MPA, VPA, MVPA, steps count, and sedentary behavior will be evaluated in addition to the health outcomes such as BMI, aerobic fitness, and perceived stress.

This intervention has addressed several recommendations and limitations pointed out by previous studies: (1) To the best of the authors' knowledge, this is the first IcPAB intervention, which will be implemented among governmental primary school girls and boys in Sri Lanka by integrating mathematics and reading curriculum components into the IcPAB content. The intervention will analyse its moderation effects by gender. Thus, this intervention's findings will fill an existing population gap and add new knowledge to academia (39, 41). (2) It is reported that the IcPAB, which requires a more prolonged duration per activity, are less feasible (12, 39, 76). At the same time, teachers prefer shorter bouts of IcPAB, at least at most 5 minutes (20, 37). This intervention will provide more evidence of the effects of using five-minute curriculum-integrated PA breaks.

(3) The intervention uses a RCT with a parallel single-masked design, ensuring a low bias risk to its methodological quality (39, 41, 44). Also, the protocol contains a precise data analysis plan for handling missing data and examining the data with a sensitivity analysis. (4) Intervention fidelity and process evaluation mechanisms will be systematically followed and reported to ensure the feasibility of the RCT in the 'real-world' context (12, 39). As for the primary outcome evaluations, curriculum-based measurements are designed. Curriculum-based measures were recommended by the previous researchers due to its sensitivity toward small changes (12, 39) and the ability to be administered frequently (12, 39).

In addition, this intervention will use accelerometer data to analyse the effects of movement behaviors. This is a strength of the IcPAB intervention, as objective measures to record PA levels, steps count, and sedentary behavior are strongly recommended (12, 44). Furthermore, the effects of IcPAB on BMI, aerobic fitness and stress levels are under-researched among preadolescents (67, 77–81). In particular, higher stress levels among fifth graders in Sri Lanka are a critical issue (18, 28, 81). Global evidence also suggests that there are few efforts to be found in analyzing the effects of academic load on stress levels among preadolescents and adolescents (67, 77–81). (5) The intervention materials were developed with fifth-grade teachers in Sri Lanka by analyzing the current capabilities, opportunities, and motivations of the prospective IcPAB implementors (20). Therefore, this intervention is equipped with a theoretical foundation, COM-B model (38, 39, 82). Thus, the IcPAB program will address these facets, a significant strength of this RCT.

3.1 Limitations

Despite the strengths mentioned above, it is possible to indirectly affect the fidelity of the intervention due to the ongoing economic crisis and post-COVID-19 pandemic in Sri Lanka (83, 84). For example, the sudden closure of schools for a few days will reduce the number of days the IcPAB can be implemented weekly (83–85). Furthermore, participants were limited to the Uva Province in Sri Lanka. This will cause a representation bias in the data (86). The classes are randomized into intervention and control groups. This may cause potential contamination effects. Therefore, use of a cluster-RCT design is recommended to in the future studies similar to a previous study (31). There may be a potential for bias as the same teacher who is delivering the IcPAB records the fidelity of the intervention (12) even though the research team plans to conduct weekly observations of the frequency of conducting IcPAB. Also, the results may be limited by poor protocol compliance if few classes are included in the study as "one teacher could skew the results" (31).

Even though, this study was designed based on COM-B model to address the hindrances to implement classroom-based PA, effect of the factors such as participants' dietary habits (87), challenges with school initiatives (88), children's preferences for outdoor activities (89) will not be measured throughout the proposed RCT.

3.2 Significance of the study

Using the COM-B model as a theoretical underpinning and behavior change technique on teacher facilitators will provide more

opportunities for children to be active at school. Active children are identified to improve their academic performance, physical behaviors, and health. Therefore, this study could improve the mathematics and reading achievement of fifth-grade girls and boys, which is a significant factor determining the performance at the Grade Five National Scholarship Examination in Sri Lanka. At the same time, the IcPAB program will help improve healthy behaviors and health, including emotional health, among primary school students. Furthermore, the IcPAB program was designed to prevent pure educational time loss by introducing curriculum-integrated short bouts of physically active breaks into the classroom routine. Therefore, future findings of this study will be significant in providing positive effects of IcPAB on primary school children as an RCT that addresses several limitations of previously implanted IcPAB programs.

Ethics statement

The studies involving humans were approved by the Ethics Review Committee of the University of Kelaniya, Sri Lanka (Ref: UOK/ERC/SS/2022/009) and Hong Kong Baptist University (Ref: SOSCSPEH-2022-23_113). The studies will be conducted in accordance with the local legislation and institutional requirements. Written informed consent will be obtained from the participants' legal guardians/next of kin prior to participation in the study.

Data availability statement

Analysed data from the intervention will be published upon the completion of the intervention. Any data that would disclose the participants' personnel information will not be made public.

Author contributions

DP: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. YD: Conceptualization, Methodology, Project administration, Supervision, Validation, Writing – review & editing. CV: Conceptualization, Methodology, Resources, Supervision, Writing – review & editing. WL: Conceptualization, Methodology, Project administration, Supervision, Writing – review & editing. JB: Conceptualization, Methodology, Supervision, Writing – review & editing.

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Conflict of interest

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

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1360210/full#supplementary-material

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Effectiveness of a school-based high-intensity interval training intervention in adolescents: study protocol of the *PRO-HIIT* cluster randomised controlled trial

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Introduction: High-intensity interval training (HIIT) is an effective strategy for improving a variety of health and fitness outcomes within school settings. Incorporating HIIT into existing physical activity opportunities appears practically feasible, yet the process evaluation and effectiveness of this strategy needs to be further evaluated. Therefore, a *PRO-HIIT* intervention will be conducted to evaluate the effectiveness of a 12-week school-based HIIT intervention on cardiorespiratory fitness, physical activity, body composition, muscular strength, bone health, cognitive function, wellbeing and academic performance among 12–13-year-olds.

Methods and analysis: Eight classes of year 7 students (12–13-year-olds) from a secondary school in Ningbo, China, will be recruited and randomly allocated into an intervention or control group. While the control group maintains their usual activities, a 6 to 10 min HIIT session will be embedded in the physical education or physical activity lessons five days a week for 12 weeks for the intervention group. Training workshops will be conducted for participants, teachers, and research staff for facilitating the intervention. Outcome data will be collected at three time points: pre- and post-intervention, and two months (summer holiday) upon completion of the intervention. Linear mixed models will be used to analyse the impact of groups (intervention and control), timepoints (pre-, post- and two-month after intervention) and group by time interactions. The implementation process of the intervention will be evaluated using a process evaluation framework.

Ethics and dissemination: Ethics approval is obtained from the Ningbo University Ethics Committee (TY2024002). Results from *PRO*-HIIT study will be disseminated via peer-reviewed journals, scientific conferences as well as local education system. The study protocol has been retrospectively registered on ClinicalTrials.gov Protocol Registration and Results System (NCT06374732), https://clinicaltrials.gov/study/NCT06374732.

KEYWORDS

high-intensity interval training, schools, adolescents, intervention, physical fitness

Introduction

Physical activity (PA) is well documented for its role to promote physical fitness and mental wellbeing in children and adolescents (1–4). However, less than 20% of adolescents meet the World Health Organization guideline for engaging in an average of 60 min of daily moderate to vigorous PA across the week (3). The most cited barriers for adhering to the recommendations include time constraints, lack of motivation and inadequate facilities (5, 6). Notably, engaging in vigorous PA is of salient health significance for children and adolescents. Vigorous PA has been independently associated with lower levels of cardiometabolic risk factors, higher cardiorespiratory fitness (CRF) and improved bone health in this population (7, 8). With time constraints for PA participation among young population, prioritising vigorous PA by employing high-intensity interval training (HIIT) might be a viable option for health promotion (9). HIIT, featuring short bursts of intense exercises interspersed with active recoveries or rests, has emerged as a time-efficient and effective exercise strategy for children and adolescents (5, 10).

Schools act as the ideal settings for PA programmes because of the abundant resources available within the education system, such as staff, space and facilities, different timing options (e.g., breaks and classes) and broad reach of children and adolescents (1, 11). Time spent in schools account for a significant proportion of children's waking hours, hence these institutions have the potential to counteract the global issues related to physical inactivity (12) and health inequalities (13). In recent years, there has been an interest in integrating HIIT into school settings. Review-based evidence indicates that school-based HIIT interventions effectively enhance body composition (14–16), CRF (15, 16) and muscular health (17). However, the impact on cognitive function and academic performance remains uncertain (15) and evidence regarding its health benefits for mental well-being (15) and bone health (18) is limited.

Despite the advantages of school settings, integration of PA programmes into schools is challenging. This is mainly because of the additional workload imposed on already overworked schoolteachers and the potential diversion of students' valuable time away from academic study (19). One practical solution to address this challenge is to incorporate PA interventions during dedicated curriculum time for PA, such as during physical education (PE) lessons. Lubans et al. (9) proposed that for school-based HIIT to be scalable, it should be integrated into existing PE or sport training sessions. Indeed, a recent review highlighted that 57.1% ($n = 24$) of the 42 identified school-based HIIT interventions were conducted during PE lessons (15). Given that less than 50% of a typical PE lesson time is spent in moderate-to-vigorous PA in secondary school (20), HIIT targeting PE lessons might potentially enhance the quality of PE (21) and health condition of children and adolescents (15, 17, 22, 23).

Recent research has highlighted the risk of fitness loss or stagnation during prolonged and unstructured days (defined as weekends or holidays when obesogenic behaviours are prevalent due to lack of compulsory PA opportunities, restriction on caloric intake, limitation on screen time, and regulated sleep schedules), a phenomenon known as the "Structured Days Hypothesis (SDH)" (24). In supporting the SDH, a survey conducted in Australia demonstrated that children spent more time watching TV or playing videogames and engaged in less PA, leading to a reduced daily energy expenditure during unstructured holidays (25). Martin et al. (26) showcased the efficacy of a 7-week school-based HIIT programme in mitigating potential CRF loss among Scottish adolescents during summer vacation. However, the impact on other health-related factors remains underexplored and their study is limited by a lack of implementation details.

One useful approach to improve the intervention reporting is through conducting a process evaluation. Process evaluation delves into implementation details, mechanisms of impact and contextual factors, offering a comprehensive understanding regarding the intervention effectiveness and underlying causality (27). It runs parallel to the outcome assessment, which contributes to future scaling up and dissemination (23, 27). Nonetheless, only a limited number of school-based HIIT interventions have included process evaluations, either as sections within intervention outcome papers (28, 29) or as standalone pieces (30–32). Among these studies, only two interventions employed a process evaluation framework (30, 32). Conducting process evaluation without proper guidance may pose challenges, potentially leading to incomplete reporting and biased results and interpretations (33).

Aims of the study

Given the above stated research gaps, the present study aims to conduct a school-based HIIT intervention named *PRO-HIIT*. The *PRO-HIIT* is a health promotion initiative designed to deliver 6–10 min of HIIT into the daily routines of Chinese adolescents, with a focus on settings of existing PA opportunities. Specifically, while the control group will take the usual PE ($n = 3$) and PA lessons ($n = 2$) every week, a 6–10 min of HIIT will be embedded at the beginning of these lessons five times per week for twelve weeks for the intervention group. The aims of the *PRO-HIIT* are to:

(1) evaluate the effectiveness of the *PRO-HIIT* on CRF (primary outcome), PA, body composition, muscular strength, bone health, executive function, wellbeing, enjoyment, motivation, affect, self-efficacy and academic performance among 12–13-year-old adolescents;
(2) examine the changes of these outcomes following a two-month unstructured summer holiday after the *PRO-HIIT* study is completed;
(3) evaluate the implementation process of the *PRO-HIIT* through a process evaluation.

Methods and analysis

Study design

The study is a multi-centre collaborative work conducted by University of Exeter and Ningbo University. Consolidated

Standards of Reporting Trials (34) and Template for Intervention Description and Replication (35) checklists will be adopted for guidance and reporting. The *PRO-HIIT* study will employ a two-arm cluster-randomised controlled trial design, with an intervention group and a treat as usual control group. Clusters in this study are eight classes of secondary school students, located in Ningbo City, China. The intervention will be delivered five times per week, commencing at the beginning of the three PE and two PA lessons. The PA lessons serve as a complementary opportunity for students to engage in exercises of their choice on days when PE lessons are not scheduled. Assessments will occur at three time points: baseline (T1), immediate post-intervention (T2) and two-month post-intervention (T3), with T3 aligning with the initial two weeks of a new school term following a two-month unstructured summer holiday. Table 1 presents an overview of the schedule for recruitment, intervention delivery and outcome assessments.

Sample size estimation

A sample size estimation was calculated based on CRF using the 20 m shuttle run test (20 m-SRT). Previous studies reported 9 laps of improvement, with effect size of $d = 0.31$ (36) and $d = 0.69$ (37), achieved through 12 or 14 weeks of resistance-based HIIT, respectively. In the current study, a conservative effect size of $d = 0.31$ was utilised for power calculation. Therefore, based on a G*Power (Version 3.1) calculation (38) and using two groups with 80% power at an α of 0.05, it is estimated to recruit 165 participants in each group. With an average enrolment of 50 students in secondary school classes in Ningbo and a conservative 20% of dropout rate (39), it is deemed that 8 classes (approximately 50 participants per class) would provide sufficient statistical power for analysis. Given the typical scale of a Chinese secondary school (10–15 classes per grade), the 8 classes will be recruited from one secondary school.

Recruitment and allocation

An invitation letter will be sent to nearby secondary schools at Ningbo University. When schools express their interest, contacts will be initiated to elucidate the participation requirements. Upon agreement from the schools, invitations will be extended to head teachers and PE teachers of year 7, who will then present the study to students for recruitment. To be eligible for participation, students are required to submit signed assent forms along with signed consent forms from their parents/guardians. Students with health or medical conditions that would restrict their ability to engage in vigorous PA will be excluded from the study. The screening process will involve reviewing the medical examination reports submitted by the participants' parents or guardians. Classes will be randomly allocated to either *PRO-HIIT* group or control group, via a computer-based random number generator by an independent researcher. The randomisation and allocation will take place after baseline assessment. The randomisation will be stratified by PE teacher, wherein each teacher's classes will be randomly assigned to either the intervention or control group.

Intervention delivery and exercise design

The present study is a quality PE/PA intervention in which a resistance-based HIIT session is embedded in the first 6–10 min of regular PE and PA lessons, replacing traditional warm-up activities. The intervention will be delivered five times a week—three PE and two PA lessons—over twelve weeks (from school term 2, week 5 to week 16, March to June 2024). Throughout the intervention, PE teachers will coordinate and supervise the HIIT intervention, while the delivery will be accomplished by two student peer-coaches, selected by the PE teacher within each intervention class. The control group will maintain their traditional warm-up activities, such as light running and static stretching.

To ensure quality and effective implementation, the leading researcher will collaborate with the PE teachers and peer-coaches for delivering the intervention during the initial two weeks. Researchers will visit the school once per month to provide on-going support and guidance. Additionally, a training logbook at each intervention class will be maintained by the PE teachers to document aspects, such as attendance, dose delivered and received, and adverse events. These records will be sent to researchers on a weekly basis to ensure prompt feedback and communication. In cases where HIIT sessions are cancelled due to inevitable factors such as large school events or severe weather, participants will be encouraged to complete these sessions during alternative times (e.g., breaks). These additional sessions will be supervised by peer-coaches and will be recorded in the training logbook. The control group will take their regular PE and PA lessons as usual.

The HIIT sessions consist of body-weight resistance exercises (e.g., high knees, jumping jacks, burpees), selected based on relevant literature (33, 40). The session length will be progressively extended from 6 to 10 min over the 12 weeks, accounting for fitness adaptations. Within each session, the work-to-rest ratio will increase from 10 s: 20 s, to 15 s: 15 s, until 20 s: 10 s as the exercise progresses. Furthermore, participants will perform one exercise (e.g., jumping jacks) twice in a minute to avoid monotony while preventing frequent exercise changes, thereby 6, 8 and 10 different exercises will be completed as the intervention duration increases. Moreover, flexibility will be allowed for each HIIT session, enabling adaptations whenever necessary (e.g., higher/lower exercise intensity). The adaptations made will be recorded on the training logbook. The details regarding the exercises are presented in Table 1.

To facilitate the implementation process, several strategies will be employed, including:

(1) training workshops for participants, peer-coaches, teachers and research staff (Table 2);

TABLE 1 Overview of the *PRO-HIIT* intervention.

Procedures		Recruitment & pre-intervention measurements				Intervention phase (12 weeks)												Post-intervention measurements			Summer holiday	Follow-up measurements	
	22–26 Jan	26 Feb–22 Mar				25 Mar–14 Jun												17–28 Jun		1–4 Jul	5 Jul–1 Sep	2–13 Sep	
	2023–2024 school term 1	2023–2024 school term 2																				2024–2025 school term 1	
	week 22	week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10	week 11	week 12	week 13	week 14	week 15	week 16	week 17	week 18	week 19		week 1	week 2
Eligibility screening		√																					
Consents & assents																							
Training workshop			√																				
Randomisation					√																		
Maturity				√																			
PA (GENEActiv)					√	√											√	√					
PA (questionnaire)				√														√				√	
Sleep																							
Body composition																							
CRF																							
Muscular strength																							
Bone health																							
Executive function																							
Wellbeing																							
Enjoyment																							
Motivation																							
Affect																							
Self-efficacy																							
Academic assessment	√																			√			
Focus groups																		√			Unstructured days		
Intervention delivery						6-min HIIT 1–2 min: 10 s: 20 s 3–4 min: 15 s: 15 s 5–6 min: 20 s: 10 s			8-min HIIT 1–2 min: 10 s: 20 s 3–6 min: 15 s: 15 s 7–8 min: 20 s: 10 s			10-min HIIT 1–2 min: 10s : 20 s 3–6 min: 15 s: 15 s 7–10 min: 20 s: 10 s			10-min HIIT 1–5 min: 15 s: 15 s 6–10 min: 20 s: 10 s						
HIIT exercises						Jumping Jacks, high knees, burpees, butt kicks, mountain climbers, lunge jumps			Running on the spot, squat jumps, high knees, star jumps, burpees, lunge jumps, mountain climbers, butt kicks			Running on the spot, rocket jumps, high knees, star jumps, burpees, lunge jumps, mountain climbers, butt kicks, jumping jacks, side to side skiers			Students choose exercises from an exercise pool								

HIIT, high-intensity interval training; PA, physical activity; yellow, preparation for the intervention; green, measurements and data collection; red, progressively increased exercise intensity and volume; grey, intervention period.

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TABLE 2 Details of training workshops for participants, peer-coaches, teachers and research staff.

Subjects	Timing	Content
Participants (CON)	Two PE lessons (40 min)	(1) Introduction of the programme; (2) outcome measurements; (3) familiarisation of executive function tasks; (4) maintain daily life.
Participants (INT)	Two PE lessons (80 min)	(1) Introduction of the programme; (2) familiarisation of equipment (e.g., HR monitor), executive function tasks and HIIT exercises; (3) outcome measurements.
Peer-coaches	One PE lessons (40 min)	(1) HIIT performing and leading; (2) HIIT rescheduling and regulation.
PE teachers	60 min	(1) Introduction of the programme; (2) familiarisation of equipment (e.g., HR monitor); (3) HIIT exercises; (4) training logbook; (5) intervention delivery.
Research staff	60 min	(1) Outcome measurements; (2) data collection principles (e.g., SAAFE).

CON, control group; INT, intervention group; PE, physical education; HR, heart rate; HIIT, high-intensity interval training; SAAFE, the supportive, active, autonomous, fair, enjoyable principles.

(2) providing participants with opportunities to choose music and exercises (from an exercise pool over the final 3 weeks of the intervention);
(3) the opportunity to win a prize upon completion of the intervention for all participants.

Theoretical frameworks

The present study draws upon guidance from two frameworks: process evaluation of complex interventions: Medical Research Council (MRC) guidance (27) and the Supportive, Active, Autonomous, Fair and Enjoyable (SAAFE) principles (41).

Process evaluation

A comprehensive process evaluation will be conducted for the *PRO-HIIT* intervention, which will be guided by the MRC process evaluation framework (27). The framework contains three domains, including implementation (i.e., fidelity, reach, recruitment and retention, dose delivered and adaptation), mechanisms of impact (i.e., mediators, dose received, unintended consequences and response) and context (i.e., barriers, facilitators, and contamination). The MRC framework, in conjunction with insights from a recent school-based HIIT review by Liu et al. (23), will guide the adaptation of process evaluation measures tailored specifically to *PRO-HIIT*, as detailed in Table 3.

It is important to highlight that while all the intervention classes will be encouraged to exercise with "all out" efforts during the HIIT sessions, the intensity will be monitored in only two randomly selected classes on one occasion per week (during one of their PE lessons) to minimise extra burden for PE teachers. The intensity in these two classes will be measured using either heart rate (HR) or rating of perceived exertion (RPE) by Polar Verity Sense and OMNI Perceived Exertion Scale for resistance exercise (42), respectively. Of note, due to resource constraints, only 10 Polar Verity Sense monitors will be utilised and rotated weekly among participants in the HR monitoring class. However, all participants will be required to report their RPE during the HIIT session once per week in the RPE monitoring class.

SAAFE principles

SAAFE principles offer a structured framework designed to inform the design, delivery, and evaluation of PA interventions (41). SAAFE principles provide essential guidelines and practical strategies to enable practitioners to organise their interventions in a way that not only maximises PA participation but also fosters positive affective, cognitive, motivational, and movement skill outcomes. The principles and strategies will be incorporated into the exercise design, intervention delivery and outcome assessment processes of the *PRO-HIIT* intervention (Table 4). These principles will be applied or achieved through the process of exercise design, training workshops, HIIT session delivery and outcome assessments.

Outcome measurements

Outcome measurements will be conducted in the school premises by trained research assistants who will remain blinded to group allocation throughout all assessment time-points. All measurements will be introduced and explained during the training workshop and will be described again prior to the commencement of the measurements to ensure clarity. The measurements will be conducted during their regular PE lessons. Details of the outcome measures are summarised in Table 5.

Primary outcome

Cardiorespiratory fitness

CRF will be assessed using the 20 m-SRT, a well-established field test for evaluating CRF (43). The 20 m-SRT requires participants to run back and forth between two lines positioned 20 meters apart. Participants must reach the other end before a designated beep sounds. The beep is set to allow the participants to start at 8.5 km/h with increases in speed of 0.5 km/h denoted by a triple beep. The test concludes if a participant fails to complete two consecutive shuttles or volitionally discontinues. Performance on the 20 m-SRT will be reported as number of laps completed. The test will be administered by the same group of research assistants at the same location, time of the day and with consistent levels of verbal encouragement across all measurement timepoints to avoid biased results.

Secondary outcomes

Physical activity

For a subset of randomly selected (stratified by sex and group) participants ($n = 60$), PA will be objectively assessed using GENEActiv wrist-worn accelerometers (Model GAT04, Activinsights Ltd, Cambridgeshire, England) over a span of four weeks, comprising one week before and after the intervention as

TABLE 3 Medical research council definition for process evaluation and its application to the *PRO-HIIT* intervention.

Measurements	MRC definition	Apply to *PRO-HIIT*	How
Implementation: The process through which interventions are delivered, and what is delivered in practice.			
Fidelity	The consistency of what is implemented with the planned intervention.	HIIT intensity.	HR and RPE
Reach	The extent to which a target audience comes into contact with the intervention.	Schools or participants contacted.	Recruitment
Dose delivered	How much intervention is delivered.	HIIT session length, frequency and intervention duration/sessions in the protocol.	Protocol
Recruitment & retention	NG	Number of participants who are randomised and completed the intervention.	Training logbook and outcome assessment
Adaptation	Alterations made to an intervention in order to achieve better contextual fit.	Changes being made to facilitate *PRO-HIIT*.	Training logbook and teachers' focus group
Mechanisms of impact: The intermediate mechanisms through which intervention activities produce intended (or unintended) effects.			
Mediator	Intermediate processes which explain subsequent changes in outcomes.	Mediators (e.g., sex, baseline CRF and BMI) influencing the outcome assessment.	Data analysis
Dose received	NG	HIIT sessions participants performed.	Training logbook
Unintended consequences	NG	Adverse events or other unanticipated fairs recorded.	Training logbook
Response	How participants interact with a complex intervention.	Feedbacks from participants and teachers.	Focus group and questionnaire
Context: Factors external to the intervention which may influence its implementation, or whether its mechanisms of impact act as intended.			
Barriers	Contextual factors which undermine implementation, intervention mechanisms and outcomes.	Anything restrains the implementation of *PRO-HIIT*.	Focus groups
Facilitators	Contextual factors which facilitate implementation, intervention mechanisms and outcomes.	Anything supports the implementation of *PRO-HIIT*.	Focus groups
Contamination	NG	Blinding	Blinding of research assistants; Focus groups.

MRC, medical research council; HIIT, high-intensity interval training; HR, heart rate; RPE, rating of perceived exertion; NG, not given.

well as the initial and concluding weeks of the intervention. Participants will be encouraged to wear the device 24 h/day, without taking off even when bathing or sleeping. GENEActive accelerometers have demonstrated acceptable reliability and validity for PA monitoring in adolescents (44). The cut-points employed to categorise sedentary, light, moderate and vigorous PA are <6, 6–21, 22–56, and >56 g s, respectively (44).

Body composition

Height and waist circumference will be measured with a portable stadiometer and a tape, respectively. Subsequently, waist-to-height ratio will be calculated (45). Body mass and body fat percentage will be determined with a Tanita device (Tanita Corp., Tokyo, Japan).

Muscular strength

Upper and lower body strength will be assessed using hand grip and standing long jump, respectively. A digital dynamometer with an adjustable grip, with participants standing and elbow in 90-degree flexion, will be employed for measuring the upper body strength in kilogrammes (46). The test will be performed once on both hands and the highest record will be reported. Standing long jump will be measured with a standing long jump mat. Participants stand behind the start line with their feet apart and are allowed to swing their arms quickly to jump as far as possible. Each participant will have three attempts, with the best one recorded.

Bone health

A heel ultrasound test will be performed via a GE Achilles heel ultrasound machine (GE Medical Systems Lunar, USA). Participants will be seated with one foot on the foot plate, and alcohol will be applied to ensure proper membrane contact. A transducer on one side of the heel will convert an electrical signal into a sound wave, which will pass through the heel to the other side and be received and analysed by another transducer. The speed of sound (SOS, in m/s) and broadband ultrasound attenuation (BUA, in dB/MHz) will be measured and used to calculate the stiffness index (SI) with the equation: $SI = (0.67 \times BUA + 0.28 \times SOS) - 420$ (47). The test will be performed on both feet and an average score will be recorded.

Executive function

Participants' executive function will be assessed on aspects of inhibition, working memory, and cognitive flexibility (48). Three tasks will be utilised, including flanker task, visual 2-back task and colour-shape switch task. The tasks are adapted from studies conducted by Wassenaar and colleague (49) and will be programmed on the Gorilla platform (50). The order of the three tasks will be randomised at individual level and will be performed collectively within the school computer room on a class-unit basis, with the presence of researchers to provide clarification if needed. One week prior to the intervention, a training workshop will be conducted to acquaint participants with the executive function tasks. A ten-minute presentation will elucidate the task procedures by research staff, and participants will engage in hands-on practise for each task. Any questions

TABLE 4 Definition and application of SAAFE principles in the *PRO-HIIT* intervention.

Principles	Definition	Apply to *PRO-HIIT*	How
Supportive	Intervention is designed to facilitate a supportive environment	Encourage praise of students' effort and improvement during HIIT sessions and outcome evaluation process.	Researchers and teachers' training workshop.
		Encourage mutual support when performing HIIT and outcome assessments.	Students' training workshop.
		Demonstrate empathy toward students when they feel frustrated or challenged.	Researchers and teachers' training workshop.
Active	Sessions are highly active	Sessions are designed without any instruction time.	Exercise design.
		Exercises are performed at high intensity.	Encourage exercise with "all out" efforts.
Autonomous	Sessions involve elements of choice	Right to play any music they like.	Students' training workshop.
		Self-organisation.	Peer coaches to lead the HIIT sessions.
		Right to choose exercises from an exercise pool (final 3 weeks).	Every Friday prior to the week the exercise will be performed.
		Perform the missed HIIT sessions themselves during breaks.	Under the supervision of peer-coaches and record on training logbook.
		Minimize controlling language.	Researchers and teachers' training workshop.
Fair	Intervention provides all students with opportunities to experience success	Encourage self-comparison rather than peer-comparison.	Students' training workshop.
		Provide personalised care for individuals with special needs (e.g., participants with lower fitness levels).	Simplify exercises or lower exercise intensity (PE teacher' discretion).
Enjoyable	Intervention is designed to be enjoyable and engaging for all students	Provide different HIIT workouts.	From existing literature.
		Provide challenging HIIT sessions.	Progressively increase the exercise duration and intervals within and across sessions.
		Play music while exercising.	Peer-coaches.

HIIT, high-intensity interval training; PE, physical education.

and inquiries will be addressed within the workshop to ensure clarity and understanding. Details for the three tasks are provided in the Additional File S1.

Wellbeing

The Chinese version of the Strengths and Difficulties Questionnaire (SDQ) will be used to assess the psychological distress of participants (51). The questionnaire will be administered online via the Gorilla platform following the completion of executive function tasks. The SDQ comprises 25 personality items, rated on a 3-point scale (i.e., "*not true*" = *0,* "*somewhat true*" = *1* and "*certainly true*" = *2*), and is composed of five subscales, each consisting of 5 items. These subscales include emotional symptoms, conduct problems, hyperactivity/inattention, peer relationship problems and prosocial behaviour. The total difficulties score ranges from 0 to 40, where a score $\geq$ 17 is considered as high difficulties (52).

Enjoyment

Enjoyment of PA will be measured using the Physical Activity Enjoyment Scale (PACES) (53), which is validated among adolescents (54). The scale commences with a prompt "when I am active" followed by 16 phrases that participants will rank on a 5-point scale, ranging from 1 (Disagree a lot) to 5 (Agree a lot). The enjoyment score ranges from 16 to 80, with a higher score representing higher level of PA enjoyment (54).

Motivation

Motivation to autonomously engage in PA will be assessed using a modified Behaviour Regulation in Exercise Questionnaire (BREQ-2), which is an 19-item validated questionnaire (55). The scale comprised of 5 subscales, including intrinsic, identified, introjected, external and amotivation. Each item was rated on a 5-point Likert scale ranging from 0 ("not true for me") to 4 ("very true for me"). The mean of the 5 subscales will be calculated to reflect the extent of each motivation type separately. A Relative Autonomy Index will be adopted by weighting (intrinsic * 3, identified * 2, introjected * −1, external * −2 and amotivation * −3) the subscales and summing the weighted scores (56). The Relative Autonomy Index ranges from −24 to 20 and higher positive scores indicate more autonomous motivation.

Affect

Affect will be assessed via a Chinese version of the International Positive and Negative Affect Schedule Short Form (PANAS-SF) (57). This 9-item questionnaire utilises a 5-point Likert scale, ranging from 1 (Not at all) to 5 (Extremely). Comprising 5 items related to positive affect and 4 items pertaining to negative affect, this instrument is considered reliable for its implementation in Chinese adolescents (57). The positive and negative affect scores will be summed and reported separately, with higher positive score indicates more positive affect and lower negative score indicates less negative affect.

Self-efficacy

A 6-item validated Perceived Physical Ability Scale (PPAS) will be utilised to evaluate the PA-related self-efficacy (58). In each item, four statements related to capabilities for doing exercises will be given and participants will be required to choose the one that best representing their personal feelings. The total score ranges from 1 to 24, with higher scores indicate a higher self-perception of physical ability and vice versa.

TABLE 5 How, when and where the outcome variables will be measured.

Outcomes	Tools	Timing	How and where (all participants, measured at class level)
Physical activity	GENEActiv	One week before and after intervention, first and last week of intervention.	A subsample of 60 participants (30 in each group, 30 males) will be randomly selected to wear the GENEActive accelerometer for 14 days consecutively for twice, covering the total 4 weeks.
Cardiorespiratory fitness	20 m shuttle run	T1, T2, T3	Multiple measurement stations will be held, and participants will be split into groups to ensure efficient measurements. Two physical education lessons are estimated to be sufficient. All these measurements will be conducted in sports hall.
Body composition	TANITA	T1, T2, T3	
Muscular strength	Handgrip, standing long jump	T1, T2, T3	
Bone health	GE Achilles	T1, T2, T3	
Executive function	Flanker tasks, visual 2-back tasks, colour-shape switch tasks	T1, T2, T3	Perform the executive function tasks online in a school computer room in one physical education lesson (40 min).
Wellbeing	SDQ	T1, T2, T3	Finish together using one physical education lesson (40 min) in a school computer room with the instruction of research staff.
Enjoyment	PACES	T1, T2, T3	
Motivation	BREQ-2	T1, T2, T3	
Affect	PANAS-SF	T1, T2, T3	
Self-efficacy	PPAS	T1, T2, T3	
Academic performance	End-of-term academic examinations	By the end of term 1 and T2	Obtained directly from head teacher.

SDQ, strength and difficulty questionnaire; PACES, physical activity enjoyment scale; BREQ-2, exercise regulations questionnaire; PANAS-SF, positive and negative affect schedule short form; PPAS, perceived physical ability scale; T1, pre-intervention; T2, immediately post-intervention; T3, 2-month follow-up.

Enjoyment and satisfaction

Enjoyment and satisfaction of the HIIT workout will be evaluated using a 2-item 5-point Likert scale, with the prompt: "I enjoyed/liked the HIIT workouts" and "I will continue to perform/use the HIIT workouts" between 1 = strongly disagree and 5 = strongly agree. This will only be assessed post-intervention among participants in the intervention group (T2).

Academic performance

Academic performance will be evaluated by utilising the school's end-of-term academic examinations, which comprehensively assess all the subjects. Mathematics, language learning (main subjects in Chinese secondary school) and a composite score for all subjects will be utilised to discern variations in academic performance between the intervention and control groups. Therefore, academic performance will not be assessed at the follow-up stage.

Focus groups

Once the intervention completed, semi-structured focus groups will be conducted with participants and PE teachers, separately. The two peer coaches and two participants (randomly selected) from each intervention classes ($n = 16$) will be invited to the participants' focus group, while all the PE teachers involved in the study will take part in the teachers' focus group. Pre-determined open-ended questions will be asked during the focus group discussion, including feedback on enjoyment/usefulness of the *PRO-HIIT* intervention, continued use of the HIIT exercises and the perceived barriers and facilitators for doing/delivering the HIIT exercises. The template of the focus group questions is provided in the Additional File S2.

Confounding variables

An estimate of the age of peak height velocity will be used to assess the somatic maturation of participants (59). Participants' PA and sleep at all time-points will be assessed by a Chinese version of the International Physical Activity Questionnaire, short form (IPAQ-SF) (60) and a validated Chinese version of the Pittsburgh Sleep Quality Index (PSQI) (61), respectively.

Statistical analyses

Data entry will be completed by one researcher with a random sample of at least 10% of entries cross-checked by a second researcher for accuracy. Prior to analysis, thorough checks for outliers and errors will be conducted using range and boxplot methods. Additionally, assessments for normality, homogeneity of variances and sphericity will be conducted as needed to verify assumptions. The baseline data for intervention and control groups will be presented and compared at individual level using independent sample *t*-test. An intention-to-treat approach will be adopted to evaluate the effects on outcome variables to avoid bias in exploring the impact of the intervention. Linear mixed-effect models will be used, with random effects, to analyse the impact of groups (intervention and control), timepoints (pre-, post-intervention and follow-up) and group × time interactions. Statistical analyses will be adjusted for the clustering effects at class level. Per protocol sensitivity analysis will be undertaken at the class level. Considering for disruptions such as school holidays, exams, severe weather, a minimum of 30 sessions is considered achievable over the 12-week period. Other sensitivity analyses, such as complete-case analysis, will be conducted where appropriate. Moderators, including sex (male, female), baseline overweight/obese (yes, no) and baseline CRF (healthy vs. needs to improve), will be examined with linear mixed models. Where appropriate, subgroup analyses will be conducted for the significant group-by-moderator interactions. PA, sleep and maturity will be included in the model to eliminate confounding effects. All data analyses will be conducted via IBM SPSS Statistics for Windows (SPSS 28.0; IBM Corporation, Armonk, NY, USA), with an alpha level of 0.05.

Patient and public involvement

Important input and feedback were sought from school leaders, teachers and students in the secondary schools located in Ningbo to inform and refine the study design of the *PRO-HIIT* intervention.

Discussion

This paper outlines the study protocol for *PRO-HIIT* intervention, which aims to investigate the effectiveness of a school-based HIIT intervention on CRF, PA, body composition, muscular strength, bone health, executive function, wellbeing, enjoyment, motivation, affect, self-efficacy and academic performance in school-aged adolescents. The *PRO-HIIT* intervention will be delivered five times per week at the beginning of the three PE and two PA lessons. The PA lessons serve as a complementary opportunity for students to engage in exercises of their choice on days when PE lessons are not scheduled. The majority of school-based HIIT interventions were administered 2 to 3 times per week (15). However, the understanding of the feasibility and effectiveness of HIIT performed five times per week is limited, with only two studies identified (62, 63). Moreau et al. reported that a daily 10 min HIIT session over 6 weeks improved cognitive control and working memory in children aged 7 to 13 years (62). In addition, a 10-month of 5×12 min/week interval running programme was found to be feasible in a primary school setting (63). While the study reported a positive effect on sprint performance, no effects were observed on CRF, BMI, muscular fitness, and bone health. Consequently, the feasibility and effectiveness of high-frequency HIIT interventions delivered among secondary school students needs to be further evaluated. The *PRO-HIIT* study aims not only examine the effects on commonly studied variables such as body composition, CRF, muscular strength and cognition, but also to explore its impact on bone health and academic performance among 13-year-old adolescents in secondary schools.

The early pubertal phase is recognised as the time when peak bone mass accrual begins. High-impact exercises, such as resistance-based HIIT, may enhance bone mass accumulation during these crucial developmental years. Yet, there is a dearth of research investigating the association between HIIT and bone health (18). Emerging evidence suggested that both acute and chronic HIIT leads to enhanced cognitive adaptations and brain health (64, 65). However, more research is needed to understand if HIIT is beneficial to general or specific domain(s) (e.g., inhibition, working memory and cognitive flexibility) of cognitive function among children and adolescents (66). Given that cognitive function is closely linked to academic performance (65, 67), a long-term HIIT intervention has the potential to enhance academic performance. Nevertheless, only one previous study has examined the effect of HIIT on academic performance (68). The researchers found that HIIT delivered twice per week for ten weeks significantly improved academic performance on mathematics and language in the intervention group as compared to the control group. It is worth noting that this study was conducted in primary schools, warranting further investigation in diverse educational settings.

Apart from the outcome measurements, the novelty of *PRO-HIIT* study lies in its attention to the implementation process, a component often overlooked in previous school-based HIIT interventions (15). The present study will scrutinise the intervention process with the guidance of the MRC process evaluation guidelines, thereby enhancing the understanding and facilitating the dissemination of the *PRO-HIIT* study. Another novelty of the *PRO-HIIT* study is its aim to determine the extent of potential fitness loss over the two-month summer holidays and how a school-based intervention may mitigate this decline, thereby contributing to the examination of the SDH. Furthermore, existing HIIT interventions in schools have predominantly taken place in western countries (15). Cao et al. (69) found that a running-based HIIT intervention conducted in a school setting improved body composition and CRF amongst Chinese secondary school students. It should be noted, however, that the study exclusively focused on obese adolescent boys, limiting its generalisability to the broader healthy population. The *PRO-HIIT* study will address this gap by providing valuable insights on the benefits of school-based HIIT within an Asian cultural context.

Ethics statement

The studies involving human participants were approved by the Clinical Research Ethics Committee, Ningbo University, China (TY2024002). Appropriate checks and training was completed for all the researchers before initiating the study to ensure the safety of participants. The studies were conducted in accordance with the local legislation and institutional requirements. The school principals and involved teachers provided consent. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

YL: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AB: Conceptualization, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – review & editing. AA: Methodology, Software, Supervision, Writing – review & editing. ML: Data curation, Investigation, Project administration, Writing – review & editing. SD: Methodology, Software, Writing – review & editing. AA: Formal Analysis, Methodology, Software, Writing – review & editing. YG: Project administration, Supervision, Writing – review & editing. HZ: Investigation, Project administration, Writing –

review & editing. CW: Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2024.1458610/full#supplementary-material

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Comparative effectiveness of school-based obesity prevention programs for children and adolescents: a systematic review and network meta-analysis

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Introduction: While many randomized controlled trials (RCTs) have demonstrated the positive effects of school-based programs in reducing body fat among children and teenagers, there is no conclusive evidence to indicate that one approach is superior to another, largely due to the lack of direct and indirect comparisons. This study evaluated the relative effectiveness of various school-based obesity prevention initiatives in improving body mass index (BMI) among children and adolescents using network meta-analysis.

Methods: Searches included four databases focusing on articles published in English between the years 2002 and 2024. The primary outcomes were the BMI and BMI z-scores (BMIz) (kg/m^2). The mean differences (MDs) for each outcome were calculated before and after treatment. The current systematic review synthesized 53 RCTs with a sample of 68,489 children and adolescents.

Results: The results illustrated that the physical activity (PA) only arm was the most effective intervention in improving BMI (MD: −0.42, 95% credible interval (CrI) −0.79, −0.07; p = 0.02), while the multiple-component intervention was the most effective in improving BMIz (MD: −0.08, 95% CrI: −0.16, −0.01; p = 0.03). Inversely, PA and another component arm were the least effective interventions in improving BMI (MD: 0.64, 95% CrI: −0.23, 1.53; p = 0.15). In addition, diet and nutrition only arm was the least effective intervention in improving BMIz (MD: 0.09, 95% CrI: −0.11, 0.28; p = 0.36).

Discussion: In conclusion, both PA-only and multiple-component arms are effective intervention tools/strategies for reducing BMI-related outcomes. However, further large-scale, well-designed studies are needed to investigate the elements of multiple-component arms.

Systematic review registration: https://www.crd.york.ac.uk/PROSPERO/ identifier CRD42021234742.

KEYWORDS

physical activity, body mass index, body composition, anthropometry, diet, intervention

1 Introduction

Childhood obesity, defined as having a body mass index (BMI) at or above the 95th percentile for a child's age and gender (1), remains a significant public health challenge, with global prevalence increasing by approximately 50% in recent years (2). Immediate health concerns associated with childhood obesity include the development of cardiometabolic risk factors, respiratory and skeletal issues, and mental health conditions (3–5). The long-term risks are well-documented in epidemiological studies (6), which show that childhood obesity often persists into adulthood. Adult obesity is strongly linked to the onset of non-communicable diseases such as heart disease, type 2 diabetes, and certain cancers (7). Moreover, obesity and its related complications place a substantial economic burden on healthcare systems worldwide, driven by both direct medical expenses and indirect costs (8). Although the causes of obesity are multifactorial (5), its underlying mechanism is a sustained positive energy balance, resulting in progressive weight gain over time (5, 9).

Currently, evidence supporting the efficacy and safety of pharmacotherapy or bariatric surgery for weight loss in children with obesity remains limited (5, 10). Concerns have been raised about the small number of Food and Drug Administration (FDA)-approved anti-obesity medications available for pediatric populations, in contrast to the broader range of options for adults (11, 12). While bariatric surgery has shown promising results in treating obesity, there are significant concerns regarding post-surgical outcomes. Studies have highlighted the risks associated with the need for repeat surgeries due to weight regain, as well as the potential necessity of combining bariatric procedures with short-or long-term weight loss medications for some patients (13, 14). Unlike genetic and environmental risk factors for obesity, behavioral factors are largely modifiable (15, 16). Consequently, the primary strategy for treating and preventing pediatric obesity focuses on interventions that promote healthier behaviors to improve body weight regulation (17).

Within the framework of energy balance (9), the most modifiable behaviors are dietary intake (caloric consumption) and physical activity (PA) (caloric expenditure through movement, excluding resting energy expenditure and the thermic effect of food) (9). Recognizing this, the World Health Organization (WHO) and other organizations (15–17) have advocated for interventions aimed at modifying health behaviors by simultaneously reducing energy intake and increasing PA to regulate body weight in children. Given that children spend approximately half their day at school and consume approximately 50% of their daily caloric intake there, schools are a critical setting for implementing obesity prevention programs. Unlike home-or community-based interventions, school-based programs leverage existing infrastructure, allowing for efficient student engagement without significantly altering their daily routines or lifestyles (18).

Caloric consumption in educational settings is influenced by the food landscape both within schools (e.g., vending machines and food kiosks) and in their surrounding areas (e.g., fast-food outlets and grocery stores), as well as the policies supporting these environments. These factors have been linked to unhealthy dietary choices and higher BMI levels in children (19–24). Evidence shows that over the past two decades, the school food environment has significantly contributed to a decline in children's consumption of unprocessed and minimally processed foods, alongside a marked increase in the intake of ultra-processed foods and high-calorie beverages, such as sugar-sweetened drinks (21, 22, 25–27). Technological advancements in food preparation and processing have made ultra-processed foods nutrient-poor, calorie-dense, and hyperpalatable (28, 29). Similarly, sugar-sweetened beverages, which have minimal impact on satiety, are hyperpalatable and often contribute substantially to children's daily caloric intake (27). The widespread availability of these highly palatable foods and beverages, both in and around schools, capitalizes on innate human taste preferences for salt, sugar, and fat (30). Their frequent overconsumption fosters an obesogenic energy imbalance, exacerbating the risk of childhood obesity.

PA levels in schools are often insufficient to offset the excessive caloric intake associated with children's dietary habits (31–34). Physical education classes frequently fail to sustain moderate-to-vigorous physical activity (MVPA) for the recommended minimum of 50% of class time. Moreover, children with higher weight status tend to engage less in MVPA during various segments of the school day (35, 36). Outside of school, increased screen time, reduced active transportation, and lower participation in leisure-time physical activities have further contributed to the global rise in childhood physical inactivity and sedentary behavior over recent decades (5, 37–39). The combination of excessive caloric intake, inadequate PA, and a genetic predisposition to store body fat has created an urgent need for public health interventions. Addressing the childhood obesity crisis requires the implementation of school-based programs that promote behaviors supportive of maintaining a healthy body weight (40).

Several school-based obesity prevention interventions have been shown to effectively reduce children's weight-related outcomes in randomized controlled trials (RCTs) (41–44). However, challenges remain in translating and disseminating these findings into widespread, effective obesity prevention programs. A key issue is the lack of empirical evidence demonstrating the superiority of one intervention over another, as direct and indirect comparisons are often absent (41). Additionally, the data are mixed regarding the relative effectiveness of single-component versus multicomponent interventions (21). To address these gaps, we conducted a comprehensive systematic review of existing literature to identify RCTs evaluating the impact of school-based obesity prevention programs on children's weight-related outcomes. This was followed by a network meta-analysis (NMA) to simultaneously assess the relative effectiveness of various intervention approaches compared to each other and to control groups. The findings offer valuable insights for policymakers and stakeholders at local, state, and federal levels, providing evidence to help identify the most effective school-based strategies for improving weight-related outcomes in children.

2 Methods

This study followed the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) extension statement for NMAs (45) and was registered with PROSPERO (CRD42021234742). As the analysis utilized previously published data and did not include individual participant data, institutional review board approval was not required.

2.1 Eligibility criteria and outcomes

The eligibility criteria were defined *a priori* using the population, intervention, comparators, outcomes, and setting (PICOS) framework (45). This review synthesized RCTs that evaluated school-based obesity prevention programs among school-aged children [6–12 years

(5)]. Studies were required to have a minimum duration of one school year and to assess a bodyweight-related outcome, specifically BMI and/or BMI z-scores (BMIz) (kg/m^2). To streamline the analysis and based on evidence that language restrictions do not consistently bias the results of quantitative syntheses (46), only studies published in English were included. Excluded studies were those that were not RCTs, were conducted outside of school settings, had a duration of less than one school year, and/or were not published in English.

2.2 Search strategy

A systematic search was conducted across the databases MEDLINE (via PubMed), Embase, the Cochrane Central Register of Controlled Trials (CENTRAL), and CINAHL from inception through 10 September 2024. The search strategy, detailed in Figure 1, utilized a combination of medical subject headings (MeSH) and relevant keywords, including "physical activity," "exercise," "obesity prevention," "nutrition," "diet," "multiple component," and "adiposity"; (ii) "body mass index," "anthropometrics," "weight loss," "BMI," "BMIz," "randomized controlled trials," "school-based intervention," "school children," and "school program." Examples of database search queries are provided in Supplementary File S1. Additionally, the researchers manually reviewed the reference lists of related systematic reviews and meta-analyses to identify any studies that might have been missed in the initial search. Three researchers (D.M., S.R., and W.Z.) independently screened titles, abstracts, and full-text articles to determine eligibility. Full-text articles of relevant RCTs were selected and evaluated for inclusion. Any discrepancies in opinion among the three researchers were resolved by a fourth author (Z.G.).

2.3 Screening and data extraction

Two independent reviewers (M.H. and J.O.) conducted an initial screening of studies by evaluating titles and abstracts. Studies that met the predefined criteria underwent a full-text review to confirm eligibility. Any disagreements between the reviewers were discussed and

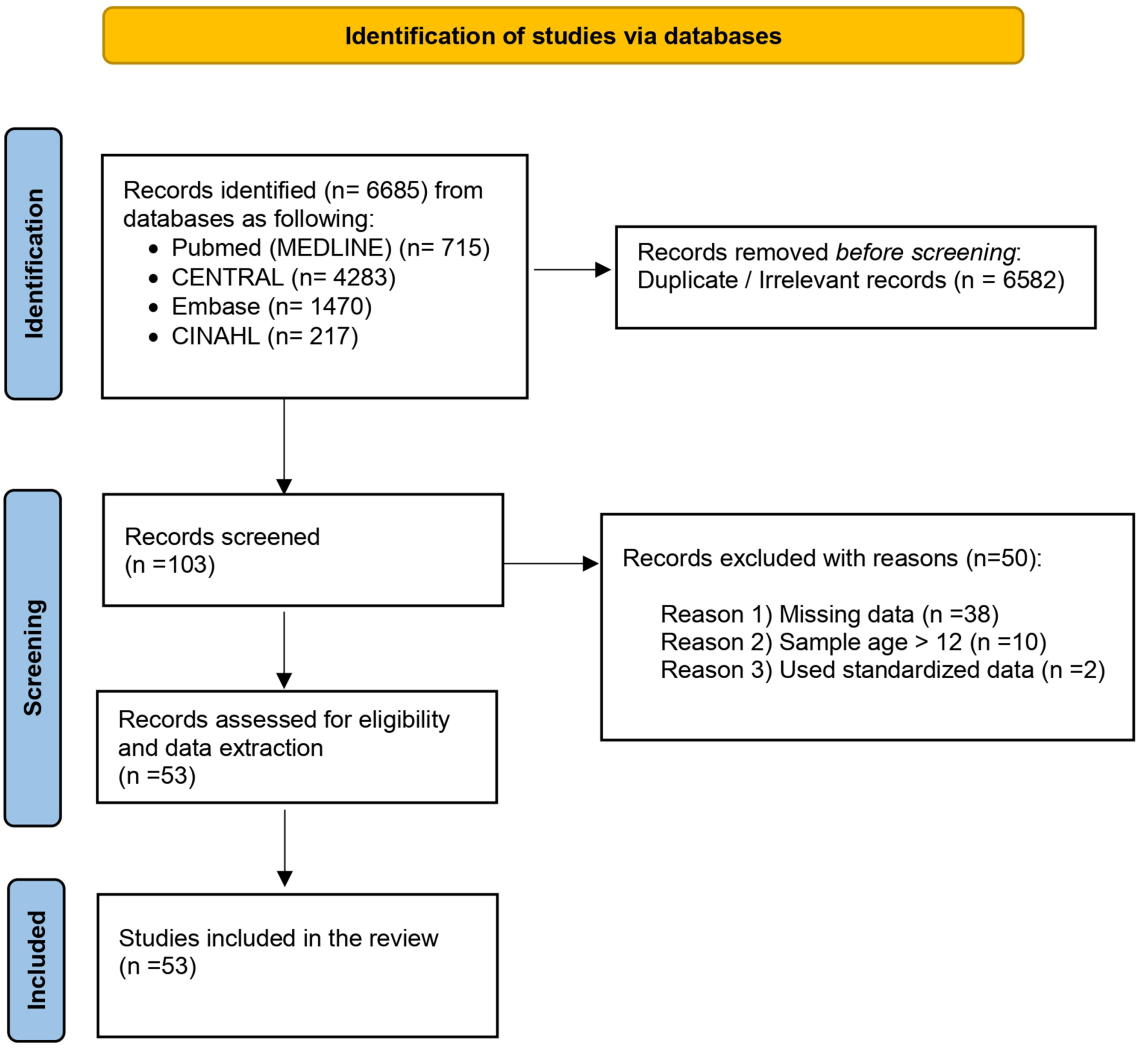

FIGURE 1
PRISMA flow chart for systematic reviews.

resolved with input from a third reviewer (Z.G.) to achieve consensus. Data from eligible studies were then independently extracted by the two reviewers using Microsoft Excel (Version 16.44 for Mac; Microsoft, Redmond, WA, United States). Any discrepancies in data extraction were resolved through consultation with the third reviewer.

The extracted data included the first author's last name, publication year, study location, group sample sizes, gender distribution, mean age with standard deviation (SD), type and duration of the intervention, and outcome measures (see Supplementary File S2). The primary outcomes of interest were the mean change (SD_{change}) from baseline to post-intervention. If these were not reported, baseline and post-intervention means and (SDs) were extracted, and the mean change was calculated as the difference, with the SD_{change} derived from pooled baseline and post-intervention variances. When only standard errors, 95% confidence intervals, *p*-values, or t-statistics were available, SDs were calculated accordingly.

For studies with multiple follow-up points, only the initial post-intervention data were extracted to focus on the immediate effects of the intervention rather than long-term outcomes. When available, intent-to-treat (ITT) analyses were prioritized, as they provide a more accurate representation of real-world scenarios where participants may not fully adhere to the intervention protocol.

2.4 Intervention categories

To identify the most effective health behavior change interventions using NMA (45), this study avoided grouping intervention types and instead evaluated six distinct interventions (comparators) against each other and a control group for their effectiveness in reducing bodyweight-related outcomes:

1 Control (usual care): Participants received no intervention beyond standard practices.
2 PA only: Participants received a school-based PA promotion intervention.
3 Diet and N only: Participants received a school-based diet and nutrition intervention.
4 PA and another component: Participants received a school-based PA promotion intervention combined with an additional component such as self-esteem instruction, education, or parent engagement.
5 PA and Diet and Nutrition (PA and Diet and N): Participants received a school-based intervention incorporating PA promotion, dietary education, and a nutritional program.
6 Multiple Components: Participants received interventions involving four or more components, such as PA, education, nutrition, lifestyle changes, parent engagement, and social media integration.

2.5 Risk of bias and quality of evidence

The risk of bias for the included studies was assessed by two researchers (S.R. and W.Z.) using the Cochrane risk of bias (RoB 2) assessment tool (47). The evaluation covered six domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other potential sources of bias. Any disagreements between the two researchers were resolved through consultation with a third author (Z.G.). The detailed results are provided in Supplementary File S3.

2.6 Statistical analysis

In health behavior change research involving multiple intervention strategies, NMA enables the pooling of results from both direct and indirect evidence while preserving the advantages of randomized, within-trial comparisons (48). The transitivity assumption was assessed to ensure that the distribution of effect modifiers (e.g., sex and age) across studies supported reliable indirect comparisons (49). Once an even distribution of effect modifiers was confirmed and the transitivity assumption held, the NMAs were conducted using R Studio (version 2021.09.0, The R Foundation) and the BUGSnet package. This package adheres to the PRISMA, ISPOR-AMCP-NPC, and NICE-DSU guidelines, using a Bayesian approach with a burn-in of 50,000 iterations, followed by 100,000 iterations and 10,000 adaptations.

A random-effects model was used, and the analyses were performed with Markov Chain Monte Carlo (MCMC) simulations utilizing vague priors. Network geometry was assessed through network plots, with interpretation methods detailed in previous studies (50, 51). Model fit was evaluated using leverage plots, total residual deviance, and deviance information criterion (DIC). Forest plots and league plots were used to present network estimates for various comparisons. Intervention rankings were generated using surface under the cumulative ranking curve (SUCRA) plots (52).

It is important to interpret SUCRA values cautiously, as they may vary across outcomes for the same intervention, and such variations could be due to chance. SUCRA values should be considered alongside the quality of evidence, as they do not reflect the magnitude of outcome differences between the two interventions (52).

The results were not dichotomized as statistically significant or not; instead, they were presented with credible interval (CrI) to enable health practitioners to interpret the range of potential effects (53, 54). Specifically, comparative mean differences (MDs) were reported along with their associated 95% CrI, with the 2.5 and 97.5% quantiles serving as the lower and upper bounds, respectively.

3 Results

3.1 Search results and study characteristics

This NMA comprehensively synthesized data from 53 studies, including a total of 68,489 participants with a mean age of 9.40 years. Among them, 35,192 participants (51%) were assigned to intervention groups, while 33,297 (49%) were in control groups. Geographically, the studies represented 18 countries, with the following distribution:

- 14 studies (26%) from the USA (55–68).
- 5 studies each from Australia (69–73), China (74–78), and Spain (79–83).
- 3 studies each from the UK (84–86), Italy (87–89), and the Netherlands (90–92).
- 2 studies each from France (93, 94), Germany (95, 96), Greece (97, 98), and Switzerland (99, 100).
- 1 study each from Chile (101), Iceland (102), Ireland (103), Mexico (104), New Zealand (105), Norway (106), and Portugal (107).

The publication years ranged from 2002 to 2023, with 28 studies (50%) published in the last 10 years. Regarding intervention types:

- 12 studies focused on PA only (55, 58, 62, 64, 74, 79, 87, 93, 94, 99, 103, 105).
- 2 studies targeted Diet and N only (84, 89).
- 3 studies examined PA and another component (66, 86, 95).
- 9 studies focused on PA and Diet and N (60, 61, 68, 73, 78, 88, 96, 101, 104).
- 27 studies implemented multiple-component interventions (56, 57, 59, 63, 65, 67, 69–72, 75–77, 80–83, 85, 90–92, 97, 98, 100, 102, 106, 107).

3.2 Risk of bias assessment and quality of studies

The quality of the included studies was evaluated using the Cochrane RoB 2 assessment, with the results detailed in Supplementary File S2. Among the studies, 87% clearly described the process of random sequence generation. Regarding allocation concealment, only four studies (7%) were identified as having a high risk of bias. For blinding of participants and personnel, 13 out of 53 studies exhibited a high risk of performance bias, while 23 studies provided unclear reports on blinding for either participants or personnel. Similarly, for the blinding of outcome assessment, 36% of the studies demonstrated a low risk of bias, while the remaining studies presented either high or unclear risks. Only a small proportion of studies (7%) showed unclear or high risk of bias in addressing incomplete outcome data, minimizing the need for calculations to account for missing data. Finally, all studies reported the expected outcomes (BMI and/or BMIz) required for this NMA, indicating no or low risk of bias in the selective reporting domain.

3.3 Network geometry

To detect all possible direct comparisons between treatments, network plots were generated to represent both BMI and BMIz outcomes, as shown in Figures 2A,B, respectively. In Figure 2A, closed loops were identified among the control group, Diet and N only, and PA and Diet and N interventions. Similarly, in Figure 2B, closed loops were observed among the control group, PA only, Diet and N only, and PA and Diet and N interventions. Closed loops indicate direct comparisons involving more than two interventions. Among all comparators, the control group and multiple-component interventions were the largest and of comparable size relative to the other comparators. Additionally, the thickest edge in the network plots represents the direct comparison between the control group and multiple-component interventions, highlighting their significant interaction.

3.4 Network meta-analysis

3.4.1 Model fit

To select the appropriate model for the NMA, two models were tested for each outcome: a fixed-effect model and a random-effect model. Figure 3 highlights the identification of potential outliers. As shown in Figures 3A,B, three key metrics were considered: the effective number of parameters (pD), total residual deviance (Dres), and DIC. These values collectively informed the choice of the most suitable model for the network. Based on the data presented in Figures 3A,B, the random-effects model was selected for both BMI and BMIz. This decision was supported by the random-effects model showing fewer outliers and lower DIC values, indicating a better fit for the data.

3.4.2 Consistency

The assumption of consistency is a fundamental component of NMA. In simple terms, it ensures there is no significant discrepancy between direct and indirect comparisons across studies, thereby confirming the network's consistency. To evaluate consistency in this NMA, two models were used: a consistency model and an inconsistency model. Model fit comparisons were assessed, and the posterior mean deviance of each combined model was plotted to visualize leverage points (Figure 4). For BMI, as shown in Figure 4A, the DIC values were lower in the consistency model. Additionally, the leverage values were more tightly clustered around zero in Figure 4B, indicating agreement between the two models and reducing the likelihood of inconsistency within the network. Similarly, the BMIz

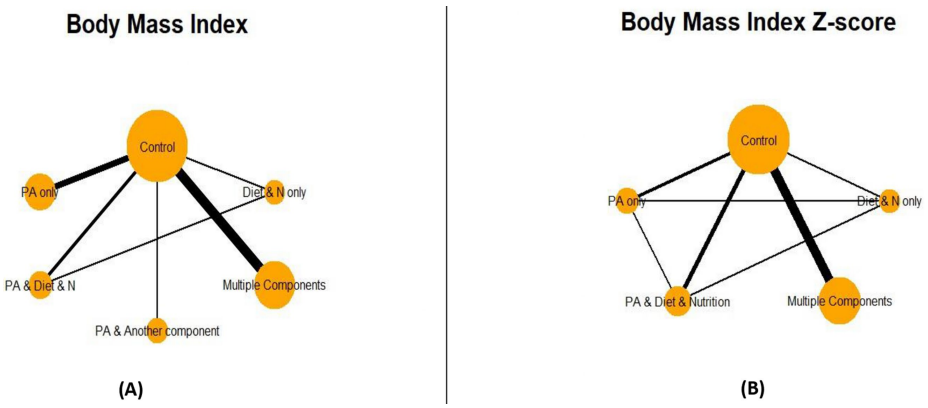

FIGURE 2
Network plot for body mass index **(A)** and body mass index *Z*-score **(B)**. PA = Physical Activity; *N*=Nutrition.

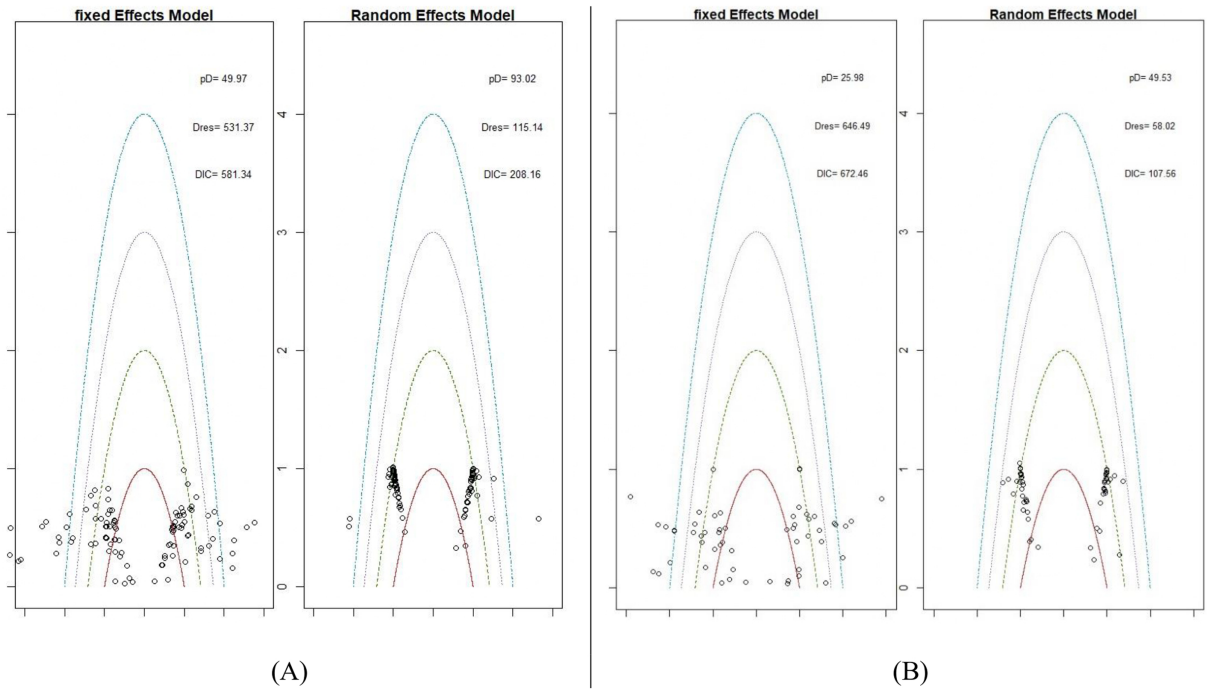

FIGURE 3
Leverage plots and DIC for fixed and random effects models for BMI **(A)** and BMIz **(B)**.

consistency model also exhibited lower DIC values (Figure 5), further supporting the consistency assumption for both BMI and BMIz outcomes in this NMA.

3.4.3 Treatment ranking

A treatment rank probability analysis and SUCRA were conducted to determine the ranking probability of each intervention within the network compared to the control group. For BMI, as shown in Figures 6A,B, PA-only interventions emerged as the most effective treatment for reducing BMI, followed by multiple-component interventions. Interestingly, the control group ranked higher than both the PA and Diet and N, and PA and another component interventions. Among all treatments, the PA and another component interventions were identified as the least effective in decreasing BMI. For BMIz, as depicted in Figures 7A,B, multiple-component interventions had the highest probability of being the most effective treatment for reducing BMIz, followed by PA and Diet and N. In contrast, the Diet and N-only group was found to be the least effective in decreasing BMIz.

3.4.4 League plots

To summarize the NMA results comprehensively, a league plot was created to illustrate the significance of all interventions compared to the control group and other treatments. For BMI, as shown in Figure 8, green cells indicate better performance when comparing treatments. While several interventions appeared effective in reducing BMI, only one—PA-only interventions—demonstrated a statistically significant difference compared to the control group (MD: -0.42, 95% CrI: −0.79, −0.07; $p = 0.02$). For BMIz, as depicted in Figure 9, fewer green cells were observed, indicating a weaker overall effect on BMIz compared to the BMI league plot. Similar to the BMI results, only one intervention—multiple-component interventions—showed a statistically significant difference compared to the control group treatments (MD: −0.08, 95% CrI: −0.16, −0.01; $p = 0.03$).

3.4.5 Forest plots

To provide a clearer visualization of pairwise comparisons among different treatments, forest plots were generated for both BMI and BMIz outcomes. Figure 10 presents a detailed illustration of MD with 95% CrI between interventions. As shown in Figure 10A, PA-only interventions demonstrated the greatest BMI reduction based on MD and 95% CrI when compared to the control group and other interventions. In Figure 10B, multiple-component interventions emerged as the most effective in reducing BMIz compared to the control group and other treatments. It is important to note that the PA and another component interventions were excluded from the BMIz analysis due to a limited amount of supporting evidence in the included studies.

3.4.6 Publication bias

Funnel plots were used to assess potential publication bias among the included studies. The plots represent the BMI (Figure 11A) and BMIz (Figure 11B). Both plots exhibited a symmetric distribution within the 95% CrI, indicating minimal bias. Although a few outliers were observed, the BMI funnel plot demonstrated a more precise distribution compared to the BMIz plot. Overall, the analysis suggests minimal publication bias or small sample size effects in the included studies.

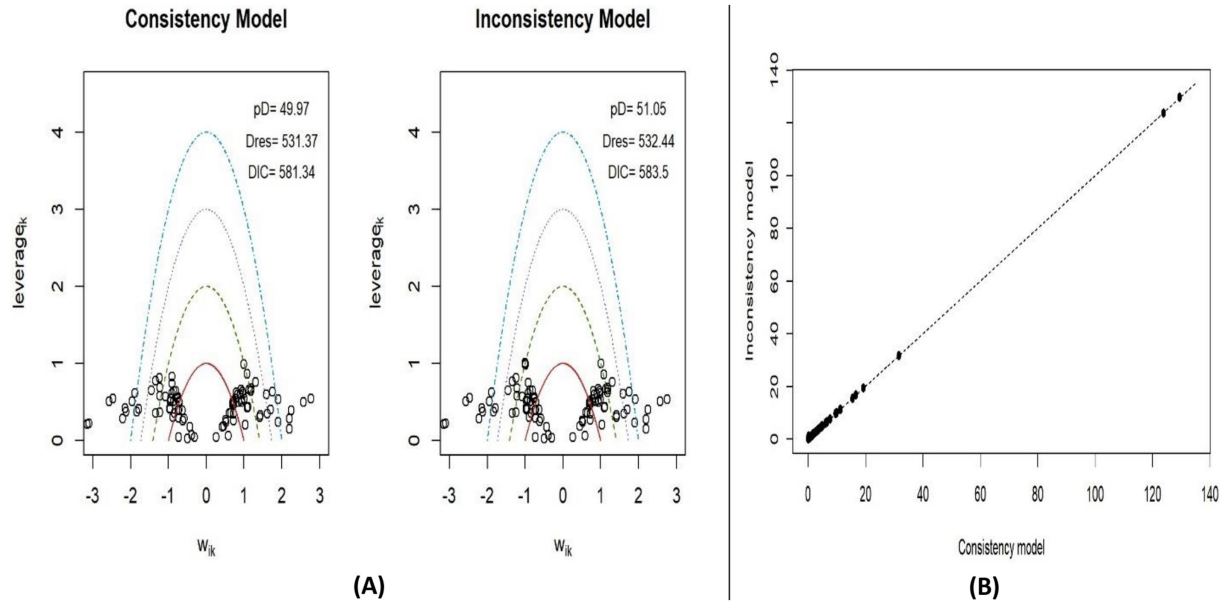

FIGURE 4
Leverage plots and DIC for consistency and inconsistency models for BMI **(A)** and plot of the posterior mean deviance of inconsistency model against consistency model for BMI **(B)**.

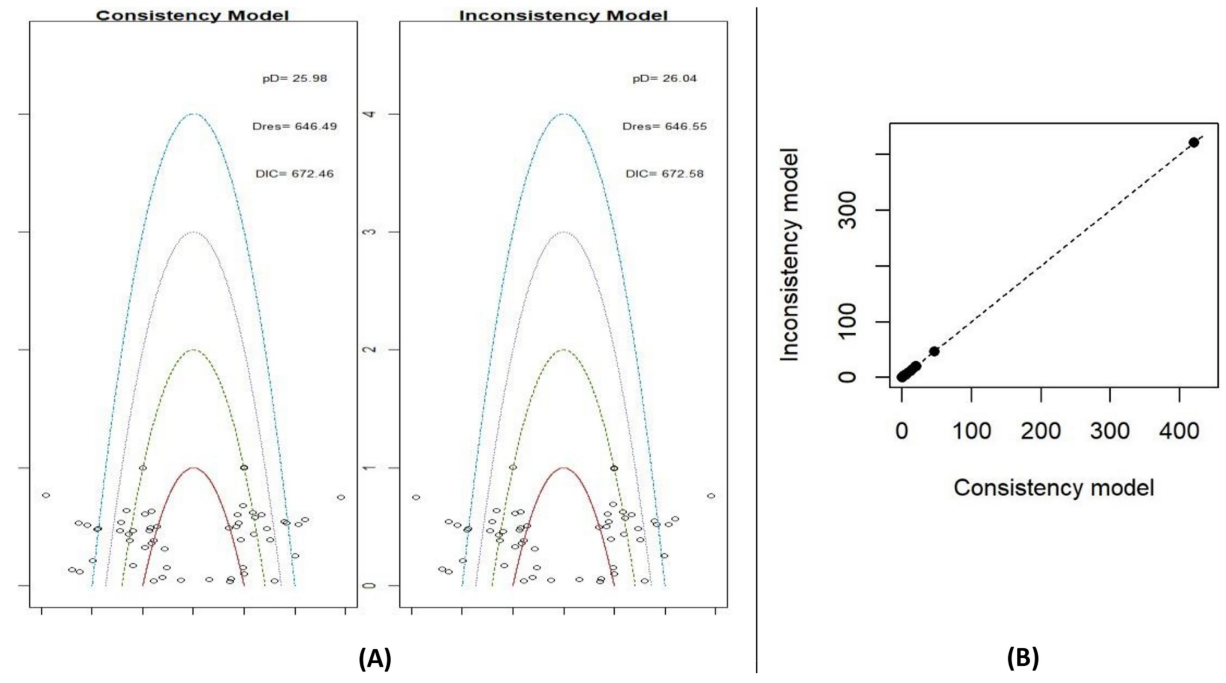

FIGURE 5
Leverage plots and DIC for consistency and inconsistency models for BMIz **(A)** and plot of the posterior mean deviance of inconsistency model against consistency model for BMIz **(B)**.

3.4.7 Sensitivity

To evaluate the stability and precision of the results, a leave-one-out sensitivity analysis was performed for both BMI (Figure 12) and BMIz (Figure 13). While a few studies were found to have some influence on the overall estimates, no substantial effects were observed that would significantly impact the results. Both figures demonstrated outcomes within marginal significance, confirming the robustness of the analysis.

4 Discussion

This NMA synthesizes current evidence on key factors influencing body composition outcomes in children and adolescents. The primary objective was to consolidate existing data to evaluate the relative effectiveness of various interventions aimed at improving body composition. Specifically, the analysis sought to determine the

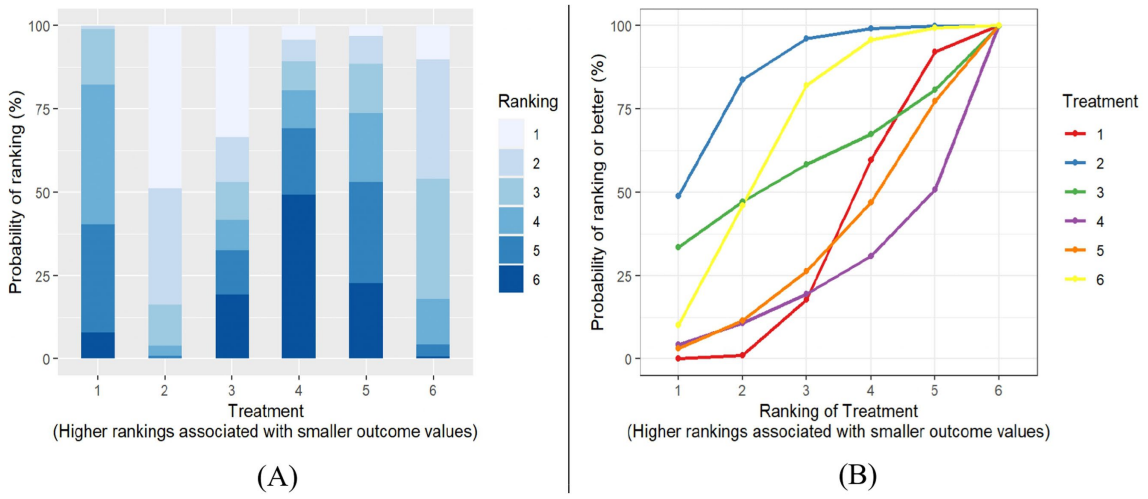

FIGURE 6
BMI Plot of treatment rank probabilities **(A)**, BMI SUCRA plot **(B)**. Treatments (1) control group; (2) PA only; (3) diet & only; (4) PA & another component; (5) PA & diet & N; (6) multiple components.

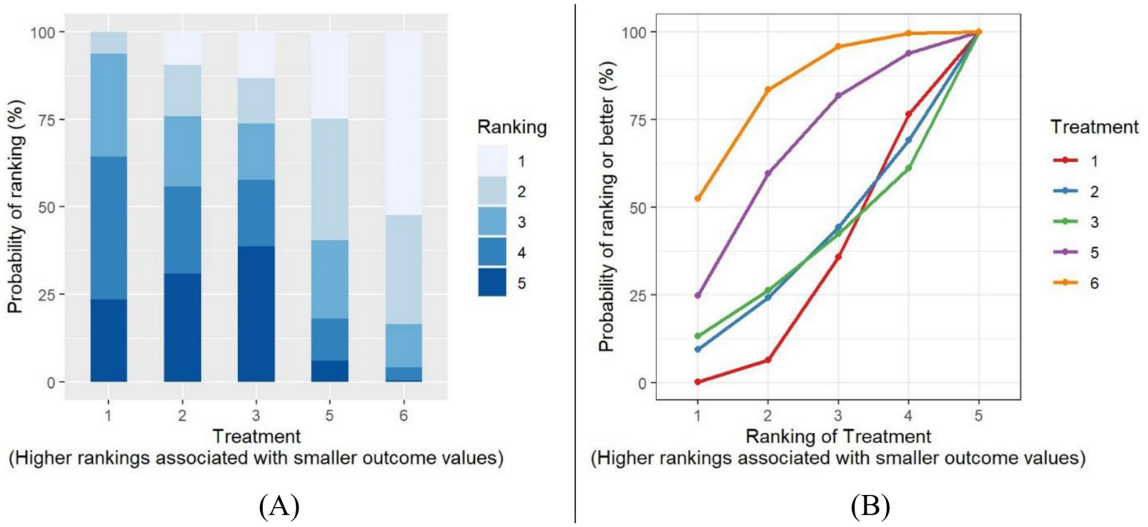

FIGURE 7
BMIz Plot of treatment rank probabilities **(A)**, BMIz SUCRA plot **(B)**. Treatments (1) control group; (2) PA only; (3) diet & N only; (5) PA & Diet & N; (6) multiple components component.

effectiveness and rank the superiority of different school-based strategies, including PA only, Diet and N only, PA and another component, PA and Diet and N, and multiple-component interventions, in reducing BMI and/or BMIz.

Regarding school-based interventions targeting PA, findings of this NMA suggest that interventions focused exclusively on PA are the most effective in reducing BMI among children and adolescents in school settings. This aligns with previous research, including a meta-analysis of 11 studies that examined differences in physical fitness and body composition between active and sedentary adolescents (108). The results indicated that participation in PA is associated with improved body composition outcomes. However, a previous systematic review and meta-analysis highlighted that the effectiveness of PA interventions may vary depending on their duration and intensity, potentially affecting the consistency of findings (109). Nevertheless, it has been confirmed that PA-only interventions, even with variations in length and intensity, still have a positive impact on reducing BMI and/or BMIz. This assumption aligns with previous research, such as a systematic review of 29 studies evaluating the effectiveness of high-intensity interval training (HIIT) and moderate-intensity continuous training on body composition and cardiorespiratory fitness (110). The results demonstrated positive improvements in BMI values with both types of training. Similar findings were reported in another study (111), which analyzed data from 38 studies involving 1,317 individuals with obesity. This study aimed to rank different PA approaches—including aerobic exercise, resistance training, and HIIT—based on their effectiveness. The

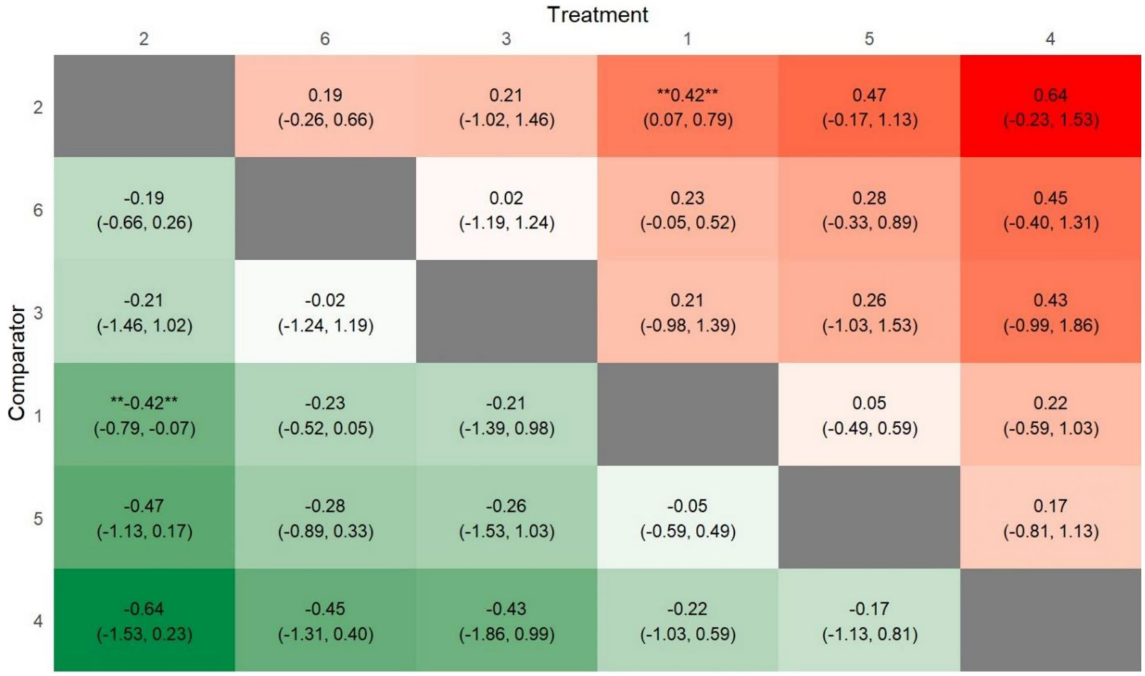

FIGURE 8
League heat plot for all treatment in the network for BMI comparators (1) control group; (2) PA only; (3) diet & N only; (4) PA & another component; (5) PA & diet & N; (6) multiple components.

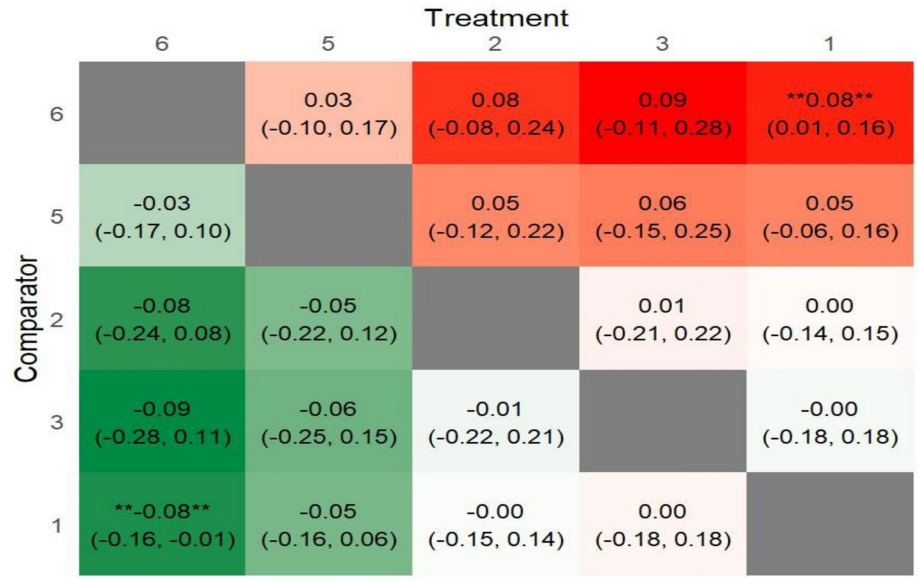

FIGURE 9
League heat plot for all treatment in the network for BMIz. Comparators (1) control group; (2) PA only; (3) diet & N only; (5) PA & Diet & N; (6) multiple components.

analysis concluded that all forms of PA contributed to BMI reduction.

Different PA modalities and intervals seem to have varying levels of effectiveness in improving anthropometric and body composition outcomes. Further research is needed to examine the influence of frequency and the long-term effects of school-based interventions. A meta-analysis evaluated the long-term effects of school-based obesity prevention interventions in children. This review included 19 studies that assessed outcomes more than 12 months post-intervention. The authors concluded that there is no clear evidence of sustained

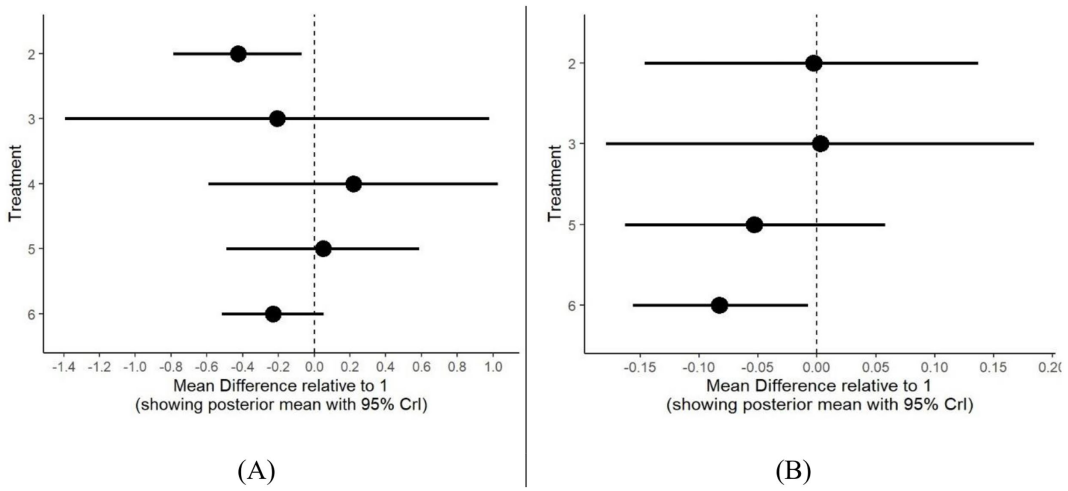

FIGURE 10
Forest plot for all treatments compared to control group as reference for BMI **(A)** and BMIz **(B)**. Treatments (1) control group; (2) PA only; (3) Diet & N only; (4) PA & another component; (5) PA & diet &N; (6) multiple components.

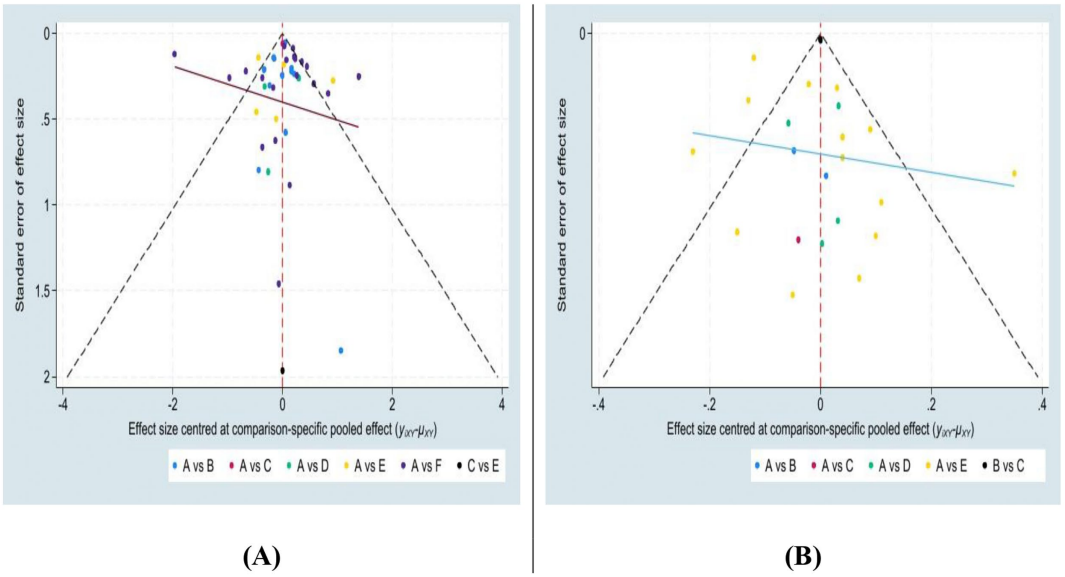

FIGURE 11
Funnel plots for the effect of intervention arms on BMI **(A)** and BMIz **(B)**.

long-term effects on obesity-related outcomes. This suggests that additional factors may play a role in achieving long-term success in preventing obesity (112).

Unsurprisingly, integrating additional components into PA interventions can lead to significant improvements in body composition outcomes. For instance, one study found that combining an exercise intervention with dietary guidance was more effective in improving body shape and BMI compared to exercise alone, diet alone, or no intervention (113). This partially supports the findings of this NMA, as PA interventions combined with diet and nutrition ranked as the second most effective approach in reducing BMIz. Other studies suggest that incorporating even more components, such as parental involvement and energy balance-related behaviors, alongside diet and PA, may further enhance the effectiveness of interventions in improving children's BMI (114). Consistent with this, several studies have focused on comprehensive, multiple-component interventions to promote healthy weight. A systematic review of 12 studies targeting multiple-component interventions to reduce obesity concluded that such approaches are more effective in reducing BMI compared to PA-only interventions (115). Similarly, another study systematically evaluated the effectiveness of combining a low-calorie diet with cognitive behavioral therapy, meal replacements, or exercise in reducing obesity (116). This analysis included 32 trials with 3,363 participants and found that multiple-component interventions were significantly associated

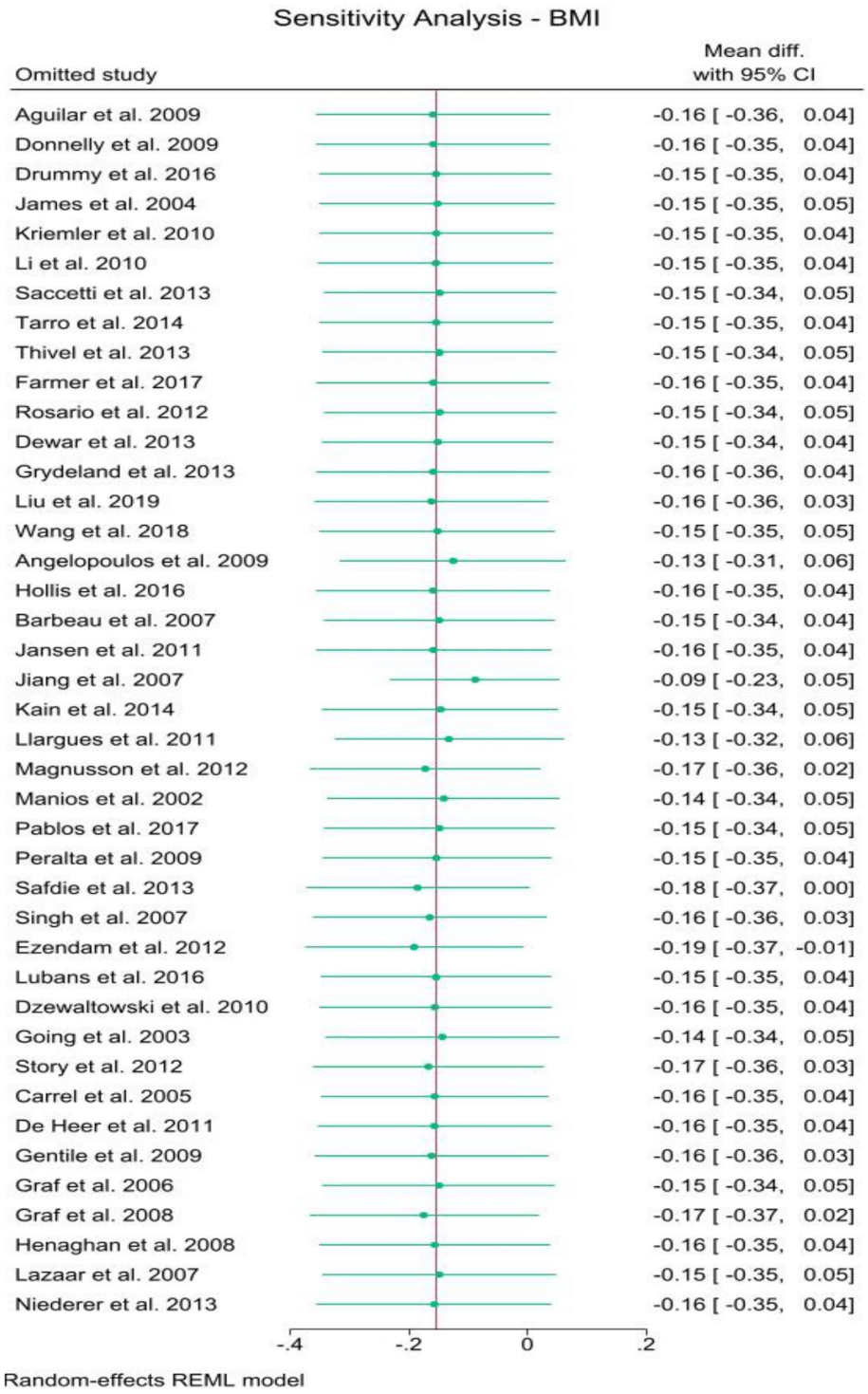

FIGURE 12
Sensitivity analysis for BMI.

with medium-level weight loss effects. Additionally, a review of 68 RCTs evaluated various interventions for promoting healthy weight in children and adults, concluding that multiple-component approaches and reduced television viewing were the most promising strategies for combating obesity (117). These findings align with the results of this NMA, further validating that multiple-component interventions represent a promising avenue for improving body composition outcomes, as demonstrated by their high ranking in the BMIz analysis.

In summary, while some discrepancies exist in the rankings of interventions based on BMI and BMIz outcomes, interventions focusing solely on PA and those incorporating multiple components appear to be the most effective in improving body composition. Specifically, PA-only interventions ranked first in effectiveness for

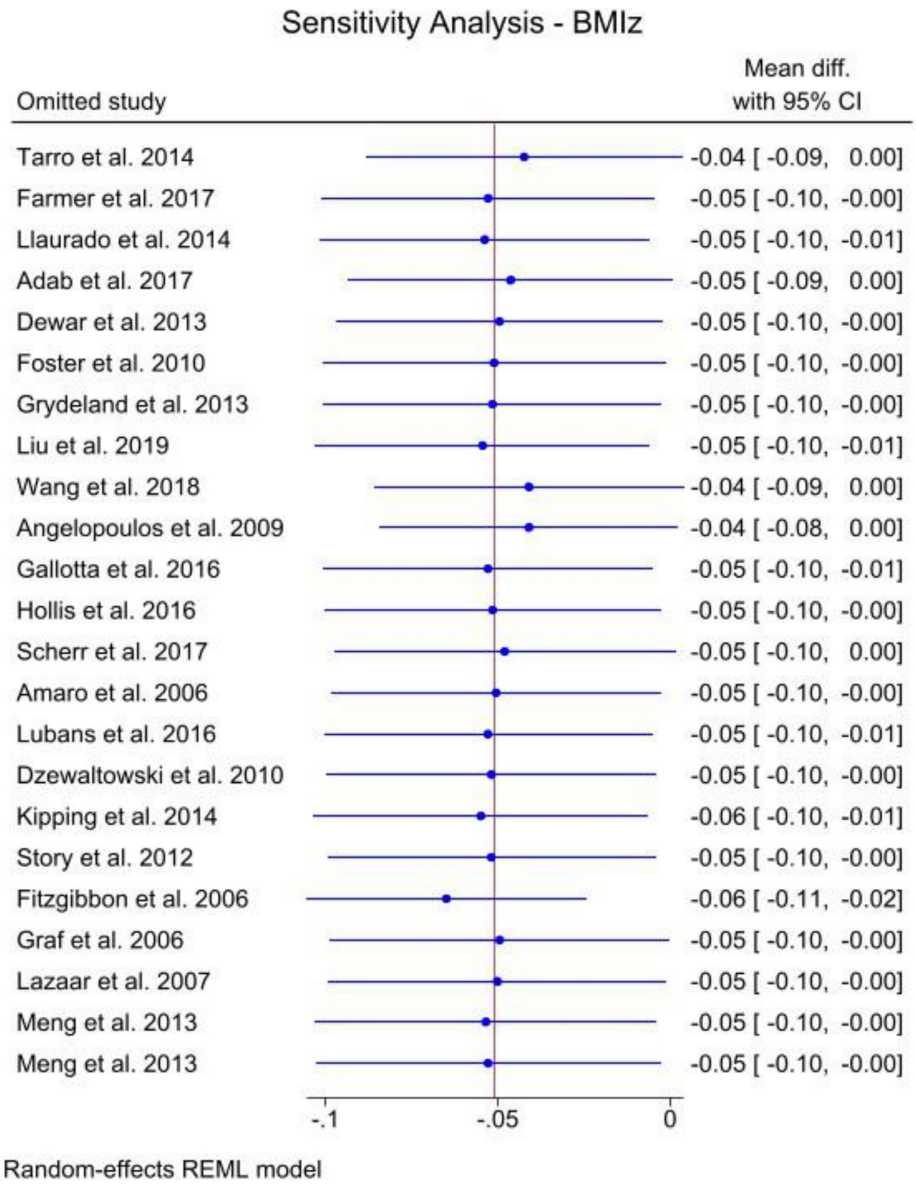

FIGURE 13
Sensitivity analysis for BMIz.

BMI outcomes, while multiple-component interventions were highly ranked, securing first place for BMI and third for BMIz. However, definitive conclusions about the effectiveness of the multiple-component approach remain elusive, primarily due to the need for greater clarity regarding the specific elements that constitute such interventions.

5 Strengths of the study

To date, this is the first NMA designed to evaluate the efficacy and relative rankings of various school-based obesity prevention interventions for improving body composition outcomes. Moreover, this NMA is highly generalizable, as it includes studies from 18 countries, representing diverse cultural and educational contexts. Finally, with a total sample size of 68,489 participants across all included studies, this analysis benefits from a relatively large dataset.

6 Limitations of the study

Several limitations were identified in this analysis. First, a number of the included studies were assessed as having a potentially high risk of bias. Second, the scarcity of studies supporting the "PA and another component" intervention arm led to its exclusion from the BMIz analysis. Third, the intensity and duration of PA interventions were not thoroughly examined, which may have introduced heterogeneity across studies. Additionally, while the "multiple components" approach appeared to be among the most effective for improving body composition outcomes, the results are potentially compromised by varying definitions of "multiple

components" across studies. Due to the lack of standardized classifications for these components, these findings should be interpreted with caution. Finally, light PA, which might also contribute to BMI or BMIz, was not explored as part of PA in the current study (118, 119).

7 Areas for further research

While PA-only and multiple-component interventions appear to be the most effective approaches, further systematic reviews are needed to examine each intervention type independently. Additional research is crucial to validate PA-only interventions, specifically regarding their intensity and duration. Moreover, future reviews are recommended to explore and standardize the classification of multiple-component interventions.

8 Conclusion

In conclusion, school-based obesity prevention interventions focusing solely on PA or utilizing multiple components have demonstrated positive effects on both BMI and BMIz. However, careful attention should be given to the specifics of PA programs, such as their duration, intensity, and modality. Additionally, evaluating multiple-component programs requires caution, as their content can vary significantly across studies. To address this variability, establishing a standardized classification for the components of multiple-component interventions is highly recommended.

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.

Author contributions

MH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. DM: Methodology, Writing – original draft, Writing – review & editing. SR: Data curation, Writing – original draft. WZ: Data curation, Writing – original draft. JO: Data curation, Writing – original draft. ZG: Conceptualization, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1504279/full#supplementary-material

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Health-related physical fitness in children among five Mediterranean countries: a cross-cultural study from the DELICIOUS project

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Background: Health-related fitness (HRF) components are essential for supporting healthy growth and reducing long-term health risks in children. This study explored cross-cultural variations in HRF among children from five Mediterranean countries—Egypt, Italy, Lebanon, Portugal, and Spain—within the framework of the DELICIOUS project.

Methods: A total of 860 children participated in the study, including 204 from Egypt (n = 204, 11.72 ± 1.46 years), 150 from Italy (9.66 ± 1.10 years), 200 from Lebanon (10.73 ± 1.90 years), 181 from Portugal (11.04 ± 1.83 years), and 125 from Spain (12.33 ± 2.27 years). Participants completed the International Physical Performance Test Profile (IPPTP), which assesses sprint speed (20 m dash), coordination (jumping sideways), upper body strength (push-ups), abdominal strength (sit-ups), lower body power (standing long jump), and cardiovascular endurance (6-min run). Children were categorized into two age groups: 8–10 and 11–14 years. ANCOVA, adjusting for BMI, was performed to analyze differences across countries and age groups.

Results: Analysis revealed significant differences in HRF across countries and age groups ($p < 0.05$). Spanish boys and girls consistently demonstrated superior sprint performance (20 m dash) and cardiovascular endurance (6-min run) compared to peers from other countries. Lebanese and Spanish girls exhibited stronger abdominal performance (sit-ups) than Egyptian girls, while Spanish girls also excelled in lower-body power (standing long jump). These findings underscore cross-cultural variations in HRF outcomes among Mediterranean children.

Conclusion: Cross-cultural differences in physical education programs and sports participation appear to influence HRF in children across the Mediterranean region. These findings underscore the need for culturally tailored physical education strategies and public health initiatives to ensure balanced fitness development in diverse cultural populations.

KEYWORDS

cross-cultural differences, physical fitness, Mediterranean countries, DELICIOUS project, children

1 Introduction

Physical inactivity is a significant global health challenge, contributing to the prevalence of chronic diseases such as obesity, cardiovascular disease, and diabetes. It is a leading cause of premature mortality, ranking as the fourth-highest cause of death worldwide (1). In 2013, inadequate physical activity (PA) was estimated to have cost the global healthcare system USD 53.8 billion, with substantial expenditures in Europe (USD 11.7 billion) and North America [USD 25.7 billion; (2)]. These economic implications highlight the urgent need for public health initiatives that promote and sustain PA levels, particularly among children and adolescents (3). Beyond its physical health benefits, PA plays a crucial role in brain health and cognitive function (4, 5). Regular activity enhances memory, attention, and executive functioning, while also supporting academic performance by improving concentration, problem-solving abilities, and emotional regulation (6–10). These cognitive and academic advantages underscore the importance of embedding physical activity into children's daily routines to foster holistic development. While the global burden of physical inactivity is well-established, less attention has been given to how cultural and environmental factors that shape children's physical activity behaviors and fitness levels across different regions. Understanding these contextual influences is vital for designing targeted strategies to address physical inactivity and its associated challenges worldwide.

Physical education (PE) programs vary significantly across Mediterranean countries, influenced by cultural priorities, educational policies, and the availability of resources for physical activity. In Portugal, PE is mandatory throughout primary and secondary education, with a focus on diverse sports and activities designed to encourage lifelong physical activity (11, 12). Similarly, Spain integrates a comprehensive PE curriculum with culturally prominent sports like soccer, fostering children's endurance and agility development (13, 14).

Italy includes PE as a core component of the standard school curriculum but emphasizes general fitness and motor skills over competitive sports, prioritizing holistic well-being and overall health rather than intense sports training (15). In Lebanon, while PE is mandatory, the quality and resources available for PE programs vary widely. Participation in physical activity among Lebanese children and youth tends to be low, and PE programs typically emphasize basic physical activity rather than specialized sports training (16, 17). Egypt, in contrast, faces challenges in delivering consistent PE curricula due to resource constraints. Many schools provide limited structured physical activity opportunities, resulting in less emphasis on physical fitness development (18, 19). These disparities in PE priorities, structure, and resources across the five countries likely influence children's health-related physical fitness (HPF). Research has shown that well-resourced and structured PE programs are strongly associated with improved fitness outcomes (20), highlighting the importance of investing in and standardizing PE initiatives to support children's physical health and development.

HPF encompasses a set of physical attributes that are essential for overall health and well-being, including cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition (21). Unlike skill-related fitness, which emphasizes motor skills or athletic performance, HPF focuses on factors that help prevent disease and promote long-term health. Developing strong HPF during childhood not only supports healthy physical growth but also fosters activity patterns that are likely to continue into adolescence and adulthood, reducing the risk of chronic diseases later in life (22).

However, despite its vital role, recent studies have revealed a global decline in HPF among children, raising serious concerns about its potential long-term health impacts (23). Understanding these trends is particularly important in regions where physical fitness outcomes are shaped by unique cultural, environmental, and socio-economic factors. Addressing the decline in HPF requires targeted strategies that consider these contextual influences to promote healthier lifestyles and reduce future health risks.

HRF in children varies widely across regions, influenced by cultural, environmental, and social factors that shape physical activity levels and fitness outcomes (24–26). The Social Ecological Model offers a valuable framework for understanding these influences, emphasizing that individual health behaviors are shaped by multiple layers of interaction, including societal norms, family dynamics, and educational environments (3). Complementing this, the Life Course Theory highlights how early-life experiences—such as access to physical education (PE) and sports—can significantly influence health trajectories into adulthood (22).

Although research comparing children's HRF across countries is limited, existing studies underscore the importance of cultural contexts in fitness outcomes. For instance, Luz et al. (27), compared motor competence and HRF between children from Portugal and the United States, while Bardid et al. (28) examined motor competence differences between children in Australia and Belgium and revealed important cultural differences. In the latter study, Belgian children outperformed their Australian peers in motor tasks such as jumping sideways and hopping for height, a disparity linked to cultural factors such as PE curricula and active transportation practices. These cross-cultural studies highlight how specific motor skills are nurtured differently depending on cultural priorities and contexts. Standardized fitness assessments can uncover these variations, providing insights into the cultural influences that shape skill development. Understanding HRF within diverse cultural settings is critical for designing equitable public health strategies that enhance fitness opportunities for children worldwide (29).

The Mediterranean region offers a unique opportunity for cross-cultural comparisons of HPF due to its blend of shared cultural traits—such as the prevalence of the Mediterranean diet (30, 63)—and distinct variations in physical education (PE) practices and youth sports cultures. For instance, while children in Spain and Portugal may share similar dietary habits, their approaches to sports participation differ. Portuguese children often specialize in a single sport, such as soccer, whereas their peers in other countries are more likely to engage in a broader range of activities (31, 32). In contrast, children in Egypt may face different opportunities for physical activity due to disparities in school-based PE programs and the availability of community sports initiatives (33). Despite these acknowledged cultural differences, limited research exists on how these factors shape physical fitness outcomes among children within the Mediterranean context. Such studies are critical for understanding the interplay between cultural practices and fitness development, paving the way for tailored interventions to promote equitable health and fitness across the region.

This study focuses on five Mediterranean countries—Egypt, Italy, Lebanon, Portugal, and Spain—examining HPF across two age groups

(8–10 and 11–14 years). It aims to explore how cultural and environmental factors influence the development of HPF in youth, with a particular focus on identifying differences in fitness levels among children in these countries. The findings are expected to offer valuable insights for shaping public health strategies and refining physical education (PE) practices, ultimately supporting improved fitness outcomes in diverse cultural contexts.

2 Materials and methods

2.1 Participants

The study sample was drawn from partner countries within the DELICIOUS consortium: Egypt, Italy, Lebanon, Portugal, and Spain. primary goals and objectives of the DELICIOUS project, a comprehensive descriptive and intervention study aimed at promoting the Mediterranean diet and an active lifestyle among school children and adolescents, have been detailed elsewhere (30, 64). For this study, a total of 860 children aged 8–14 years were recruited from participating schools in urban areas across five Mediterranean cities: Assiut (Egypt), Lisbon (Portugal), Beirut (Lebanon), Cordoba (Spain), and Giugliano in Campania (Italy). To account for potential age-related differences in fitness levels, participants were stratified into two age groups: 8–10 years and 11–14 years. Written informed consent was obtained from parents or legal guardians of all participants prior to the children's participation. The study adhered to the ethical standards outlined in the Declaration of Helsinki and was approved by the ethics committee of Mondragon University (no. IEB-20230704).

2.2 Measures

2.2.1 Physical fitness

The International Physical Performance Test Profile (IPPTP) is a standardized and validated test battery designed to assess HPF in children and adolescents. It provides a comprehensive evaluation of key fitness components, including speed, agility, strength, endurance, and coordination, making it particularly well-suited for cross-cultural studies (6, 18, 34–37). Developed based on the methodologies of Bös and Mechling (38) and the German Motor Test 6–18 (39), the IPPTP comprises eight test items that encompass the five fundamental dimensions of physical fitness: endurance, strength, speed, coordination, and flexibility. For this study, six specific tests from the IPPTP were selected to target the core aspects of physical fitness relevant to children's HPF. These tests were chosen for their high validity in measuring fitness components across culturally diverse populations and their robustness in cross-cultural applications. For this study, six tests were selected to target core aspects of children's HPF: the 20 m Dash Test assessed speed by recording sprint times over 20 meters; the Sideways Jumping Test measured agility and coordination through the number of lateral jumps in 15 s; the Push-Up Test evaluated upper body strength and endurance by counting the total push-ups completed in 40 s; the Sit-Up Test assessed core strength through the number of sit-ups performed in 40 s; the Standing Long Jump Test measured lower body strength by the distance jumped from a standing position in centimeters; and the 6-Minute Run assessed cardiovascular endurance by the total distance covered in meters. All tests were conducted under standardized conditions to ensure consistency and reliability across the diverse sample populations. The reproducibility and validity of the IPPTP have been established in previous research (6, 18). For additional details on these test items, readers are referred to the corresponding manuals (35, 39).

2.2.2 Anthropometry

Height and weight were recorded prior to testing. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Seca GmbH & Co. KG, Hamburg, Germany), while weight was measured using a Tanita digital body composition scale (BF-350 Total Body Composition Analyzer, Amsterdam, the Netherlands), following standardized anthropometric protocols. Body mass index (BMI) was then calculated using the formula: BMI = weight (kg)/height (m^2).

2.3 Statistical analysis

Descriptive statistics (means and standard deviations) were computed to characterize HPF across age groups and sex. Prior to conducting further analyses, data were assessed for normality using the Shapiro–Wilk test and for homogeneity of variances using Levene's test to ensure the assumptions required for parametric testing were met. To account for the potential influence of body mass index (BMI), analyses were adjusted for BMI as a covariate. Differences in physical fitness measures across countries (Egypt, Italy, Lebanon, Portugal, and Spain) and age groups (8–10 years and 11–14 years) were examined separately for boys and girls by a two-way analysis of covariance (ANCOVA) was conducted. *Post hoc* pairwise comparisons were conducted using the Games-Howell test, which is robust to unequal variances and sample sizes. Significance was set at $p < 0.05$ for all analyses. Data were analyzed using R software (40), with *post hoc* tests performed using the "PMCMRplus" package. Effect sizes (eta squared) were calculated to evaluate the magnitude of differences between groups.

3 Results

3.1 Sample characteristics

Table 1 presents descriptive statistics for height, weight, BMI, and HPF variables across five Mediterranean countries, stratified by age group and sex. For both sexes, ANCOVA revealed significant performance improvements across age groups ($p < 0.01$) for all fitness variables, except for push-ups, sit-ups, standing long jump, and the 6-min run in boys (Table 2).

3.2 Cross-cultural differences in HRP components

The analysis of ANCOVA, controlling for BMI and examining country and age as factors, revealed significant cross-cultural differences in HRP components. For the 20 m dash, Spanish boys and

TABLE 1 Health-related fitness components (mean ± SD) by age group and sex across five Mediterranean countries.

Variable	8–10 years					11–14 years				
	Egypt	Italy	Lebanon	Portugal	Spain	Egypt	Italy	Lebanon	Portugal	Spain
Boys										
Height (cm)	139.26 ± 6.76	140.58 ± 7.41	136.93 ± 8.34	134.89 ± 5.48	146.83 ± 8.07	153.55 ± 10.88	144.09 ± 7.21	158.13 ± 9.04	155.05 ± 9.52	162.40 ± 12.57
Weight (kg)	33.96 ± 7.89	39.40 ± 11.09	33.39 ± 9.67	31.35 ± 6.05	45.06 ± 11.53	45.81 ± 12.50	40.61 ± 10.21	50.42 ± 12.42	45.05 ± 9.77	56.47 ± 14.61
BMI (kg/m^2)	17.40 ± 3.27	19.77 ± 4.37	17.52 ± 3.35	17.14 ± 2.52	20.85 ± 4.64	19.20 ± 3.98	19.31 ± 3.34	20.02 ± 4.02	18.58 ± 2.84	21.35 ± 5.03
20 m dash	4.38 ± 0.39	4.55 ± 0.36	4.59 ± 0.46	4.39 ± 0.40	4.32 ± 0.42	3.97 ± 0.47	4.03 ± 0.28	4.01 ± 0.40	4.06 ± 0.62	3.88 ± 0.58
JSW (n)	22.26 ± 3.54	29.07 ± 4.52	23.02 ± 7.75	31.76 ± 6.90	34.33 ± 6.76	25.60 ± 4.42	33.30 ± 8.10	24.64 ± 4.20	35.80 ± 5.31	34.68 ± 5.96
PU (n)	13.13 ± 2.87	16.14 ± 4.21	15.14 ± 4.23	14.89 ± 4.10	14.17 ± 4.77	14.27 ± 3.63	18.13 ± 6.94	15.75 ± 3.79	18.00 ± 5.06	16.74 ± 6.83
SU (n)	19.00 ± 3.85	21.72 ± 4.05	20.34 ± 6.47	22.49 ± 5.67	21.72 ± 2.30	19.96 ± 5.21	25.09 ± 7.13	25.30 ± 5.69	26.35 ± 6.41	27.85 ± 6.80
SLJ (cm)	112.13 ± 21.85	134.51 ± 14.71	135.43 ± 20.80	136.97 ± 16.17	132.39 ± 14.16	135.24 ± 25.38	137.83 ± 11.26	150.32 ± 28.83	164.95 ± 29.73	149.06 ± 31.38
6 min run	759.04 ± 117.89	897.26 ± 159.34	907.52 ± 140.12	1015.62 ± 77.96	996.61 ± 171.68	866.97 ± 117.54	991.91 ± 227.70	964.02 ± 160.22	1100.23 ± 196.92	1093.70 ± 211.18
Girls										
Height (cm)	143.08 ± 7.63	140.12 ± 7.93	138.50 ± 7.19	137.39 ± 9.30	146.21 ± 7.54	151.82 ± 9.86	142.94 ± 7.34	156.96 ± 8.57	155.33 ± 8.65	156.59 ± 8.39
Weight (kg)	39.50 ± 10.12	38.49 ± 8.85	34.21 ± 8.60	33.24 ± 7.25	43.00 ± 9.52	46.18 ± 10.95	41.63 ± 8.74	48.76 ± 11.09	44.88 ± 9.69	51.02 ± 11.21
BMI (kg/m^2)	19.16 ± 4.09	19.42 ± 3.09	17.72 ± 3.78	17.43 ± 2.43	19.95 ± 3.46	19.89 ± 3.73	20.49 ± 4.89	19.68 ± 3.61	18.47 ± 2.98	20.67 ± 3.64
20 m dash	4.95 ± 0.50	4.76 ± 0.48	4.89 ± 0.63	4.55 ± 0.38	4.30 ± 0.26	4.57 ± 0.49	4.25 ± 0.43	4.11 ± 0.36	4.35 ± 0.56	4.22 ± 0.42
JSW (n)	18.23 ± 3.06	27.81 ± 3.96	20.58 ± 6.27	29.38 ± 3.44	31.21 ± 6.52	21.80 ± 3.06	30.25 ± 5.69	23.77 ± 4.42	31.82 ± 4.76	33.35 ± 6.86
PU (n)	8.31 ± 2.71	14.49 ± 2.61	13.37 ± 4.21	13.73 ± 2.80	10.93 ± 3.52	10.02 ± 2.97	16.06 ± 3.38	14.45 ± 2.93	15.71 ± 4.05	13.76 ± 4.01
SU (n)	9.85 ± 4.63	19.69 ± 3.65	15.79 ± 4.71	19.61 ± 4.00	18.50 ± 4.64	11.36 ± 4.27	22.50 ± 4.73	22.29 ± 5.90	23.18 ± 3.92	21.72 ± 6.75
SLJ (cm)	88.96 ± 13.99	128.01 ± 14.50	121.87 ± 15.88	131.79 ± 11.23	119.00 ± 13.05	101.03 ± 17.23	131.19 ± 14.04	138.00 ± 26.15	158.06 ± 20.39	125.41 ± 27.35
6 min run	691.88 ± 75.12	810.62 ± 152.56	836.10 ± 105.32	945.00 ± 99.66	902.00 ± 179.40	723.12 ± 62.40	870.94 ± 71.83	854.21 ± 111.38	992.61 ± 155.67	913.09 ± 162.78

JSW, jumbling sideways; PU, push up; SU, set up; SLJ, standing long jump.

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TABLE 2 Interaction and main effects on health-related fitness variables according to country and age group.

Variable	$F_{Country}$	η_p^2	F_{age}	η_p^2	$F_{Country \times age}$	η_p^2
Boys						
20 m dash (sec)	4.59**	0.04	9.98**	0.02	1.59	0.01
JSW (*n*)	0.57	0.0053	15.78**	0.04	1.64	0.02
PU (*n*)	1.93	<0.001	0.01	<0.001	0.29	<0.001
SU (*n*)	0.79	0.0073	3.32	0.0077	2.65*	0.02
SLJ (cm)	3.03**	0.03	2.35	0.0054	3.85**	0.03
6 min run (m)	2.95*	0.03	3.67	0.0085	1.95	0.02
Girls						
20 m dash (sec)	9.58**	0.09	14.85**	0.03	2.08	0.02
JSW (*n*)	1.90	0.02	9.95**	0.02	1.98	0.02
PU (*n*)	1.80	0.02	6.56*	0.02	0.28	0.002
SU (*n*)	5.42**	0.05	11.15**	0.03	0.41	0.0039
SLJ (cm)	2.56*	0.02	7.23**	0.02	2.08	0.02
6 min run (m)	2.21	0.02	8.69**	0.02	2.04	0.02

*$p < 0.05$, **$p < 0.01$. JSW, jumbling sideways; PU push up; SU, set up; SLJ, standing long jump.

girls demonstrated significantly faster sprint times than participants from Egypt, Lebanon, Italy, and Portugal, who showed no differences among themselves (Figures 1A,B). In the standing long jump, Egyptian girls exhibited significantly lower performance compared to Spanish girls, while participants from Lebanon, Italy, and Portugal did not differ significantly from either group (Figure 1C). The sit-up test showed that Lebanese and Spanish girls performed significantly better than Egyptian girls, with no significant differences between girls from Italy, Portugal, and Egypt (Figure 1D). Lastly, for the 6-min run, Spanish boys outperformed Italian boys, while participants from Egypt, Lebanon, and Portugal showed no significant differences compared to either Spain or Italy (Figure 1E). These findings highlight notable cultural variations in specific physical fitness components across the sampled countries.

3.3 Country × age group interaction effects

For the standing long jump test in boys, ANCOVA revealed a significant interaction effect between country and age group. Among the younger age group (8–10 years), no significant differences were observed between the five counties. In the older age group (11–14 years), boys from Portugal exhibited the best performance, and boys from Lebanon performed significantly better than those from Egypt and Italy, with no significant differences observed among boys from Portugal, Spain, and Lebanon (Figure 1F). For the sit-up test in boys, a significant interaction effect between country and age group was observed, but *post hoc* comparisons did not reveal any significant pairwise differences ($p > 0.05$).

4 Discussion

This study assessed HPF levels among children from five Mediterranean countries—Egypt, Italy, Lebanon, Portugal, and Spain—while accounting for BMI as a covariate to explore how cultural and environmental factors influence fitness development. Significant differences were observed across countries and age groups in all fitness components, even after adjusting for BMI. Spain and Portugal consistently outperformed other countries in endurance, coordination, and strength tests, while Egypt demonstrated lower performance across several areas. These findings emphasize the influence of structured physical education (PE) programs and sports participation on fitness outcomes, underlining the need for tailored public health policies in countries with lower fitness levels to improve HPF outcomes (1).

Adjusting for BMI revealed that cross-country differences in HPF persisted across fitness components. The present study showed that boys and girls from Spain exhibited significantly faster sprint times compared to participants from Egypt, Lebanon, Italy, and Portugal, with no significant differences among the latter group, highlighting the potential influence of Spain's structured PE programs and sports culture on sprint performance. Spain's emphasis on endurance-based and speed-focused sports, such as soccer and track and field, likely contributes to the development of sprint-specific motor skills and physical conditioning from an early age (41). In contrast, the lack of significant differences among Egypt, Lebanon, Italy, and Portugal may reflect a more generalist approach to PE curricula (42) or a lack of targeted sprint training in these countries (43–45). Additionally, Spain's investment in youth sports infrastructure and participation in organized sports might create opportunities for regular practice, which enhances speed and power output in sprinting tasks (46, 47). These results underscore the role of cultural and environmental factors in shaping specific fitness components, such as sprint speed, and highlight the need for other countries to consider incorporating more sprint-focused activities into their PE programs to enhance athletic. Importantly, BMI did not substantially alter these patterns, indicating that cultural and environmental factors may play a stronger role than body composition in shaping HPF.

In the sit-up test, girls from Lebanon and Spain significantly outperformed their peers from Egypt, while participants from Italy and Portugal showed no significant differences compared to Egyptian

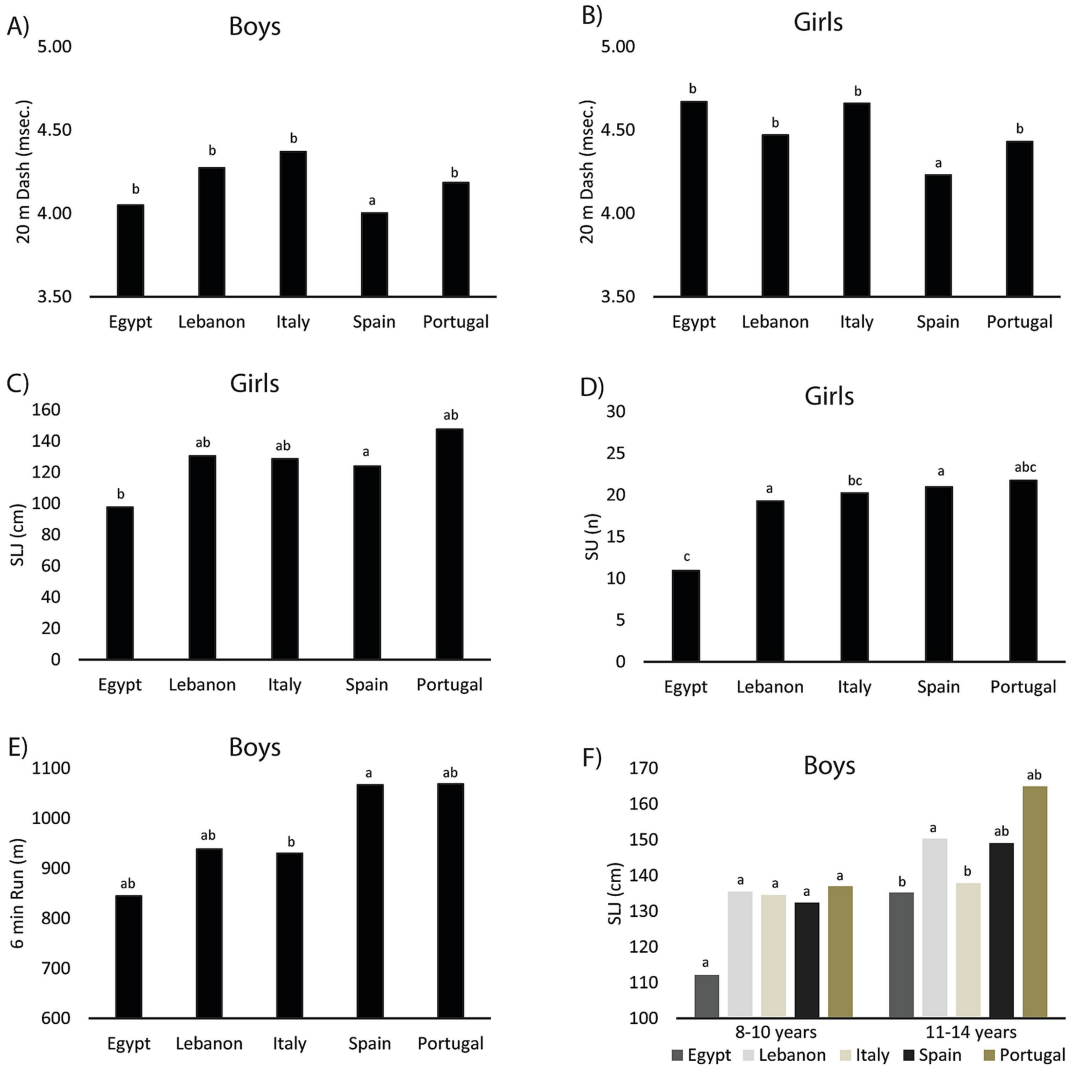

FIGURE 1
Performance values for boys and girls from Egypt, Italy, Lebanon, Portugal, and Spain in the following tests: **(A,B)** 20 m Dash, **(C,F)** Standing Long Jump (SLJ), **(D)** Sit-Up (SU), and **(E)** 6-Minute Run. Countries with the same letters are not significantly different.

girls. This highlights cross-cultural variations in abdominal strength and endurance, which may be influenced by differences in PE program design. Lebanon's sporadic but targeted focus on fitness components such as core strength (48), and Spain's comprehensive approach to physical training, appears to foster better performance in these areas (49). On the other hand, cultural and infrastructural challenges in Egypt may limit children's opportunities to engage in activities that build abdominal strength, particularly for girls (19).

The standing long jump results revealed that girls from Egypt performed significantly worse compared to those from Spain, while participants from Lebanon, Italy, and Portugal demonstrated comparable performance, with no significant differences from either Egypt or Spain. These findings highlight disparities in lower-body power across countries, likely reflecting differences in the emphasis on explosive strength activities in PE programs. For boys, the significant interaction effect between country and age group for the standing long jump test highlights important cross-cultural and developmental variations in physical fitness. The lack of significant differences among countries in the younger age group (8–10 years) suggests that early development in lower-body strength and explosive power, as measured by the standing long jump, may be relatively homogeneous across the sampled populations. However, in the older age group (11–14 years), boys from Portugal and Lebanon demonstrated superior performance, with Portuguese boys leading, and Lebanese boys significantly outperforming their peers from Egypt and Italy. This finding may reflect differences in cultural and environmental factors that influence physical activity opportunities and training habits in these countries, underscoring the potential benefits of targeted physical education interventions during critical developmental periods (50).

The 6-min run results highlighted Spain's consistent advantage in cardiovascular endurance, with Spanish boys outperforming their Italian counterparts significantly. Participants from Egypt, Lebanon, and Portugal demonstrated similar performance levels, suggesting comparable cardiovascular endurance across these countries. Spain's superior performance could be attributed to a stronger emphasis on

endurance-based sports and structured aerobic activities within its physical education curricula, which likely contribute to better cardiovascular fitness. The significant interaction effect for the sit-up test in boys, despite the lack of significant pairwise differences in *post hoc* analyses, suggests that while there are overall differences between countries and age groups, these differences may not be pronounced enough at the pairwise level. This could be due to the conservative nature of the post hoc test (51), small effect sizes (52), or variability within groups (53).

The disparities observed in this study emphasize the need for targeted public health strategies to enhance HPF while accounting for factors such as BMI and contextual influences. Countries with lower performance, such as Egypt, would benefit greatly from national-level policies aimed at improving PE programs and increasing access to organized sports. Early interventions focused on fitness development, particularly in areas such as sprint speed, abdominal strength, and endurance, are critical for reducing the risk of chronic diseases later in life (23, 54). Educational institutions play a pivotal role in implementing these interventions, as inclusive and culturally relevant PE programs can help address barriers such as gender disparities and unequal access to physical activity opportunities (55). The success of countries like Spain demonstrates the effectiveness of well-structured, evidence-based programs in fostering physical development and promoting long-term health. By adopting similar strategies tailored to their specific needs, countries with lower HPF levels, such as Egypt, can work toward achieving more equitable health outcomes for their youth populations.

The cross-country differences in HPF observed in this study likely stem from variations in PE curricula and their implementation, even after accounting for BMI. Structured PE programs that emphasize sports and fitness from an early age contribute to enhanced physical development in sprint speed, coordination, endurance, and strength (11–14). The consistent advantage in HPF observed in European Mediterranean countries and Lebanon highlights the effectiveness of these programs. For example, Italy's PE curriculum, which prioritizes general fitness and motor coordination over competitive sports fostering motor skill development without the intensity of sport-specific training (15). In contrast, Egypt faces additional challenges, such as inadequate infrastructure and limited resources, which contribute to its lower performance in several fitness components, including endurance and strength, particularly among girls (19).

These disparities underscore the importance of addressing both systemic and individual-level challenges to improve HPF in children. Barriers such as poor-quality PE classes, a limited variety of activities, insufficient equipment, and inadequate teacher training and commitment have been consistently reported across different contexts (56, 57). Furthermore, low levels of student participation, often linked to a lack of interest and engagement, pose significant obstacles to achieving the desired outcomes of school-based PE programs (58). However, facilitators such as increasing the diversity of PE activities, improving teacher training (particularly for temporary staff), and fostering peer and parental support have been identified as critical strategies to enhance active participation and improve fitness levels (26, 59–62). Implementing these evidence-based interventions could help address the disparities in physical fitness among children and enhance the effectiveness of school-based programs in promoting HPF and reducing inequalities. By targeting improvements in PE programs and addressing these barriers, balanced fitness development and equitable health outcomes can be fostered across diverse educational contexts.

Adapting PE curricula to address country-specific strengths and weaknesses can significantly enhance HPF across diverse cultural contexts. For instance, in countries like Egypt, where children demonstrate lower performance in cardiovascular endurance and strength, PE programs focusing on endurance-building and strength-oriented activities could be particularly beneficial. Furthermore, implementing age-appropriate fitness goals that align with observed age-related improvements will also optimize fitness outcomes. These recommendations align with frameworks such as the Social Ecological Model and Life Course Theory, which highlight the impact of cultural, social, and environmental factors on physical activity and fitness outcomes (3, 22). Research has consistently shown that HPF in children varies significantly across regions, influenced by societal norms, family dynamics, and educational contexts (24–26). Comparative studies like those by Luz et al. (27) and Bardid et al. (28), reveal how motor competence and fitness levels differ due to cultural practices and PE infrastructure. Cross-cultural research is essential for understanding these contextual influences and supporting public health strategies that ensure equitable access to fitness opportunities across diverse cultural settings (29). By developing culturally and developmentally tailored fitness programs, public health officials and educators can foster balanced fitness development and reduce the long-term health risks associated with physical inactivity.

While this study provides valuable insights into HPF across multiple Mediterranean countries, several limitations must be acknowledged. First, the sample size and regional coverage were limited, potentially affecting the generalizability of the findings. Future research should aim to include larger, more representative samples from a wider range of regions within each country to capture a more comprehensive range of fitness outcomes. Second, the study did not account for biological maturation, a key factor influencing physical development, particularly for strength and speed-related components. Variations in maturation rates may explain some of the observed differences in physical fitness outcomes. Therefore, future studies should incorporate measures of biological maturation to provide a more accurate understanding of developmental trajectories for different fitness components.

Additionally, socio-economic factors, dietary habits, and motivational aspects, which are known to significantly influence physical fitness, were not considered in this study. These variables may differ across cultural contexts and contribute to variations in fitness outcomes. Future research should explore the role of these factors to offer a more holistic view of the determinants of HPF among children. Finally, longitudinal studies are needed to track changes in fitness levels over time. These studies would provide valuable insights into how PE interventions or lifestyle changes impact fitness development in diverse cultural contexts. Addressing these limitations will enable the design of more culturally relevant, evidence-based interventions to promote balanced fitness development across populations.

5 Conclusion

This study highlights the significant influence of cultural, educational, and environmental factors on HPF components among children in five Mediterranean countries. Regions with

well-established PE programs and higher levels of sports participation demonstrated stronger performance in various fitness components, underscoring the importance of structured PE and accessible sports opportunities. In contrast, areas with lower fitness performance emphasize the need for policy-level interventions to enhance access to quality PE and sports programs. These cross-cultural comparisons offer valuable insights for developing targeted public health strategies that promote equitable fitness opportunities and support healthy lifestyles for children across diverse cultural settings. By addressing these disparities, policymakers and educators can implement tailored approaches that encourage balanced fitness development and foster long-term health benefits at the population level.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Ethics committee of Mondragon University (no. IEB-20230704). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MA: Conceptualization, Formal analysis, Funding acquisition, Investigation, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NE-G: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Writing – original draft. AS: Conceptualization, Formal analysis, Investigation, Methodology, Validation, Writing – original draft. OA: Conceptualization, Formal analysis, Funding acquisition, Investigation, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

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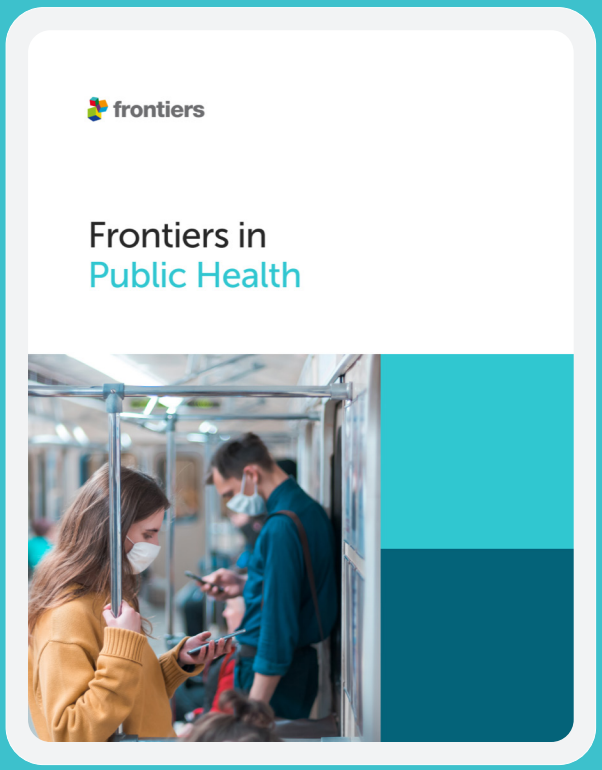

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