CHILDREN'S DEVELOPMENT DURING SOCIAL TRANSITION

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CHILDREN'S DEVELOPMENT DURING SOCIAL TRANSITION

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EDITORIAL
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Editorial: Children's Development During Social Transition

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Editorial on the Research Topic

Children's Development During Social Transition

INTRODUCTION

Adaptability is one of the key traits that enabled human kind to survive numerous environmental challenges throughout its history and spread throughout all the continents. Initially the main drivers of adaptations were natural factors such as climate and availability of food but with the settling down, society started to emerge and started adding its demands also for social adaptation. Culture and technology became the main sources of adaptational pressure which strongly intensified in modern times with industrial revolution and especially with communication revolution. The pace of lifestyle changes from the mid-twentieth century onwards has been exponentially increasing and profoundly changing the relationship between humans and our technology. Our natural environment has merged with technological environment and the constant technological revolution is forcing people to adapt to our own inventions. In adults, such environmental pressures induce mostly changes in our behavior, while in children, the environmental pressure can irreversibly alter the mode and pace of their development. Technological revolution is simultaneously intensifying also the socio-economic changes which are further altering children's environment. This environment is becoming extremely unstable and is characterized by constant transition.

When John Locke developed his "Tabula Rasa" theory as early as the seventeenth century in which he explained that "children come into the world with an empty mind, and that knowledge and learning is received through experience and converted to understanding through reasoning," he couldn't have imagined the multiplication of factors that influence the development of contemporary children. In this regard children's development has become extremely complex because the biological laws are being tested by various changes of economic, cultural, technological, ecological, and institutional developments on different scales (1). Facing the challenges of children's development in social transition, this Research Topic was created with intention to help the upbringing of strong children rather than to repair broken adults.

The purpose of this Research Topic was to gather the latest knowledge in the field of children's development during social transition. The 12 studies that emerged as the output of this special issue have advanced the field in several ways.

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First, some very interesting findings were reached in this Research Topic related to the monitoring of trends in children's development. The geographical variation in physical fitness among Chinese children and adolescents was explored by Dong et al. The authors concluded that the physical fitness showed an improved trend from 2005 to 2014 and that region-specific interventions with priority policies could be useful to sustainably reduce geographical inequalities in fitness of Chinese children, especially in the western provinces. Additionally, two systematic reviews analyzed trends in physical fitness among school-aged children and adolescents over the last 50 years (Masanovic et al.), and identified available field-based health-related physical fitness tests in children and adolescents that can be used in school settings (Marques et al.). These studies detailed the complex trend in physical fitness among school-aged children and adolescents that differed across the globe, and highlighted a need for a consensus and standardization of physical fitness assessments in school environment.

Another important stream of work is reflected in the studies that analyzed: (1) trajectories in body height, body weight, BMI, and nutrition status of male adolescents from the capital city of Montenegro (Popovic et al.), and (2) relationship between national economic development and body mass index in Chinese children and adolescents (Bu et al.). These studies help to characterize secular trends in one of the tallest nations in the world from the beginning of the twentieth century—Montenegro—which has specific body proportions, as well as the relationship between economic development and body mass index in Chinese children and adolescents during the economic transition. Both studies emphasized the importance of globalization and recognized its impact on children's development.

Next, one study in this special issue examined the influence of skeletal age and chronological age on pre-schoolers' physical fitness performance and found both to be related to skill-related, but not health-related fitness (Ke et al.). Another investigation examined dietary patterns and weight status of 6–9 year-old children and identified irregular breakfast consumption and sugar-sweetened bevarages intake as the most important risk factors for obesity (Bozic et al.). The timeliness of this topic is particularly reflected in two studies that have investigated the impact of COVID-19 pandemic on children's development. Vuković et al. investigated the children's daily routine response to COVID-19 emergency measures, while López-Bueno et al. evaluated health-related behaviors among school-aged children and adolescents during the COVID-19 confinement. These studies show support for a marked decrease in children's physical activity, but also suggest that more active children showed higher mental resilience during this public health crisis. Similarly, Ahad et al. in their opinion paper warned about possible spill over trends of child labor during the COVID-19 crisis.

Lastly, one of the studies from this special issue (Chao and Cheng) found that an educational course can be effective in improving the teenagers' understanding of the impact of adolescence on attitudes toward life, sex, gender equality, and mental health, while another study (Mieziene et al.) explored the direct and indirect relationships within the extended trans contextual model for moderate-to-vigorous physical activity in Physical Education and during leisure time, and demonstrated that the main goal of physical education of enhancing physical activity not only in school but also outside of school, is working.

CONCLUSION

Children's development is determined by genetic, but also by social factors, which shape and determine their everyday life. However, environmental factors in the contemporary world are becoming less stable and less predictable, especially in the conditions of rapid social changes such as socio-political, economic, and public health-related events that have been profoundly affecting the lifestyles of children in the last three decades. In this period, we witnessed the arrival of capitalist consumerism in ex-socialist European countries, rapid worldwide urbanization of previously rural societies, the global financial crisis of 2007–08, and the global COVID-19 pandemic of 2020, which all triggered profound and sudden transformations of society. Children had to adapt to each new situation, and studies compiled in this special issue indicate that these newly adapted social practices most often displaced otherwise habitual physical activity with sedentariness, causing the myriad of increased risks to normal somatic and motor development of children. Therefore, now, more than ever, understanding and developing strategies to promote physical activity behavior and to improve children's fitness levels are essential. These strategies can be developed in the school setting or in different contexts. To this end, this Research Topic leveraged high-quality research studying changes in children's development during social transition to offer guidance to policy makers around the globe on how to alleviate the consequences of abrupt societal changes.

AUTHOR CONTRIBUTIONS

SP drafted the editorial. GS, MS, and JJ revised and approved the final version. All authors contributed to the article and approved the submitted version.

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OPINION
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Spillover Trends of Child Labor During the Coronavirus Crisis- an Unnoticed Wake-Up Call

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Keywords: child labor, Coronavirus, unemployment, poverty, school

INTRODUCTION

The worldwide surge of Covid-19 pandemic threatens the lives of impoverished and vulnerable segments of society. Children, particularly, are at greater risk of maltreatment and neglect rather than disease contamination. Children in labor are the highly overlooked topic in research and national plans than other aspects of child abuse provoked by the Covid-19 outbreak.

DISCUSSION

According to estimates of the International Labour Organization (ILO) (1), there is still staggering 152 million child laborers, of which around 73 million are in hazardous work. This estimate of child laborers was around 210 million in 2000. Between 2002 and 2006, an 11% fall of child labor was noticed globally with a sharp decline of hazardous child labor (2). The present prevalence of child labor is deemed to be slowing in comparison with previous decades because of increased education, booming economies and improved labor laws (3). This has resulted in a significant proportion of child laborers being able to attend school. Unfortunately, it is predicted that the effects of the on-going Covid-19 pandemic and public health measures will break this cycle and revitalizing the presence of children in this illegitimate activity (4).

Public health measures such as lockdowns or social isolation during the Covid-19 outbreak have resulted in fears of economic recession and falls in stock market indices in most countries. Border shutdowns and travel restriction have subsequently led to a crash in demand for consumer goods, disruption in supply chains, falling product prices, low investment in manufacture, and curbed remittances between countries (4, 5). These unprecedented disruptions in the global production market have increased the risk of unemployment evoked by the Covid-19 outbreak. The ILO (6) reported that the dramatic decline of jobs and aggregated hours of work have already affected the world's 3.3 billion workers during the recent lockdown measures. The United Nations (UN) labor body projected that the economic disruption caused by the Covid-19 outbreak may wipe out 195 million jobs worldwide (7). In the USA alone, around 30.3 million initial claims for unemployment insurance were lodged between March 21 to April 25 of 2020 (8). This forecasts a massive increase in job losses during this outbreak both in high- and middle-income countries.

Despite the comprehensive surveillance strategies, many low- and middle-income countries (LMICs) are overwhelmed by the precipitous spread of Covid-19 contamination. Bong et al. (9) postulate that LMICs will suffer from overcrowded hospitals as a result of Covid-19 infected patients due to large populations, disregarding the imposed public health measures, and insufficient health care facilities. The aftermath may not be limited to respiratory infections but may result in precarious social and economic vulnerability in many afflicted and impoverished countries. The United Nations Development Programme (UNDP) report stresses that the forecast of income

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opportunity loss in poor or developing countries could exceed US $220 billion, which could take many years to recover (10). This economic recession would further expose rapid escalation of unemployment and poverty in these countries. The ILO and United Nations Children's Fund (UNICEF) (4) estimate that around 40 to 60 million people could fall into extreme poverty this year alone. The effects could also result in prolonged socio-psychological stressors.

A significant proportion of poor communities in the LMICs will experience extreme exploitation and hunger, as many parents fall into a poverty cycle. For instance, around 9.1% of the population in Sub-Saharan Africa are already in extreme poverty including 3.9 million children who are deprived of food at the end of first 8-weeks of the lockdown during the Covid-19 outbreak (11). Sufficient financial supports from public or private stakeholders to these impoverished people of many LMICs is also not evident in the media or in current research. The pressure of poverty will force parents to seek employment prospects for their children. Becker (12) suggests that one of the effects of Covid-19 may result in parental unemployment, sickness or death, a drop in household incomes, children will be forced into labor to meet the basic needs of their family members. The escalating prospect of child labor is associated with the upsurge of poverty rates. Sasmal and Guilen (13) note that when poverty persists, parents are forced to send their children to work.

The World Economic Forum reports that in the Ivory Coast, there has been a 10% decrease in households' income which led to an increase in child labor of 5% (14). Children from marginalized minority groups, homeless, migrant refugees, disabled, and those living in war or disaster-prone areas are at particular risk of extreme deprivation or starvation in this unprecedented crisis. The ILO and UNICEF (4) estimates that a 1% rise in poverty can result in a 0.7% surge in child labor. However, child labor violates the fundamental rights of children including their education, health, recreation, and other development prospects. The engagement in hazardous job in exhausting environment and working long hours will be prompted by poverty.

School closures during the Covid-19 outbreak will also trigger a resurgence of child labor plight. Research reveals that children who do not attend school are more likely to join the workforce than those who go to school (12). Past experiences reveal that in every pandemic, this complex experience emerges. For example, school closures during the Ebola pandemic crisis of 2014 resulted in an escalation of child labor (15). Of note, children lacking access to technology and the internet, will be unable to join in the online remote learning during the school closures. Kluttz (16) suggests that child labor is not simply an indicator of poverty, it is also a consequence of poor access to education. Even when schools re-open, many parents or guardian may no longer be able to afford to continue to pay for their child's schooling. Rural out-of-school children could be more vulnerable than urban child laborers. Due to poor maintenances of lockdown policies in rural precincts, the shutdown of schools and poor access to online education, families may tend to propel their children into work particularly in the rural agriculture sectors. Roughly 71% of child laborers are involved in the agriculture sector doing hazardous works. A significant proportion of them are bonded laborers (1). The exploitation of children in labor due to school closure would particularly be acute in Africa and Asia, where the majority of child laborers work in agriculture.

These explicit risk factors of the Covid-19 pandemic may apparently accelerate the growth of child labor around the globe. This sudden rise in the prevalence of child labor may wipe out the target of achieving Sustainable Development Goal 8.7, which focus on ending child labor in all its form such as eradicating forced labor, modern slavery, human trafficking and elimination of the worst forms of child labor, including recruitment and use of child soldiers by the year 2025 through integrated thinking, co-ordinated actions, effective policy practices, and use of resources (1). Therefore, to ensure the current gains are not lost, the governments of the affected countries should take immediate measures. Alongside raising public awareness to prevent child labor in this unprecedented crisis, the respective governments must set up cash transfer programmes with a priori-focus on the impoverished and vulnerable households and promote online education platforms with the necessary aids for vulnerable children.

AUTHOR CONTRIBUTIONS

MA, YP, and EW wrote this opinion paper together. MA developed the idea and wrote the first draft of the opinion paper. All authors contributed to the article and approved the submitted version.

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Health-Related Behaviors Among School-Aged Children and Adolescents During the Spanish Covid-19 Confinement

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In response to the coronavirus disease 2019 (Covid-19) world pandemic, affected countries such as Spain enacted measures comprising compulsory confinement as well as restrictions regarding free movement. Such measures likely influence children's and adolescents' lifestyles. Our study aimed to investigate the impact that the Covid-19 confinement has on health-related behaviors (HRBs) among Spanish children and adolescents. An online survey was administered to 516 parents to collect data about 860 children and adolescents (49.2% girls) aged between 3 and 16 years in relation to physical activity, screen exposure, sleep time, and fruit and vegetable consumption during the Covid-19 confinement. Respectively, *t*-paired test and *t*-test between groups served to check differences between HRBs levels before and during the confinement as well as between strict and relaxed confinement. Significant differences were found for a reduction of weekly minutes of physical activity during the confinement (−102.5, *SD* 159.6) ($p < 0.001$), an increase of daily hours of screen exposure (2.9, *SD* 2.1) ($p < 0.001$), and a reduction of daily fruit and vegetable consumption (−0.2, *SD* 1.6) ($p < 0.001$). Sleep time showed a significant difference between strict and relaxed confinement (−0.3, *SD* 0.1) ($p < 0.05$), whereas binomial logistic regression adjusted for covariates (age, sex, education of the parents, siblings, current condition, exposure to Covid-19, and previous health risk behavior) showed significantly lower odds for screen exposure risk behavior with relaxed confinement (OR 0.60, 95%CI 0.40–0.91). The present study suggests that Covid-19 confinement reduced physical activity levels, increased both screen exposure and sleep time, and reduced fruit and vegetable consumption. Therefore, most HRBs worsened among this sample of Spanish children and adolescents. Closure of schools, online education, and the lack of

policies addressing the conciliation between labor and family life could have played an important role in HRBs worsening among pupils, which might be mitigated with adequate conciliation policies, parental guidance, and community support.

Keywords: children, adolescents, health-related behaviors, lifestyle habits, coronavirus disease, confinement

INTRODUCTION

The global pandemic of coronavirus disease 2019 (Covid-19) has forced many countries to enact confinement measures to reduce the spread of the virus (SARS-CoV-2). The Spanish Government declared a state of alarm followed by a compulsory set of measures including strict free movement restrictions implemented from 15 March 2020 onwards (1, 2). To date, these measures have been observed to be effective since new contagious have been substantially reduced, which has permitted to start with a de-escalation phase toward usual daily routine. However, the experience of a long period of confinement may have had a significant impact on those who have suffered the strictest restrictions of free movement and other potential consequences such as the problems for families derived from the lack of conciliation between labor and family life.

In this regard, the compulsory movement restriction meant the prohibition of movement of children outside households up to 6 or more weeks in a row, with no certainty about potentially damaging consequences on their health and well-being. Additionally, because 94.1% of the Covid-19-infected children do not present symptoms or have mild-to-moderate disease (3), affecting mainly the elderly with whom the minors share households with (4), social distancing measures were put in place across Europe to reduce the human-to-human infection; such measures included the closing of schools and high schools. Consequently, several pupils have been affected by the temporary closing of their schools and high schools and the adoption of online learning platforms instead (5).

The United Nations stated that the mitigation measures may inadvertently do more harm than good (6), and in this context, the closing of schools and high schools supposedly isolates and socially deprives many children of all ages around the world. Numerous studies have previously linked isolation to different conditions such as cardiovascular disease among children (i.e., elevated total cholesterol, elevated blood pressure, overweight, low high-density lipoprotein level, low maximum oxygen consumption, and elevated glycated hemoglobin concentration), and social deprivation has been observed to have a negative effect over social cognition and both emotional and motor developments (7–10). Therefore, since a substantial amount of children and adolescents might have been temporarily deprived of parental care, adequate healthy and sustained routines, and cognitive and physical stimuli for their age, research relating to this topic is urgently required. For instance, due to the Covid-19 movement restrictions, a higher homestay would be expected, which, in turn, might increase screen exposure (11); at the same time, higher levels of screen exposure might also lead to lower levels of physical activity and, eventually, lower sleep time (12, 13), which along with circadian deregulation may influence Covid-19 infection and severity (14). Furthermore, recent studies have observed a significant reduction in physical activity levels of adults during the Covid-19 confinement (15, 16). Moreover, such studies have found that adults experiencing higher reductions in physical activity levels or performing lower levels of physical activity during the Covid-19 pandemic have poor mental health and well-being (17, 18). Indeed, similar associations observing poorer mental health as a consequence of a reduction of physical activity levels due to the Covid-19 confinement might also exist for children and adolescents.

In this unprecedented situation due to Covid-19 confinement, where infection mitigation measures may have had an impact on the usual lifestyle, there are no studies yet examining how the experience of Covid-19 confinement has influenced health-related behaviors (HRBs) in children and adolescents. Therefore, the present study aimed to analyze the influence of confinement over HRBs in Spanish children and adolescents, which could contribute to informing future public health strategies as aimed at this specific population. Based on previous literature, we hypothesized that both strict and relaxed Covid-19 confinement would be associated with unfavorable HRBs when compared with pre-Covid-19 confinement setting. Indeed, stronger associations between strict confinement and worse HRBs are expected.

METHODS

A parent-reported questionnaire was conducted to assess associations between phases of confinement and HRBs during the Covid-19 pandemic in children and adolescents.

The Survey

A web-form link served to collect data regarding HRBs during the period 22 March to 10 May 2020 (i.e., from the 7th day of enacted national confinement in Spain up to the 15th day of relaxed confinement for children). The survey was launched on social media on 22 March 2020, together with initial information about the aim of the study. Adults residing in Spain, aged 18 years and over, having children, and currently confined due to Covid-19 were eligible to participate. Convenience sampling was used to select the participants of the study; according to server analytics, 650 adult media users covering all the Spanish regions were invited to participate. Participants were provided with an information sheet about the study aims as well as the instructions for the survey, gave informed consent to participate, and confirmed the confined status of their children. Provided data were anonymously treated in accordance with Spanish law for general data protection. At the end of the survey, participants were provided with recommendations regarding health habits. Overall, 516 parents provided data about 860 children and adolescents in relation to the following variables:

age, gender, education of the parents, previous condition, number of siblings, phase of confinement, exposure to Covid-19, physical activity, screen exposure, sleep time, and fruits and vegetable consumption.

Ethics

The study was conducted following the principles of the World Medical Declaration of Helsinki and was approved by the Ethics Committee of Research in Humans of the University of Valencia (register code 1278789). The study was reported accordingly to the Strengthening the Reporting of Observational Studies in Epidemiology statement (19).

The Phase of Confinement (Exposure)

Data from web server corresponding to the date of completing the survey served to categorize this variable into those experiencing strict confinement (i.e., those completing the questionnaire from 1 April up to 25 April) and those experiencing relaxed confinement (i.e., those completing the questionnaire from 26 April up to 10 May). These date intervals were set in accordance to the measures enacted by the Spanish Government in relation to the Covid-19 pandemic (1, 2); strict confinement did not allow any free movement of minors outside the household if not for medical reasons or, in the case of those aged 15 or over, to do the shopping or take a dog for a short walk once a day, and, in any case, keeping a compulsory social distance of 1.5 m from others. On the other hand, relaxed confinement permitted minors aged below 14 years to go outside once a day for no more than an hour, accompanied by an adult, in a time band from 9:00 a.m. to 9:00 p.m. and keeping a social distance of 2 m from others. Also, minors aged 14 years joined the group of those aged 15 years or over to be allowed to do the same from that moment. Finally, from 2 May, those aged 14 years or over were permitted to do physical activity outside the household in two specific time bands (6:00 a.m. to 10:00 a.m. and 8:00 p.m. to 11:00 p.m.), whereas the time band for those aged below 14 years was restricted to 12:00 a.m. to 7:00 p.m. for activities outside the home. **Figure 1** displays an illustration of the key dates regarding this study.

Health-Related Behaviors (Outcome)

Outcome variables were estimated through a set of four questions included in the survey in relation to four HRBs (i.e., physical activity, screen exposure, sleep time, and fruit and vegetable consumption). The answers of the parents to the following single-item questions were used as proxy measures of their children's HRBs: "How many minutes of physical activity does your child usually perform weekly?" and answers ranging from "0" to "More than 720;" "How many hours is your child usually exposed to screens such as TV, cell phone, and tablet daily?," with possible answers ranging from "0 h" to "more than 10 h;" "How many hours does your child usually sleep daily?, with answers comprising from "<5 h" to "more than 10 h;" "How many pieces of fruit and vegetables do your child usually eat daily?, and possible answers ranging from "0" to "more than 5." These questions were asked twice to the parents; first, referred to before the confinement setting and, second, regarding the confinement setting. Single-item questions used to estimate HRBs such as physical activity have shown high reproducibility [Spearman's rank correlation coefficients ($r = 0.72$–0.82)], as well as a strong agreement when meeting physical activity guidelines (kappa = 0.63, 95%CI 0.54–0.72) (20). Also, the use of parents' self-reporting to estimate children's physical activity and sedentary time has shown significant positive associations when both were accelerometer-measured ($p < 0.001$) (21).

Based on current guidelines and relevant research, a corresponding health risk behavior was defined for each HRB as follows: <420 weekly minutes of physical activity (physical activity); more than 2 h of daily screen time (screen exposure); <9 daily sleep hours (sleep time); and <3 pieces of fresh fruits and vegetables a day (fruit and vegetable consumption) (22–25). For each HRB, participants were categorized into those meeting the definition of health risk behavior and those not meeting the definition of health risk behavior.

Covariates

According to previous research (26–28), the present study also estimated age, gender, education of the parents, previous condition, number of siblings, and exposure to Covid-19. Responses of the parents regarding their children were categorized as follows: age [cutoff points for years were set according to current school stages in Spain: infants (3–5 years), primary (6–12 years), and secondary (13–16 years)]; education of the parents ("any of the parents holding a university degree" or "none of the parents holding a university degree"); current condition ("experiencing any physical or mental condition" or "not experiencing any physical or mental condition;" number of siblings ("having one or more siblings" or "not having any sibling"); and Covid-19 exposure ("infected with Covid-19 or close to an infected person" or "not exposed"). Finally, the previous health risk behavior of the children (i.e., meeting or not meeting the definition of health risk behavior before the Covid-19 confinement) was also considered.

Statistical Analyses

Statistical analyses were conducted through Stata version 16.1 (StataCorp, Texas, USA). The Kołmogorov–Smirnov test served to check normality. Differences between each HRB before and during the confinement as well as between strict and relaxed confinement were respectively assessed using paired *t*-test and *t*-test between groups. Also, the effect size for these differences was checked calculating Cohen's d. Associations between type of confinement due to Covid-19 and each HRB were assessed using binomial logistic regressions adjusted for covariates, providing adjusted odds ratios (ORs) and 95% CIs for the whole sample. We also conducted stratified analyses to check associations concerning gender and age. Finally, propensity score with nearest-neighbor matching served to further check the differences between strict and relaxed confinement for each HRB. Participants with missing data in any study variable were discarded for the study ($n = 45$). Levels of significance were set at $p < 0.05$.

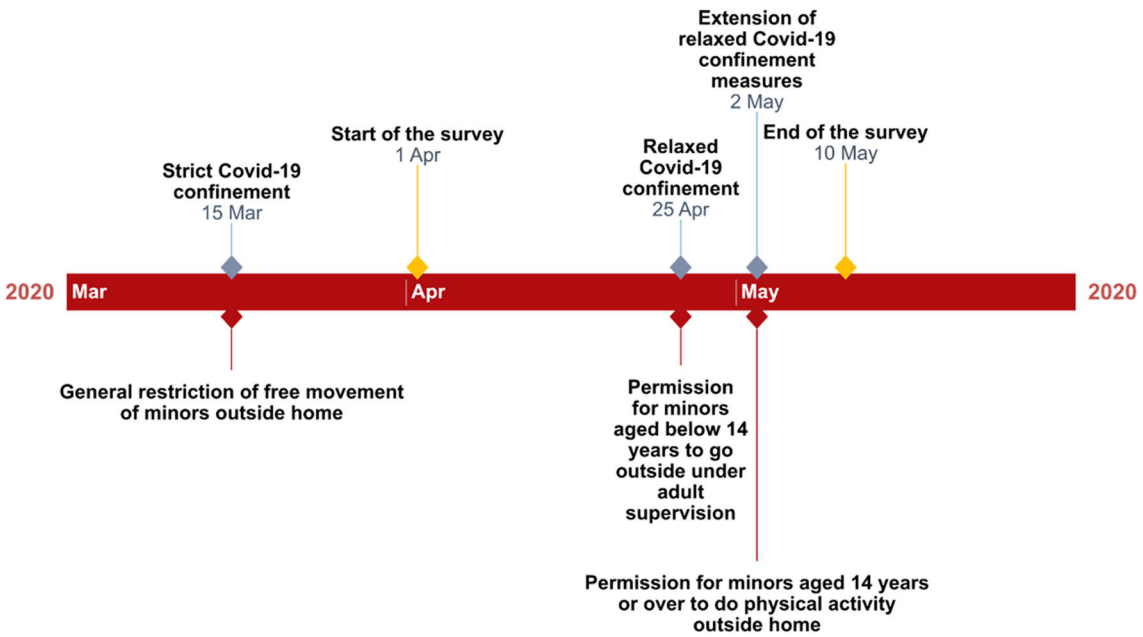

FIGURE 1 | Timeline of the most important Covid-19 confinement measures regarding minors in Spain.

RESULTS

The characteristics of the sample are presented in **Table 1**. A total of 860 children and adolescents on average aged 9.6 (*SD* 3.9) participated in this study. Of those, 423 (49.2%) were girls, and 611 (71.1%) were experiencing strict confinement. At the time of the questionnaire reply, 35 (4.1%) participants declared having being exposed to Covid-19 and 144 (16.7%) having a previous condition. Overall, the number of participants with siblings is 692 (80.5%), whereas that with any parent holding a university degree represents 28.8% of the sample.

Table 2 shows previous levels for each HRB as well as differences between before and during Covid-19 confinement. Previous physical activity levels were estimated in 198.6 (*SD* 180.9) weekly minutes for the whole sample; boys and younger participants reached the highest levels with 211.9 (*SD* 188.4) and 223.0 (*SD* 198.0) weekly minutes, respectively. Screen exposure was overall estimated as 2.0 (*SD* 1.6) daily hours; boys 2.1 (*SD* 1.7) and older participants reach the highest levels 2.4 (*SD* 1.3) for this HRB. Concerning daily sleep hours, these are estimated in 9.1 (*SD* 1.2) for the entire sample; the subgroup of younger participants shows the highest values for this HRB: 9.8 (*SD* 1.2). Finally, daily fruit and vegetable consumption is estimated in 3.2 (*SD* 2.0) pieces for all the participants: boys with 3.3 (*SD* 2.1), and those from the younger subgroup present the highest values for this HRB with 3.7 (*SD* 2.1) daily pieces in subgroup comparisons. Overall physical activity and all gender and age subgroups display significant reduction between before and during the confinement; the subgroup of participants aged between 6 and 12 years displays the highest reduction of weekly minutes [−120.4 (*SD* 159.0)]. Also, screen exposure shows a significant increase for all the participants as well as for all subgroups; the highest increase is observed for older participants who show 3.3 (*SD* 2.1) more daily hours. Sleep time presents significant differences only for the younger and older participant subgroups with, respectively −0.4 (*SD* 1.8) and 0.6 (*SD* 1.7) daily hours. Concerning daily fruits and vegetable consumption, all the subgroups present significant reductions with the exception of the subgroup of older participants; the highest reductions are presented in the subgroup of the younger participants [−0.6 (*SD* 2.0)].

Table 3 shows differences concerning HRBs between strict and relaxed Covid-19 confinement. Sleep time is the only HRB that shows significant differences in both overall and specific subgroups such as boys [−0.4 (*SD* 0.2) daily sleep hours] and participants aged between 6 and 12 years [−0.3 (*SD* 0.2) daily sleep hours].

Adjusted ORs for each health risk behavior during COVID-19 confinement are presented in **Table 4**. Solely screen exposure shows significant odds reduction of health risk behavior overall (OR 0.60 95%CI 0.40–0.91) as well as in girls (OR 0.55 95%CI 0.31–0.99) and participants aged between 6 and 12 years (OR 0.26 95%CI 0.03–0.92).

Finally, **Table 5** shows the average treatment effect on treatment (relaxed confinement participants), in which none of the HRBs present significant treatment effects.

DISCUSSION

The present study provides novel data from an unprecedented set of public health measures restricting the mobility of children

TABLE 1 | Characteristics of the study sample.

N = 860	*n* (%)	Mean (*SD*)
Gender		
Boys	437 (50.8)	
Girls	423 (49.2)	
Age		9.6 (3.9)
Confinement		
Strict	611 (71.1)	
Relaxed	249 (28.9)	
Education of the Parents		
Holding a university degree	248 (28.8)	
Not holding a university degree	612 (71.2)	
Siblings		
Yes	692 (80.5)	
No	168 (19.5)	
Current Condition		
Yes	144 (16.7)	
No	716 (83.3)	
Exposure to Covid-19		
Yes	35 (4.1)	
No	825 (95.9)	
Physical Activity (weekly minutes)		
Before confinement		198.6 (180.9)
During strict confinement		95.5 (123.8)
During relaxed confinement		97.8 (121.4)
Screen Exposure (h/day)		
Before confinement		2.0 (1.6)
During strict confinement		4.9 (2.3)
During relaxed confinement		4.8 (2.3)
Sleep Time (h/day)		
Before confinement		9.1 (1.2)
During strict confinement		9.3 (1.6)
During relaxed confinement		9.0 (1.7)
Fruit and Vegetable		
Consumption (portion/day)		
Before confinement		3.2 (2.0)
During strict confinement		3.1 (2.1)
During relaxed confinement		2.8 (1.9)

and adolescents as a result of the Covid-19 pandemic. The most relevant finding in this study with an important sample of the Spanish child and adolescent population was that overall examined HRBs, except for sleep time, worsened with the confinement. Also, only levels and odds of health risk behavior for screen exposure significantly improved during the 1st weeks of relaxed confinement, although further analyses did not confirm such a trend. Values for physical activity, screen exposure, and fruit and vegetable consumption also worsened during the confinement in all gender and age subgroups except for ≥13 and ≤16 years' subgroup for the last case (i.e., fewer minutes of weekly physical activity, more hours of daily screen exposure, and less daily pieces of fruit and vegetable consumed), whereas only screen exposure improved (i.e., less time exposed to screens).

Physical Activity

The association between social isolation and lower levels of physical activity in children was reported a few decades ago (29). More recently, a reduction of physical activity (i.e., 2.30 h/week) has been found in prior research regarding confined children and adolescents due to Covid-19 (30); such values were higher than those found in the present study, which observed a difference of 1.40 h/week in respect to previous confinement levels. Differences between the two studies concerning physical activity could be attributed to different sample characteristics; for instance, children from higher socioeconomic backgrounds have shown higher levels of physical activity, whereas the context of confinement might influence physical activity levels (e.g., more time confined or experiencing stricter confinement can modify ordinary levels of physical activity) (28–32). Closure of schools during both strict and relaxed confinement might play a key role in this found reduction since schools, and, particularly physical education classes provide an adequate environment to promote active behaviors among children and adolescents (33–35). Also, current research does not show evidence enough to consider the possibility that such activity behaviors could be compensated at home (36, 37). Finally, because healthy habits such as active commuting to schools (i.e., walking or cycling), which has been associated with increasing overall physical activity, and reducing sedentary behaviors (38, 39), have been restricted during both strict and relaxed confinement, it was difficult to expect that those physically active behaviors could be compensated at home; this might partially explain the finding of a recent study observing adolescents living in rural areas as more prone to reduce their physical activity levels during the Covid-19 pandemic when compared with their rural counterparts (40). Particularly, adolescents with lower physical fitness were observed to greatly reduce their physical activity levels during the Covid-19 pandemic (40, 41).

Screen Exposure

With higher time spent at home, it was expected that screen exposure could reach higher levels than before the Covid-19 confinement. A recent study found screen exposure to increase by 4 h/day among Italian children and adolescents during Covid-19 strict confinement (30). Furthermore, online gaming and streaming activity have been observed to rise in different countries during the Covid-19 confinement (42). Also, ordinary school attendance has been largely substituted by both digital homework and digital classes in Spain, which could have added more screen time to the already existing before the confinement. Particularly, mobile phones could have had a significant impact on teenagers' socialization processes and have added more screen time while confined (43); the lower odds for health risk behavior observed for the ≥13 and ≤16 years' subgroups with the relaxed confinement could be also explained by higher opportunities to physically meet their friends. Moreover, since Spanish workers have been instructed to telework at home during the Covid-19 confinement, the use of electronic devices might have contributed

TABLE 2 | Differences regarding health-related behaviors before and during Covid-19 confinement.

	n (%)	Before confinement Mean (*SD*)	During confinement Mean (*SD*)	Difference (before and during confinement) (*SD*)	*t*	df	*p*-value[a]	*d*[b]
Physical Activity (min/week)								
Overall (*n* = 860)		198.6 (180.9)	96.1 (123.0)	−102.5 (159.6)	18.8	859	0.0000	0.66
Gender								
Boys	437 (50.8)	211.9 (188.4)	104.8 (130.0)	−107.1 (170.2)	13.1	436	0.0000	0.66
Girls	423 (49.2)	184.9 (172.0)	87.2 (114.9)	−97.7 (148.0)	13.6	422	0.0000	0.67
Age								
≥3 and ≤5 years	162 (18.8)	223.0 (198.0)	131.0 (160.2)	−92.0 (174.0)	6.7	161	0.0000	0.51
≥6 and ≤12 years	459 (53.4)	209.0 (180.0)	88.6 (112.4)	−120.4 (159.0)	16.2	458	0.0000	0.80
≥13 and ≤16 years	239 (27.8)	162.1 (165.3)	86.9 (109.3)	−75.2 (146.4)	7.9	238	0.0000	0.54
Screen Exposure (h/day)								
Overall (*n* = 860)		2.0 (1.6)	4.9 (2.3)	2.9 (2.1)	39.4	859	0.0000	1.43
Gender								
Boys	437 (50.8)	2.1 (1.7)	5.0 (2.4)	2.9 (2.2)	28.0	436	0.0000	1.43
Girls	423 (49.2)	1.9 (1.5)	4.7 (2.3)	2.8 (2.1)	27.7	422	0.0000	1.44
Age								
≥3 and ≤5 years	162 (18.8)	1.7 (1.9)	3.9 (2.0)	2.2 (2.4)	11.6	161	0.0000	1.13
≥6 and ≤12 years	459 (53.4)	1.9 (1.5)	4.7 (2.3)	2.9 (2.0)	30.8	458	0.0000	1.46
≥13 and ≤16 years	239 (27.8)	2.4 (1.3)	5.8 (2.3)	3.3 (2.1)	24.7	238	0.0000	1.74
Sleep Time (h/day)								
Overall (*n* = 860)		9.1 (1.2)	9.2 (1.6)	0.1 (1.8)	1.5	859	0.1288	0.06
Gender								
Boys	437 (50.8)	9.1 (1.2)	9.3 (1.6)	0.2 (1.7)	1.9	436	0.0648	0.11
Girls	423 (49.2)	9.1 (1.2)	9.1 (1.7)	0.0 (1.8)	0.3	422	0.7635	0.02
Age								
≥3 and ≤5 years	162 (18.8)	9.8 (1.2)	9.4 (1.7)	−0.4 (1.8)	3.1	161	0.0025	0.30
≥6 and ≤12 years	459 (53.4)	9.2 (1.1)	9.2 (1.6)	0.0 (1.7)	0.1	458	0.9563	0.00
≥13 and ≤16 years	239 (27.8)	8.5 (1.0)	9.1 (1.7)	0.6 (1.7)	5.4	238	0.0000	0.44
Fruit and Vegetable Consumption (portion/day)								
Overall (*n* = 860)		3.2 (2.0)	3.0 (2.1)	−0.2 (1.6)	3.4	859	0.0007	0.09
Gender								
Boys	437 (50.8)	3.3 (2.1)	3.1 (2.2)	−0.2 (1.6)	2.3	436	0.0213	0.08
Girls	423 (49.2)	3.1 (1.9)	2.9 (1.9)	−0.2 (1.6)	2.5	422	0.0125	0.11
Age								
≥3 and ≤5 years	162 (18.8)	3.7 (2.1)	3.1 (2.1)	−0.6 (2.0)	3.7	161	0.0003	0.28
≥6 and ≤12 years	459 (53.4)	3.1 (2.0)	2.9 (2.0)	−0.2 (1.5)	2.7	458	0.0064	0.10
≥13 and ≤16 years	239 (27.8)	3.0 (2.0)	3.1 (2.1)	0.1 (1.4)	1.1	238	0.2800	0.05

[a] *t-paired test (before and during confinement).*
[b] *Cohen's d: small 0.20; medium 0.50; large 0.80.*

to increasing children's behavior as regards exposure to screen since there is a possibility of children being influenced by their parent's behaviors regarding this issue; family environment concerning screen exposure has been observed to directly associate with children's exposure to screens (44). Further, the increase of hours exposed in front of a screen observed in this study might also explain the lower levels of physical activity found since higher screen time has been previously associated with lower physical activity among Spanish adolescents (12).

Sleep Time

Because children were experiencing a change as regards their usual daily habits, it was expected to find different sleep times in this study; overall, sleep time variations are normal among children aged between 3 and 7 years (45). However, contrary to expected, sleep time tended to slightly increase during the confinement, even though higher screen time and lower physical activity could have reduced sleep time since the opposite was observed in prior research with children (46, 47). However,

TABLE 3 | Differences regarding health-related behaviors between strict and relaxed Covid-19 confinement.

	n (%)	Strict confinement Mean (*SD*)	Relaxed confinement Mean (*SD*)	Difference (strict and relaxed confinement) (*SD*)	*t*	df	*p*-value[a]	*d*[b]
Physical Activity (minutes/week)								
Overall (*n* = 860)		95.5 (123.8)	97.8 (121.4)	2.3 (9.3)	0.2	858	0.8051	0.02
Gender								
Boys	437 (50.8)	103.8 (130.0)	107.4 (130.6)	3.6 (13.7)	0.2	435	0.7924	0.03
Girls	423 (49.2)	86.9 (116.7)	87.9 (110.8)	1.0 (12.3)	0.1	421	0.9341	0.01
Age								
≥3 and ≤5 years	162 (18.8)	119.8 (148.0)	156.2 (183.7)	36.4 (27.2)	1.3	160	0.1826	0.23
≥6 and ≤12 years	459 (53.4)	90.2 (119.9)	84.9 (93.2)	−5.3 (11.4)	0.5	457	0.6414	0.05
≥13 and ≤16 years	239 (27.8)	89.6 (113.0)	78.8 (99.5)	−10.8 (16.3)	0.7	237	0.5098	0.10
Screen Exposure (h/day)								
Overall		4.9 (2.3)	4.8 (2.3)	0.1 (0.2)	0.8	858	0.4345	0.06
Gender								
Boys	437 (50.8)	5.1 (2.4)	4.8 (2.3)	−0.3 (0.2)	1.2	435	0.2075	0.13
Girls	423 (49.2)	4.7 (2.3)	4.7 (2.4)	0.0 (0.2)	0.2	421	0.8478	0.02
Age								
≥3 and ≤5 years	162 (18.8)	4.0 (1.9)	3.9 (2.2)	−0.1 (0.3)	0.3	160	0.7290	0.06
≥6 and ≤12 years	459 (53.4)	4.7 (2.3)	4.8 (2.3)	0.1 (0.2)	0.4	457	0.6543	0.05
≥13 and ≤16 years	239 (27.8)	5.9 (2.3)	5.4 (2.4)	−0.4 (0.3)	1.2	237	0.2315	0.18
Sleep Time (h/day)								
Overall		9.3 (1.6)	9.0 (1.7)	**−0.3 (0.1)**	2.3	858	0.0209	0.17
Gender								
Boys	437 (50.8)	9.4 (1.6)	9.0 (1.6)	**−0.4 (0.2)**	2.2	435	0.0255	0.23
Girls	423 (49.2)	9.2 (1.6)	9.0 (1.8)	−0.2 (0.2)	1.0	421	0.2956	0.11
Age								
≥3 and ≤5 years	162 (18.8)	9.5 (1.6)	9.2 (1.8)	−0.3 (0.3)	0.9	160	0.3715	0.15
≥6 and ≤12 years	459 (53.4)	9.3 (1.6)	9.0 (1.7)	**−0.3 (0.2)**	2.1	457	0.0350	0.21
≥13 and ≤16 years	239 (27.8)	9.2 (1.6)	9.0 (1.8)	−0.2 (0.2)	0.8	237	0.4010	0.13
Fruit and Vegetable Consumption (portion/day)								
Overall		3.1 (2.1)	2.8 (1.9)	−0.2 (0.2)	1.6	858	0.1127	0.12
Gender								
Boys	437 (50.8)	3.2 (2.3)	2.9 (1.9)	−0.3 (0.2)	1.4	435	0.1554	0.15
Girls	423 (49.2)	2.9 (1.9)	2.8 (2.0)	−0.2 (0.2)	0.8	421	0.4356	0.08
Age								
≥3 and ≤5 years	162 (18.8)	3.2 (2.0)	3.1 (2.4)	−0.1 (0.4)	0.2	160	0.8463	0.03
≥6 and ≤12 years	459 (53.4)	3.0 (2.1)	2.7 (1.8)	−0.3 (0.2)	1.3	457	0.2073	0.13
≥13 and ≤16 years	239 (27.8)	3.2 (2.2)	2.8 (1.9)	−0.3 (0.3)	1.1	237	0.2828	0.16

[a] *t-test between groups (strict and relaxed confinement).*
[b] *Cohen's d: small 0.20; medium 0.50; large 0.80.*
Bold values mean significant values ($p < 0.05$).

this increase was similar to what was found in another study among Italian children and adolescents during the Covid-19 confinement (30); thus, this situation might have contributed to reinforcing timetables, which, in turn, might have been useful to mitigate potential detrimental effects over adequate sleep time (48). In contrast, a recent study among French adults found that 47% reported a decrease in sleep quality during quarantine, with sleep reduction being the most associated factor (49).

Fruit and Vegetable Consumption

There is no prior evidence on how Covid-19 confinement might have influenced eating habits as regards fruits and vegetables among children and adolescents. Interestingly, our study found an important significant reduction of fruit and vegetable consumption during the Covid-19 confinement for the subgroup of children aged between 3 and 5 years. A possible explanation for this finding might be related to difficulties balancing family and working life since many parents have had to

TABLE 4 | Adjusted odds ratios (95% confidence interval) for each health risk behavior during Covid-19 confinement in the entire study population and in age and gender subgroups (reference group: strict confinement).

n = 860	Confinement	*n* (%)	Physical activity		Screen exposure		Sleep time		Fruits and vegetable consumption	
			Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]	Model 1[a]	Model 2[b]
All	Strict	611 (71.1)	1	1	1	1	1	1	1	1
	Relaxed	249 (29.0)	0.98 (0.50–1.92)	0.72 (0.34–1.54)	**0.66 (0.44–0.99)**	**0.60 (0.40–0.91)**	1.40 (1.03–1.93)	1.31 (0.95–1.81)	1.13 (0.77–1.66)	0.79 (0.46–1.36)
Gender										
Boys	Strict	311 (71.2)	1	1	1	1	1	1	1	1
	Relaxed	126 (28.8)	1.04 (0.44–2.42)	0.78 (0.30–2.03)	0.66 (0.36–1.20)	0.63 (0.34–1.19)	1.34 (0.86–2.11)	1.30 (0.81–2.09)	0.93 (0.56–1.56)	0.60 (0.28–1.28)
Girls	Strict	300 (70.9)	1	1	1	1	1	1	1	1
	Relaxed	123 (29.1)	0.85 (0.28–2.60)	0.74 (0.20–2.71)	0.66 (0.38–1.14)	**0.55 (0.31–0.99)**	1.47 (0.95–2.28)	1.31 (0.83–2.05)	1.42 (0.80–2.54)	1.03 (0.47–2.28)
Age										
≥3 and ≤5 years	Strict	112 (69.1)	1	1	1	1	1	1	1	1
	Relaxed	50 (30.9)	0.51 (0.19–1.39)	0.36 (0.11–1.22)	0.60 (0.29–1.27)	0.57 (0.26–1.23)	1.17 (0.55–2.49)	1.02 (0.46–2.62)	0.97 (0.43–2.17)	1.10 (0.28–4.29)
≥6 and ≤12 years	Strict	320 (69.7)	1	1	1	1	1	1	1	1
	Relaxed	139 (30.3)	2.10 (0.57–7.17)	1.10 (0.26–4.39)	0.81 (0.48–1.38)	0.78 (0.45–1.36)	1.38 (0.90–2.11)	1.25 (0.80–1.93)	1.36 (0.79–2.32)	0.90 (0.44–1.84)
≥13 and ≤16 years	Strict	179 (74.9)	1	1	1	1	1	1	1	1
	Relaxed	60 (25.1)	1.05 (0.20–5.45)	0.66 (0.11–4.16)	**0.31 (0.09–0.99)**	**0.26 (0.03–0.92)**	1.62 (0.88–2.96)	1.60 (0.86–2.98)	0.92 (0.44–1.94)	0.31 (0.09–1.05)

[a]Adjusted for age and gender (all participants), for gender (age categories), and for age (boys, girls).
[b]Model 1 + education, siblings, current condition, exposure to Covid-19, and previous health risk behavior.
Bold values mean significant values ($p < 0.05$).

TABLE 5 | Differences between relaxed confinement and strict confinement for each health-related behavior.

Health-related behavior	ATT			
	Treated	Control	Difference (*SD*)	*p*
Physical activity (min/week)	97.8	90.0	7.8 (9.5)	0.393
Screen exposure (h/day)	4.8	4.9	−0.1 (0.2)	0.464
Sleep time (h/day)	9.0	9.1	−0.1 (0.2)	0.270
Fruits and vegetable consumption (portion/day)	2.8	3.1	−0.3 (0.2)	0.105

ATT, average treatment effect on treated calculated as a difference for each health-related behavior between the relaxed confinement (treated) and strict confinement (control); difference, treated—controls; SD, standard deviation.

telework while taking care of their children during the Covid-19 pandemic; this situation might have led to poorer eating habits, particularly among those children potentially less independent (i.e., younger children). Similarly, a study with Italian children and adolescents confined due to Covid-19 pandemic showed higher red meat, potato chip, and sugary drink consumption (30), which suggests that, as observed in the present study, eating habits overall might have worsened during the confinement. In contrast, a recent survey among 600 Spanish adults reported that most of the participants maintained vegetable and fruit consumption during the first 5 confinement weeks, although these results might have changed after the whole confinement period (50). Also, lower food away from home consumption was linked to changes in diet quality (i.e., less added sugars and added fats, and more fiber consumption) (51), although, for this specific and unprecedented context differences regarding usual eating habits and socioeconomic family status (i.e., higher family socioeconomic status usually lead to healthier eating habits), self-regulating behaviors and knowledge might play an important role (52). Also, school canteen deprivation could influence the fruit and vegetable consumption since that has observed to worsen healthy habits concerning diet (53). Besides, since the likelihood of eating at convenience during Covid-19 confinement might have increased, that could have contributed to maintaining similar levels of fruit and vegetable consumption during this period as the active choice could benefit this behavior among children (54).

Overall, both parental guidance and example can strongly influence children's and adolescent behaviors regarding diet, screen, and physical activity habits (55, 56), which, in turn, could be also influenced by socioeconomic variables such as education and income (i.e., higher education or higher income may lead to healthier HRB) (52, 57). Health complications for children and adolescents derived from prolonged confinement or repeated viruses' outbreaks might comprise a higher fat percentage, lower bone mineral density, lower motor competence, higher blood pressure, and higher socio-emotional behavior problems later, among others (58–63). Therefore, further research examining longitudinal consequences of confinement over objectively assessed health behaviors (e.g., use of accelerometers for estimating physical activity) would contribute to better understand the reasons for changes in

HRBs as well as to define better strategies aimed at vulnerable populations such as children and adolescents; also, the study of adaptive patterns for HRBs as those observed for adults during the Covid-19 confinement could contribute to better understand the nature and severity of these changes (28).

Strengths and Limitations

Strengths of the current study consist of examining a large and well-disseminated sample of Spanish children and adolescents (i.e., participants from all the Spanish regions), and the analysis of an important set of control variables such as previous health conditions or exposure to Covid-19 in the referred time. Besides, the trends for specific HRBs such as physical activity or screen exposure remain consistent overall as well as in subgroup analyses. On the other hand, an important limitation of this study was self-reported data by parents, which may lead to recall bias; as suggested by Thorn et al. (64) outcomes such as physical activity, screen, and diet reported by children possibly lead to different estimations as regards their parents. Owing to their brevity, single-item questions have been recommended to apply in specific contexts of illness and frailty (65); thereby, the authors decided to use it in this specific context of confinement due to Covid-19 pandemic even though these specific questions were not specifically validated. Also, the convenience sampling method used to recruit participants might lead to a selection bias, which, in turn, could have shown a biased estimation of the study variables concerning the study population; thus, interpretation of the results of this study should be made in the light of this information. Further, the wide age range used for this study hampers generalizations on populations of children of a specific age. Last, the observational design of the study does not allow us to infer any causality.

CONCLUSION

The results found in the present study suggest that Covid-19 confinement substantially reduced physical activity levels, increased both screen exposure and sleep time, and reduced fruit and vegetable consumption; thus, most of HRBs worsen among a sample of Spanish children and adolescents. Also, the 1st weeks of confinement did not seem to significantly improve HRBs, except sleep time. Restrictive mobility measures with the closure of schools and high schools could have played an important role in this HRB worsening, which could be mitigated with policies for labor and family time conciliation, parental guidance, and community support.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

RL-B, GL-S, AG-S, IG, LS, and JC contributed to the conception and design of the study. RL-B organized the database and wrote the first draft of the manuscript. RL-B and LS performed the statistical analysis. JC, AG-S, LS, IG, MT, and JAC wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Trajectories in Body Height, Body Weight, BMI, and Nutrition Status From 1979 to 1987: A Measurement-Based Analysis of 15,717 Male Adolescents From the Capital City of Montenegro

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Introduction and Objective: This study aimed to consolidate body height and body weight, as well as the body mass index and nutrition status data of the entire male population of adolescents from Podgorica, the capital of Montenegro, in order to estimate trajectories in ahead mentioned variables from 1979 to 1987.

Methods: The sample includes 15,717 male adolescents divided into nine groups according to their year of birth. The sample of variables includes body height, body weight, and body mass index, as well as nutrition status, which was presented based on BMI standardized categories (underweight, normal weight, pre-obese, obese). The descriptive statistics were expressed as a mean and standard deviation for each variable, while *post-hoc* test with ANOVA were employed to explore differences between the means.

Results and Discussion: This study did not find significant differences in the body proportions of the measured group of subjects during the observed period, but some descriptive differences were observed that might be of interest for further analysis, especially when it comes to nutritional status.

Conclusions: The novelty and the original contribution of this study is reflected in the fact that descriptive data from the second half of the 20th century have been published, which can significantly help to follow the secular trend of one of the tallest nations in the world from the beginning of the 20th century—Montenegro—which has specific body proportions.

Keywords: anthropometry, secular trend, body proportions, youngsters, Montenegro

INTRODUCTION

Trends in men's body height have been monitored and analyzed around the world for a very long time, almost 250 years (1, 2), and have been attracting a great deal of attention from people all over the world. In recent decades, in most industrialized countries, gradual progressive changes in mean body height values can be observed (1). Average adult body height has dramatically increased in Montenegro too (3, 4). The cause of this might be much better lifestyles adopted by the population, and it might be the result of better living conditions and improved nutritional, hygienic, economic, and health status (5–7). However, there is a lack of data within this population, which will be further elaborated. Namely, it is necessary to mention that Montenegro is located on the slopes of the Dinaric Alps, an area that has historically been recognized as a habitat of above-average tall people [cited in (4)]. The unusual height of Montenegrins was first observed by Robert Ehrich, measuring the male inhabitants of this area in the early 20th century (8, 9). The following studies that estimate the average body height of Montenegrins appear at the beginning of the 21st century, and all of them confirm that Montenegrins are one of the tallest nations in the world (10–14). Among the above-mentioned studies, a lack of record-keeping is noticeable. There is a multi-decade gap of quality data, which made it impossible to conduct a precise analysis of the factors that influenced the mentioned trends. This type of data is available throughout Europe and the rest of the world, which allows a detailed analysis of the secular trends. A great example can be found in the Netherlands where the tallest population nowadays live. Dutch central government created a system of key registers based on digital data, collected by government organizations for administrative purposes and databases are available to scientists on the basis of which they claim with certainty that their people have become taller and heavier since 1981 and accurately determine the secular trend. However, the ahead mentioned gap in Montenegro will be partly alleviated by this study and briefly explained and compared to other nation in the discussion section.

Trends in men's body weight have also shown a tendency to increase in previous studies (15–19), which is a logical consequence because the increase in size and magnitude must be accompanied by an increase in body weight but the accumulation of excess adipose tissue is the cause as well. However, body weight is not a variable that was analyzed by Montenegrin scientists very much. Although the body weight and body mass indexes, as well as nutritional status, are very important variables in many settings, organized national surveys were not conducted in Montenegro. Each set of data that can be accessed within the Montenegrin population from the 20th century is beneficial for further public health investigations. Although several studies evaluate changes in body height and monitor underweight, overweight, or obesity problems in school children (not in adolescents), very few monitor average body weight and body mass index (BMI) changes for a longer period; such trend studies have only been emerging recently (20–22). However, they are limited to local samples and do not include a sufficient number of respondents to generalize the conclusions. For this reason, in anticipation of a new statistics act that would stipulate that reduce the administrative burden to a minimum and allow scientists to access government key registers for statistical purposes, the Ministry of Defense and the University of Montenegro started a joint project to digitalize all the available data from the old archives of the Yugoslav People's Army, mostly because each male adolescent had to pass a medical examination, and the results were stored in their medical records.

As one of the first outcomes of this project, this study brings together the body height, body weight, and body mass index data of an entire young male population of the capital of Montenegro, Podgorica, which is the largest city in the country, including almost 30% of the nation's population, to evaluate the possible trends from 1979 to 1987, for the purpose of collecting information on possible acceleration, as well as the trajectories (changes) of nutrition status in adolescence.

METHODS

The population of this retrospective cross-sectional study contains the entire male population of the capital city of Montenegro, Podgorica, measured during mandatory medical examinations to test their ability for military service. Most future recruits underwent this examination before they were 18 years old, but military service could be postponed until the age of 27, so some of the future recruits had their medical examinations later, which increased the average age in each generation. However, the detailed analyses in the results section described it precisely.

In the period from 20 April 1979 to 1 July 1987, 16,401 future recruits of the Yugoslav People's Army with permanent residence in Podgorica underwent this examination, but male adolescents that were born in 1957 ($n = 108$), 1958 ($n = 115$), 1959 ($n = 156$), and 1960 ($n = 305$) were excluded from the analysis because their numbers were not large enough to represent (and reliably describe) an entire generation. Consequently, the analyzed data in this study covers the sample of 15,717 future recruits (17.93 $\pm$ 64 years) divided into nine groups: 1,326 subjects that were born in 1961 (18.54 $\pm$ 95 years), 1,927 in 1962 (18.22 $\pm$ 49 years), 1,859 in 1963 (17.92 $\pm$ 69 years), 1,021 in 1964 (17.77 $\pm$ 77 years), 1,822 in 1965 (17.82 $\pm$ 7 years), 2,346 in 1966 (17.91 $\pm$ 62 years), 1,634 in 1967 (17.88 $\pm$ 5 years), 1,897 in 1968 (17.72 $\pm$ 31 years), and 1,885 in 1969 (17.71 $\pm$ 17 years).

Anthropometric measurement was implemented in medical infirmaries, and subjects accessed the procedure in their underwear. From the sample measures that were collected for this research, body height and body weight were isolated; the body mass index is calculated using them. For body height and body weight assessment, a medical scale with moving weights with a stadiometer was used. Anthropometrical measurement was implemented by respecting the basic rules and principles of the International Biological Program (IBP). The body mass index was calculated based on the protocol handbook for physical form assessment connected to health (23), while the nutrition status was presented based on BMI standardized categories (underweight, normal weight, pre-obese, and obese) (24).

TABLE 1 | Descriptive and Comparative Data of Male Adolescents from the Capital City of Montenegro enrolled in the study.

	Mean ± SD			
Year of Birth (Number of Subjects)	**Age (years)**	**Body Height (cm)**	**Body Weight (kg)**	**Body Mass Index (kg/m²)**
1961 (*N* = 1,326)	18.54 ± 0.95	177.12 ± 6.98	68.70 ± 8.93	21.86 ± 2.24
1962 (*N* = 1,927)	18.22 ± 0.49	177.71 ± 6.80	68.74 ± 8.82	21.73 ± 2.16
1963 (*N* = 1,859)	17.92 ± 0.69	177.74 ± 6.89	68.46 ± 9.50	21.64 ± 2.48
1964 (*N* = 1,021)	17.77 ± 0.77	176.64 ± 7.37	67.35 ± 9.16	21.57 ± 2.48
1965 (*N* = 1,822)	17.82 ± 0.70	176.57 ± 6.88	68.13 ± 9.51	21.82 ± 2.52
1966 (*N* = 2,346)	17.91 ± 0.62	177.46 ± 6.77	68.45 ± 9.11	21.71 ± 2.50
1967 (*N* = 1,634)	17.88 ± 0.50	177.27 ± 7.25	68.79 ± 9.04	21.87 ± 2.39
1968 (*N* = 1,897)	17.72 ± 0.31	176.73 ± 7.06	68.33 ± 9.29	21.86 ± 2.27
1969 (*N* = 1,885)	17.71 ± 0.17	177.12 ± 6.95	69.01 ± 9.64	21.97 ± 2.59
1961–1969 (*N* = 15,717)	17.93 ± 0.64	177.19 ± 6.98	68.49 ± 9.26	21.79 ± 2.45

No statistically significant difference between study groups were found.

The data obtained in the research were processed using SPSS 20.0 software (Chicago, IL, USA). The descriptive statistics were expressed as a mean and standard deviation for each variable, while *post-hoc* test with ANOVA were employed to explore differences between the means.

RESULTS

An analysis of the average body height, body mass, and body mass index of young male subjects is shown in **Table 1**.

The average body height of the overall sample of male subjects was 177.19 ± 6.98 cm. The tallest group were subjects that were born in 1963 (177.74 ± 6.89), while shorter ones were subjects that were born in 1965 (176.57 ± 6.88). The average body weight of the overall sample of male subjects was 68.49 ± 9.29 kg, while the heaviest subjects were those that were born in 1969 (69.01 ± 9.64), and the least heavy were those born in 1964 (67.35 ± 9.16). The average body mass index of the overall sample of male subjects was 21.79 ± 2.45 kg/m², while the highest values were among subjects that were born in 1969 (21.97 ± 2.59 kg/m²), and the lowest values had those that were born in 1964 (21.57 ± 2.48 kg/m²). The *post-hoc* test with ANOVA were employed to explore differences between the means and no statistically significant difference between study groups were found.

From **Table 2**, it can be observed that, in the overall sample of subjects, 6% were underweight, 85.16% were normal weight, 8.11% were pre-obese, and 0.74% were obese. The highest percentage of underweight is in the group of subjects that were born in 1964 (8.74%), while the lowest percentage is in the group of subjects that were born in 1961 (3.77%). The highest percentage of subjects with normal body weight is in the group of subjects that were born in 1961 (88.99%), while the lowest percentage is in those that were born in 1968 (82.24%). The highest percentage of pre-obesity is in the group of subjects that were born in 1968 (10.33%), while the lowest percentage is in those that were born in 1963 (6.13%). Lastly, the highest percentage of obesity is in the group of subjects that were born in 1963 (1.08%), while the lowest percentage is in those that were born in 1962 (0.21%).

DISCUSSION

This study aimed to make a specific contribution in an attempt to resolve the centuries-old dilemma regarding the specifics of the body composition of Montenegrins. It was known that Montenegrins were the tallest nation in the world at the beginning of the 20th century (3, 8, 10) and that this fact has changed little in the last 100 years; Montenegrins were the second tallest nation at the beginning of the 21st century (4), just behind the Dutch (25). However, it remains unknown whether the growth trend was continuous or whether certain periods particularly influenced the growth and development of Montenegrins, and there are no scientific studies that would aid in answering this research question.

A deeper analysis and knowledge of specific growth and development trends would significantly help, first, in explaining the specifics of body height and other indicators of body composition, as well as providing a significant context for the further assessment of growth and development of Montenegrins in the future. Nevertheless, the answer could not be determined that far, and it will not be after the publication of this study. However, this study will, to a certain measure, help to reduce the existing gap and initiate the need for studies with relevant data to emerge that scientists could rely on in the future.

As a large number of scientists believe that the secular trend has not concluded in this population, the significance of this issue is gaining in importance, not only among physical anthropologists, but also among researchers from other related fields, because body height, as well other parameters that describe human body composition, are very important in many areas of human life (26). For example, from the fact the impact of better material living standards make people taller, the body height became a relevant indirect measure for living conditions in the periods for which little or no other data is available.

TABLE 2 | The Nutrition Status of Male Adolescents from the Capital City of Montenegro enrolled in the study.

Year of Birth	Total	Underweight		Normal weight		Pre-obese		Obese	
	N	*N*	%	*N*	%	*N*	%	*N*	%
1961	(*n* = 1,326)	50	3.77	1,180	88.99	88	6.64	8	0.60
1962	(*n* = 1,927)	94	4.88	1,705	88.48	124	6.43	4	0.21
1963	(*n* = 1,859)	130	6.99	1,595	85.80	114	6.13	20	1.08
1964	(*n* = 1,021)	80	7.84	857	83.94	78	7.64	6	0.59
1965	(*n* = 1,822)	124	6.81	1,525	83.70	158	8.67	15	0.82
1966	(*n* = 2,346)	157	6.69	1,990	84.83	176	7.50	23	0.98
1967	(*n* = 1,634)	77	4.71	1,392	85.19	156	9.55	9	0.55
1968	(*n* = 1,897)	127	6.69	1,560	82.24	196	10.33	14	0.74
1969	(*n* = 1,885)	104	5.52	1,580	83.82	184	9.76	17	0.90
1961-1969	(*n* = 15,717)	943	6.00	13,384	85.16	1,274	8.11	116	0.74

The fact that Montenegrins have grown by 6.36 cm in a little over 100 years (3), and that it is not known within what dynamics this growth took place, any study that would fill the gap in the database is welcome. The best comparative example is the Netherlands where the tallest people currently live but also where the secular trend is over. Dutch have grown by 14.37 cm in a little over 100 years (2, 25), much more than Montenegrins. So, if hypotheses are right that the secular trend in Montenegro is not over, there is a real possibility that Montenegrins will once again become the tallest nation in the world as soon as they reach the maximum body height.

One of the most important steps in proving the above claim is the capital city, which is partially, perhaps the most important part for analysis, since 30% of the entire Montenegrin population lives in it today, while three other Montenegrin cities have been processed too, namely Cetinje, Niksic, and Bar (20–22). The results of the research in the first two mentioned cities, which together with Podgorica, make up the central region of Montenegro, can already be very interesting in interpreting the obtained results, while the results from other Montenegrin cities are expected shortly, since the work on the digitization of the entire national data remains in process. It is interesting to note that particular attention will be paid to the results that will be obtained in research on the body composition of future recruits in cities across the northern and southern regions (at present only Bar is available), because it is generally known that there are traditional socio-economic and demographic differences between people in these regions (27).

Nevertheless, it is necessary to return to the discussion of the results of this study, in which the entire population of the capital of Montenegro is processed. In the 1980s, Podgorica was, demographically speaking, a completely different city. At that time, there were 132,290 inhabitants in Podgorica (22.64% of the total population of Montenegro), while today's Podgorica officially has 185,937 inhabitants, which represents 29.99% of the total population (28, 29). Changes in the number of inhabitants are conditioned by the constant development of the city in recent decades, and migrations to Podgorica were directed, primarily from rural areas of Montenegro, but also from smaller cities, as Podgorica offered many more opportunities to achieve a better lifestyle, both adult and younger population, as a secondary school and university center. It is worth noting that the increase of more than 50,000 inhabitants represents a significant figure for a small population such as Montenegro, while there is a suspicion that this number is even higher, as there are many citizens of the capital whose official residences are still in their home towns, since they are not significantly geographically dislocated.

The population of today's capital could, methodologically speaking, almost be a representative sample of the entire Montenegrin population, given that Podgorica is inhabited by people from all parts of Montenegro. However, the study in which Popovic (3) processed body height, primarily the entire population (183.36 cm), then the region (north = 183.01 cm; middle = 183.58 cm; south = 182.55 cm), but also Montenegrin cities (Podgorica = 182.04 cm), clearly indicates that huge gap reached over several decades do not allow the data from Podgorica to be used as a representative sample of the Montenegrin population when it comes to body height. Also, the results from Popovic's study (3) cannot even be compared with the data collected from the capital city in the 1980s, due to the large migrations from rural areas to Podgorica over last few decades. However, it is interesting to discuss the fact that the average body height of Montenegrins from the beginning of the 20th century was 177 cm, while a similar average was determined in the 80s in Podgorica (177.19 cm) that is only 0.19 cm higher. In contrast, current inhabitants of Podgorica are 182.04 cm tall, which is about 5 cm more, and the difference was achieved in a much shorter period. For that reason, the research question again arises as to what influenced such a drastic change: migration, socio-economic factors, or something completely different? The results of some local studies from Niksic, where the citizens of this city were on average 178.58 cm tall in the 1980s (20), or 184.57 cm at the beginning of the 21st century (3), can aid in answering this question, Cetinje, where the citizens of this city, on average, were 178.38 cm tall in the 1980s (21), or 181.25 cm at the beginning of the 21st century (3) and Bar, where the

citizens of this city were on average 175.82 cm tall in the 1980s (22), and 182.13 cm at the beginning of the 21st century in Bar and Ulcinj (3). On the hand, Dutch have grown by 6.50 cm in since 1981 (2, 25), similarly like Montenegrins in this period of time, and make this research question more complex. However, altogether it leads us to collect a vast amount of data that would reveal the true picture of the growth and development trend of the Montenegrin young male population during the 20th century. Therefore, it is necessary to wait for the results of other ongoing studies in other Montenegrin cities and municipalities and attempt to access data from other periods; it will then be possible to answer much more precisely the research question of this study and related questions regarding the growth trends of the young male Montenegrins.

In contrast, with body weight, body mass index, and nutritional status, the situation is much more complex with regards to previous studies. There are no national studies from the beginning of the 20th century, as is the case with body height, but also in the later period. Studies can be found that are reflected in student papers and research projects done on small samples. In accordance with all the above, the project of the Ministry of Defense and the Faculty of Sports and Physical Education of the University of Montenegro is a crucial activity, primarily introducing us to the body weight, body mass index, and nutritional status of Montenegrins at the national level. This study finds that the average body weight of the citizens of Podgorica in the specified period was 68.49 ± 9.26 kg, while the body mass index was 21.79 ± 2.45 kg/m^2. However, as with body height, the same data have already been published from Niksic (Body Weight = 68.56 ± 8.66; BMI = 21.48 ± 2.27), Cetinje (Body Weight = 70.16 ± 9.17; BMI = 22.02 ± 2.58), and Bar (Body Weight = 68.33 ± 9.73; BMI = 22.06 ± 2.58), which significantly opens the way to answer research questions regarding body weight and body mass index, and is still not close to that answer (20–22). However, it is unfortunate that there are no studies that describe Montenegrins as is the case with the Dutch, which can be said that for each additional centimeter in body length, the average Dutchman has become 2.3 kg heavier between 1981 and 2018 (30), but there is hope that in Montenegro, too, all available data will become digitized and available very soon. From the local perspective, it is interesting to note that the study by Gardasevic et al. (31), although on a small sample, indicates the possibility of a certain positive trend when it comes to body weight, since they found obvious differences in 18-year-old boys from Niksic who weighed an average of 78.5 kg and their average body mass index was 22.9 kg/m^2, much more in body weight than from the current study, while the body mass index remains in equal values.

Finally, it is worth noting that a large number of studies have examined the nutritional status of the school population in Montenegro, but also amateur and professional athletes, as well as adults; however, the problem that occurs is the same as with the previous variables, primarily because the results obtained cannot be adequately compared for several reasons. In the first place, no data depict the situation before the results obtained in this study (Underweight = 6.00%; Normal weight = 85.16; Pre-obese = 8.11; Obese = 0.74), while methodological principles question the comparison of the results from the 1980s and the results obtained at the beginning of the 21st century, in the same way as described in the part that was dedicated to body height. However, it is necessary to conclude that the nutritional status of the 1980s was at an enviable level and it points out to the fact that adolescents were much more physically active at the time, all the way to the peak reached in the mid-90s (32) and the availability of information technology on a larger scale. Insufficient activity among adolescents is a major concern from the mid-90s up to nowadays, and this kind of studies are more than welcomed.

It is also worth noting that this study has achieved its goal: specifically, it has notably supplemented the existing database regarding the body height, body weight, body mass index, and nutritional status of the Montenegrin male adolescents. A complete sample of the population of the capital gives us a clear picture of what the situation was in Podgorica on this issue in the 1980s. However, although the sample covered the entire male population and filled and existing gap, this study has limitations. The main limitation of this study was to consider the age category of the subjects as the population consists of subject who are younger than 18 years old on average, mostly due to the reason there are assumptions that growth and development does not end at age 18, as it is previously believed, but rather growth and development systematically continues in the torso after 18 years of age (Starc, personal communication), which would ultimately cause an increase in body height. On the other hand, the fundamental methodological limitations do not allow us to compare the existing results from different periods of the 20th and 21st centuries in which they exist in the first place, but also the fact that this study did not include the female population, which is equally interesting for the professional and scientific public. Therefore, the recommendations for future research refer to the further expansion of the existing database, both in the periods where there are individual research studies in certain geographical locations and in the periods when there are none. Although the conclusion of the mentioned project of the Ministry of Defense and the Faculty of Sports and Physical Education of the University of Montenegro will significantly enrich the existing database, further research must treat the female population much more carefully in order to make these results available.

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 Ministry of Defense. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

SP wrote the manuscript, performed analyses, and revised manuscript. BM wrote the manuscript, performed analyses, and revised manuscript. SM collected the data. DB overviewed previous studies and discussed the results. JG discussed the results. All authors contributed to the article and approved the submitted version.

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SYSTEMATIC REVIEW
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Trends in Physical Fitness Among School-Aged Children and Adolescents: A Systematic Review

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Introduction and Objective: This systematic review aimed to analyse the international evolution of fitness with its distributional changes in the performance on tests of physical fitness among school-aged children and adolescents.

Methods: In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, the search was undertaken in four international databases (ERIC, PubMed, Scopus, and Web of Science) to identify the studies reporting temporal trends in the physical fitness among school-aged children and adolescents.

Results: A total of 485 potential articles were identified, of which 19 articles were relevant for the qualitative synthesis; 1,746,023 children and adolescents from 14 countries (China, Finland, Sweden, Belgium, New Zealand, Denmark, Spain, Norway, Mozambique, Poland, USA, Lithuania, Portugal, Canada), for the period between 1969 and 2017 were included. The subjects were tested using 45 motor tests from eight battery tests. The quality of the study in eight articles was rated as strong, while in 11 articles it was rated as moderate.

Discussion: The vast majority of studies show a constant decline in strength and endurance. Three Chinese studies show an increase in strength from 1985 to 1995 and then a decline until 2014. For endurance, similar patterns were found in the two most comprehensive Chinese studies. The decline in flexibility is also evident in European countries. For agility, speed, balance, and coordination, the trend differs among populations.

Keywords: secular trends, physical fitness, fitness changes, physical performance, youngsters

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INTRODUCTION

Physical fitness is a multicomponent construct that is closely related to the ability to perform physical activity (1, 2). It is considered to be an important health marker, because high levels of fitness during childhood and adolescence have a positive impact on adult health (3, 4). Additionally, higher levels of physical fitness enable participation in a variety of physical activities and decrease the risk of health problems (5–7).

Physical fitness is determined by genetic factors and the level of regular exercise and physical activity (8). The modern era has brought changes in ways of life and work that are associated with lower levels of physical activity (9). From a traditionally active lifestyle in which physical fitness was necessary to manage daily tasks, most people switched to the more sedentary lifestyles. In the previous four decades, studies have indicated an association between the lower physical activity levels (10) and change in body composition and somatotype (11, 12). Also, declines in physical fitness are often recorded (13), which are likely influenced by the decreasing trend in physical activity and changes in body composition (14, 15). The decline in cardiorespiratory fitness has been extensively documented (16–18). Moreover, a decline in flexibility (19), repetitive strength and running speed were also recorded (20). Given the reported declining trends in physical activity and consequently physical fitness, some researchers predict the emergence of serious public health concerns (6, 21). Contrary to this evidence, in some countries, an increase has been registered on certain components of physical fitness. Examples of this include an increase of muscular fitness in Finland (22) and cardiorespiratory fitness and strength in Canada (23).

These differences in physical fitness among countries have not been examined in detail to date (3). Furthermore, previous studies have only analyzed trends of single physical fitness components (e.g., cardiorespiratory fitness, muscular fitness), which underscores the need for a comprehensive review study that covers more than one physical fitness component and gives a general picture of its trends, which would facilitate conclusion drawing and monitoring. Thus, the objective of this systematic review was to gather the available information on all components of physical fitness among children and adolescents and to analyse the international trends of their performances on the respective physical fitness tests.

METHODS

Data selection, collection, and analyses were performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (24).

Inclusion Criteria

Scientific articles containing data on temporal trends in physical fitness published up to April 2020 were included. Eligibility criteria were the following: (1) cross-sectional, longitudinal, and interventional studies (design criterion); (2) articles published in scientific journals, book chapters, books, conference proceedings, and theses (publish criterion); (3) fitness battery, physical fitness, cardiovascular fitness, speed, flexibility, agility, muscular strength, body composition (outcome measure criterion); (4) children and adolescents aged 10 to 18 years (participant criterion); (5) articles published in English, French, Portuguese, Spanish, or German (language criterion).

Search Strategy

The literature search was undertaken in four international databases: the Education Resources Information Center (ERIC), PubMed, Scopus, and Web of Science. The search was conducted on April 17, 2020. In each database, a search was conducted by title, taking a predefined combination of keywords (through discussion among the research team) into account. The combination of used keywords was the following: "field-based test" OR fit* OR "physical performance" OR "sport performance" OR "physical condition" OR "aerobic capacity" OR "maximum oxygen consumption" OR strength OR flexibility OR motor OR endurance OR speed OR agility OR balance OR "body composition" OR anthropometry OR "body mass index" OR BMI OR skinfolds OR "waist circumference" AND trend* OR tendenc* AND adolescent* OR child* OR young* OR "school age" OR school-age OR youth. The keywords were selected through discussion among the research team, finally defined by the consensus of all authors.

Data Extraction and Selection

After performing a search in the databases, the necessary data were transferred to a software tool for publishing and managing bibliographies. The process of data extraction was performed based on PRISMA guidelines (24). The articles were downloaded from the databases, after which duplicates, identified by title and author, were removed. Two researchers screened titles and abstracts of the remaining records. Then, the full-text of relevant articles were read and examined according to the inclusion criteria, to decide whether or not to include them in the systematic review. The following information was extracted from each study: author's name and year of publication, study design, country, sample characteristics (number of participants, gender, and age), the instrument/battery for assessing physical fitness, main results, and study quality.

Study Quality and Risk of Bias

The methodological quality of the studies was assessed using the Quality Assessment Tool for Quantitative Studies (25), which is a 19-item checklist, assessing eight methodological domains: selection bias, study design, confounders, blinding, data collection methods, withdrawals and dropouts, intervention integrity, and analyses. Each section was graded as being of strong, moderate, or weak methodological quality. A global rating is determined based on the scores of each component. Two researchers rated the studies in each domain, as well as the overall quality of each study. Discrepancies were resolved by consensus.

RESULTS

Figure 1 shows the flow chart of records selection. A total of 485 potential articles were identified through the electronic database search (three from ERIC; 145 from PubMed; 166 from Scopus; 171 from Web of Science). After exclusion of the duplicates (279), the title and abstract of 206 were assessed for eligibility. After elimination at the title and abstract level 157 articles, the remaining 49 articles were subsequently read. After reading, another 30 articles were eliminated, leaving 19 relevant articles that satisfied the inclusion criteria and were included in the qualitative synthesis.

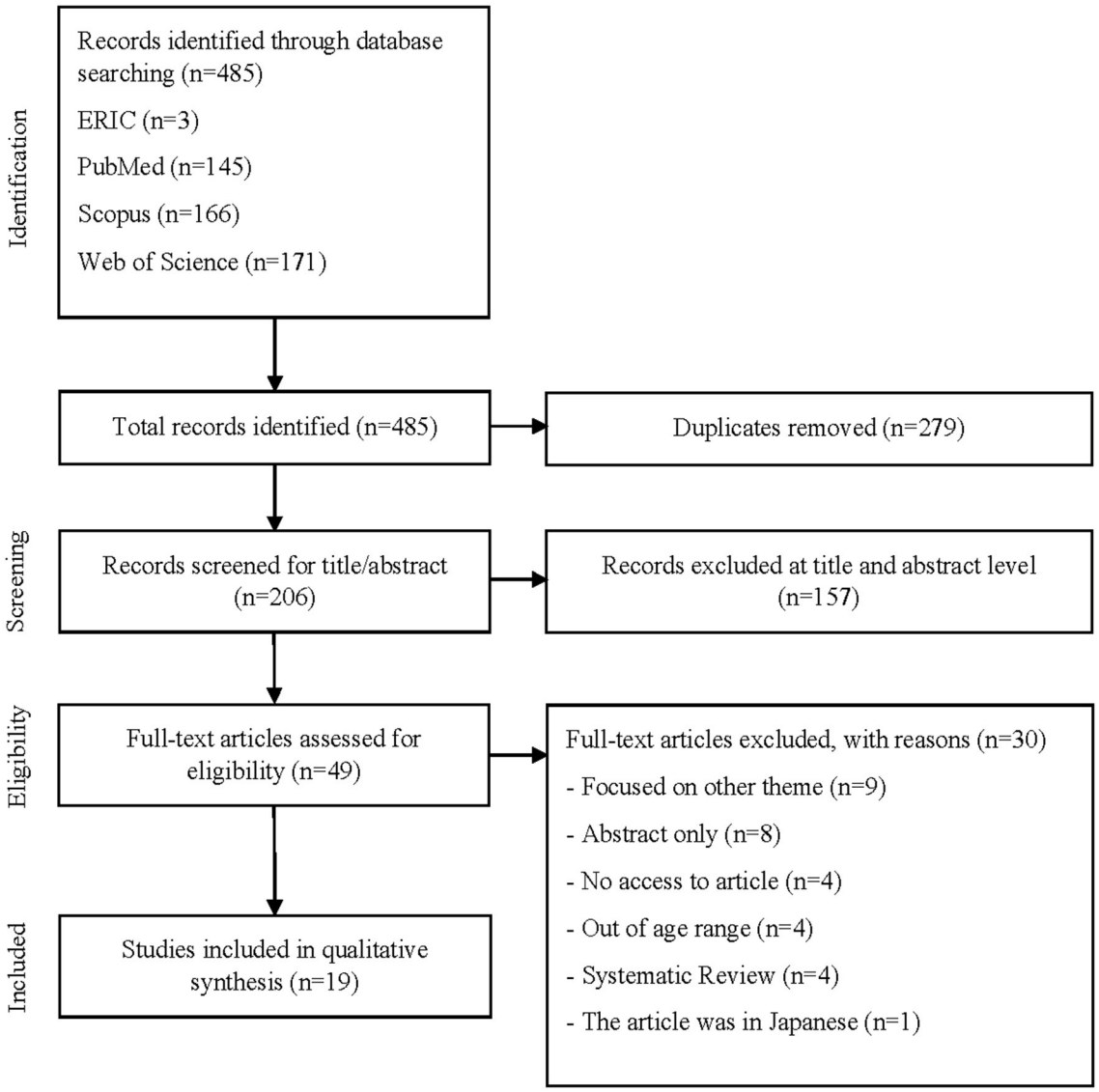

FIGURE 1 | Flow diagram of study selection.

Study Characteristics

In **Table 1**, the studies' characteristics are presented. From 19 studies included in the qualitative synthesis, a total sample of 1,746,023 children and adolescents from 14 countries was represented. All studies had a cross-sectional design with two, three, or more samples from the same number of time-points. Three studies were performed in China and another three in Finland, two in Sweden, and one in each of the following countries: Belgium, New Zealand, Denmark, Spain, Norway, Mozambique, Poland, the United States of America, Lithuania, Portugal, and Canada. The period covered by the studies was between 1969 and 2017. Overall, participants' performance in 45 fitness tests from eight different fitness tests batteries was recorded. Strength was most frequently tested, followed by endurance, flexibility, agility, speed, balance, and coordination. The quality of the studies in eight articles was rated as strong, while in 11 articles it was rated as moderate.

Strength

Strength was mostly tested topographically (arm and shoulder belt strength in 10 papers for boys and eight for girls; lower limb strength in 10 papers for boys and 11 for girls; abdomen strength in five papers for boys and nine for girls). With the exception of one study, which applied a test assessing the strength of the entire body, eight tests were used to evaluate arm and shoulder strength: handgrip strength (kg), bent-arm hang (s), arm pull (kg), bench-press (n): all four for both boys and girls; pull-ups (n), oblique body pull-ups (n), pull-ups (n/min): three for boys only, and flexed-arm hang (s): only for girls. Three tests were used to evaluate the strength of the lower limbs in both sexes: standing

TABLE 1 | Characteristics of the studies.

Author, Year	Study design	Country	Sample characteristics (number of participants, gender, age)	The instrument/battery for assessing physical fitness	Main results	Study quality
Westerstahl et al. (26)	Cross-sectional	Sweden	*n* = 855: 417 girls, 426 boys; mean age 16.4	Sit-ups (number), Bench-press (number), Sargent jump (cm), Two-hand lift (N), Run-walk (m/9 min)	Both girls and boys performed less well in bench-press, sit-ups, and run-walk tests in 1995 compared to 1974. Boys performed better in the Sargent jump in 1995 than in 1974, but there was no difference among the girls for this test. Both girls and boys performed better in the two-hand lift in 1995 than in 1974. There were decreased aerobic fitness and an increased maximal static strength among adolescents in Sweden between 1974 and 1995	Strong
Matton et al. (27)	Cross-sectional	Belgium	*n* = 19,999: 11,899 boys (in 1969–1974), 4,899 girls (in 1979–1980), 1,429 boys (in 2005), 1,772 girls (in 2005) aged 12–18 years	Cross Sectional: Bent-arm hang (s), Sit-and-reach (cm), Flamingo balance (*n*/min), 10 × 5 m shuttle run (s); Parent offspring study: Plate tapping (*n*/20 s), Vertical jump (cm), Arm pull (kg), Leg lifts (*n*/20 s)	Boys tested in 2005 perform significantly better on the 10 × 5 m shuttle run test, but they perform significantly worse on sit-and-reach and bent-arm hang in cohort 12- to 14-year-olds compared to 1969–1974. Girls tested in 2005 perform significantly worse on bent-arm hang, flamingo balance, 10 × 5 m shuttle run test, and sit-and-reach for cohort 14 year-olds compared to 1969–1974. Boys (2002–2004) perform significantly worse on sit-and-reach plate tapping, and arm pulls (1969–1974). Girls (2002–2004) perform significantly worse on bent-arm hang, sit-and-reach, 10 × 5 m shuttle run, plate tapping, vertical jump, and arm pull compared to their mothers (1979–1980)	Moderate
Huotan et al. (14)	Cross-sectional	Finland	*n* = 1,275: 717 adolescents (384 boys, 333 girls) took part in the 1976 study, 558 (305 boys, 253 girls) took part in the 2001 study; aged 13–18 years	2,000 m running (s) for boys and a 1,500 m running (s) for girls	The mean 2,000 m running test time was longer in 2001 compared to 1976 in boys. The mean 1,500 m running test time was longer in 2001 compared to 1976 in girls, which indicates that on average, a boy in 2001 would finish about 180 m behind the average 1976 boy over the 2,000 m distance. In girls, the corresponding difference in the 1,500 m run was 83 m	Strong
Albon et al. (28)	Cross-sectional	New Zealand	*n* = 3,306: 1,456 girls, 1,850 boys aged 10–14 years	Sit-and-reach (cm), 4 × 9 m run (s), Abdominal curl ups (*n*), Standing broad jump (cm), 550 m run (s); AAHPER battery	Results on the 550-m run test decreased for boys (1.5%) and girls (1.7%), respectively. Results on the 4 × 9 m agility run test decreased for boys (0.2%) and girls (0.4%), respectively. Standing broad jump results for boys and girls in 2003 was less than their 1991 counterparts (0.3 and 0.2% per year for boys and girls, respectively). In contrast, for boys, performance in the curl-up test improvement is 1.5% per year, whereas improvement was of 2.1% per year for girls. Similarly, boys and girls were more flexible in 2003 compared to 1991; the improvement is 2.8 and 1.8% per year for boys and girls, respectively	Moderate

(Continued)

TABLE 1 | Continued

Author, Year	Study design	Country	Sample characteristics (number of participants, gender, age)	The instrument/battery for assessing physical fitness	Main results	Study quality
Andersen et al. (29)	Cross-sectional	Denmark	*n* = 1,050: 466 boys, 584 girls; aged 15–19 years	The VO2 max was estimated from maximal power output in a cycle test with the progressively increasing workload on a mechanically braked cycle ergometer (Monark 839, Varberg, Sweden)	No change in cardiorespiratory fitness over time (1983, 1997, 2003), and quite high levels were found in these representative cohorts. It founded substantial differences in maximal power output, but no differences when VO2 max was estimated from the equations derived in the validation studies	Moderate
Moliner-Urdiales et al. (3)	Cross-sectional	Spain	*n* = 731: 339 adolescents (155 boys, 184 girls) obtained between 2001 and 2002, 392 adolescents (206 boys, 186 girls) obtained between 2006 and 2007; aged 12.5–17.5 years	Handgrip strength (kg), bent-arm hang (s), Standing broad jump (cm), 4 × 10 m shuttle run (s), 20 m shuttle run (stages)	Performance in 4 × 10 m shuttle run and 20 m shuttle run tests was higher in 2006–2007 compared with 2001–2002. Performance in handgrip strength and standing broad jump tests was lower in 2006–2007 compared with 2001–2002. The bent-arm hang test was not significantly different. Levels of both speed/agility and cardiorespiratory fitness were higher in 2006–2007 than in 2001–2002. Upper body muscular strength is on the same level	Moderate
Huotari et al. (22)	Cross-sectional	Finland	*n* = 1,222: 643 adolescents (312 boys, 331 girls) took part in the 1976 study, 579 adolescents (308 boys, 271 girls) in the 2001 study; aged 13–16 years	Standing broad jump (cm), Sit-ups (*n*/30 s), 4 × 10 m shuttle run (s) for both sexes. Besides, Flexed-arm hang (n/s) was measured in girls and Pull-ups (repetition max) in boys	No statistically significant changes in the standing broad jump results among boys from 1976 to 2001, in girls a mild tendency toward higher scores (1.9%). Upper body muscular fitness in boys decreases by 21.2% (averaged pull-ups number had fallen). The results of the girls' flexed-arm hang test showed no difference. Sit-ups improved significantly over time in both sexes, in boys (13.6%), in girls (9.1%). The results for the agility 4 × 10 m shuttle run had also improved over time, 4.7% in boys, and by 2.3% in girls	Moderate
Dyrstad et al. (17)	Cross-sectional	Norway	*n* = 4,006 pupils: 2,384 boys, 1,622 girls; age 16–18	3,000 m running (s)	The 3,000 m running time decreases from the 1969 s to the 1979 s for boys. The distribution showed an increase in aerobic fitness in this decade. The running times have increased from the 1980 s to the 2000 s for boys and girls, respectively. The distribution showed a decline in aerobic fitness by 10 and 6%. The cohort of 16- to 18-year-old boys and girls in the decade 2000–2009 had a poorer aerobic fitness performance in the 3,000 m running test compared with earlier decades	Moderate
Dos Santos et al. (30)	Cross-sectional	Mozambique	*n* = 3,851: 591 subjects in 1992 (276 boys, 315 girls), 1,840 subjects in 1999 (854 boys, 986 girls), 1,420 subjects in 2012 (661 boys, 759 girls); aged 8–15 years	Handgrip strength (kg), 10 × 5 m shuttle run (s) from EUROFIT battery; Sit-and-reach (cm), 1-mile run-walk (s) from AAHPERD and FITNESSGRAM batteries, respectively	Children in 1992 were more flexible than those from 2012. Boys' handgrip strength increased from 1992 to 2012, while girls decreased their handgrip strength. Youth in 1992 were faster and more agile than their 2012 peers. A decrease was observed in cardiorespiratory fitness between 1992 and 1999 and between 1992 and 2012 for both sexes	Moderate

(Continued)

TABLE 1 | Continued

Author, Year	Study design	Country	Sample characteristics (number of participants, gender, age)	The instrument/battery for assessing physical fitness	Main results	Study quality
Karpowicz et al. (31)	Cross-sectional	Poland	$n = 169$: 21 girls (measured in the 2006), 21 (2007), 20 (2008), 21 (2009), 21 (2010), 21 (2011), 22 (2012), 22 (2013); mean age 15.5 ± 0.5	50 m sprint (s), 800 m endurance running (s), 4 × 10 m shuttle run (s), Standing long jump (cm), sit-ups (*n*/30 s), Handgrip strength (kg), Flexed-arm hang (*n*), Standing trunk flexion (cm); International Physical Fitness Test (IPFT) battery	The overall physical fitness of young women basketball players has been declining year by year. Girls obtained lower results in 6 of 8 tests (50 m run, Long jump, Flexed-arm hang, 4 × 10 m run, Sit-ups, Standing forward bend), compared with members of the Teams in 2006, with the differences for long jump, arms hang, sit-ups, and trunk flexion tests being statistically insignificant. A slight improvement was observed only in the 800 m run and hand strength	Moderate
Morales-Demori et al. (32)	Cross-sectional	USA	$n = 435$: 249 (male), 186 (female) healthy children and adolescents, aged 4–18 years, mean age 12.6 ± 3.2 years	Bruce protocol treadmill test	There was a significant difference in the mean endurance time between children grouped in 5-year intervals (1983–1990, 1991–1995, 1996–2000, 2001–2005, 2006–2010) with a significant downward trend in endurance time over the years, especially after 2001	Strong
Venckunas et al. (33)	Cross-sectional	Lithuania	$n = 16{,}199$ (8,131 girls, 8,068 boys): 5,775 in 1992, 5,325 in 2002, 5,099 in 2012; aged 11–18 years	Flamingo balance (*n*/min), Sit-and-reach (cm), Standing broad jump (cm), Sit-ups (n/30s), bent-arm hang (s), 10 × 5 m speed shuttle run (s), 20 m shuttle run (*n* stages); Eurofit test battery	The study has shown a loss of flexibility, leg muscle power, upper body strength, and cardiorespiratory fitness between 1992 and 2012, although there was an improvement in abdominal muscle strength in girls, agility in boys, and balance in both genders during the same period. Negative trends in aspects of fitness seen between 1992 and 2002 have not slowed down between 2002 and 2012. Positive trends in agility and abdominal muscle strength were seen before 2002 have regressed or were reversed between 2002 and 2012, while balance continued to improve at an increased pace	Strong
Costa et al. (19)	Cross-sectional	Portugal	$n = 1{,}819$: 881 boys, 938 girls; aged 10–11 years	Horizontal jump (without preparatory running) (cm), 40 m sprint (s) from AAHPERD test batteries; Curl-up (*n*), Sit-and-reach (cm) from the FITNESSGRAM test batteries	Children from the 1993 cohort were less flexible than those from 2013. Boys in 2013 were faster than their 1993 counterparts. A similar trend was found for girls but without statistical meaning. The curl-up assessment, showed a similar pattern in both genders, with better scores reached in the most recent quinquennial. Horizontal jump performance also showed slight improvements throughout those years but without reaching the significance of cut-of value	Moderate
Ao et al. (34)	Cross-sectional	China (Han ethnicity)	$n = 136{,}539$: 34,238 (in 1985); 11,664 (in 1991); 17,485 (in 1995); 18,057 (in 2000); 19,254 (in 2005); 17,962 (in 2010); and 17,906 (in 2014); aged 12 years	50 m run (s), Standing broad jump (cm), 10 × 50 m run (s), Pull-ups (*n*/min), Sit-ups (*n*/min); A battery test from the Chinese National Measurement Standards on People's Physical Fitness for young children	There was a general decline in physical fitness in both urban and rural children after 2000. Some components have upward trends: running speed in boys and girls in urban areas, cardiorespiratory fitness in boys and girls in both urban and rural areas	Strong

(Continued)

TABLE 1 | Continued

Author, Year	Study design	Country	Sample characteristics (number of participants, gender, age)	The instrument/battery for assessing physical fitness	Main results	Study quality
Huotari et al. (35)	Cross-sectional	Finland	*n* = 3,736: 2,390 students (1,207 boys, 1,183 girls) in 2003, 1,346 students (683 boys and 663 girls) in 2010; aged 15–16 years	Figure 8 (*n*/min), Lateral jumping (*n*/15 s), Motor coordination track (s)	Results demonstrate that scores of the coordination track decreased slightly in both gender groups between 2003 and 2010. Scores for the Figure 8 test increased slightly among girls but not in the boys' group between 2003 and 2010. There were no significant changes in the lateral jumping test scores in either gender group between 2003 and 2010	Moderate
Colley et al. (23)	Cross-sectional	Canada	*n* = 6,284: 2,081 (2007–2009), 2,133 (2009–2011), 2,070 (2016–2017); aged 6–19 in 10–year period	mCAFT step, Handgrip strength (kg), Sit-and-reach (cm); CSEP-PATH Manual	The fitness measures have changed across the three cycles (2007–2009, 2009–2011, 2016–2017), by age group and sex. Statistically significant differences between cycles are noted. Decreases in cardiorespiratory fitness were observed for 8- to 14-year-old boys. Grip strength decreased in 11- to 19-year-old boys. Flexibility was stable across time with a slight improvement observed in 6- to 10-year-old girls	Strong
Dong et al. (36)	Cross-sectional	China	*n* = 1,494.485: 409.836 (in 1985), 204,763 (in 1995), 216,073 (in 2000), 234,289 (in 2005), 215,223 (in 2010), 214,301 (in 2014); aged 7–18 years	Forced vital capacity (ml), Standing long jump (cm), Sit-and-reach (cm), Oblique body pull ups (*n*) and pull ups (*n*) for boys; sit ups (*n*/min) for girls), 50 m dash (s), 8 × 50 m shuttle runs (s), 1,000 m run (s) for boys, 800 m run (s) for girls	The mean levels of the six core items of the physical fitness indicator shifted substantially over this period. The total normal physical fitness indicator increased between 1985 and 1995, reached its peak in 1995, and then decreased in 2014, with overall physical fitness 167% lower between 1995 and 2014. Except for sit-and-reach, the other components of fitness (forced vital capacity, standing long jump, body muscle strength, 50 m dash, endurance running) significantly declined over time from 1995–2014, particularly forced vital capacity and endurance running	Strong
Bi et al. (37)	Cross-sectional	China	*n* = 49,357 participants: 14,548 (in 1985), 7,198 (in 1995), 10,255 (in 2005), 17,356 (in 2014); aged 7–18 years	Forced vital capacity (ml), Standing long jump (cm), Sit-and-reach (cm), Oblique body pull-ups (*n*) and pull-ups (*n*) for boys; sit ups (n/min) for girls, 50-m dash (s), 8 × 50 m shuttle runs (s), 1,000 m run (s) for boys, 800 m run (s) for girls; CNSSCH guidelines	Comprising the six core physical fitness items (forced vital capacity, standing long jump, sit-and-reach, body muscle strength, 50-m dash, endurance running), the physical fitness indicator increased in 1995 and then fell sharply in 2005 and continued to decrease in 2014, taking the 1985 dataset as reference. The physical fitness indicator of all age groups reached a peak in 1995, followed in descending order by 1985, 2005, and 2014	Strong
Johansson et al. (15)	Cross-sectional	Sweden	*n* = 705 children: 356 girls, 349 boys; aged 8–20 years.	Maximal oxygen uptake VO2 max (Astrand-Rhyming submaximal bicycle test)	There was a statistically significant negative time trend for cardiorespiratory fitness in both sexes. Absolute VO2 max (L/min) decreased in girls and in boys per year. Relative VO2 max (mL/kg/min) decreased in girls and in boys per year	Moderate

long jump (cm), vertical jump (cm), and leg lifts. The sit-ups test was used for both sexes to evaluate the strength of the abdomen. In one study, a two-hand lift (N) test, which assessed the strength of the entire body, was used for boys and girls.

For the strength of the arms and shoulder belt, a declining trend was found in nine studies for boys and seven for girls. In three Chinese studies (34, 36, 37), a growth trend from 1985 to 1995 was initially found for all cohorts of boys, followed by a trend of decline until 2014. In the additional six studies for boys (3, 22, 23, 26, 27, 33) and seven for girls (3, 3, 23, 26, 27, 30, 31, 33), a steady decline was observed between 1969 and 2017. For a cohort of Chinese 12-year-olds, the results of upper-body strength showed an increase until 2005, followed by a decline (34). Significant changes were not shown in the cohort of Canadians aged 15 to 19 (23), in Finnish adolescents aged 13 to 16 (22), in boys in Belgium (27), and in Spanish boys and girls on a static strength test (3). Finally, a growth in strength was noted in Mozambique children and adolescents between 1992 and 2012 (30), in Canadian girls aged between 11 and 14 (23), and in Polish girls aged 15.5 years on an absolute strength test (31).

For the explosive strength of the lower extremities, a declining trend was found in six studies for boys and eight for girls. Three Chinese studies for boys and girls (34, 36, 37) found an initial growth trend from 1985 to 1995 (it peaked in 1995), followed by a downward trend until 2014. In three studies for boys and girls (3, 28, 33) and two girls only (27, 31), a steady decline was noted between 1969 and 2013. No significant changes for explosive strength were noted in the study by Huotari et al. (22) of Finnish boys, the study by Westerstahl et al. (26) for Swedish girls, and in the study with Portuguese adolescents of both sexes (19). Furthermore, no significant changes were noted for the repetitive strength of the subjects of both sexes in Belgium (27). Progress was recorded for a cohort of Swedish adolescents aged 16.4 between 1974 and 1995 (26), which is consistent with the results of studies in China in which a decline in strength occurs after that period. The growth trend was recorded for a cohort of Finnish adolescents aged 13–16 between 1976 and 2001 (22).

The trend of abdomen strength decline in both sexes was found in Swedish adolescents between 1974 and 1995 (26), and in Polish girls (31) between 2006 and 2013. A cohort of Portuguese school-aged boys from 1993 to 2008 and girls from 1993 to 2003 found a trend of decline, followed by a growth trend until 2013 (19). Studies in China have noted a trend of decline in repetitive strength in girls from 1985 to 1995, followed by a growth trend (34, 36, 37). The growth of repetitive strength in both sexes was recorded in New Zealand from 1991 to 2003 (28) and in Finland between 1996 and 2002 (22). In contrast, between 1992 and 2012, only Lithuanian girls showed an increase, while there were no significant changes among the boys (33).

Westerstahl et al. (26) examined complete body strength and found progress for both sexes of a cohort of Swedish adolescents aged 16.4 years, for the period between 1974 and 1995, which is a similar result to those in Chinese studies indicating fitness growth also up to 1995 and reaching a peak in that period (34, 36, 37).

Endurance

Endurance was assessed in boys within 14 research studies and in girls within 15 studies. Eleven tests were used for both sexes: 10 × 50 m run (s), 1-mile run-walk (s), 20 m shuttle run (*n* stages), 3,000 m running (s), 550 m run (s), 8 × 50 m shuttle run (s), Bruce protocol treadmill test, Astrand-Rhyming submaximal bicycle test, cycle test with progressively increasing workload, mCAFT step, run-walk (m/9 min). Two tests were used only for boys [1,000 m run (s) and 2,000 m run (s)] and two for girls only [1,500 m run (s) and 800 m running (s)]. Two studies have applied a vital capacity (ml) test.

The constant trend of decline in boys' and girls' endurance is indicated by the results of eight studies covering the period between 1969 and 2017 [(Huotari et al., 2009), (15, 23, 26, 28, 30, 33)]. Studies in China did not show significant changes in results for both sexes from 1985 to 1995 followed by a period of continuous decline (36, 37). Dyrstad et al. (17) pointed to the growth of endurance of Norwegian adolescents from 1969 to 1989 and for girls from 1980 to 2000, and its decline between 1990 and 2009 for boys and between 2000 and 2009 for girls. A study in Canada (23) for an older cohort of boys and girls (15–19 years) showed no significant changes between 2007 and 2017, as well as in Danish adolescents of both sexes between 1983 and 2003 (29). Some studies pointed to the growth in the endurance of some cohorts, such as Chinese 12-year-olds (34) of both sexes (Han ethnicity) between 1985 and 2014, Spanish adolescents of both sexes aged 12.5 to 17.5 years between 2001 and 2007. (3), and girls in Poland (15.5 years) from 2006 to 2013 (31).

Two studies have shown a trend for forced vital capacity (ml) that shows functional ability, as people with high lung capacity are predisposed to endurance-type sports. The results for this parameter were calculated together for both sexes for children and adolescents aged 7–18 years and show inconsistent results. For the entire population of China, forced vital capacity decreased from 1985 to 2005, after which it increased until 2014 (36), while for residents in Xinjiang (China) it increased until 1995 (reached a peak in 1995), then declines until 2005 after which it remains at a similar level until 2014 (37).

Flexibility

Flexibility was tested within nine research studies for both sexes. For boys, a sit-and-reach test was used, and a sit-and-reach test and standing trunk flexion were used for girls. Tests in Belgium (27), Lithuania (33), Portugal (19), and testing of girls in Poland (31) show a decrease in the flexibility between 1969 and 2013. In China, from 1985 to 1995, progress was seen (reaching a peak in 1995), after which the results decreased until 2014 for both sexes (37). The opposite trend is cited by another Chinese study showing a decline in the flexibility of boys and girls until 1995, followed by an increase to the year 2000 and retention at similar values until 2010, and finally a slight decline until 2014 (36). Colley et al. (23) found a decrease in flexibility for the period between 2007 and 2009 and then an increase until 2017 in a sample of Canadian boys aged 15–19, while for boys between 11 and 14 years they found no significant change in the results of the flexibility test. The same authors demonstrate girls' progress of flexibility for both ages. The growth of flexibility for both sexes is reasonable in the cohort of school children (10–14 years) of New Zealand (28) for the period between 1991 and 2003 and children (8–15 years) in Mozambique (30) for the period between 1992 and 2012.

Agility

Agility was tested within six studies for boys and within seven studies for girls. Three tests for both sexes were used for assessment: a 10 × 5 m shuttle run (s), a 4 × 10 m shuttle run (s), and a 4 × 9 m run (s). In both sexes, agility declines in Mozambique (30), and New Zealand (28), moreover, for girls in Belgium (27) and Poland (31). The growth of agility for both sexes was found in Spain (3) and Finland (22) and only for boys in Lithuania (33), while the girls showed no significant changes. In Belgium, there is a trend of increasing results for boys between 1969 and 2005, but there were no significant changes between parents and their children (27).

Speed

Speed testing was performed within six studies. For the evaluation of both sexes, the following tests were used: 50 m sprint (s), 40 m sprint (s), and the speed of movement frequency was measured by the Plate tapping test (*n*/20 s). Tests show a negative trend in the speed of boys and girls in the cohort of Flemish subjects in Belgium (27) and in girls in Poland (31). In a study by Ao et al. (34), Chinese girls' (Han ethnicity) speed decreased from 1985 to 1991 and increased thereafter but only in rural areas, while in boys a constant decrease was recorded. In the Chinese province of Xinjiang, the speed decreased for both sexes from 1985 to 1995, then increased until 2005, after which it remained stable (37). In contrast, the results for the whole of China for both sexes (36) show an increase in speed until 1995, then a decrease until 2005 and retention at a similar level until 2010, followed by a slight increase in 2014. The increase in speed was also visible in urban areas of China (Han ethnicity) for 12-year-olds of both sexes (34), and Portugal (19).

Balance

Balance was tested for both sexes as part of two research studies with the Flamingo balance (*n*/min) test. Balance tests show that in the cohort of Flemish subjects in Belgium (12–18 years) there are no significant changes when comparing the results of parents and their children later when they reached the same age; however, for the entire female population there is a decrease in balance (27). In Lithuania, greater improvement in balance scores was found in the previous decade and still more in girls 11–18 (33).

Coordination

Only one study shows coordination results for both sexes using three tests: motor coordination track (s), lateral jumping (*n*/15 s), and Figure 8 (*n*/min). The only study that examined coordination was conducted by Huotari et al. (35) for a cohort of Finnish adolescents (15–16 years) in the period between 2003 and 2010. The motor coordination track (s) test shows a decrease during the tracked period for both sexes. Lateral jumping test (*n*/15 s) which evaluates dynamic balance, quickness, and the explosive strength of lower limbs with coordination indicates that there are no significant changes for both sexes, while the Figure 8 test (*n*/min) test, which evaluates object control skills with coordination, shows that there are no significant changes in boys, while girls have made progress in results.

DISCUSSION

This study provides a comprehensive overview of longitudinal changes in the physical fitness of children and adolescents and thereby indicates relevant knowledge to develop appropriate public health strategies. The articles that were included in the qualitative synthesis describe the temporal trends for seven physical fitness attributes. Overall, a declining trend was found for one or all three topological areas of strength (9 of 10 studies for boys and in 8 in 11 for girls), endurance (9 in 14 studies for boys and in 8 in 15 for girls), flexibilities (4 in 9 studies), agilities (4 in 6 studies for boys and 4 in 7 for girls), and speed (2 in 6 studied).

Based on the analysis of all three topological areas of strength (arm and shoulder belt strength, lower limb strength, abdomen strength), it can be noted that most studies indicate a declining trend, which is not surprising given the changing lifestyle of children and adolescents, physical inactivity, and increasing screen-time around the world in the previous three decades (38). However, in some studies, in certain cohorts a trend of increase in strength has been noticed whereas in other cohorts a decrease in strength was not evident (19, 22, 23). It should be emphasized that these are studies with children and adolescents in which (according to the decisions of the governments in these countries) special programmes of additional exercise were applied. Possibly, even in these cohorts there would have been a declining trend in strength levels if there had been only the regular school curriculum, without additional exercise. In several studies, the handgrip strength test shows a growth trend in strength for girls (23, 31, 36). These results are in line with previous research, since absolute strength is proportional to the size of the muscle cross-sectional area (39) and body height, and which increased over the last 40 years (11, 12).

Noteworthy is the fact that the majority of studies point to a trend of declining levels of endurance, which can be explained by the same causes as for the trend of declining strength. A small number of cohorts in certain studies show that there is no decline in endurance levels or even a growth trend. However, these are cohorts for which intervention programmes mirror the longitudinal effects (23, 31) or studies covering insufficient periods (3), or studies with non-representative populations (29, 34). In summary, the results of these studies must be interpreted with caution, when drawing conclusions about longitudinal trends.

Notably, research conducted in Europe has recorded a trend of declining levels of flexibility. In other parts of the world, growth trends have been reported, for example, in Canada (23), where additional exercise programmes have been conducted. However, the reasons for the growth trend in New Zealand (28) and Mozambique (30) have not yet been determined.

Given the diversity of agility trends in the available studies, it is not possible to discuss a specific direction of movement for this motor ability in children and adolescents. The speed trends are very difficult to interpret because results indicate differences. In particular, the three Chinese studies are quite contradictory. The trend of increasing speed in Portugal (19) probably results from the government's policy on additional exercise, although it is known that speed is highly genetically determined.

Two studies examining the balance are not enough to define the trajectory of the global trend. The results of studies conducted in Belgium (27) and Lithuania (33) are contradictory at first glance, but they are focused on different time periods, and it is possible that in identical periods differences would not exist.

Only one study that have examined coordination (35) does not provide a possibility to discuss global trends.

Generally, the decline of physical fitness of children and adolescents around the world is caused by various factors. In recent years, several studies showed that weight gain is related to physical fitness (14, 15, 31). As body weight increased, so did BMI, which influenced this trend in China (37), Sweden (26), and New Zealand (28). In addition to these two components, the increase in the thickness of the skin folds caused a decline in physical fitness in Belgium (27). Two Chinese studies showed that the decline in physical fitness was caused by changing lifestyles, characterized by higher media and fast food consumption (34, 36). Morales-Demori et al. (32) linked the trend of declining endurance to a sedentary lifestyle, and Venckunas et al. (33) with additional risk factors of smoking, alcohol consumption, non-active lifestyle and long-term television viewing.

This study also has certain limitations. One of the most significant is the insufficient differentiation of the samples by age (e.g., 10–12; 12–14; 14–16; 16–18) which would show the most accurate data. However, the results for the whole population are mostly combined. Also, the authors themselves are self-critical and reported the following limitations in their works: some studies combined results for both sexes; field tests although used worldwide with this age, carry the possibility of individual errors of measurement performers; when testing aerobic fitness, the results will have real values only if all subjects are highly motivated; in some studies urban i rural area are divided, but did not take into account the urbanization of certain rural areas, which likely cause a certain contradiction; results of non-representative samples of some studies can't be generalized for the whole population. Finally, it should be noted, that causes and determinants of physical fitness trends have not been fully identified by researchers. However, weight gain and higher BMI levels are mainly the cause of the declining trend in physical fitness, which facilitates the need to monitor several health-related factors (e.g., food intake) among several settings of the living environment.

Studies from Finland (22), Canada (23), and Portugal (19) show that changing policies, including the development and implementation of health-enhancing programmes, can reduce the negative impact of a sedentary lifestyle, which have taken precedence in our population.

Finally, consistent conclusions about the development of strength and endurance were drawn, because these dimensions were assessed with the largest number of tests, while the other motor skills (flexibility, agility, speed, balance, coordination) were less frequently and insufficiently tested to draw a meaningful conclusion. We encourage researchers to develop a comprehensive and easily applicable test battery enabling the assessment of all motor skills. Doing so would clearly enhance the evidence regarding the longitudinal trends of physical fitness among children and adolescents around the world.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

BM wrote the manuscript, collected the data, and performed analyses. JG wrote the manuscript, overviewed previous studies, and discussed the results. AM performed analyses. MP discussed the results. YD revised manuscript. DS revised manuscript. SP discussed the results and revised manuscript. All authors contributed to the article and approved the submitted version.

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SYSTEMATIC REVIEW
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Field-Based Health-Related Physical Fitness Tests in Children and Adolescents: A Systematic Review

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Physical fitness (PF) is a multi-component construct and a biomarker of health. Worse PF is related to vulnerability and predicts worse academic achievements. Thus, assessing PF is important to monitor health in youth. This systematic review aimed to identify and inform physical education, health professionals and entities about existing PF batteries and field-tests that can be used in school settings. A comprehensive literature search was carried out in five electronic databases (Academic Search Complete, Education Resources Information Center, PubMed, Scopus, and Web of Science) to identify PF battery protocols that can be carried out in the school setting. Overall, 24 PF batteries were identified. Regarding the PF components assessed, only cardiorespiratory fitness and upper body strength were contemplated in all batteries. Middle-body strength and lower body strength were presented in most batteries (21 and 19 of 24, respectively). Agility (16 of 24) and body composition (16 of 24) were also considered in several batteries, although to a lesser extent. Flexibility (14 of 24) and speed (12 of 24) were the PF components less represented in the batteries. Among the 24 identified PF batteries, 81 PF tests assessing the different PF components were encountered. The advances in the PF field-based assessment in school settings and health in youth resulted in the amplification of the number of existing batteries. Considering the connection between PF and health and the opportunity that the school setting provides to assess fitness in children and adolescents, there is a need for standardization and a consensus of PF assessments in this specific setting.

Keywords: body composition, cardiorespirarory fitness, fitness testing, musculoskeletal, physical education, vulnerability

INTRODUCTION

Physical fitness (PF) is a multi-component construct and a biomarker of health (1, 2). Worse PF is related to vulnerability (3) that can negatively affect human development, such as cognitive functioning (4, 5). This has important consequences children and adolescents. For instance, it has been shown that worse PF predicts substantially reduced improvements in academic achievement over time (6). PF is influenced by genetic and external factors (7). The genetic heritage has an essential role in trainability and describes the magnitude of the physiologic response to physical stress (2, 8). External factors such as regular PA, sleep, nutrition also have an impact on PF components (9–11). Assessing PF through specific and validated test protocols allows monitoring the biological and physiological adaptations that are achieved through natural development or training (12). Health-related PF components include body composition measures (i.e., body mass index [BMI], waist circumference), cardiorespiratory fitness (CRF), muscular fitness, speed, agility, balance, and coordination (13, 14). These components have been consistently associated with indicators of obesity, cardiovascular health, metabolic health, bone health, and mental health (1).

Assessing PF reflects the impact of genetic and environmental factors on health-related PF components and consequently on health indicators (15). In light of this, assessing PF is a simple, safe, and low-cost tool that allows examining several health indicators. Based on the PF level of children, pedagogical, and public health strategies and policies can be developed. However, to correctly and accurately assess PF, the validity, reliability, and feasibility of PF assessment tools are essential. This is especially true when health and government entities aim to monitor a variety of health indicators in local, regional, national, or worldwide populations to guide policy actions.

Previous systematic reviews identified a large number of test batteries available worldwide to test children's and adolescents' PF levels (16–18). These reviews showed that different tests address different components of fitness such as cardiorespiratory fitness, musculoskeletal fitness, body composition, and central body fat. Although the selected tests are extensively used and recognized, they do not determine all physical fitness aspects. Moreover, a large number of field-based fitness tests presented in these systematic reviews have limited evidence (16, 18). Furthermore, previous reviews sought to identify physical fitness tests that could be used with children and adolescents. However, some of the contexts identified for the application of some batteries were the sport context. This context is elitist because few children and adolescents practice physical activity in the sports context.

So far no systematic review that provides a summary of all existing fitness test batteries for children and adolescents that can be carried out in the school setting under the specific circumstances of the school (e.g., time constraints, equipment at schools, the scope of testing, costs) has been carried out. Therefore, this systematic review aimed to identify and summarize the existing field-based health-related PF batteries that can be performed in children and adolescents to monitor and improve their health status.

METHODS

Data selection, collection, and analyses were performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (19).

Search Strategy and Data Sources

Five international databases (Academic Search Complete [ASC], Education Resources Information Center [ERIC], PubMed, Scopus, and Web of Science) were searched for scientific articles published in peer-reviewed journals until the 30th of April 2020 containing PF battery protocols. In each database, a search was conducted taking into account a predefined combination of keywords. The combination of keywords used in each database was the following: "field-based test" OR "fit*" OR "physical performance" OR "sport performance" OR "physical condition" OR "aerobic capacity" OR "maximum oxygen consumption" OR "strength" OR "flexibility" OR "motor" OR "endurance" OR "speed" OR "agility" OR "balance" OR "body composition" OR "anthropometry" OR "body mass index" OR "BMI" OR "skinfolds" OR "waist circumference" AND "batter*" OR "protocol*" OR "assess*" OR "valid*" OR "reproduct*" OR "feasab*" OR "measur*" AND "adolescent*" OR "child*" OR "young*" OR "school age" OR "school-aged" OR "youth". The keywords were selected and defined by consensus from all authors. Furthermore, the reference lists of individual studies that reported results or used PF batteries in their methodologies but did not present the protocol were searched for records containing those protocols. Records identified through this method were added as records identified through other sources.

Inclusion Criteria

This systematic review includes scientific articles from peer-reviewed journals that contained PF battery protocols published until the 30th of April 2020. Only records presenting PF batteries comprising field-based health-related PF tests for children and adolescents that could be performed in the school setting were included. Thus, inclusion criteria were the following: (1) presenting results on the identification, structure, validity, reliability or feasibility of PF batteries, or parts of it (including specific tests), assessing health-related PF components in children and adolescents; (2) containing PF batteries comprising field-based tests that can be performed in the school setting; (3) having a cross-sectional, prospective, observational, experimental, or narrative review study design; (4) being written in English, French, German, Spanish, or Portuguese. Records presenting findings on motor skills, other populations that were not children or adolescents, or not meeting all inclusion criteria were excluded.

Data Extraction and Selection

The data extraction process was conducted based on PRISMA guidelines (19). After downloading the records from the databases to a reference managing software and integrating further records identified through other sources, duplicates were removed. Two authors (DHN and MP) screened the remaining records for title and abstract to identify studies that met the

inclusion criteria. Relevant articles were retrieved for a full read. Then, the two authors reviewed the full text of potential studies, and decisions to include or exclude studies in the review were made by consensus. Disagreements were solved by consensus and, when necessary, a third reviewer served as a judge (AM). Agreement between reviewers was assessed using k statistics (k=0.96) for full-text screening and rating of relevance.

Data Analysis

Each identified PF battery was entered into a Microsoft Excel (Microsoft Corp., Redmond, Washington, DC, USA) spreadsheet, including information on author and year of publication; country; setting and age range of application; PF components assessed, and the PF tests used for each assessed component. The considered components of PF were body composition, CRF, upper body strength, lower body strength, middle-body strength, speed, agility, and flexibility. Also, a narrative synthesis was performed to describe each field-based health-related PF test in the identified PF batteries.

RESULTS

Study Selection

A total of 10223 records (1506 from ASC; 167 from ERIC; 1559 from PubMed; 2610 from Scopus; 4358 from Web of Science; and 23 from other sources) were identified. After removing duplicates (n=5,838), 4,385 records were screened based on title and abstract, resulting in 4,154 records excluded. A total of 231 records were assessed for eligibility by full-text reads. Finally, 33 articles matched all inclusion criteria and were included in the qualitative synthesis. The flow chart of records selection is presented in **Figure 1**.

Summary of the Identified Physical Fitness Batteries

Table 1 presents a summary of the PF batteries identified in the included records, showing author, year, country, setting, age-range, and test for the following PF components: body composition, CRF, upper body, middle-body and lower body strength, endurance and power, speed, agility, and flexibility. From the 33 included records, 25 PF batteries were identified. Nine PF batteries were from America (six from the United States, two from Canada, one from Brazil) (20–28), nine were from Europe (two from the Czech Republic, one from each of the following countries Norway, Slovenia, Portugal, Italy, France, and Spain, one from the European Union) (15, 23, 24, 27, 28, 30, 32, 41, 42), four were from Asia (one from each of the following countries: Japan, Singapore, China, and Russia) (33, 34, 38, 40), two were from Oceania (one from Australia, one from New Zealand) (22, 36), and one from the Middle East (Bahrain) (31).

Most PF batteries (21 of 25) are exclusively for children and adolescents, while four of them are also extended to young adults (33) and adults (26, 40, 42). Also, even though all PF batteries can be performed in the school setting with the purpose of monitoring health-related indicators, some of them can be used in other settings such as sports and the army to assess physical performance. Two examples are the National Youth Physical Program from the United States Marines Youth Foundation (NYPFP) and the Ready for Labour and Defense (GTO) from Russia that is usually used to monitor PF for military purposes.

Regarding the PF components assessed in the batteries, only the CRF and the upper body strength, endurance and power were contemplated in all PF batteries. Middle-body and lower body strength, endurance and power were presented in most of the PF batteries, 21 of 25 and 20 of 25, respectively. Other components as agility (17 of 25) and body composition (16 of 25) were also contemplated in most PF batteries, although to a lesser extent. Flexibility (14 of 25) and speed (13 of 25) were the PF components less represented in the batteries, notwithstanding they were present in at least 50% of the identified PF batteries.

Among 25 identified PF batteries, a total of 87 PF tests, assessing the different PF components, were encountered. The PF component with the widest variety of different tests, that is, with 23, was CRF. It was followed by upper body strength, endurance and power with 21, speed with 10, middle-body strength and endurance with nine, body composition with eight, agility with seven, lower body endurance and power with five and flexibility with four different tests.

DISCUSSION

This systematic review provides a summary of existent PF batteries from around the world containing field-based health-related tests that can be performed by children and adolescents and used to monitor health status. A total of 25 different PF batteries from European, American, Asian, and Oceanian countries were identified. This knowledge can be useful for selecting standardized and validated PF tests and batteries, adjusted for the school setting and considering different PF components, and simultaneously, allows direct comparison between peers of the same age from different geographic locations.

Among children and adolescents, PF is associated with numerous health indicators, thus assessing PF has been suggested to be a reliable tool to monitor health in youth (1). Furthermore, PF batteries are considered a valid, simple, precise, and low-cost health monitoring tool (44). Given that in several countries, such as Australia, Bahrain, Brazil, Canada, Czech Republic, China, France, Italy, Japan, Norway, Portugal, New Zealand, Russia, Singapore, Slovenia, Spain, and the USA, the military, sport, health, and education sectors have been implementing and using PF batteries. Findings from this review corroborate the popularity of PF assessments, once 25 PF batteries from four different continents were identified.

Being a multi-component construct, examining PF as a whole, using only one or two tests is a misconception, as different associations between PF components and health indicators are observed (1, 45). Because of that, the existence of detailed PF batteries is of importance. Such batteries allow taking into account a cluster of PF tests that are validated for each PF component, and that together it is possible to monitor complementing indicators of health and vulnerability. In this

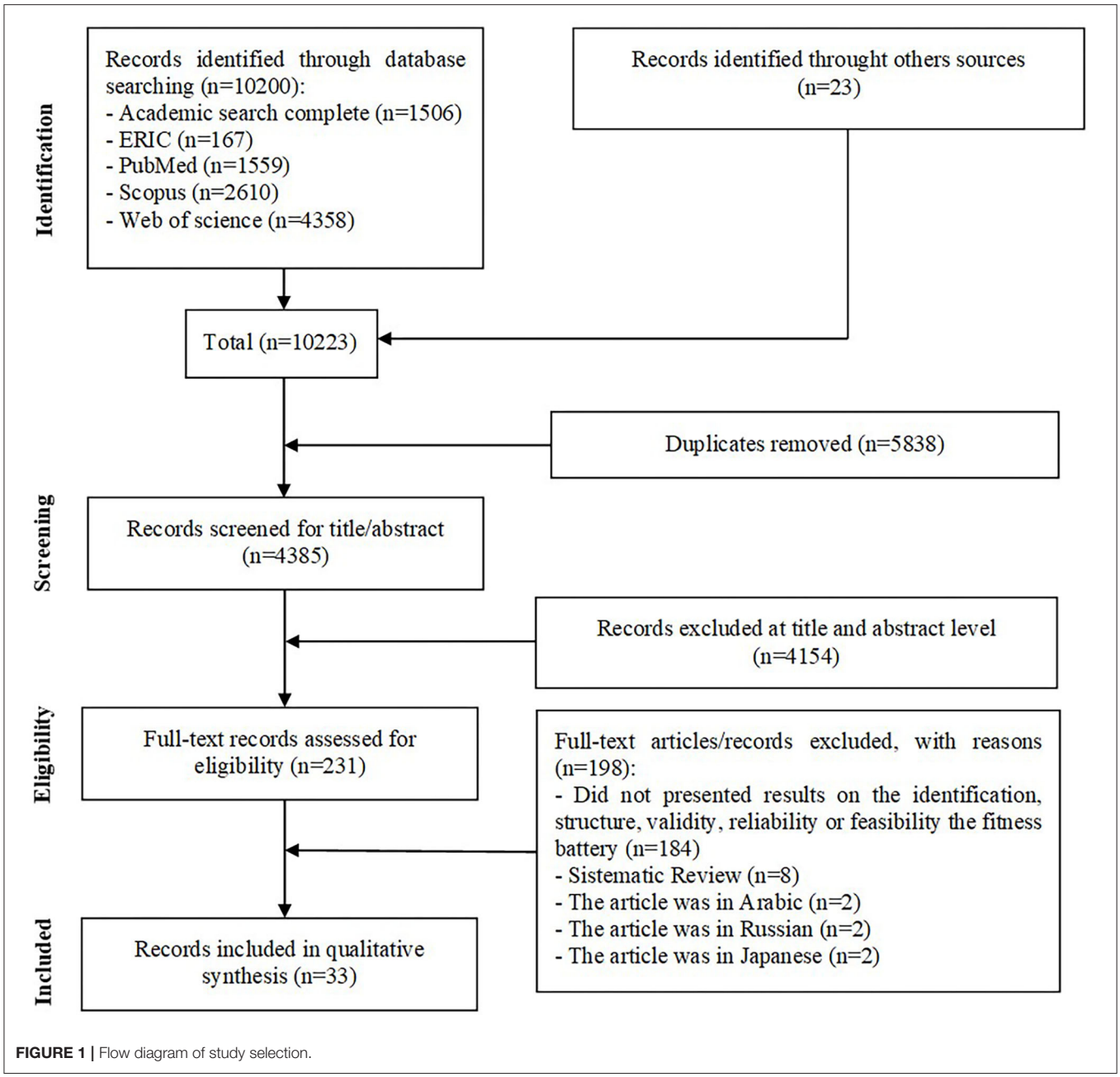

FIGURE 1 | Flow diagram of study selection.

review, body composition, CRF, and muscular fitness (MF) were identified as the components of PF most frequently assessed in PF batteries.

Assessing body composition is usually the result of different anthropometric measures and their relation, such as height, weight, or waist circumference, as well as methodologies to analyse the % of body fat, muscle mass, and hydration (44). The measures of body composition, used in PF batteries, identified in this review were BMI, waist circumference, % of body fat (skinfolds), height to waist ratio, waist to hip ratio, wingspan, and bioelectrical impedance analysis. Requiring only height and weight, the BMI is a non-invasive, inexpensive, practical, and a largely applicable anthropometric indicator of obesity (48, 49). On the other hand, BMI does not differentiate fat mass from lean mass and is thus an insufficient indicator of body fat or abdominal adiposity (50). In this line, to avoid misclassifications international experts have been suggesting waist circumference, which is a better indicator of central adiposity, as an alternative to BMI (50, 51). More precise measures of body composition, namely the % of body fat were also present in some batteries, assessed by skinfolds or bioelectrical impedance analysis. Skinfolds allow calculating the % of fat mass and fat-free mass, through specific equations and are a low-cost methodology but specific and intensive

TABLE 1 | Presentation and summary of the physical fitness batteries identified in the included records.

Batteries (country); author (year)	Setting; age range	Physical fitness measurements/tests										
		Body composition	Cardiorespiratory fitness	Upper body			Middle-body		Lower body		Speed	Agility	Flexibility
				Strength	Endurance	Power	Strength	Endurance	Endurance	Power			
AAHPER (USA); (20)	School and health; 5 to 18 years	None	Half-mile run/walk	None	Bent arm hang; pull-ups	Softball throw	None	Sit-ups	None	Standing broad jump	50-yard dash	4 × 30ft shuttle run	None
AAUTB (USA); (21)	School and sports; 6 to 17 years	None	Shuttle run test (Hoosier-60ft)	None	Modified push-ups; isometric push-ups; bent arm hang	None	None	Sit-ups	Phantom chair	Standing broad jump	50 m dash; 100m dash	4 × 10 m shuttle run	Sit and reach
ACHPER (Australia); (22)	School and health; 9 to 18 years	Height; weight; BMI	PACER	None	None	Basketball throw	None	Sit-ups	None	None	None	None	Sit and reach
ALPHA (Spain); (15)	School, sports, and health; 6 to 18 years	Height; weight; BMI; WC; %BF (skinfolds)	PACER	Handgrip	None	None	None	None	None	Standing broad jump	None	4x10m shuttle run	None
ASSO-FTB (Italy); (23)	School and health; 13 to 17 years	Height; weight; BMI; WC	PACER; 1-mile run / walk	Handgrip	None	None	None	Sit-ups	None	Standing broad jump	None	4x10m shuttle run	None
Bouge (France); (24)	School and health; 6 to 18 years	Height; weight; BMI	Half-mile run / walk; Navette test (20m)	None	None	Basketball throw	None	Curls-ups	None	Standing broad jump	50m dash	10x5m shuttle run	Sit and reach; shoulder stretch
CAHPER-FPT (Canada); (25)	School; 7 to 17 years	None	Half-, 1- and 1.5-mile run / walk; 1000m run	None	Bent harm hang	None	None	Sit-ups	None	Standing broad jump	50m dash; 100m dash	4x10m shuttle run	None
CPAFLA (Canada); (26)	School and health; 15 to 69 years	Height; weight; BMI; WC; HC; waist to hip ratio; %BF (skinfolds)	Step test	None	Handgrip; push-ups	None	None	Modified curl-ups; trunk-lift	None	Standing broad jump	None	None	Sit and reach
EUROFIT (Europe); (27)	School and health; 6 to 18 years	Height; weight and %BF (skinfolds)	PACER; 6 minute run test.	None	Handgrip; bent arm hang	None	None	Sit-ups; trunk-lift	None	Standing broad jump	Plate tapping	10x5m shuttle run	Sit and reach
FITescola (Portugal); (28)	School, sports, and health; 10 to 18 years	Height; weight; BMI; WC; %BF (skinfolds); BIA	PACER; 1-mile run / walk	None	Push-ups	None	None	Sit-ups	None	Standing broad jump; vertical jump	20m and 40m dash	4x10m shuttle run	Sit and reach test; shoulder stretch
FitnessGram (USA); (29)	School, sports, and health; 5 to 17 years	Height; weight; BMI; %BF (skinfolds); BIA	PACER; 1-mile run	None	Push-ups; bent arm hang; pull-ups; modified pull-ups	None	None	Curl-ups	None	None	None	None	Sit and reach; shoulder stretch
Physical Fitness Test Battery (Norway) (30)	School and health; 5 to 12 years	None	Reduced Cooper test	None	None	Tennis ball throw; medicine ball (1kg) throw	None	None	Jumping a distance of 7m on two feet and on one foot	Standing broad jump	20m dash	10x5m shuttle run; Climbing up wall bars	None
IPFT (Bahrain); (31)	School and health; 9 to 19 years	Height; weight; %BF (skinfolds)	1-mile run/walk test	Handgrip	None	Back throw	None	None	None	None	None	4x10m shuttle run	None
INDARES (Czech Republic); (32)	School and health; 7 to 18 years	Height; weight; %BF (skinfolds); BIA	PACER; 1500m run / walk	None	Push-ups	Cricket ball throw	None	Modified curl-ups	Chair squats	None	60m dash	4x10m shuttle run	V sit and reach; shoulder stretch

(Continued)

TABLE 1 | Continued

Batteries (country); author (year)	Setting; age range	Physical fitness measurements/tests											
		Body composition	Cardiorespiratory fitness	Upper body			Middle-body		Lower body		Speed	Agility	Flexibility
				Strength	Endurance	Power	Strength	Endurance	Endurance	Power			
NAPFA (Singapore); (33)	School and military; 12 to 24 years	None	1.5-mile run / walk	None	Pull-ups; flexed-arm hang (30 seconds)	None	None	Sit-ups with twist (1 minute)	None	Standing broad jump	None	4x10m shuttle run	Sit and reach
NFTP-PRC (China); (34)	School and health; 9 to 19 years	None	Shuttle run (50x8m); 4-, 3- and 2-minutes shuttle run (25m); Quarter-, half- and 1-mile run / walk; 1-minute jump rope	None	Bent arm hang; pull-ups; modified pull-ups; parallel-bars dips	None	None	Sit-ups	None	Standing broad jump	50m dash; 100m dash	4x10m shuttle run	None
NYPFP (USA); (35)	School, health, and military; 5 to 17 years	None	1-mile run / walk	None	Push-ups; modified push-ups; bent arm hang; pull-ups; modified pull-ups; parallel-bars dips	None	None	Sit-ups	None	Standing broad jump	None	None	None
NZFT (New Zealand); (36)	School and health; 6 to 12 years	Height; weight; %BF (skinfolds)	Cooper test (9 minutes)	None	None	Medicine ball throw; shot put (1 to 5kg); sand ball throw	None	Curl-ups	None	Standing broad jump	None	None	Sit and reach
PCPF (USA); (37)	School and health; 6 to 17 years	Height; weight; BMI; %BF (skinfolds)	PACER (20m and 15m), TAMT (aerobic behavior, level 1); 1-mile run/walk	None	Push-ups 90°; bent arm hang; pull-ups	None	None	Curl-ups; trunk lift	None	None	None	None	Sit and reach; shoulder stretch
PFAAT (Japan); (38)	School, sports, and health; 6 to 17 years	Height; weight; BMI	PACER	Handgrip	Pull-ups	Softball / handball throw	Back strength test	None	None	Vertical jump; standing broad jump	50m dash	Side-to-side steps	Sit and reach; stand and reach
PROESP (Brazil); (39)	School, sports, and health; 6 to 17 years	Height; weight; BMI; WC; height to waist ratio; wingspan	6-minutes run / walk	None	None	Medicine ball (2kg) throw	None	Sit-ups (1 minute)	None	Standing broad jump	20m dash	Square test (4x4m)	Sit and reach
Ready for Labor and Defense - GTO (Russia); (40)	School and military; 10 to 60 years	None	Running test (1 or 2 km); cycling (5km); cross-country running (0.5 to 1km)	None	Push-ups; pull-ups; rope climbing with legs	Tennis ball throw	None	None	None	Vertical jump; standing broad jump	30m, 50m, 60m, 80m or 100m dash	None	None

(Continued)

TABLE 1 | Continued

Batteries (country); author (year)	Setting; age range	Body composition	Cardiorespiratory fitness	Physical fitness measurements/tests									
				Upper body			Middle-body		Lower body		Speed	Agility	Flexibility
				Strength	Endurance	Power	Strength	Endurance	Endurance	Power			
SLOfit (Slovenia); (41)	School and health; 6 to 19 years	Height; weight; %BF (skinfolds).	Half-mile run	None	Bent arm hang	None	None	Sit-ups (1 minute)	None	Standing broad jump	60m dash; 20-seconds plate tapping	Polygon backward	Stand and reach
UNIFITTEST (Czech Republic); (42)	School, sports, and health; 6 to 60 years	None	12-min run/walk	None	None	Medicine ball throw	None	Sit-ups (1 minute)	None	Standing broad jump	None	4×10m shuttle run	None
YMCA-YFT (USA); (43)	School and health; 6 to 17 years	Height; weight; %BF (skinfolds)	1-mile run / walk	None	Modified pull-ups	None	None	Curls-ups	None	None	None	None	None

AAHPER, American Association for Health, Physical Education, and Recreation; AAUTB, Amateur Athletic Union Test Battery; ALPHA, Assessing Levels of Physical Activity and Fitness; ASSO-FTB, Adolescents and Surveillance System for the Obesity prevention – Fitness Test Battery; ACHPER, Australian Council for Health, Education and Recreation; CAHPER-FPT, Canadian Association for Health, Physical Education and Recreation-Fitness Performance Test II; CPAFLA, Canadian Physical Activity, Fitness and Lifestyle Approach; IPFT, International Physical Fitness Test; INDARES, International Database for Research and Educational Support; NAPFA, Singapore National Physical Fitness Award/Assessment; NFTP-PRC, National Fitness Test Program in the Popular Republic China; NYPFP, National Youth Physical Program; NZFT, New Zealand Fitness Test; PCPF, President's Challenge: Physical Fitness; PFAAT, Physical Fitness and Athletic Ability Test; PROESP, Projeto Esporte Brasil; USA, United States of America; YMCA-YFT, Young Men's Christian Association Youth Fitness Test.

***Note:** Middle-body power and lower body strength are not shown in the table because no measurements / tests on these physical fitness components were presented in the analyzed physical fitness batteries.*

training is required to minimize potential measurement error (52). Bioelectrical impedance analysis is more precise and allows to examine the % of fat mass, muscle mass or hydration status, however, it requires specific equipment, individual calibration and is more difficult to operationalize (53).

The CRF is the most studied component of PF among children and adolescents (54), and not surprisingly was assessed in each of the PF batteries identified in this systematic review. Higher levels of CRF are associated with a lower risk of several health outcomes, namely obesity, cardiovascular diseases, and mental health (1). The importance of assessing CRF was also reflected in a large number of tests observed, and among these tests, the PACER and the 1-mile run/walk seemed to be present in the most PF batteries. Both, the PACER and 1-mile run /walk are widely validated and reliable for assessing the CRF in young populations (15, 55). From these test results, maximum aerobic capacity can be estimated. From all equations to estimate maximum aerobic capacity through these field-based PF tests, the equations proposed by Cureton et al. (56) for the 1-mile run/walk test and Barnet et al. (57) for the PACER had the strongest evidence of validity with Léger equation (56–59). However, recently some issues have been raised regarding the estimation of maximum aerobic capacity considering that a multitude of factors (e.g., sex, adiposity) have an influence, emphasizing that estimations should be carefully interpreted to avoid misconceptions (60–62). Also, using test results in terms of the number of laps, stages, or time may provide a clearer picture of the individual's CRF.

Muscular fitness, another important PF component, was also assessed in each of the PF batteries identified. However, different components of MF (i.e., upper body, middle-body and lower body strength, endurance and power, agility, speed, and flexibility) were assessed across the batteries. Similar to CRF, MF is also associated with several health outcomes in youth (45, 46). A total of 56 different tests to assess the several components of MF were identified. For the upper body, the most common tests were the handgrip, push-ups or bent arm hang test, which assessed endurance and power. Regarding the lower body, the standing broad jump and the vertical jump, both assessing power, were the most usual tests. Lastly, for the middle-body, curl-ups and sit-ups were the most common tests, assessing endurance. Most of these tests require minimum equipment and are easily applied within a school or class setting. Agility, speed, and flexibility were present in fewer PF batteries than the other components of muscular fitness. This may be because there is more evidence observing the associations of lower, upper, and middle body strength with health indicators (47).

A total of 25 PF batteries were identified in this systematic review and across them 87 different PF tests for body composition, CRF, and MF. A previous systematic review focused on PF tests indicated that the PACER (or 20-meter shuttle run), the handgrip strength and standing broad jump tests, the 4×10m shuttle run test, weight, BMI, skinfolds, circumferences, and % body fat estimated from skinfold thickness were the most reliable field-based PF tests for children and adolescents (63). In this review, the aforementioned tests are among the most used in the identified PF batteries, which also corroborates previous research on this topic (17). Notwithstanding, when

selecting a measurement/ protocol test of body composition, CRF or MF to perform factors such as staff training, equipment cost and time should be considered, as they heavily influence data collection, validity, and feasibility. Also, to avoid data contamination and misinterpretations, all protocols should be clear and performed by trained personnel, such as physical education teachers and other specialists (44). Despite being beyond the scope of this paper, it is important to acknowledge that physical education, sport, and health professionals should have a pedagogical approach in the application of PF batteries. This means that the application of the PF batteries must be aligned with the promotion of meaningful, relevant, and positive experiences for children and adolescents (64).

This systematic review is not without some limitations. Firstly, the large number of articles and protocols for the same PF test may have resulted in an overlap of tests. Secondly, the terms selected to identify investigations and other documents describing the PF batteries, although highly thorough nevertheless may have excluded documents not matching the inclusion criteria. Also, the search was conducted in only five databases. Lastly, because of the different study designs and the integration of gray literature (not following a scientific structure, such as protocols) the risk of bias and study quality assessment was unfeasible. Yet, most importantly, the major strength of this review is the ample number of articles reviewed and time interval search, which resulted in the identification of a rich set of PF batteries from around the globe.

CONCLUSION

The advances in the PF field-based assessment on school settings and health in youth resulted in the amplification of the number of existing batteries. On the one hand, diversity allows choosing the battery that most fits the specific purpose and setting of the assessment. On the other hand, it somehow complicates the comparability of data from different contexts, countries, or regions. Therefore, considering the connection between PF and health and the opportunity that the school setting provides to assess fitness in children and adolescents, we highlight the need for standardization and a consensus of PF assessments in this specific setting. In the European Union, a unique and actualized European PF battery would allow comparisons between European children and adolescents from different countries, to contribute to adequate and specific education and health public policies in the future.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

AM and MP: conception and design and drafting the manuscript. DH-N, MP, JM, and FG: data acquisition. AM, SP, and BM: data analysis and interpretation. YD, AS, JM, DH-N, and AI: critical revision for intellectual content. DH-N and FG: administrative, technical or material support. All authors read and approved the final manuscript.

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The Direct and Indirect Relationships Within the Extended Trans-contextual Model for Moderate-to-vigorous Physical Activity

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Given the low levels of physical activity (PA) in adolescence, there are challenges to increasing students' PA outside of the school setting. Thus, researchers emphasize the supportive role that physical education (PE) teachers can play in PA motivation both in and out of school. The aim of the present study was to examine an expanded trans-contextual model (TCM) model for the transit of teachers' perceived support of students' autonomy in terms of contextual and situational motivation in PE to objectively measured moderate-to-vigorous physical activity (MVPA) in PE across different PE contents as well as to the motivational sequence for, and participation in, subjective MVPA during leisure time. This cross-sectional study involved 283 high school students, of whom 43.9% were boys. The autonomous support students received and other motivational factors and objective measures of MVPA in PE and subjective MVPA in leisure time were measured. The results indicate that support for autonomy was significantly and directly related to needs satisfaction ($\beta = 0.61$, $p < 0.001$) and indirectly to autonomous motivation in PE ($\beta = 0.19$, $p < 0.001$) and leisure time ($\beta = 0.16$, $p < 0.001$), intention in PE ($\beta = 0.03$, $p < 0.05$) and leisure time ($\beta = 0.07$, $p < 0.001$), and leisure time MVPA ($\beta = 0.04$, $p < 0.001$), although not MVPA in PE. Gender was a significant covariate for both MVPA in PE ($\beta = -0.62$, $p < 0.001$) and MVPA in leisure time ($\beta = -0.37$, $p < 0.001$), with higher MVPA in boys than girls. This study filled a gap in the scientific literature by demonstrating the full motivational sequence resulting in actual MVPA in PE classes. It also demonstrated that the main goal of PE of enhancing PA not only in school but also outside of school is working. The main motivator is needs satisfaction based on PE teachers' support.

Keywords: high school students, need satisfaction, autonomy support, objective moderate-to-vigorous physical activity, leisure time moderate-to-vigorous physical activity

INTRODUCTION

Physical education (PE) is meant to not only keep children physically active in school but also encourage them to be physically active outside of school (1). Students often fail to engage in a sufficient amount of moderate-to-vigorous PA (MVPA) during PE class (2–4). In general, insufficient physical activity (PA) is a problem among adolescents, as ∼80% of adolescents are physically inactive worldwide (5). Only around 30% of high school students meet the World Health Organization's recommendation that they be physically active at a moderate-to-vigorous level for at least 1 h a day (6).

Given the low levels of PA in adolescents, the challenges to increasing their PA outside of school include lack of access to facilities, unsafe neighborhoods, and attractive sedentary alternatives. Hence, maximum active movement time in PE should be a public health priority (3). There is evidence to suggest that students' PA levels vary by PE lesson content (7–9). Researchers also emphasize the supportive role that PE teachers play in PA motivation both in and out of school (10). A systematic review of interventions in PE used to achieve higher MVPA in students suggests that interventions developed in reference to a theory of behavior change, and specifically those that target hypothesized motivational mediators of behavior change, are more successful than interventions that are not grounded in theory (3). Many behavior-change models suggest predictors for health-related behaviors, including PA. Some predictors are present across models, while others are distinct to a particular model. The shortcomings of isolated models indicate the need to integrate them. By integrating models explaining PA, it is possible to not only grasp the factors that explain motivation for PA but also evaluate the sequences (paths) between different predictors (11). This last point is crucial as the main purpose of applying a model or theory is to track how factors relate to behavior rather than simply identify a specific relationship.

Trans-Contextual Model

The current study aimed to explain how PE motivational factors impact MVPA in PE as well as during high school students' leisure time via the trans-contextual model (TCM) of behavioral change. The primary focus of the TCM is to explain the motivational transition from the PE domain to the leisure time domain triggered by support for autonomy (12). The underlying premise of the TCM is that the predictors of PA are easier to target in the organized context of PE rather than in the leisure time, context; however, benefits can be accrued in both contexts. In addition, the TCM integrates qualitative and quantitative factors from different motivational perspectives.

The TCM integrates two classical behavioral theories—self-determination theory [SDT, (13)] and the theory of planned behavior [TPB, (14)]. The former theory– SDT—analyzes motivation, which is divided into autonomous motivation (self-determined) and controlled motivation (not self-determined). Individuals differ in terms of the manifestations of their autonomous and controlled motivations. However, the degree of autonomy present in different behavioral contexts may vary (e.g., a person can be more autonomous in terms of exercising than in terms of taking medication regularly). The motivational level attained along the self-determination continuum depends upon the levels to which three main psychological needs are satisfied. These needs are autonomy (free will to make self-determined decisions), competence (perception of self-efficacy), and relatedness (close, trusting relationships with significant others), all of which are interdependent (15). In SDT, motivation gained through the satisfaction of psychological needs is affected by the perceived support for autonomy, a certain degree of which can promote or interfere with an individual's self-determination (13). Hence, SDT considers the role of an external agent in an individual's motivational transition. Support for autonomy emphasizes choice, although choices should be provided within specific rules and limits, with rationalizations provided for tasks and limits, acknowledgments of students' feelings and perspectives, respect, opportunities for initiative, and avoidance of controlling behaviors (16). Empirical evidence indicates the positive effect of perceived teacher support for student autonomy on students' motivational outcomes, including outcomes in PE (17–22). It has been determined that perceived teacher support for autonomy is related to higher levels of PA in PE classes ((23)). This transfer is triggered by the motivational process, in which an environment that is supportive of autonomy increases levels of autonomy, competence, relatedness, and self-determination (24). The latter theory—TPB—also includes social-cognitive factors. The central construct of this theory of motivation is intention, which serves an indicator of readiness for action, investment in planned efforts, and future behavior. Intention reflects the amount of motivation an individual has, i.e., how much an individual is motivated to perform a specific behavior. Thus, intention can serve as a generalized quantitative characterization of motivation. Intention largely depends on an individual's attitudes (positive or negative feelings with respect to behavior), subjective norms (the level of motivation arising from the expectations of significant others regarding the individual's involvement in a particular behavior), and perceived behavioral control (beliefs about their self-efficacy with regards to engaging in a behavior) (14).

Some authors have stated that qualitative motivation determines quantitative motivation (12). For instance, in SDT, the qualitative motivation of an individual with an autonomous motivation for physical activity, i.e., their behavioral context, will lead them to be equally motivated to perform various physical activity activities (25). Thus, qualitative motivation is contextual motivation. Meanwhile, TPB identifies the level of readiness or plan for performing a very specific behavior at a certain frequency within certain time limits, for instance, exercising at a particular frequency for a specified period of time. Such motivation is considered to be situational. The integration of the SDT and TPB models, which cover different motivational perspectives, helps in the identification of the correct actors as the scene shifts from context to situation and provides insights for interventions in a targeted, cost-effective, and efficient way. The integration of TPB and SDT to form the TCM is based on following three arguments:

(1) Both TPB and SDT are based on cognitive, i.e., decision-making, processes. Both theories stress that behavior is a conscious decision (26) and not spontaneous.
(2) The theoretical premises of SDT include the preposition that autonomous motivations become intentions regarding behavior via beliefs (27). TPB includes intention as the most proximal predictor of a specific behavior as the result of a set of beliefs but does not explain the more general reasons as to why those beliefs are held (28). The level of self-determination might explain differences in behavioral beliefs (29), as beliefs go along with the level of autonomy (26). However, SDT is not focused on the decisional processes for very specific behavior regarding frequency or time dedicated (29). The integrated model avoids these shortcomings in the two models. In particular, the contextual motivation determined by SDT is related to behavior through the intentional decision-making processes in TPB (26).
(3) TPB is focused on the quantitative aspect of motivation, i.e., the strength of the intention. However, a strong intention does not always turn into actual behavior (30). Hence, reducing motivation to its quantitative dimension is not always justified. Meanwhile, SDT focuses on qualitative differences in motivation. For instance, two students might have the same intentions to be physically active in PE; however, one could be driven by his/her inner motivation, whereas the other student could be driven by pressure from a teacher (31). Thus, including the qualitative aspects of motivation could be helpful in explaining situational behavior in a more rational way.

The Present Study

Using the TCM to explain the transition of motivation from PE to the leisure domain has received empirical support across multiple studies (25, 32, 33). Classical TCM ignores needs satisfaction, which is the key to enhancing autonomous motivation in SDT. Similar to a study on Spanish adolescents (34), this study broadened TCM to include needs satisfaction. Moreover, few TCM-based studies have examined objectively measured PA (33), specifically objectively measured MVPA in PE. In research similar to this study, the integrated TCM model has explained the transition of motivation from PE to leisure time (25, 33, 35). However, many previous studies have limited their explorations of the transition of motivation for PA in PE to leisure-time motivation and/or actual behavior (33, 36, 37). In particular, very few studies have examined PA in PE alongside leisure-time PA. Finally, none of these studies examined the motivational sequence triggered by teachers' support for autonomy in terms of MVPA measured objectively across PE classes with different educational contents. Meanwhile, researchers have suggested that non-traditional PE class activities might increase students' motivation and engagement in comparison with traditional activities (38). Playing games, practicing skills, and fitness lessons had the greatest impact on MVPA (8). Hence, it is of interest to examine the effect of teachers' support for MVPA on different educational contents in PE classes. **The aim** of the present study was to use the expanded TCM model to explore the transit of perceived teacher support for student autonomy through contextual and situational motivation in PE to objectively measured MVPA in PE across different PE contents as well as to the motivational sequence in the leisure time domain and subjective leisure time MVPA. Thus, the current study attempted to gather information on what has been missed in other studies, namely, the motivational sequence and its transition to PE and leisure-time MVPA. No other study has provided such a full picture to date.

Several hypotheses were developed (**Figure 1**): (1) in the PE domain, PE teacher's perceived support for autonomy will be directly and positively associated with students' needs satisfaction, whereas needs satisfaction will be related to autonomous motivation in PE, autonomous motivation in PE will be associated with the intention to be physically active in PE, and intention in PE will predict MVPA in PE; (2) in the leisure-time domain, autonomous motivation will be related to intention to engage in leisure-time PA, and this intention will be associated with leisure-time MVPA; (3) there are trans-contextual direct relationships between the PE and leisure-time domains, specifically between the contextual autonomous motivations and situational motivations, i.e., intentions, within these two domains; (4) needs satisfaction will be significant mediator in the effect of support for autonomy on MVPA in PE; (5) the indirect effect of perceived support for autonomy will be transferred from PE to the leisure-time domain through other motivational factors arising in PE.

METHODS

Participants

Initially, 318 students were selected for the study. Due to illness or other reasons, 35 students (11% of the total sample) did not attended one or more PE classes. They were subsequently withdrawn from the study. In the end, this cross-sectional study included 283 high school students. Among them, 43.9 % were boys, and 56.1% were girls. The ages of the participants varied from 15 to 17 years old, with a mean M = 15.62 years, and a standard deviation SD = 0.67 years. Body mass indexes ranged from 14.48 to 29.63, with a mean M = 20.5, and standard deviation SD = 2.54.

Measures

Support for autonomy in PE was evaluated using a modified version of the short form of the Sport Climate Questionnaire [SCQ, (12)]. The six items on the short form were changed slightly to adapt them to the PE context, for example, "I feel that my PE teacher provides me with choices and options" and "My PE teacher listens to how I would like to do things in PE lessons." Answers for each item were recorded on a seven-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Cronbach's α, which was used to measure the internal consistency of the scale, was 0.808.

Needs satisfaction in PE was assessed in terms of autonomy, competence, and relatedness using 16 items within three respective subscales. The development of the subscales is described in detail elsewhere (21). Satisfaction in terms of autonomy was measured with six scale items (e.g., "I have some choice in what I want to do"), one of which was reverse coded ("I have to force myself to do the activities"). Satisfaction in terms

of competence was measured with five scale items (e.g., "I am pretty skilled at PE"). Relatedness was also assessed with five scale items. These items had a common stem, namely, "With the other students in my PE class, I feel…," which was then followed by terms such as "close," "valued," and "supported." Responses on all 16 items were indicated on a seven-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree") (21). Confirmatory factor analysis (CFA) confirmed the factor structure of the three needs scales, with the exception that the root mean square error of approximation (RMSEA) was above the satisfactory threshold ($\chi^2 = 525.99$; $df = 101$; RMSE = 0.122; [95% CI= 0.112–0.132]; Comparative fit index (CFI) = 0.971; Tucker–Lewis index (TLI) = 0.965; standardized root mean square residual (SRMR) = 0.057).

Autonomous motivation in PE was identified using a revised version of the Perceived Locus of Causality (PLOC) scale developed by Vlachopoulos et al. (39). This scale was first developed by Ryan and Connell (40), then initially revised by Goudas et al. (41). The scale consists of 19 items. Responses are indicated on a seven-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). Scores on the Intrinsic, Identified, Introjected, External, and Amotivation scales were summed up individually and divided by the number of items in that scale, then the Relative Autonomy Index in PE was used to calculate the final overall score [(Intrinsic x +2) + (Identified x +1) + (Introjected x−1) + (External x−2) + (Amotivation x−3)]. The CFA demonstrated satisfactory parameters ($\chi^2 = 514.47$; $df = 143$; RMSE = 0.096 [95% CI = 0.087–0.105]; CFI = 0.978; TLI = 0.974; SRMR = 0.053), confirming the structure of the original scales. The Cronbach α's of the scales ranged from 0.811 to 0.932.

To assess the autonomous motivation for participating in physical activities during leisure time, the BREQ-2 questionnaire was used (42). This 19-item questionnaire is comprised of five subscales that reflect intrinsic, identified, introjected, and external motivation as well as amotivation. Answers are provided on a 5-point Likert scale ranging from 0 = "not true for me" to 4 = "very true for me." Subscale scores were calculated by summing the individual item scores and dividing by the number of items. For this study, the Relative Autonomy Index (RAI) score, which indicates the degree to which a student's physical activity motivation is autonomous, was used. The RAI is calculated by multiplying each subscale score by a specific ratio, then summing the scores. The RAI score ranges from−24 to +20, with higher positive scores indicating more autonomous motivations (15). CFA was performed and indicated that the parameters were good ($\chi^2 = 262.64$; $df = 86$; RMSE = 0.042 [95% CI = 0.036–0.048]; CFI = 0.993; TLI = 0.986; SRMR = 0.014), confirming the structure of the original scales. The Cronbach α's of the scales ranged from 0.817 to 0.899.

The intention to participate in PE class and leisure-time PA over a two-week period was assessed with three items designed for leisure-time PA by Chatzisarantis et al. (43) and three similarly-worded items for PE class PA. The items were developed in accordance with the work of Ajzen and Madden (44) and worded to reflect behavioral criteria in terms of time, context, target, and action (45). For instance, "I intend to exercise/play sport at least 3 times a week during the next two weeks" was used for leisure-time PA, and "I intend to exercise/play sport until I sweat at least half a PE class during the upcoming classes" was used for PE class PA. Responses were indicated on a 7-point scale ranging from 1 (very unlikely) to 7 (very likely). The Cronbach α's for leisure-time and PE class PA intention scales were 0.880 and 0.920, respectively.

Physical activity in PE was measured using an accelerometer (Tri-axis ActiTrainer Activity Monitor) validated in other study (46). In accordance with the Lithuanian PE curriculum (47), compulsory PE content should include games (basketball, volleyball, and other sports games as well as general gymnastics), practice in motor skills (correct posture, breathing, and movement when running, carrying an object, pushing, rolling, crawling, and balance, along with intellectual skills, such as concentration, and self-confidence), and non-traditional physical activities (age-appropriate non-traditional, non-Olympic sports: dancing, aerobics, skateboarding, roller skating sports, darts, bowling, weightlifting, yoga, fighting arts, discus, and more). MVPA in these three different areas was identified. The mean percentage of MVPA in these three types of classes for a student was considered to be the indicator of their PA in PE and was calculated as follows. Vertical and horizontal accelerations in motion were counted in epoch time lengths of 60 s. The recorded count for each epoch represented the intensity of the activity undertaken during that time period. Five PA levels were distinguished in accordance with the count obtained during the epochs: sedentary (0-149), light (150-499), moderate (500-3999), vigorous (4000-7599), and very vigorous (7600 and above) (48). Minutes spent in moderate, vigorous, and very vigorous PA were first summed up, then divided by 45 (45-min classes) to obtain percentages.

PA in leisure time was measured using the short form of the International Physical Activity Questionnaire [IPAQ, (49)]. The questionnaire is described in detail elsewhere; however, for the purpose of this study, four items from this 7-item questionnaire were used, specifically those recording the frequency of, and time spent engaged in, vigorous and moderate physical activity (e.g., "During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking," and "How much time did you usually spend doing moderate physical activities on one of those days?"). These items showed positive intercorrelations with the objectively measured PA at its respective intensities (50). Weekly minutes spent on vigorous and moderate physical activity were calculated separately by multiplying the number of days per week by the duration on an average day, then summing and dividing by 60 to arrive at hours per week.

Gender was used as the control variable in this study.

Procedure

The protocol for this study was approved by the Ethics Committee of the Lithuanian Sports University (No. SMTEK-13), and the study was conducted in accordance with the Declaration of Helsinki. Study participants and their parents provided informed consent before participation. The subjective

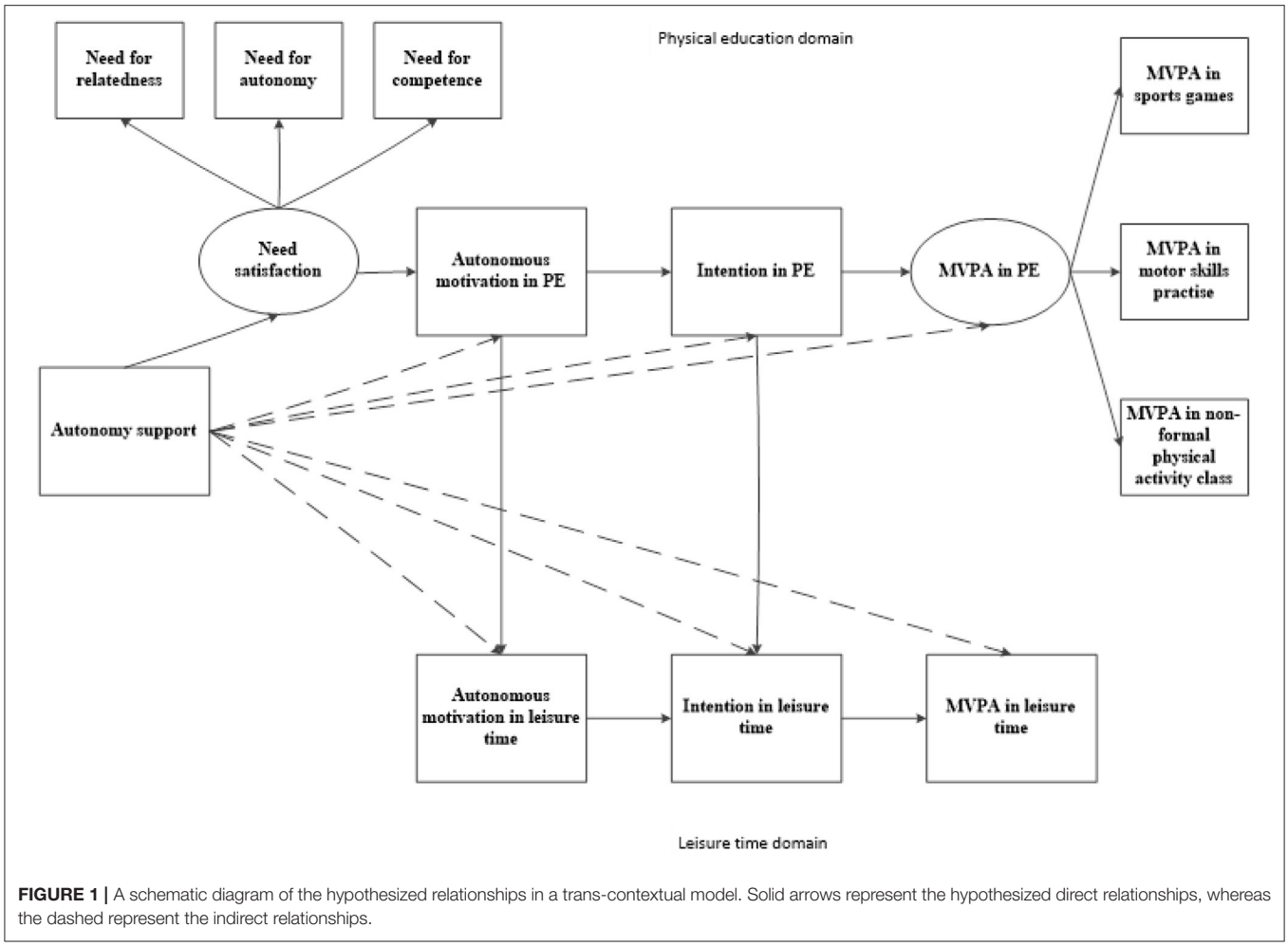

FIGURE 1 | A schematic diagram of the hypothesized relationships in a trans-contextual model. Solid arrows represent the hypothesized direct relationships, whereas the dashed represent the indirect relationships.

and objective measures were obtained from two schools in the city of Kaunas. Twenty classes in total across two grades (9th and 10th) were used. Students completed the paper questionnaire in the classroom two weeks before the objective measurements were taken. The Researchers explained the aim of, and procedures to be used in, the study prior to the completion of the questionnaire, which took 20–25 min to complete. The objective measurements of MVPA were taken two weeks later than the subjective measurements and across three PE lessons (one game, one motor-skill practice, and one informal physical activity) within the two-week period. Actigraphs were attached to belts by the researchers and worn on students' left hips. All PE classes in Lithuania last 45 min. PA was monitored from the first minute of PE class until class ended ("from bell to bell"). Students changed into their PE clothes prior to the start of each class. However, PE class time included receiving instructions from the PE teachers, during which time the students did not really move; nonetheless, we were still specifically interested in determining the percentage of time students spent in moderate-vigorous activity during their entire "from bell to bell" PE lesson. We followed the same practice for all three PE classes in all schools and for all students.

Statistical Analysis

Data were analyzed using SPSS 24.0 (SPSS Inc., Chicago, IL, USA) and MPLUS 8.4 software. The means (Ms), standard deviations (SDs), and frequencies of the variables used in the study were measured. Pearson's r was used in correlational analyses. CFA was used to confirm the questionnaire's structure. Structural equation models (SEMs) were used to identify direct and indirect relationships. The χ^2/df statistic was used as a goodness of fit index for CFA and the SEMs, i.e., the fit was acceptable if $2 < \chi^2/df < 3$. In addition, the root mean square error of approximation (RMSEA), along with its 90% confidence interval (CI), was used. The RMSEA is a population-based fit index that is insensitive to the sample size. Moreover, the SRMR, which is a direct assessment of how well and a priori model reproduces the sample data, was employed. Values of RMSE and SRMR <0.05 were considered to indicate a very good fit, and values <0.08 were interpreted as indicating a good fit. Also, the comparative fit index (CFI) and Tucker–Lewis index (TLI), both incremental indices used to compare the fit of a hypothesized model with that of a baseline model (i.e., the model with the worst fit), were used. Values of CFI and TLI >0.90 indicate a good model fit, and values

TABLE 1 | Descriptive statistics of study variables.

Study variables	M	SD	Skewness	Kurtosis
Autonomy support (within 1 to 7)	4.66	1.23	−0.010	−0.434
Need for autonomy (within 1 to 7)	4.79	1.18	−0.129	−0.509
Need for competence (within 1 to 7)	4.83	1.30	−0.308	−0.340
Need for relatedness (within 1 to 7)	5.05	1.60	−0.524	−0.534
RAI in PE	23.31	6.55	0.075	−0.494
RAI in leisure	8.87	6.08	−0.822	0.301
Intention in PE (within 1 to 7)	5.19	1.73	−0.603	−0.694
Intention in leisure (within 1 to 7)	5.38	1.74	−0.777	−0.552
Sports games MVPA (mean %)	36.19	22.34	−0.669	0.083
Motor skills practice MVPA (mean %)	33.85	17.63	−0.366	−0.475
Non-traditional physical activity MVPA (mean %)	34.48	20.85	−0.182	−0.930
Total MVPA in PE (mean %)	35.38	14.75	0.492	−0.404
MVPA in leisure (h/week)	4.04	1.54	−0.490	−0.777

RAI, Relative Autonomy Index; PE, Physical Education; MVPA, moderate-to-vigorous physical activity; h, hours.

>0.95 reflects a very good model fit (51). Statistical significance was set at a *p*-value of less than 0.05.

RESULTS

Table 1 presents Ms and SDs for the main study variables. The mean value of the support for autonomy variables was just above 4.5 in a range from 1 to 7. The means of the three needs satisfaction variables all approached 5 and had ranges from 1 to 7. The mean for autonomous motivation in PE exceeded 23 points, and the same indicator in leisure time reached nearly nine points. Intentions for MVPA in both PE and leisure had means just above 5. Participation in MVPA in PE classes having different contents averaged about 35% of the 45-min PE class. The mean MVPA in leisure was around 4 h a week.

The correlational analysis presented in **Table 2** reveals that support for autonomy was positively related to higher needs satisfaction and especially to a need for relatedness. Support for autonomy was also positively related to autonomous motivation for PA in PE and leisure time, intentions to be physically active in PE and leisure time, and more hours of leisure time MVPA. However, support for autonomy was not related to MVPA in PE, regardless of content. Total MVPA in PE was positively related the need for autonomy, stronger intentions for PA in both PE and leisure, and higher autonomous motivation for leisure-time PA, although these associations were rather weak. It was not positively related to motivation for PA in PE. Meanwhile, hours of MVPA per week were positively associated with all the rest of the variables, with the strongest positive associations showing up for autonomous motivation for leisure time PA and intention to engage in PA during leisure periods.

Table 3 presents the direct and mediating effects within the TCM. Two models, one for PE only with three final outcomes represented by MVPA effort by PE class content, and a second one with two final outcomes, namely, latent MVPA in PE and MVPA in leisure time, were developed. The results of the path analysis for the first model involving final outcomes in PE, i.e., MVPA in games, practicing motor skills, and non-traditional physical activities, revealed that the hypothesized model exhibited an acceptable data fit ($\chi^2 = 40.00$, $df = 23$; CFI = 0.97; TLI = 0.93; RMSEA = 0.055 [90% CI= 0.024–0.083]; SRMR = 0.038). The results of the path analysis for the second model involving final outcomes of latent MVPA in PE and MVPA in leisure time also showed an acceptable fit ($\chi^2 = 82.54$, $df = 33$; CFI = 0.95; TLI = 0.93; RMSEA = 0.078 [90% CI= 0.057–0.100]; SRMR = 0.049). Latent MVPA in PE was aggregated from the observed MVPAs in classes emphasizing games ($\beta = 0.59$), practice in motor skills ($\beta = 0.43$), and non-formal physical activities ($\beta = 0.53$). The needs satisfaction in each of the models was a latent variable aggregated from the need for autonomy ($\beta = 0.72$), competence ($\beta = 0.67$), and relatedness ($\beta = 0.75$).

In the PE domain, direct relationships in the model were observed between support for autonomy and needs satisfaction, needs satisfaction and RAI in PE, RAI and intention in PE, intention in PE and MVPA in games and practicing motor skills but not non-traditional physical activities. Intention in PE also predicted latent MVPA in PE. Meanwhile, RAI in leisure was directly predicted by RAI in PE, revealing a trans-contextual relationship. Further, RAI in leisure time as well as intention in PE predicted intention in leisure, which, in turn, was related to MVPA in leisure, again confirming the trans-contextual effect.

Indirectly, support for autonomy was related to intention in PE, with the path mediated by latent needs satisfaction and RAI in PE, and had a trans-contextual effect on intention in leisure that was mediated by needs satisfaction, RAI in PE, and RAI in leisure. Accordingly, support for autonomy was related to RAI in PE through needs satisfaction and to RAI in leisure through needs satisfaction and RAI in PE. However, support for autonomy was not indirectly related to MVPA in any of the PE classes. It was indirectly associated with MVPA in leisure along a path mediated by needs satisfaction, RAI in PE, RAI in leisure, and intention in leisure. As a covariate, gender was significant for all physical activity indicators, revealing the association of the female gender with lower MVPA in PE, regardless of content, and MVPA in leisure time.

DISCUSSION

The purpose of the current study was to examine the direct and indirect relationships of motivational factors in the PE and leisure domains and the associations of those motivational factors with objectively measured MVPA in PE class and subjectively measured MVPA in leisure with an expanded TCM. More specifically, a search was made for paths facilitating the transit of the effect of support for autonomy in PE to MVPA in PE across different PE contents and leisure-time PA through contextual and situational motivation in PE and leisure time. Given that PE is the only organized way to encourage PA and that PE teachers are obliged to deliver

TABLE 2 | Correlations between study variables.

Study variables	1	2	3	4	5	6	7	8	9	10	11	12
1.Autonomy support	1											
2. Need for autonomy	0.464**	1										
3. Need for competence	0.320**	0.521**	1									
4. Need for relatedness	0.522**	0.508**	0.514**	1								
5. RAI in PE	0.147*	0.512**	0.474**	0.396**	1							
6. RAI in leisure	0.197**	0.330**	0.471**	0.380**	0.444**	1						
7. Intention in PE	0.178**	0.419**	0.441**	0.348**	0.404**	0.449**	1					
8. Intention in leisure	0.117*	0.276**	0.397**	0.328**	0.329**	0.642**	0.567**	1				
9. Sports games MVPA (mean %)	0.073	0.121	0.102	0.025	0.010	0.096	0.025	0.107	1			
10. Motor skills practice MVPA (mean %)	0.009	0.099	0.026	0.068	0.120	0.090	0.032	0.022	0.278**	1		
11. Non-formal physical activity MVPA (mean %)	0.044	0.108	0.109	0.107	0.102	0.096	0.021	0.141*	0.291**	0.339**	1	
12. Total MVPA in PE (mean %)	0.017	0.142*	0.076	0.006	0.108	0.144*	0.138*	0.198**	0.473**	0.528**	0.556**	1
13. MVPA in leisure (h/week)	0.130*	0.167**	0.329**	0.197**	0.238**	0.504**	0.274**	0.568**	0.233**	0.145*	0.206**	0.356**

*RAI, Relative Autonomy Index; PE, Physical Education; MVPA, moderate-to-vigorous physical activity; h, hours. *p<0.05; **p<0.01.*

PE in such a manner as to encourage PA not only in PE classes but in leisure time (1, 52), it is important to track the motivational sequence triggered by teachers that leads to PA. The expanded TCM includes needs satisfaction as a latent variable derived from support for autonomy, competence, and relatedness.

The results showed that students engaged in MVPA for around 35% of the time spent in PE class, varying from 34.48% in non-traditional PA to 36.19% in classes involving games. A recent meta-analysis of studies along this vein indicated very similar results, showing that, on average, students engaged in MVPA during 33.0% of their PE classes (53). Specifically, studies measuring MVPA using accelerometers showed that students spent 34.7% (95% CI = 25.1–44.4%) of a lesson engaging in MVPA (54). Results of other studies suggest that teachers should devote a greater portion of time to games if their aim is to encourage student PA (55).

Gender was a significant covariate in our study, indicating higher MVPA in PE class and leisure time for boys compared to girls. Many studies have also revealed that girls were less physically active in PE classes than boys (56–58). One possible explanation for these results is that male teachers conduct PE lessons with significantly more vigorous activity than female teachers (59). In Lithuanian, girls are taught by female PE instructors, and boys are taught by male PE instructors. The same difference between boys and girls was found in MVPA during leisure time across many countries in a previous cross-national study (60).

Direct Relationships Within the Physical Education Domain

The current study supports multiple propositions as the result of the use of the expanded TCM. Specifically, higher perceived support for autonomy in PE was directly and positively related to needs satisfaction, which, in turn, was directly and positively related to autonomous motivation in PE. The findings of another recent study revealed that needs for autonomy, competence and relatedness satisfaction were positively related to autonomous motivation (32). Meanwhile, autonomous motivation in PE, which represented contextual motivation in the model, was further related positively to situational motivation, as represented by intention in PE, which is in line with the theoretical presumption that situational motivation is defined by contextual motivation (25). The current study indicated that the intention to participate and be physically active in PE classes predicted objectively measured total MVPA and MVPA in games and practicing motor skills, in particular, but not MVPA in non-traditional physical activity classes. Few studies have dealt with tracking further links to actual PA behavior in PE, especially when it comes to using objective methods (23, 61). Thus, the

TABLE 3 | Direct and indirect effects across five models predicting MVPA in sports games, motor skills practice, non-traditional physical activity lessons, total MVPA in physical education and leisure time MVPA.

Independent variable	Dependent variable	Pathway	β	CI (95%)		*P*
				LL	UL	
Direct effects						
Autonomy support	Latent Need satisfaction	n/a	0.611	0.049	12.722	**<0.001**
Latent Need satisfaction	RAI in PE	n/a	0.311	0.061	5.095	**<0.001**
RAI in PE	Intention in PE	n/a	0.214	0.075	2.843	**0.004**
Intention in PE	Sports games MVPA	n/a	0.137	0.058	2.384	**0.017**
Intention in PE	Motor skills practice MVPA	n/a	0.141	0.061	2.302	**0.021**
Intention in PE	Non-traditional MVPA	n/a	0.053	0.060	0.881	0.378
Intention in PE	Latent MVPA in PE	n/a	0.214	0.075	2.843	**0.004**
RAI in PE	RAI in leisure	n/a	0.813	0.022	36.152	**<0.001**
RAI in leisure	Intention in leisure	n/a	0.471	0.081	5.838	**<0.001**
Intention in PE	Intention in leisure	n/a	0.504	0.046	10.942	**<0.001**
Intention in leisure	MVPA in leisure	n/a	0.533	0.042	12.622	**<0.001**
Indirect effects						
Autonomy support	Intention in PE	Latent Need satisfaction, RAI in PE	0.031	0.014	2.270	**0.023**
Autonomy support	Intention in leisure	Latent Need satisfaction, RAI in PE, RAI in leisure	0.073	0.019	3.765	**<0.001**
Autonomy support	RAI in PE	Latent Need satisfaction	0.190	0.041	4.602	**<0.001**
Autonomy support	RAI in leisure	Latent Need satisfaction, RAI in PE	0.155	0.034	4.539	**<0.001**
Autonomy support	Sports games MVPA	Need satisfaction, RAI in PE, Intention in PE	0.007	0.004	1.638	0.101
Autonomy support	Motor skills practice MVPA		0.008	0.005	1.611	0.107
Autonomy support	Non-traditional physical activity MVPA		0.003	0.003	0.821	0.412
Autonomy support	Latent MVPA in PE		0.007	0.004	1.763	0.078
Autonomy support	MVPA in leisure	Need satisfaction, RAI in PE, RAI in leisure, Intention in leisure	0.039	0.011	3.575	**<0.001**
Covariate effect						
Gender	Sports games MVPA		−0.803	0.103	−7.796	**<0.001**
Gender	Motor skills practice MVPA		−0.457	−3.827	−3.827	**<0.001**
Gender	Non-traditional MVPA		−0.654	0.112	−5.847	**<0.001**
Gender	Latent MVPA in PE		−0.622	0.068	−9.207	**<0.001**
Gender	MVPA in leisure		−0.368	0.047	−7.871	**<0.001**

MVPA, moderate-to-vigorous physical activity; PE, Physical Education; RAI, Relative Autonomy Index; n/a, not applicable. Bold p values indicate statistically significant results.

first premise in this paper mostly confirmed the motivational sequence in PE, except that it failed to validate the intention—MVPA link in the non-traditional PA class relationship. Its failure to do so could be explained by the fact that non-traditional activities are less familiar or not familiar at all to students, meaning that students formed their intentions without knowing what to expect in these PE classes. It is possible that the reality they faced in these classes did not match their intentions. Meanwhile, their intentions to participate in games and practicing motor skills were based on their previous experiences in similar classes, allowing them to formulate more accurate intentions.

Direct Relationships Within the Leisure-Time Domain

The relationships within the leisure time context were as expected. Autonomous motivation was positively related to intention, and intention was positively related to leisure-time MVPA. Similar results were obtained when attempting to predict objectively measured MVPA in leisure time, although a study of Estonian adolescents found that leisure-time MVPA was not related to MVPA in PE class (62). This finding is in line with results obtained by Ickes et al. (63), who reported that perceived support for autonomy increases intentions to be physically active during free time. Other studies have confirmed the premise that

behavior is predicted by intention ((25)). Further, intention can predict leisure-time MVPA, which is in line with the theoretical premise (14) and empirical evidence (64) that intention is the most proximal predictor of behavior. Also, this statement is especially relevant when behavior is self-determined, i.e., based on autonomous motivation (65). Thus, the results of this study confirmed the second hypothesis of this research. Here again, contextual motivation determined situational motivation, which, in turn, led to a specific behavior (25). However, measurements of intention and MVPA in leisure were self-reported, and the relationship between them was remarkably stronger than the relationship between intention and objectively measured MVPA in PE ($\beta = 0.53$ vs. $\beta = 0.21$, respectively). Hence, the findings regarding the strength of the relationship might have been influenced by the self-reported nature of the measurements. This suggestion is supported by the other studies in which leisure-time MVPA was measured objectively and the strength of the relationship of PA with intention was notably lower ($\beta = 0.11$) (33).

Direct Trans-contextual Links

The direct trans-contextual links within TCM were confirmed, thus validating the third premise of the current study. Namely, autonomous motivation for PA in PE predicted autonomous motivation in leisure time. This finding is in line with Vallerand's (11) theory that autonomous forms of motivation in one context are linked to autonomous motivation for the same kind of behavior in similar contexts and confirmed by empirical evidence (32). These similar but distinct constructs are related when behavior is autonomous in a certain context and subsequently creates motivational representations and anticipated patterns of action in that context that serve as a useful template for motivation and action in closely related contexts (25). This linkage also explains why intention in leisure time can be predicted by intention in PE. These two representations of situational motivation lay within different domains of behavior, with one representing motivation for activities in compulsory PE, and the other representing motivation for out-of-school activities, most likely coming from within. The strong relationship between them again suggests that it is important to pay attention to motivation on a more general level.

Mediation Effects

The addition of needs satisfaction in the current study as a mediator confirmed the fourth hypothesis of this study, as needs satisfaction, along with autonomous motivation, mediated the indirect relationship between support for autonomy and intention to participate and be physically active in PE classes. In accordance with SDT, teachers' support for students' autonomy in the classroom substantially add to students' needs satisfaction, thus enhancing their autonomous motivations and shifting the locus of causality from the external to the internal (66, 67). However, support for autonomy failed to have an indirect effect on MVPA in PE classes and was not related to MVPA in any of the PE classes when a correlational analysis was performed. These results might reflect the control teachers exert in PE. With a curriculum to follow, teachers cannot avoid using controlling types of behavior in PE, even though they may support autonomy. Another study revealed that despite the support for autonomy, exerting control via rewards in PE has a strong and positive direct link ($\beta = 0.70$) to the objectively measured MVPA in PE, while intimidation was negatively related to MVPA in PE (68). These findings indicate that students might confuse rewards in PE with support and were very likely applicable in this study, given the competition involved in games or practicing motor skills. On the other hand, the literature shows that teachers' controlling behaviors are linked to satisfaction with competence (69), which is crucial for furthering the motivational sequence and behavior (70). However, future intervention design studies should explore the direct relationships between support for autonomy and MVPA in PE as well as the motivational sequence facilitating the transit of support for autonomy to actual PA in class.

Moreover, needs satisfaction was an important mediator for the transferring support for autonomy in PE to the leisure-time PA context, namely, autonomous motivation and intention in leisure as well as leisure-time MVPA. While the latent variable needs satisfaction was used in the current study, other studies have found unique mediation effects for the needs for autonomy and competence but not for relatedness satisfaction for autonomous motivation in PE and a mediation effect for the need for competence satisfaction for autonomous motivation in leisure (36). Other studies suggest that perceived support for autonomy is associated with PA in leisure through the motivational sequence, including needs satisfaction and autonomous motivation (71, 72). Even though PA in the PE context has a certain structure, and PA in leisure time is mostly a choice, the shared autonomy in these distinct contexts is partly affected by support for autonomy in PE, which satisfies needs for autonomy (thus providing choice in PE), the competence (thus helping students gain confidence in their abilities to engage in physical activities), and relatedness (thus creating the perception that the one can rely on, trust, and be close to other people.) These perceptions go beyond the PE context, as they are naturally more general. The current study also found an indirect link between support for autonomy in PE and MVPA in leisure time. Hence, the results above are in line with the fifth premise. The transfer of factors leading to increased PA in PE domain to the leisure-time domain can be referred to as nurturing basic psychological needs associated with encouraging PA outside of school (25). Some research has shown that students are more likely to engage in PA outside of school if they perceive pleasure and autonomy in PE lessons (73, 74). Furthermore, the results stress the importance of education, as teachers' encouragement of their students' autonomous motivation during PE is likely to persist in leisure time. Researchers have suggested that in order to improve students' outcomes, it is essential that all students receive positive and satisfying PE experiences (75). In order to identify the magnitude of the effect of support for autonomy t in PE on MVPA in PE, further interventional studies should be performed.

Summing up, the results of this study provide clear indications that needs satisfaction should be included in the TCM, as it is an important predictor of autonomous motivation for PA in PE and leisure time as well as a significant mediator in transmitting the effect of perceived teachers' support for autonomy to other motivational factors in PE and even transferring it to the

leisure-time domain. This study also confirmed that psychosocial factors are crucial for behavior. This fact should be considered not only by PE teachers engaged in PE practice but also by PE teacher educators. PE study programs should prepare future teachers to respond to students' needs and enhance their motivation by supporting needs satisfaction.

STRENGTHS AND LIMITATIONS

First, among the strengths, objective measurements of MVPA in PE classes were taken. No other study, to the best of our knowledge, has measured PA in PE classes using objective methods when testing TCM. Second, each student's MVPA was measured for three different PE classes, namely, games, practicing motor skills, and non-traditional physical activities, covered the compulsory PE curriculum in Lithuania. Among the limitations, the main one is that leisure-time MVPA was identified via students' subjective evaluations. However, using these measurements should not have compromised the results of the model, given that subjectively measured MVPA correlates with objectively measured MVPA (76). The two-week period between measurements of intention and physical activity was shorter than the four-week period used in other studies. The greater the time period between these measurements, the higher the robustness of the long-range effects under scrutiny (12). However, this fact is more important for intervention studies. Our study studied habitual behavior. Also, as this study was correlational in nature, the causal effects of predictors on outcomes could not be identified. However, in this study, predictors and outcomes were not supposed to change over time. Accordingly, the momentary relationships determined in this study were also supposed to remain the same over time.

CONCLUSIONS

Extending the TCM with needs satisfaction produced two outcomes—objectively measured MVPA in PE and subjectively measured MVPA in leisure time—that met the main theoretical assumptions of the motivational sequence. Namely, perceived PE teacher support for autonomy was directly and positively associated with student needs satisfaction. Needs satisfaction was positively related to autonomous motivation in PE; in turn, the latter was positively associated with intention to be physically active in PE. Intention in PE predicted MVPA in games and motor skills PE classes and the averaged MVPA across three types of PE classes but in non-traditional PE classes. Needs satisfaction mediated the relationship between perceived support for autonomy and autonomous motivation and, alongside with autonomous motivation, the relationship between support for autonomy and intention. The indirect effect of support for autonomy on MVPA in PE was not confirmed. In the leisure-time domain, autonomous motivation time was related to intention to engage in leisure-time PA, and intention was associated with MVPA in leisure time. Trans-contextual relationships between autonomous motivation in PE and the corresponding motivation in leisure time as well as between intention in PE and intention in leisure time were observed. Finally, the indirect effect of support for autonomy on f motivation and MVPA in leisure was captured when mediated through need satisfactions, autonomous motivation, and intention in the PE sequence. The study filled a gap in the scientific literature by demonstrating the full motivational sequence resulting in actual MVPA in PE classes. It also demonstrated that the main goal of PE to enhance PA not only in school but also outside is being fulfilled. The main result is that needs satisfaction must be obtained with PE teachers' support.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of Lithuanian Sports University (No. SMTEK-13). The study was conducted in accordance with the Declaration of Helsinki. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

BM and AE: conception and design. VP and AE: data acquisition. BM and DN: data analysis and interpretation. BM, AE, and VP: drafting the manuscript. DN and AE: critical revision for intellectual content. BM and AE: Administrative, technical or material support. All authors read and approved the final manuscript.

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BRIEF RESEARCH REPORT
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Children's Daily Routine Response to COVID-19 Emergency Measures in Serbia

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Objective: The emergence of coronavirus in Serbia as well as in other European countries led to the declaration of a state of emergency, which, among other measures, included a switch to online education, the lockdown of public life and organized sports, and a curfew from 5 pm to 5 am. This study aimed to investigate the extent to which these measures affected children's daily routines. More specifically, it aimed to determine how children maintained their learning, physical activity, and screen time routines from the period before the state of emergency was declared.

Methods: Response to an online parent-reported questionnaire was conducted ($N = 450$). The factorial validity of the scales was prepared using confirmatory factor analysis, with acceptable fit indices. Based on that, the authors tested the interrelations between dimensions using structural equation modeling in SPSS, AMOS 24.0.

Results: The study results indicate a positive relationship between school achievement and study time ($\beta = 0.25$). They also indicate that children who were physically active before the pandemic continued their activities during the emergency state ($\beta = 0.53$). Physical activity impact during the COVID-19 emergency measures reduces children's behavior changes ($\beta = 0.55$). Finally, they highlight that children who spent more time with multimedia content had greater changes in anxiety, sensitivity, nervousness, and worry due to COVID-19 emergency measures ($\beta = -0.38$).

Conclusions: Healthy lifestyle habits formed in childhood are suggested to be responsible for the greater "resistance to change" shown by the children from this study.

Keywords: children, school achievement, physical activity, screen time, COVID-19 pandemic emergency measures

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INTRODUCTION

As the pandemic Coronavirus Infectious Disease 2019 (COVID-19) has now been going on for a year, the results of numerous scientific studies suggest that the virus has left a major impact on the psychophysical health as well as on the social life of children and adults (1–3), namely, by the end of May 2020, 2.5 months after the pandemic was declared on March 11, 2020, (4), COVID-19 was already present in 188 countries, with 5,604,461 infected and 350,752 dead (5).

The first case of a COVID-19-positive patient in Serbia was reported on March 6, 2020. Following the example of other European countries and in the absence of other effective epidemiological measures, state authorities declared a state of emergency on March 15, 2020 to keep people at home, minimizing physical contact. These measures in Serbia included closing kindergartens, schools, and universities and switching to online teaching; recommending that the working population works from home; closing of parks, sports, and fitness centers to minimize physical contact. People over 65 years old were completely banned from leaving their homes, and for all other age groups, the curfew applied on March 16, 2020 was from 8 pm to 5 am and then on March 22, 2020 to April 30, 2020 from 5 pm to 5 am. According to official statistical data, by the end of May 2020, 11,275 positive cases for COVID-19 were registered in Serbia, with a total number of 240 deaths (6).

Concerning the fact that the focus of this research is on children aged 7–15 years, the epidemiological measures mentioned included a sudden transition to online education as well as a reduction in physical contact and finally a reduction of organized physical activity (PA) and free play outside houses and apartments. The results of previously published studies suggest that school-age children are at a higher risk after a long period without school commitments, especially in terms of nutrition, PA, motor skills, and, finally, general psychophysical health (5, 7, 8). More negative emergency epidemiological measure consequences were confirmed by the US research findings of significant decreases in physical activity, increases in sedentary behavior, and disrupted sleep schedules/sleep quality in children and adolescents (9). Certain differences of PA level have also been shown in a survey of US children where parents of older children (ages 9–13) *vs*. younger children (ages 5–8) perceived greater decreases in PA and greater increases in sedentary behavior in comparison to pre- to early-COVID-19 emergency measure (EM) periods (10). A Slovenian study also raises concerns about the consequences of EM time without school PA and sports. Data from more than 20,000 children from 1st to 9th grade of primary schools showed alarming trends of change: a decline in motor skills in both boys and girls, with overall motor performance decreased on average by more than 13%. The greatest decline occurred in endurance and in whole-body coordination between the last measurements in April 2019 and the measurements after the epidemic status in June 2020 (11). The above-mentioned changes of children's behavior will develop into long-term poor health outcomes in children and adolescents (12). With this in mind, we were interested in the level and type of daily PA of children attending "school from home" under exceptional conditions (the state of emergency, with emphasis on restricted freedom of movement).

For this purpose, we create a questionnaire on PA of children during the state of emergency caused by the COVID-19 pandemic. The survey was conducted in the Republic of Serbia, in the autonomous province of Vojvodina territory.

Based on the new "externally imposed" framework of children's daily life, we decided to analyze several key parameters of their lives, namely, we conducted the analysis of interrelation of children's PA before and during the pandemic COVID-19 within the variables: school achievement, study time, and screen time. For the purpose of this study, we have chosen these "pillars" of children's daily lives because they are key parameters whose continuity could be maintained, reduced, or increased during EM. The above-mentioned literature review considered that children's time during the EM could influence their behavior changes. Thus, we expected that factors that describe part of the children's daily routines before COVID-19 EM (such as school achievement and PA) could influence their daily routine during EM (PA, study time, and screen time). The examination of these interrelations was defined in hypotheses H1a, H1b, H1c, H2a, H2b, and H2c (see **Figure 1**). Furthermore, we expected that spending time during EM by children could influence the tested model's dependent variable—changes in children's behavior (hypotheses H3a, H3b, H4, H5, and H6 in **Figure 1**).

MATERIALS AND METHODS

Data Collection

The online parent-reported questionnaire was conducted after the cancelation of the state of emergency in Serbia. According to a convenient way of collecting questionnaires that did not endanger the respondents' safety, the dissemination was conducted *via* schools, with the mediation of an association of physical education teachers who supervised the data collection. At the beginning of the online survey, all participants were informed about the research purpose. It lasted ∼10 min, with protection of the anonymity of the respondents. The field research was conducted between May 29 to June 6, 2020.

Study Sample

The survey included parents of children (228 males and 222 females, $N = 450$) from primary schools from the territory of Vojvodina, Serbia. The parent sample included 165 respondents (36.7%) whose children belong to younger school-age and 285 respondents (63.3%) with children of older school-age. By developing the research strategy, we decided that the online questionnaire should be completed by the parents, namely, we considered that the scale of parental assessment of the children's daily activities during COVID-19 EM would be more valid than the children's answers for two main reasons: this would prevent a possible misunderstanding of some questions at a younger age (7–10) or giving socially desirable answers at an older age (11–13, 13–15). The respondents' type of housing showed that 25.1% of them have apartments and houses without a yard, and 74.9% have houses with a yard. Furthermore, related to the type of settlement, the respondent sample consisted of respondents from the countryside (24.6%), suburbs (17.4%), and urban area (58.0%).

Measures/Variables

The average grade measured the child's school achievement at the end of the previous grade. For this variable, an item that provided a score for academic efficiency was used, where score two means sufficient achievement, 3—good, 4—very good, and 5—excellent.

Three items measured PA before COVID-19 EM: (1) children's previous participation in an organized way of PA (three

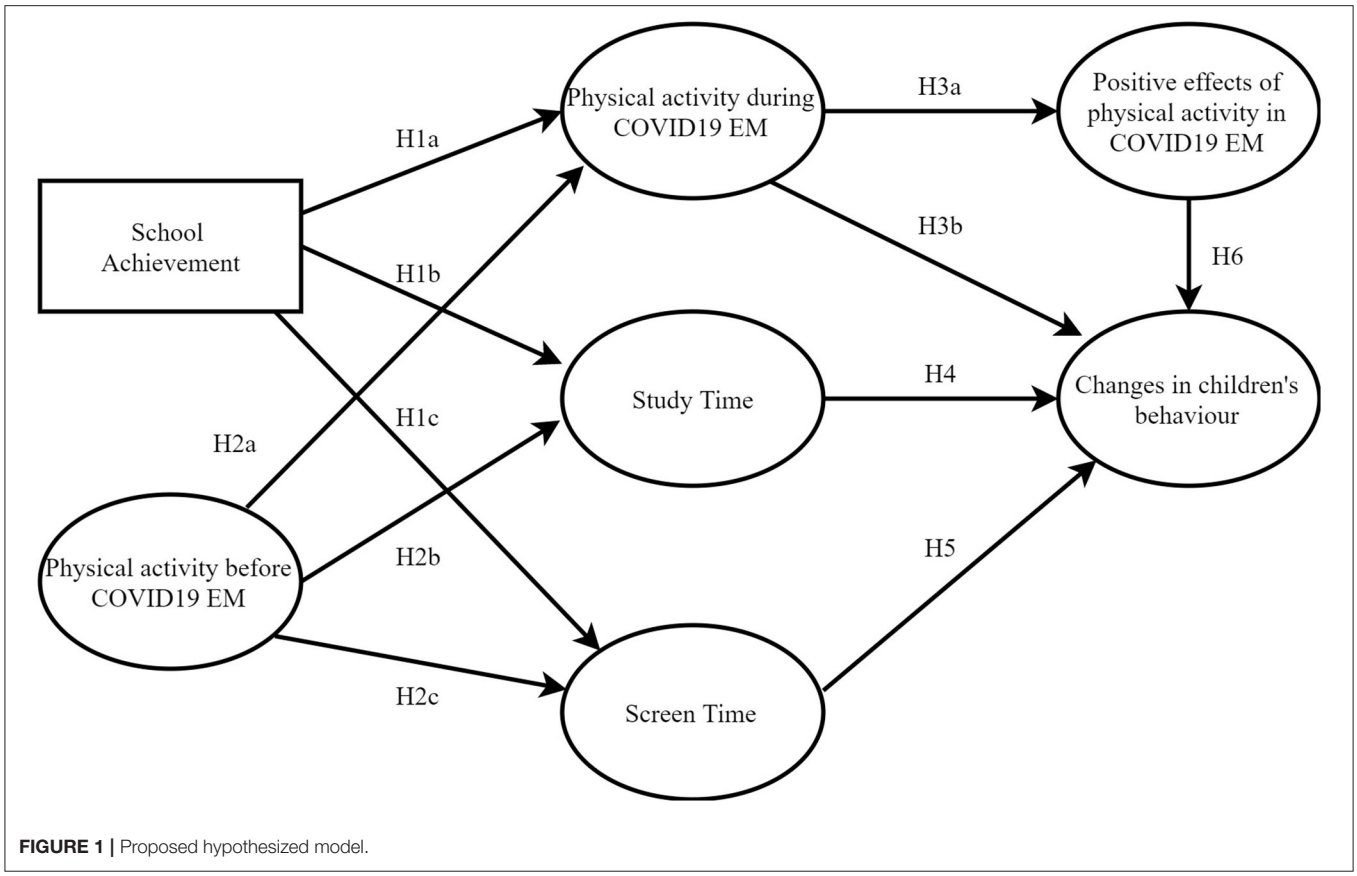

FIGURE 1 | Proposed hypothesized model.

times a week) as members of sports clubs (yes or no), (2) previous regular sports and recreational activity or a combination of several different recreational activities such as aerobics, jogging, dancing, gymnastics, basketball, swimming, *etc*., (yes or no), and (3) children's involvement in any sports and recreational exercises in a sports club, outdoor sports, and exercise at home (in hours).

Physical activity during COVID-19 EM was measured with three items. The first item provides information about the children's PA at home (yes or no). Furthermore, this dimension includes items related to the amount of time the child spends in exercising at home (in minutes) and overall status of the children's physical form with exercise at home compared to the pre-quarantine period, with responses on five-point Likert scales (e.g., 1 = in the lowest level to 5 = completely as before). It should be emphasized that online school sports for children in primary school were performed *via* TV shows, and athletic training for children in sports clubs *was* via remote platforms (with a delay due to adaptation to the new circumstances).

Study time was measured with three items (e.g., how much time per day that your child spent on reading books, taking online classes, and learning or searching for information needed for class assignments in the last 2 months).

Screen time was measured by including four items that summarize information about the time (in hours) the child spent in using various multimedia sources: (1) single or multiplayer computer games, (2) video and music, (3) TV, and (4) social networking.

The positive effects of PA in COVID-19 EM were measured with three items related to the parents' opinions on the impact on their child's concentration, motivation, and good mood (e.g., I notice that my child has, after exercising at home, better concentration, motivation, *etc*.).

Changes in children's behavior were assessed with four items related to the parents' perceptions of various statements regarding their children's worry, anxiety, sensitiveness, and nervousness during quarantine (e.g., I notice that my child is more sensitive, worried, anxious, and nervous than before).

Data Analysis

Statistical procedures included structural equation modeling (SEM), conducted using SPSS, IBM, and AMOS 24.0, which tested the relationships of a hypothesized model of constructs. This method was applied as a multivariate, complex method that included factor and multiple regression analysis.

At the beginning of the statistical procedure, the SEM measurement model's reliability and validity were applied. Reliability was tested using Cronbach's alpha, considering the thresholds for α as proposed by Kline (14), according to which excellent values are $\alpha \geq 0.90$, good values were between 0.80 and 0.90, and values between 0.70 and 0.80 are considered acceptable.

TABLE 1 | Descriptive statistics of children's school achievement and physical activity before COVID-19 emergency measures (EM) and children's daily routine during COVID19 EM.

	Total	Male	Female
School achievement (%)			
Sufficient	1.2	1.8	0.5
Good	6.2	7.7	5.2
Very good	27.3	31.4	23.0
Excellent	65.4	59.1	71.8
Physical activity before COVID19 EM (%)			
Member of sports clubs			
Yes	70.2	71.1	69.4
No	29.8	28.9	30.6
Combination of different sports recreation activity of children			
Yes	74.8	75.0	74.7
No	25.2	25.0	25.3
Average in sports recreational activity per day			
<1/2 h	12.2	14.1	9.8
<1 h	29.3	30.0	29.4
<2 h	30.9	30.8	30.4
<3 h	12.4	11.9	13.1
>3 h	11.1	11.0	11.2
Do not know	4.0	2.2	6.1
Physical activity during COVID19 EM			
Exercise at home (%)			
Yes	63.4	64.2	63.4
No	36.6	35.8	36.6
Assessment of the measure of maintaining physical form (%)			
Partially	69.0	64.5	73.6
Satisfactorily	24.4	29.5	18.9
Complete	6.6	6.0	7.5
Exercise at home (min)			
<10 min	18.1	15.4	19.2
<30 min	50.0	55.2	44.9
≥60 min	31.9	29.4	35.9
Study time			
Reading books			
<1 h	25.0	28.3	21.2
<2 h	29.5	33.6	25.0
≥3 h	45.5	38.1	53.8
Online teaching, learning per day			
<1 h	16.0	12.6	19.8
<2 h	33.3	31.8	33.5
≥3 h	51.7	55.6	46.7
Searching information for teaching on the Internet (hours)			
<2 h	83.3	83.6	84.0
2–4 h	12.7	13.3	11.7
4–6 h	4.0	3.1	4.2
Screen time			
Single and multiplayer computer games			
<2 h	84.1	84.4	83.5
2–4 h	12.3	11.1	13.7
4–6 h	3.6	4.4	2.8
Social networks (%)			
<2 h	65.0	65.5	63.8
2–4 h	22.3	19.0	26.3
4–6 h	12.7	15.5	9.9
Video, music			
<2 h	87.6	89.7	84.8
2–4 h	10.1	7.6	13.3
4–6 h	2.2	2.7	1.9
Television			
<2 h	79.5	80.9	78.4
2–4 h	19.2	17.3	21.1
4–6 h	1.3	1.8	0.5
Positive effects of physical activity	Yes	No	Yes
Concentration	65.1	34.9	64.8
Motivation	63.7	36.3	65.3
Attention	55.6	44.4	54.5
Changes in children's behavior			
Sensitivity	26.4	73.6	25.0
Worry	29.8	70.2	29.4
Anxiety	38.3	61.7	34.9
Nervousness	25.5	74.5	26.4

The SEM measurement model's validity was realized using the factor loadings and the average variance extracted (AVE). An accepted value of 0.50 is suggested as a minimum threshold for AVE (15, 16). The root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker–Lewis index (TLI), and non-normed fit index (NNFI) have been calculated as model fit indices. According to Byrne (17) and Steiger (18), the value of RMSEA shows a good fit in the range from 0.05 to 0.10, and a "good fit" for CFI, TLI, and NNFI "was >0.95 (18, 19). Otherwise, the values of CFI, TLI, and NNFI ≥0.90 can be recognized as an acceptable fit.

In this model, school achievement and PA before COVID-19 EM were set as independent variables, three dimensions (physical activity during COVID-19 EM, study, and screen time) were mediator variables, and changes in children's behavior were set as a dependent variable. Mediation analysis (20, 21) was conducted using the Sobel test ($p < 0.001$).

RESULTS

The obtained results were divided into three segments: (1) descriptive statistics, (2) confirmatory factor analysis, and (3) structural equation modeling. According to the descriptive statistics (**Table 1**) of school achievement, the sample consisted of mostly excellent (65.4%), very good (27.3%), some less good (6.2%), and sufficient pupils (1.2%). The status of children's PA before COVID-19 EM considered that 70.2% of children were in sports clubs three times per week. Concurrently, other

TABLE 2 | Descriptive statistics and CFA item statistics and validity and reliability indices of the measurement model.

Constructs	Items	Descriptive statistics				Standardized factor loadings ($p < 0.001$)		Validity and reliability measures		
		M	SD	SK	KT	Factor loading	SE	SMCs	α	AVE
School achievement	SA1	4.57	0.66	−1.49	1.85					
Physical activity (PA) before C19 Quarantine	PAB1	1.70	0.45	−0.89	−1.22	0.51	0.02	0.26	0.81	0.55
	PAB2	1.74	0.45	−1.32	0.32	0.91	0.07	0.83		
	PAB3	3.63	1.34	0.11	−0.60	0.90	0.12	0.01		
PA during C19 quarantine	PAD1	2.47	0.54	−0.28	−1.12	0.51	0.01	0.39	0.80	0.61
	PAD2	3.77	1.22	−0.06	−0.86	0.91	0.11	0.83		
	PAD3	3.82	1.34	−0.18	−0.66	0.58	0.11	0.34		
Study time	LT1	5.08	1.09	−1.23	1.20	0.65	0.07	0.01	0.90	0.72
	LT2	2.72	0.89	0.48	0.12	0.55	0.10	0.30		
	LT3	2.26	0.85	0.69	0.68	0.86	0.21	0.74		
Screen time	ST1	2.80	1.38	0.03	−1.26	0.57	0.13	0.32	0.91	0.68
	ST2	2.29	1.03	0.46	−0.42	0.45	0.06	0.20		
	ST3	2.12	1.18	0.74	−0.55	0.56	0.09	0.31		
Positive effects	PE1	1.65	0.48	−0.63	−1.61	0.80	0.01	0.63	0.90	0.70
	PE2	1.64	0.48	−0.57	−1.68	0.77	0.01	0.59		
	PE3	1.56	0.50	−0.22	−1.96	0.66	0.01	0.44		
Changes in children's behavior[#]	CB1	1.73	0.44	−1.04	−0.93	0.55	0.01	0.05	0.81	0.59
	CB2	1.86	0.35	−2.05	2.22	0.55	0.01	0.30		
	CB3	1.54	0.50	−0.14	−1.99	0.54	0.01	0.29		

M, mean; SD, standard deviation; SK, skewness; KT, kurtosis; SE, standard error; SMCs, squared multiple correlations; α, Cronbach's alpha; AVE, average variance extracted.
[#]A variable with inverse metrics.

variables in this dimension showed a high level of PA (about 75% participated in a combination of different sport recreation activities three times per week, and only 12.2% of children had <0.5 h in sport recreation activity per day).

Table 1 also shows the descriptive statistics of children's daily routine during COVID-19 EM. A comparison of PA before and during COVID-19 EM revealed a small decrease in the number of PA participants. Thus, it is visible that 70.2% of children were a member of sports clubs before COVID-19 EM compared to 63.4% of children who exercise at home during the pandemic. That difference was confirmed in another dimension of the PA variables during COVID-19 EM, where 69% of parents considered PA level only enough to maintain physical form partially. Almost two-thirds of children exercised at home for <30 min.

An evaluation of screen time showed that children spent more hours using different screen devices than the American Academy of Pediatrics' recommendations. These recommendations considered 1 up to 1.5 h per day for elementary school-aged children and up to 2 h per day for middle school-aged children (22).

The positive effects of the PA were revealed on the concentration (65.1%), motivation (63.7%), and attention (55.6%) of children. Otherwise, every fourth child felt more sensitive, worried, and nervous than before COVID-19 EM.

The validity and reliability measures are calculated in **Table 2**. Firstly, it is considered that Cronbach's alpha values were acceptable (>.80), which is suggested by Kline (14). Subsequently, AVE values fulfill the criteria >0.50 as proposed by Fornell and Larcker (15), ranging from 0.55 to 0.72.

The measurement model was shown to be with acceptable fit: $\chi^2 = 2{,}130.6$, $df = 530$, $\chi^2/df = 4.02$, CFI = 0.91, TLI = 091, NNFI = 0.90, and RMSEA = 0.05. Therefore, the values of CFI, TLI, and NNFI confirmed the acceptable fitting of the model suggested by Byrne (17) and Hu and Bentler (19). RMSEA of 0.05 also satisfied the criteria proposed by Byrne (17), and Steiger (18) fits within the range from 0.05 to 0.10. All calculated factor loadings are more than 0.4, which is a suggestion by Kaiser (23). Their minimum value is 0.45, which means that the applied measurement model fits well with the empirical data.

In **Figure 2**, the path analysis showed that the applied model explains 47% of the variance of the criterion variable changes in children's behavior, suggesting a further search for additional variables whose inclusion in the model would increase this percentage of variance explanation (to 80% and more).

The variable physical activity of the child before COVID-19 EM had a positive indirect effect through the variable physical activity during the COVID-19 EM on the dependent variable changes in children's behavior. It shows that physically active children had less anxiety, worry, nervousness, and sensitive behavior during the pandemic. This finding is consistent with previous research indicating that PA reduces, among other things, anxiety and the risk of obesity and early metabolic risk factors (24–27). Additionally, during childhood, PA levels tend to impact adolescence and adulthood, which is another reason for regular PA in childhood (24, 28).

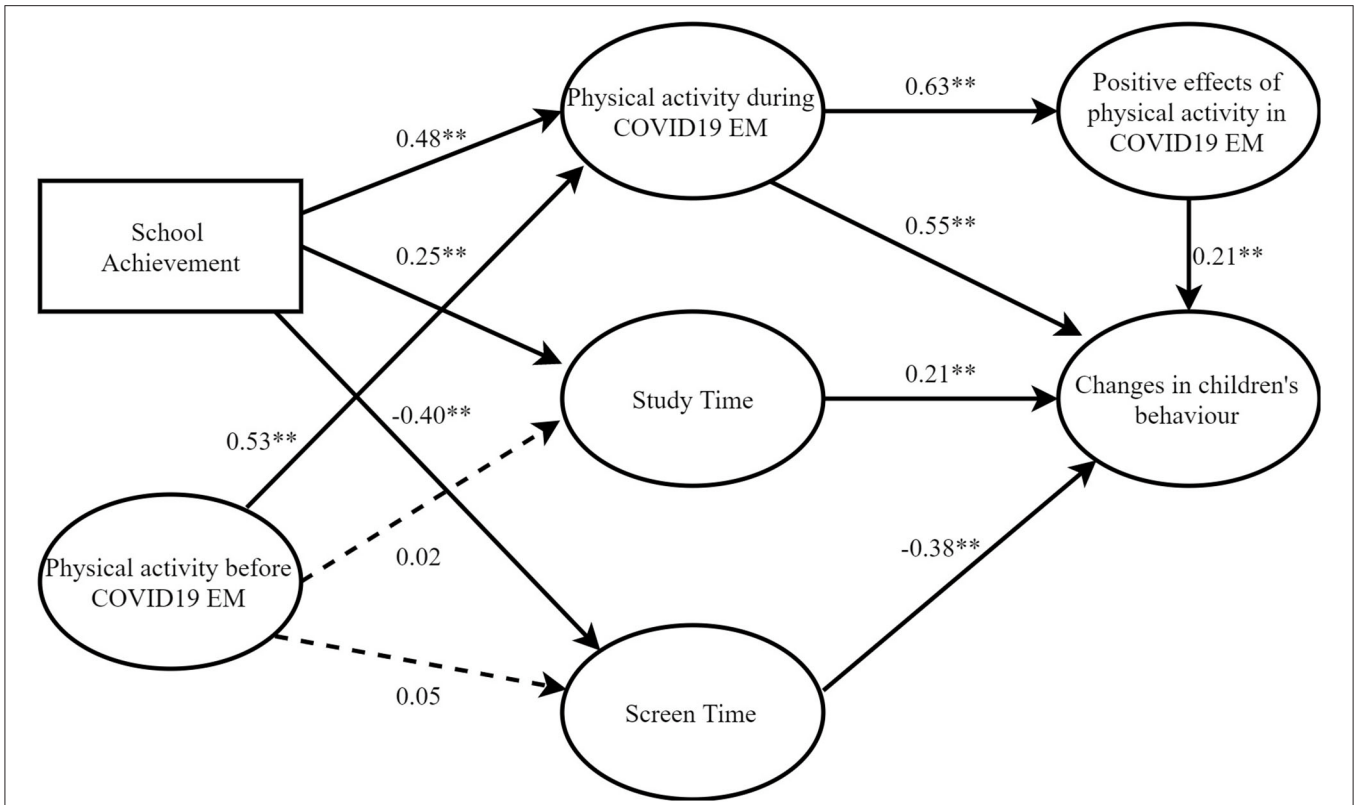

FIGURE 2 | The results of the proposed hypothesized model - Direct and Indirect Impact of School Achievement, Physical Activity before COVID19 EM, Physical Activity during COVID19 EM, Study Time and Screen Time on Changes in children's behavior.

School achievement directly affected the variable study time, showing that better students spent more time studying or searching for study materials during the EM. Such a result shows that children's study habits are resistant to changes in the daily routine.

During COVID-19 EM, PA showed a direct effect on reducing changes in the variable changes in children's behavior, suggesting that physically active children had fewer behavior changes during quarantine than children who were not physically active. This result also suggests that positive/healthy routines formed in early childhood are more resistant to change. Such results (school achievement and PA during COVID-19 EM) are significant, especially if we consider that the closure of schools, distance learning, and minimization of physical contact with other people is the first state of emergency in the lives of Vojvodina children.

The variable screen time showed a negative direct impact on the variable changes in children's behavior, suggesting that children who spent more time with multimedia content showed greater changes in anxiety, worry, sensitivity, and nervousness to COVID-19 EM. The findings are consistent with previous research indicating a linear association between total screen time and less acceptable temperament dispositions, degraded socio-emotional relations, and decline of health-related indicators of quality of life (29).

The variable study time showed a direct effect on changes in children's behavior, which means that more time focused the children's attention on learning materials, which contributed to reducing changes in the mentioned characteristics of children's behavior.

DISCUSSION

This research represents a contribution to the study and understanding of school-age children's response and adaptation to the EM caused by the first wave of COVID-19 pandemic in Spring 2020. The research covered several "pillars" of children's daily lives: school achievement, study time, PA (before and during the pandemic), and screen time during the pandemic.

School Achievement and Study Time

A positive correlation between school achievement and study time was confirmed (29), which is consistent with spending more time studying or searching for study materials by better students during the EM. Additionally, it showed that the children's study habits are more resistant to changes in the daily routine. This result indicates the importance of establishing healthy lifestyle and learning habits already in early childhood. Sociologically speaking, the dispositions

for action—the "habitus" of a family that carries acceptable action patterns for the family and society—will, based on the practices of action, design a "healthy" or "unhealthy" lifestyle. Parents are the ones who form permanent dispositions for future behavior, namely, as family practices through the child's perceptions (experiences) are also considered as appropriate by the society as well as within the possibilities (material resources), attitudes, and behaviors (30) and form a "healthy family lifestyle."

PA (Before and During the Pandemic)

The results of the study show the continuation of PA routine at children who were physically active before the pandemic and consequently showed fewer negative behavioral changes such as anxiety, fear, quarrelsome behavior, indifference, and laziness developed due to COVID-19 EM in contrast to children who spent more time with multimedia content and were less physically active and sedentary. Although the recommendations for regular PA of children basically refer to living in "ordinary" social circumstances, the results of this research indicate that their importance became even more obvious during COVID-19 EM. The limited freedom of outdoor movement and the prolonged stay in the house/apartment are circumstances for development of risk of new inactive lifestyle habits.

Screen Time During the COVID-19 Pandemic

A negative direct impact of screen time on the variable changes in children's behavior suggests negative and greater changes in children who spent more time with multimedia content as shown in their anxiety, worry, sensitivity, and nervousness to COVID-19 EM. These results are consistent with previously conducted research (31), pointing to the fact that the long-term exposure of children to screens (watching television and movies) leads to changes in children's behavior that manifest themselves in the area of social problems, thinking problems, and aggressive behavior as well as social withdrawal and social isolation (in the case of video games). In addition, the more time that children spend in front of screens, the less time they have for all other daily activities. The consequences of such daily activities in childhood are directly reflected in lifestyles at later stages of adolescent development.

CONCLUSION

The research findings suggest that healthy lifestyle habits formed in childhood, emphasizing regular PA and study habits, are responsible for the greater "resistance to change" of the children from this study. Considering that this was the first epidemiological EM life experience for the studied population, the results' significance is more obvious. Additionally, this result is compatible with a similar research conducted on Italian adolescent samples (2). The results showed that adolescents manifested the ability to live and adapt to the new, insecure life situation, which led them to the "new normal" daily life.

Finally, our results related to screen time are consistent with the findings of previous studies on children and youth populations (31–33). Screen time and sedentary behaviors are features of people's lifestyles in contemporary societies (34–37). However, despite some limitations of the study, this research indicates the need to emphasize the impact of lockdown and limited freedom of movement on behavioral or daily routine changes in line with the health-promoting recommendation of balanced PA and sedentary behavior in children and adolescents.

A brief research report has study limitations, which can be marked as significant for directions in similar future research. There were independent variables selected in the theoretical model, school achievement, and PA as important indicators of the children's previous daily routines before COVID-19 EM. This model does not include the local community's effect on its pandemic strategies and actions on the ground. Regarding the pandemic situation, the environment for children's daily routine functioning and manifestation could be different. The sample included children from the whole administrative province of Vojvodina, where some pandemic measures were different during the pandemic period.

Additionally, the model could be developed with more variables for examining children's active or passive lifestyle before the beginning of the pandemic. Therefore, this model can be tested in different contexts (e.g., other destinations, additional lifestyle dimensions, *etc.*). Finally, it was cross-sectional research, which means that there is a lack of detailed monitoring of changes in children's behavior.

However, this type of research can provide valuable information about how children's daily routines respond to unforeseen circumstances. This brief report's results can provide insight for the academic community and policymakers on what healthy life habits are essential for children's daily routine in potentially similar social circumstances. Finally, since the family and the school are important agents of children's socialization, the role of parents and teachers in promoting and maintaining the above-mentioned healthy lifestyle habits of children is of key importance. Therefore, it is important to inform them on the results of this and similar research. By warning and empowering both classroom teachers and parents about the importance of healthy lifestyle education, the negative consequences of similar EM can be mitigated in the future.

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 Ethical Committee of the Faculty of Sport and

Physical Education, University of Novi Sad, Serbia (46-11-07/2020-1). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JV, RM, IM, and SP wrote the manuscript, performed analyses, and revised the manuscript. JV, RM, and DK collected the data. IM, RM, and NM overviewed previous studies and discussed the results. All authors contributed to the article and approved the submitted version.

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Relationship Between National Economic Development and Body Mass Index in Chinese Children and Adolescents Aged 5–19 From 1986 to 2019

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Obesity represents a major risk factor for population health. No studies have evaluated how economic expansion impacts the prevalence of obesity. The purpose of this study was to assess the relationship between national economic development and body mass index (BMI) in Chinese children and adolescents. Data of mean BMI in children and adolescents aged 5–19 from 1986 to 2019 were extracted from an international database of cardiometabolic risk factors. Chinese economic development was quantified by the gross domestic product (GDP), which was extracted from the International Monetary Fund. The relationships between GDP and BMI were assessed in 1-year age groups for ages 5–19 years. In addition, the linear regression from the main data and estimated GDP growth allowed the projections of mean BMI for each age group between 2020 and 2025. The results suggest there was a linear increase in BMI over years, which means that there has been a steady increase in BMI over the economic expansion. Overall, 97% of the variance (Pearson correlation coefficient) of BMI in boys can be explained by the GDP expansion, and the same pattern (98% of the variance) occurred in girls. Projected mean BMI were provided for constructing future national strategies to prevent overweight and obesity in youth. In conclusion, BMI in children and adolescents aged 5–19 trended upwards between 1986 and 2019. Our analyses for the first time suggest that globalization has a major impact on BMI in China. Economic expansion was highly predictive of BMI increases.

Keywords: obesity, overweight, gross domestic product, economic growth, supply-side economy

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INTRODUCTION

Obesity has emerged a global health problem and posed health risks to the world's population of all ages. According to the World Health Organization, the worldwide prevalence of obesity has tripled between 1975 and 2020 (1). In 2016, more than 1.9 billion adults aged 18 years and over were overweight, whereas over 340 million children and adolescents aged 5–19 were overweight or obese (1). More recently, data have shown that 38 million children worldwide under the age of 5 were overweight or obese in 2019 (1). The prevalence of overweight and obesity in childhood is

high and continues to increase globally (2–5), generating an increasing health risk. The same trend is occurring in China, which is facing this major public health concern. Between 1995 and 2014, Chinese children and adolescents aged 7–18 saw a four-fold increase in overweight and obesity, with around 1 in 5 children and adolescents being either overweight or obese (6). Population data show that prevalence of overweight continually increased from 1.1% in 1985 to 20.4% in 2014 in Chinese school-aged children (7), making childhood obesity a critical health issue in China.

The etiology of obesity is complex. Although the genetic susceptibility to obesity is high (8), the rising global prevalence of obesity highlights behavioral changes associated with modern lifestyles (e.g., excessive intake of simple carbohydrates and sugar, physical inactivity) that contribute to its development (9, 10). A vital effect that has not yet been reported in the literature is the role of economic expansion in the development of overweight and obesity. For example, it has been suggested that rising obesity can be attributed to factors related to globalization processes, which can be related to flooding developing economies with western-style, inexpensive but obesogenic fast foods (11).

However, current literature shows conflicting results about the relationship between economic development and obesity. Rapid emergences of overweight and obesity are widely documented, even in the poorest countries of sub-Saharan Africa (12), which exhibit little economic expansion in the past decade. In general, Seydel et al. (13) suggested that economic growth leads to increase of overweight and obesity in developing countries. Specifically, 1% increase in income leads to around a 0.2 and 0.3% increase in the overweight and obesity prevalence, respectively (14). For instance, compared with adult women living in poorest households in Nepal, the odds of being overweight were, respectively 3.44, 2.12, 1.46, and 1.19 times higher for women living in richest, richer, middle and poorer wealth status households (15). As a result, accompanying with rapid economic growth, emerging economies are undergoing a noticeable shift in the disease structure marked by increasingly higher proportion of non-communicable disease-related morbidities (6, 16). However, among developed economies, higher gross domestic product (GDP) predicted lower body mass index (BMI) (11).

Coincident with economic development, China has experienced a marked transition from undernutrition to overweight and obesity since the reform and opening up of Chinese economy (6, 7). An important step in addressing the growing overweight and obesity trend in China, as well as in the global community where obesity has literally become an epidemic, is understanding all key factors, including national economic development, associated with childhood and adolescent obesity. Given the critical impact that childhood and adolescent obesity has on lifetime health (17), it is crucial to explore the relationship between rapid expansion of the Chinese economy and BMI, the most commonly used measure for assessing obesity. Therefore, the purpose of this study was to evaluate the relationship between an economic factor (GDP) and BMI in children and adolescents aged 5–19 in China. In addition, we projected the trend change in BMI between 2020 and 2025, which should offer national policy makers to design more targeted strategies to combat youth overweight and obesity. This study is first of its kind in China.

METHODS

Data Sources

BMI data were available from an international database on cardiometabolic risk factors managed by the Non-Communicable Disease Risk Factor Collaboration (18). This database is continuously updated and national data (i.e., mean BMI of China Mainland) used in this study were extracted as of 31 December 2020. While the total sample sizes for country specific data are not available, BMI data collected by the Non-Communicable Disease Risk Factor Collaboration currently consist of 2,181 population-based studies with 65 million participants, which is considered to be the most comprehensive international scientific endeavor documenting trend change in BMI. GDP data of China Mainland between 1986 and 2019 were available from the International Monetary Fund (19).

Statistical Analysis

Since linear function yielded same results as the first order polynomial function, we used linear regression to explore the relationship between GDP and BMI. Pearson correlation coefficients were used to quantify associations between GDP and BMI. Linear regression for each age group allowed us to project the trend development of BMI. We used a real GDP annul growth of 2.3% for 2020 (19), and projected real GDP annul growth of 6.0% between 2021 and 2025 (20) to calculate the GDP growth and subsequently projected change in BMI from 2020 to 2025. Prism 9 (GraphPad Software, San Diego) was used to conduct the analyses in this study.

RESULTS

Scatter plots with respective correlation coefficients and linear regression lines are depicted in **Figures 1**, **2**. There has been a steady increase in BMI over the measured 35 years. Linear regression revealed that GDP expansion was associated with increased BMI in children and adolescents over the time. In general, this pattern was seen in both boys ($R^2 = 97\%$) and girls ($R^2 = 98\%$).

Using the economic growth model, projected BMI in 2020–2025 is shown in **Table 1**. Overall, it is projected that economic expansion over the next 6 years could yield around 0.80 and 0.51% annual increase in BMI occurrence for boys and girls aged 5–19, respectively.

DISCUSSION

This is the first study of the relationship between national economic development and BMI in China. Results from this study show for the first time that higher BMI in both boys and girls and in all age groups between 5 and 19 was strongly related to the economic expansion in the past 35 years in China. From

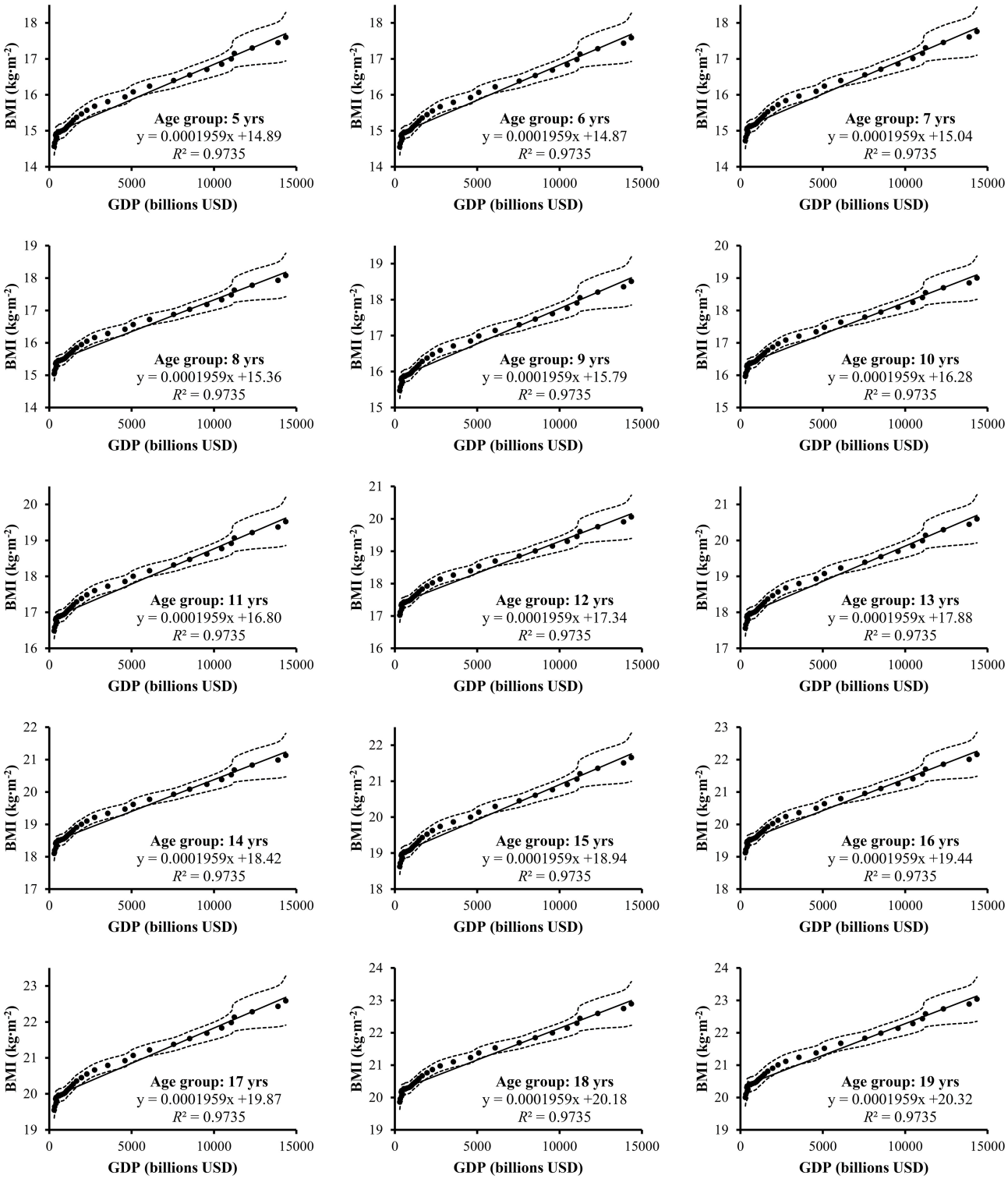

FIGURE 1 | Scatter plots with linear regression lines of gross domestic product (GDP) and body mass index (BMI) of Chinese boys aged 5–19 with respective Pearson correlation coefficients. Dotted lines represent 95% confidence interval.

the epidemiological point of view, the increase in BMI was related to the rapid and strong economic growth in China, which should constitute an important public health concern in modern China.

The current study aligns with substantial evidence that overweight and obesity among Chinese school-aged children and adolescents are trending upwards since the twenty-first

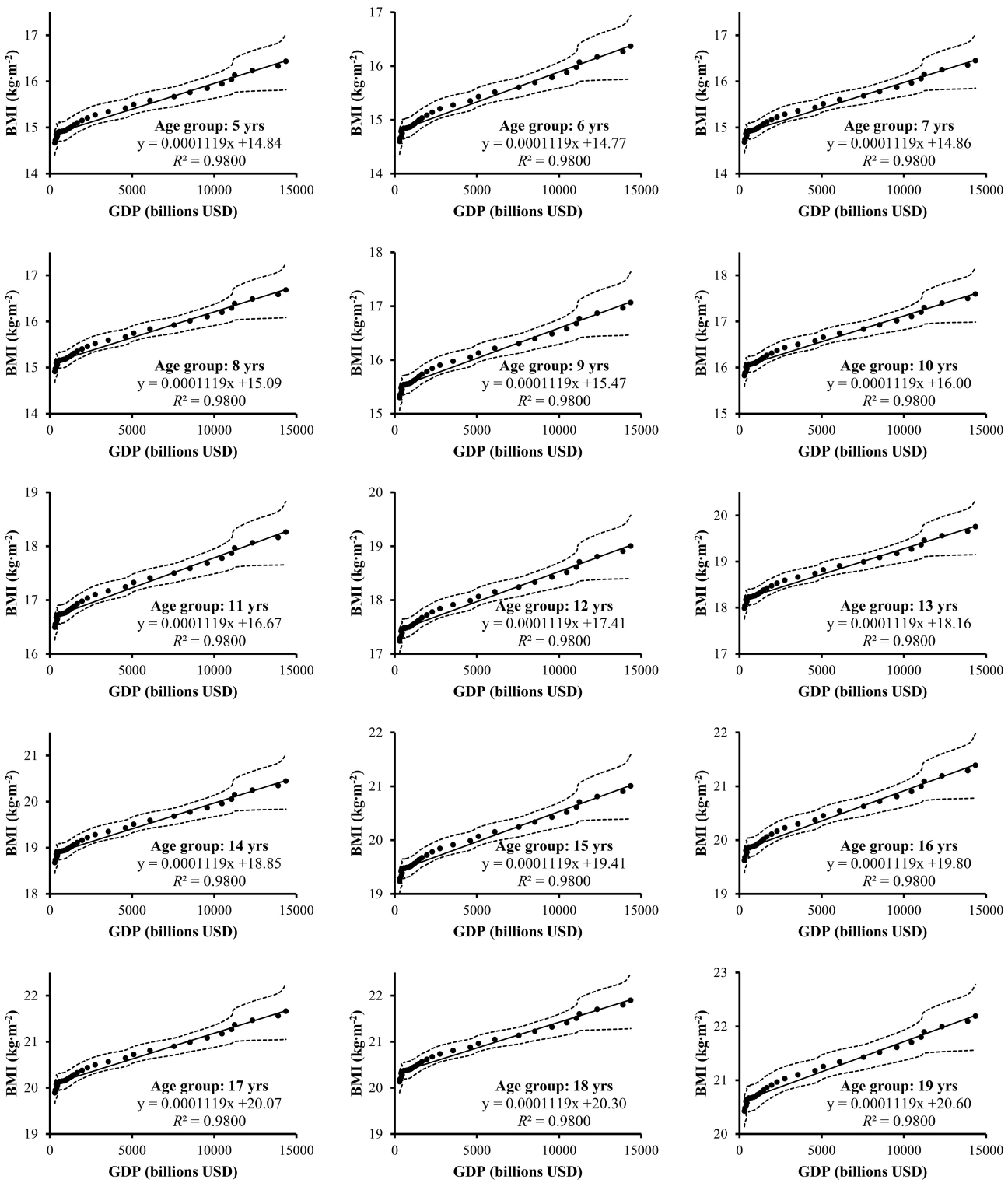

FIGURE 2 | Scatter plots with linear regression lines of gross domestic product (GDP) and body mass index (BMI) of Chinese girls aged 5–19 with respective Pearson correlation coefficients. Dotted lines represent 95% confidence interval.

century. For instance, Zhang et al. (21) found that between 2010 and 2015, the age-adjusted prevalence of overweight and obesity among boys increased from 21.2 to 31.7% and from 10.6 to 16.9% among girls. As the evidence accrues, this study first provides a readily available macro-indicator for explaining temporal trends of overweight and obesity in

TABLE 1 | Projected mean body mass index of Chinese children and adolescents aged 5–19 between 2020 and 2025.

Age group (years)	2020 BMI ($kg \cdot m^{-2}$)		2021 BMI ($kg \cdot m^{-2}$)		2022 BMI ($kg \cdot m^{-2}$)		2023 BMI ($kg \cdot m^{-2}$)		2024 BMI ($kg \cdot m^{-2}$)		2025 BMI ($kg \cdot m^{-2}$)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
5	17.8	16.5	17.9	16.6	18.1	16.7	18.3	16.8	18.5	16.9	18.7	17.0
6	17.7	16.4	17.9	16.5	18.1	16.6	18.3	16.7	18.5	16.8	18.7	17.0
7	17.9	16.5	18.1	16.6	18.3	16.7	18.5	16.8	18.7	16.9	18.9	17.1
8	18.2	16.7	18.4	16.8	18.6	16.9	18.8	17.0	19.0	17.2	19.2	17.3
9	18.7	17.1	18.8	17.2	19.0	17.3	19.2	17.4	19.4	17.5	19.6	17.7
10	19.2	17.6	19.3	17.7	19.5	17.8	19.7	18.0	19.9	18.1	20.1	18.2
11	19.7	18.3	19.9	18.4	20.0	18.5	20.2	18.6	20.4	18.7	20.7	18.9
12	20.2	19.1	20.4	19.2	20.6	19.3	20.8	19.4	21.0	19.5	21.2	19.6
13	20.8	19.8	20.9	19.9	21.1	20.0	21.3	20.1	21.5	20.2	21.7	20.4
14	21.3	20.5	21.5	20.6	21.7	20.7	21.8	20.8	22.1	20.9	22.3	21.0
15	21.8	21.1	22.0	21.2	22.2	21.3	22.4	21.4	22.6	21.5	22.8	21.6
16	22.3	21.4	22.5	21.5	22.7	21.6	22.9	21.8	23.1	21.9	23.3	22.0
17	22.7	21.7	22.9	21.8	23.1	21.9	23.3	22.0	23.5	22.1	23.7	22.3
18	23.1	21.9	23.2	22.0	23.4	22.1	23.6	22.3	23.8	22.4	24.0	22.5
19	23.2	22.2	23.4	22.3	23.6	22.4	23.7	22.6	24.0	22.7	24.2	22.8

BMI, body mass index.

China. Very importantly, this study allows a projection of BMI. We estimate by 2025, BMI will increase to 21.1 $kg \cdot m^{-2}$ for boys and 19.6 $kg \cdot m^{-2}$ for girls in China. This can allow public health administrators to construct more targeted policy interventions for the prevention of overweight and obesity among youth. Specifically, relevant governing bodies in China can establish expert panels consisting of policy makers and health professionals and researchers, to construct national strategies on combating negative consequences related to the trending childhood overweight and obesity in China. Should this upwards trend of BMI among the young population be controlled, not only it could be translated to reduced health burdens for the society as a whole, but it could also further boost the Chinese economy in the long run as suggested in an economic model by Kelly et al. (22). Hence, the current results could be very important.

Although the overall BMI is still in the normal range, the physiological impact of overweight and obesity is greater among Chinese population compared to westerners. At the same BMI, risks for the development of metabolic and cardiovascular diseases are elevated for Chinese ethnicities compared to westerners (23, 24). The risk for developing hypertension is doubled in Chinese with BMI between 23.0 and 24.9 $kg \cdot m^{-2}$ and tripled with BMI between 25.0 and 26.9 $kg \cdot m^{-2}$ (25). Therefore, BMI cut points for overweight and obesity in Asians were lowered to 23.0–27.4 $kg \cdot m^{-2}$ and $\geq$27.5 $kg \cdot m^{-2}$, respectively, compared to standard BMI cut points for overweight (25.0–29.9 $kg \cdot m^{-2}$) and obese ($\geq$30.0 $kg \cdot m^{-2}$) in western nations (26).

Based on the trend analyses, BMI among the young Chinese population continues to increase, and this trend may be more important than ever for health providers and national policy makers. It is expected that the Chinese economy will continue to expand at 6% annual rate (20), and according to this study's regression model, this economic growth rate will be translated to 0.80 and 0.51% annual increase in BMI for Chinese boys and girls, respectively. Thus, healthy weight management and obesity prevention protocols should be included in the national education system and those establishing the BMI cut-off point used to identify obesity need to carefully consider the Chinese specific difference in relation to the cardiovascular risk spanning through childhood and adulthood.

It should be notated that a correlation does not allow for causal inference but can provide a framework to guide future investigations and interventions. In our study, the Chinese GDP expansion was highly predictive of BMI increase in Chinese children and adolescents, which is in line with findings from other developing economies (15, 16). However, overweight and obesity are also growing in countries where GDP are not growing continuously (12). Furthermore, as countries develop economically, overweight prevalence remains mostly unchanged among the wealthiest countries (27). This should not be surprising though. Increase in population BMI is driven by many factors, including the human development index (HDI) (14). HDI is a summary measure of average achievement in key dimensions of human development, including a long and healthy life, being knowledgeable and have a decent standard of living (28). Although rising income per capita tends to push populations toward unhealthy western eating habits, in the very high HDI countries, there is a positive effect on eating habits of any further improvement in per capita income (14). China have witnessed a marked transition in its diet, activity and nutritional status patterns during the rapid economic expansion. According to the latest "Report on Nutrition and Chronic Disease Status of Chinese Residents (2020)" (29), the Chinese dietary pattern has shifted toward a dietary pattern with high consumption

of meats and edible oil but low consumption of cereals and vegetables. Children and teenagers' frequent drinking of sugary beverages and insufficient physical activity are widespread. The net effect of all these changes in diet has been to increase in total energy intake and consequently higher prevalence in overweight and obesity among Chinese residents. Taken collectively, there is a pressing need for national policy adjustments to extend beyond an emphasis on rapid economic growth alone, and to campaign on healthy diets and lifestyles to achieve synchronized improvement in HDI.

As has been mentioned in the methods, the present study has an inherent limitation from data source. The study used BMI data from an international database where neither the sample sizes nor the quality of these data collection can be verified independently. It is possible that not all studies were of similar quality in terms of randomization and convenience sampling. Thus, the impact of these limiting factors on the current analysis is unclear. However, the Non-Communicable Disease Risk Factor Collaboration is internationally recognized databases that collect data from peer-reviewed literatures. Nonetheless, we acknowledge the present conclusion may change as future studies appear in the literature and merit future continuous investigation.

Although the causation for the relationship between GDP and BMI is beyond the scope of this study, our data provide the first insight on how globalization impacts BMI. An important implication is that resolving this health epidemic should not only rely on traditional health-based guidelines. The present results could help launch a comprehensive national obesity initiative, while laying the foundations for physical well-being into 2021–2025. Future task forces for designing pediatric practice should also attempt to explore the influence of targeted economic activities.

From the macro-perspective, the present results could offer novel insights to reverse-engineer a positive economic impact that stimulates not only supply-side economy but also demand-side related social changes. We recommend health professionals and economists jointly assess how reduced reliance on ultra-processed foods related to globalization could yield positive economic and health outcomes. For instance, the recent booming of fresh food e-commerce in China, a market valued at ∼200 billion Chinese Yuan in 2020 (30), may provide an excellent opportunity to better control the curve of population weight gain, should consumer behaviors be driven to the consumption of healthy fresh foods. Together with traditional promotion of active lifestyles (e.g., daily walking for 8,000 steps per day), comprehensive nationwide interventions containing novel economic approaches could creatively reduce overweight and obesity whilst stimulating the high-quality, health-related consumer economy in China.

CONCLUSION

China was, and still is, one of the fastest growing economies in the world. With obesity on the rise across the nation, plus an increased risk at lower BMI cut points among Chinese ethnicities for chronic diseases, it is important to acknowledge and understand how rapid economic expansion affected this process. This study's findings on the strong linear relationship between national economic development and BMI highlight the need for alternative economic interventions and strategies tailored for the young Chinese population to control overweight and obesity through adulthood. We expect that a carefully planned, innovative approach could simultaneously help change consumer behaviors and yield enhanced health outcomes and economic growth in modern China.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

TB and SP contributed conception and design of the study. HH and TF helped design and coordinate data collection. TB, HH, and TF performed the statistical analyses and wrote the first draft of the manuscript. SP and JG critically reviewed and edited the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Chronological and Skeletal Age in Relation to Physical Fitness Performance in Preschool Children

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Introduction: Physical fitness is an adaptive state that varies with an individual's growth and maturity status. Considering that the difference in skeletal maturity already existed among preschool children, this study was designed to determine the influence of skeletal age and chronological age on preschoolers' physical fitness performance.

Methods: This cross-sectional study was conducted in 945 healthy preschoolers (509 males, 436 females) aged between 3.0 and 6.0 years in Shanghai, China. We used the method of TW3-C RUS to determine skeletal age. Chronological age was measured by subtracting the date of birth from the test date. Sit and reach, 2 × 10 m shuttle run test, standing long jump, tennis ball throw, 5 m jump on both feet, and balance beam walk were considered for physical fitness performance. Correlation coefficients and partial correlations adjusting height and weight were used to determine the relationships among the variables of skeletal age/ relative skeletal age, chronological age/relative chronological age, and physical fitness items.

Results: Skill-related physical fitness was weakly to moderately associated with skeletal age (the absolute value of r: 0.225–0.508, $p < 0.01$) and was moderately to strongly associated with chronological age (the absolute value of r: 0.405–0.659, $p < 0.01$). Health-related physical fitness items (BMI and sit and reach) showed a fairly weak to no correlation with skeletal age and chronological age. After adjusting the height and weight, an extremely weak to no correlation was observed between skeletal age and both health- and skill-related physical fitness, and weak-moderate correlations were noted between chronological age and skill-related physical fitness (the absolute value of r: 0.220–0.419, $p < 0.01$). In children in Grade 1, skill-related physical fitness (except for balance beam walk) showed a weak to moderate correlation with relative chronological age (the absolute value of r: 0.227–0.464, $p < 0.05$).

Conclusion: (1) both skeletal age and chronological age are associated with skill-related rather than health-related physical fitness performance, and after adjusting height and weight, chronological age, rather than skeletal age, is associated with skill-related physical fitness performance; (2) for preschool children, skill-related physical fitness performance is influenced by relative chronological age rather than individual differences in skeletal maturation, especially in the lower grades.

Keywords: physical activity, motor performance, motor competence, bone age, growth and maturation, pediatrics

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INTRODUCTION

Physical fitness refers to the ability of the body systems to work effectively in harmony to enjoy leisure time, stay healthy, and cope with emergencies (1). Monitoring of physical fitness in children should receive considerable critical attention because it has previously been observed that physical fitness is not only positively associated with academic achievement and cognitive functions (2–4) but also is a potent health marker of cardiovascular, metabolic, and skeletal health (5) in childhood and adolescence. Further, a longitudinal study showed a moderate to a highly significant correlation between health-related physical fitness components in childhood and those in adulthood (6). With the growing public health concern worldwide, there is an overall declining trend of physical fitness among children (7). Hence, the improvement and maintenance of physical fitness have become the main challenges for many researchers.

Physical fitness is an adaptive state relevant to the individual's growth and maturity status, lifestyle, and environmental factors (1, 8). The preschool age is a critical period for dramatic physiological changes, neuromuscular development, and the acquisition of fundamental motor skills (8). Thus, the influencing factors of physical performance in early childhood are more complicated. Several attempts have been made to examine the effects of lifestyle (i.e., physical activity, nutrition intake, and sedentary behaviors) (9, 10) and environment (i.e., kindergarten, family, and community) (11, 12) on preschooler's physical fitness performance. Growth and maturity are suggested to be the most important factors influencing young children's physical fitness (8); however, there is much less evidence on this.

An individual's growth and maturity are usually determined by chronological age and biological age. The chronological age is easily determined by the date of birth, and it has been used as the age category in the physical fitness standards worldwide. As mentioned in extensive research, chronological age significantly influences physical fitness in preschool children (13, 14). In recent years, there has similarly been an increasing interest in the impact of relative chronological age (the difference in birth month) on the physical performance of preschool children of the same grade (15). The biological age is usually expressed by the skeletal age, which reflects the actual physical growth and maturity status. Previous studies on adolescents have reported that the skeletal maturation status significantly affects their physical performance (16–18), and maturity-age should be used during the selection and competition of young athletes (19, 20). Relevant studies on preschool children are extremely limited, and there is only one study conducted among children aged 3–6 years demonstrating that skeletal maturation has a relatively minimal effect on fundamental motor skills and motor performance (21). However, as shown in our previous study, the difference in skeletal age at the same chronological age is as high as 2.0 years (22). This could result in a significant difference in height and weight (23) that might steeply influence physical fitness performance. However, there are no published data on the association between skeletal age and physical fitness among preschool children, especially after adjusting height and weight.

Therefore, a cross-sectional study was designed among a cohort of Chinese preschool children to determine the influence of skeletal age and chronological age on their physical fitness performance. This research could contribute to providing some evidence on the importance of the effect of skeletal age and chronological age on the physical fitness of preschool children, which might be useful for physical education practitioners who are concerned about targeted methods to improve preschooler's physical fitness levels.

MATERIALS AND METHODS

This study was approved by the Shanghai Nutrition Society Medical Ethics Committee (No. 2019–007) on July 11, 2019, and the participants' confidentiality was strictly maintained throughout the study. Prior to participation, the purpose and procedures of this study were explained to the participants' parents and teachers in each kindergarten. In addition, written informed consent was obtained from the parents.

Participants

This cross-sectional study was conducted at school entry (autumn 2019) in Shanghai, China. The participants were recruited from three non-randomly selected public kindergartens rated as First-level Kindergarten (24), and notably, all children were recruited, except for those in four classes who were quarantined due to influenza. Written study information and informed consent forms were sent to the participants' guardians. In addition, the teachers of the kindergartens were informed about the study introduction content. The participants were formally included in the study after the informed consent was received. In total, 1021 Chinese children were registered for this study. After excluding the missing data and outliers rejected, a total of 945 participants (509 males, 4.8 ± 0.8 years; 436 females, 4.8 ± 0.8 years) were included in the final analyses. The sample selection process is detailed in **Figure 1**.

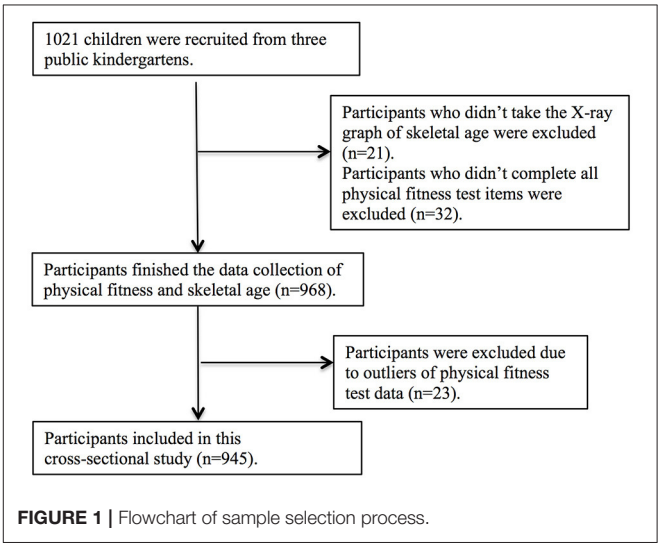

FIGURE 1 | Flowchart of sample selection process.

Chronological and Skeletal Age

The individual chronological age was measured by subtracting the calendar birth date from the test date. Since the enrollment age in China was calculated as ending on August 31, relative chronological age was calculated by dividing the difference of birth date and August 31 by 365, and the difference is specifically the gap between the date of birth and August 31 (for children born from January to August) or August 31 of the following year (for children born from September to December).

The determination of skeletal age has been previously reported (22). Briefly, the skeletal age was assessed by comparing the obtained X-ray film of the left hand and wrist, which was taken with a digital portable X-ray apparatus (MOVIX4.0+D Ream, Stephanie, France) with the standard of Tanner-Whitehouse 3-Chinese Radius-Ulna-Short Bones (TW3-C RUS) (25). The reliability of skeletal age evaluation has been reported in our previous study (22). The relative skeletal age is determined by the difference between the skeletal age and the chronological age (skeletal age minus chronological age), which indicates skeletal maturity (8).

Physical Fitness Assessment

The participant' weight (0.1 kg) and height (0.1 cm) were measured by a mechanical stadiometer (Ningbo Finer Medical Instruments Co., Limited, Zhejiang, China) and a body fat and weight measurement device (V-BODY HBF-371, Omron, Japan), respectively, without shoes and coats on. Body mass index (BMI) was calculated using the equation as follows: BMI (kg/m^2) = Weight (kg)/Height^2 (m^2). The physical fitness performance was determined according to the Chinese National Physical Fitness Measurement (preschool children version) (26). The test battery is widely used in China as an official manual, and a previous study reported its reliability and validity (27). This physical fitness test battery includes six test items: sit and reach, 2 × 10 m shuttle run test, standing long jump, tennis ball throw, 5 m jump on both feet, and balance beam walk. The test was conducted by trained researchers in the activity room and playground of each kindergarten. The assessment details are as follows.

Sit and Reach

The participants removed their shoes and were instructed to sit on the floor with legs fully extended with feet against the front end of the test equipment (Reliable Co., Ltd., Beijing, China), and then slowly bend forward to push the Vernier as far as possible with their fingertips. The participants performed the test twice, and the better result was recorded (0.1 cm). Longer distance reflects better flexibility.

2 × 10 m Shuttle Run

The test was conducted between groups of two participants. A marker tube was placed on the turn-back line of the 10 m long and 1.22 m wide runways, respectively. The participants placed their front foot behind the starting line. With the signal "Go!," the participants sprinted to the turn-back line, touched the tube, and ran back across the finish line. The participants performed the test once and recorded the time spent (0.1 s). The shorter time spent reflects better speed of movement and agility.

Standing Long Jump

The participants jumped as far as possible with their feet together (separate from each other at about the shoulder's width) while staying upright. The distance between the start line and the landing position was measured. The participants performed this test twice, and the better result was recorded (1.0 cm). Longer distance reflects greater lower limb explosive strength.

Tennis Ball Throw

The participants stood in front of the starting line and were instructed to hold one tennis ball with their dominant hands and throw (overhand) it as far as possible. The longer distance of the two attempts was recorded as the test score (0.5 m), and longer distance reflects greater upper limb power/strength and better coordination.

5 m Jump on Both Feet

Ten horizontal lines were drawn 0.5 m apart on the flat ground, and a soft square bag (length 10 cm, width 5 cm, height 5 cm) was placed on each line. The participants stood in front of the start line, and upon the signal "start," continuously skipped 10 bags. The observer recorded the time spent (the better of the two attempts) as the test result (0.1 s). The shorter time spent reflects better coordination and lower limb strength.

Balance Beam Walk

The participants walked over the balance beam (3 m long, 10 cm wide, and 30-cm high; a square platform with the same height and a side length of 20 cm was added to both ends of the balance beam as the starting and ending areas) (Reliable Co., Ltd., Beijing, China) at the fastest speed without falling down. Each participant walked twice, and the lesser time required was recorded as the result (0.1 s). The shorter time spent reflects better dynamic balance.

Statistical Analyses

The data were entered into an Excel spreadsheet and imported into SPSS Statistics for Mac. Version 21.0 (IBM Co., Armonk, NY, USA) for analyses. All variables were expressed as the mean ± standard deviation. The differences in each measurement parameter between the chronological age and skeletal age groups were analyzed using one-way analysis of variance (ANOVA), and differences across genders were analyzed using analysis of the independent-samples *t*-test. Subsequently, a Spearman's correlation analysis was performed between chronological age, skeletal age, body size (height and weight), and physical fitness tests in gender groups. The relationship between relative chronological age, relative skeletal age, body size (height and weight), and physical fitness was evaluated using Pearson correlation coefficient in gender and grade groups. Additionally, partial correlations, adjusting height and weight, were used to determine the relationships among the variables of skeletal age, chronological age, relative skeletal age, relative chronological age, and physical fitness items. Notably, the differences were considered statistically significant at $p < 0.05$.

RESULTS

The means and standard deviations by chronological age group and gender are stated in **Table 1**, and in addition, analyses by skeletal age group are presented in **Supplementary Table 1**. As shown in **Table 1**, from the 3.0-year group to the 6.0-year group, male's height increased from 99.2 ± 3.9 to 119.1 ± 5.9 cm, and weight increased from 16.2 ± 2.0 to 24.0 ± 3.6 kg. Similarly, female's height increased from 97.9 ± 3.3 to 118.1 ± 4.7 cm, and weight increased from 15.6 ± 1.9 to 22.5 ± 3.4 kg, and significant differences were observed between age groups. Regarding health-related physical fitness, there was no significant change in BMI and female's sit and reach, except for male's sit and reach performance, which decreased from 10.9 ± 3.6 cm in the 3.0-year group to 5.5 ± 4.7 cm in the 6.0-year group ($p < 0.01$). Skill-related physical fitness performance significantly improved with age ($p < 0.01$). Regarding sit and reach that reflects flexibility, the females consistently performed better than males in five of the seven age groups ($p < 0.01$); on the contrary, in four of the seven age groups, males significantly showed better performance than females in tennis ball throw ($p < 0.05$). In other items, gender-related differences were relatively small, and a similar result is presented in **Supplementary Table 1** grouped by skeletal age.

The relationships between chronological age, skeletal age, height, weight, and physical fitness are presented in **Table 2**. This table includes the coefficients of correlations and partial correlations (adjusting height and weight) between ages and physical fitness items. As shown, height and weight are strongly associated with skeletal age and chronological age ($p < 0.01$), respectively. Skill-related physical fitness performance was weakly-moderately associated with skeletal age (the absolute value of r: 0.225–0.508, $p < 0.01$) and moderately-strongly associated with chronological age (the absolute value of r: 0.405–0.659, $p < 0.01$). However, health-related physical fitness items (BMI and sit and reach) showed a fairly weak to no correlation with skeletal age and chronological age, respectively. After adjusting the height and weight, there was no or very weak correlation between skeletal age and both health- and skill-related physical fitness. In contrast, weak-moderate correlations were observed between chronological age and skill-related physical fitness (the absolute value of r: 0.220–0.419, $p < 0.01$).

Table 3 shows the correlations and partial correlations of relative chronological age and relative skeletal age with height, weight, and physical fitness. Height and weight showed a weak to moderate correlation with relative skeletal age in all grade and gender groups (the absolute value of r: 0.219–0.451, $p < 0.01$), and physical fitness items showed very weak or no correlations and partial correlations with relative skeletal age. Regarding relative chronological age, in Grade 1, skill-related physical fitness items (except for balance beam walk) showed weak-moderate correlation with relative chronological age (the absolute value of r: 0.227–0.464, $p < 0.05$), and after adjusting height and weight, most test items still showed weak correlations. However, in Grade 2 and 3, the items and correlation coefficients associated with the relative chronological age decreased, and in Grade 3, only standing long jump showed a very weak correlation

TABLE 1 | Descriptive statistics for body size, physical fitness by gender and chronological age.

	N	Body size		Health-related physical fitness		Skill-related physical fitness				
		Height (cm)	Weight (kg)	BMI (kg/m^2)	Sit and reach (cm)	2 × 10 m SRT (s)	Standing long jump (cm)	Tennis ball throw (m)	5 m jump on both feet (s)	Balance beam walk (s)
Male ($n = 509$)										
3.0 ∼ <3.5	36	99.2 ± 3.9	16.2 ± 2.0	16.4 ± 1.1	10.9 ± 3.6	12.5 ± 2.8	50.0 ± 17.1	2.4 ± 1.1	10.7 ± 4.6	29.9 ± 16.0
3.5 ∼ <4.0	66	101.7 ± 4.3	17.1 ± 2.3	16.5 ± 1.5	9.8 ± 4.2	11.0 ± 2.3	59.6 ± 18.2	3.0 ± 1.0	9.0 ± 4.0	26.4 ± 14.2
4.0 ∼ <4.5	59	106.7 ± 4.6	18.9 ± 2.7	16.5 ± 1.8	9.4 ± 4.3	9.5 ± 1.6	73.3 ± 15.4	3.6 ± 1.3	7.6 ± 2.8	22.0 ± 11.7
4.5 ∼ <5.0	106	109.2 ± 4.2	19.1 ± 2.2	16.0 ± 1.3	8.7 ± 4.7	9.0 ± 1.5	82.5 ± 17.7	3.9 ± 1.4	7.7 ± 3.2	20.0 ± 14.7
5.0 ∼ <5.5	104	112.4 ± 4.4	20.5 ± 3.1	16.1 ± 1.9	7.0 ± 4.4	8.2 ± 1.0	87.9 ± 17.9	4.7 ± 1.7	6.1 ± 2.0	15.7 ± 11.5
5.5 ∼ <6.0	107	115.9 ± 4.8	22.0 ± 4.0	16.3 ± 2.2	8.0 ± 5.2	7.9 ± 1.1	95.5 ± 15.5	5.6 ± 1.8	5.7 ± 1.8	11.1 ± 10.2
6.0 ∼ <6.5	31	119.1 ± 5.9	24.0 ± 3.6	16.8 ± 1.7	5.5 ± 4.7	7.9 ± 1.2	100.5 ± 17.4	5.7 ± 2.0	5.3 ± 1.0	11.4 ± 7.2
One-way ANOVA		**	**	ns	**	**	**	**	**	**
Female ($n = 436$)										
3.0 ∼ <3.5	35	97.9 ± 3.3	15.6 ± 1.9	16.3 ± 1.4	11.8 ± 2.1	12.1 ± 2.3	44.9 ± 17.8	2.1 ± 0.5	9.7 ± 4.2	25.3 ± 14.5
3.5 ∼ <4.0	55	101.1 ± 3.6	16.3 ± 1.8$^{\#}$	15.9 ± 1.4$^{\#}$	11.7 ± 3.3$^{\#\#}$	10.9 ± 1.5	58.9 ± 13.9	2.7 ± 0.8	8.1 ± 2.8	24.2 ± 13.6
4.0 ∼ <4.5	58	104.9 ± 4.6$^{\#}$	17.0 ± 2.1$^{\#\#}$	15.4 ± 1.1$^{\#\#}$	10.2 ± 3.5	9.8 ± 1.5	70.0 ± 13.0	3.1 ± 1.0$^{\#}$	7.3 ± 1.8	24.4 ± 13.7
4.5 ∼ <5.0	81	108.3 ± 4.1	18.4 ± 2.4	15.7 ± 1.5	11.9 ± 3.5$^{\#\#}$	9.0 ± 1.4	78.3 ± 14.6	3.5 ± 1.0$^{\#}$	6.6 ± 1.6$^{\#\#}$	21.3 ± 13.5
5.0 ∼ <5.5	109	112.1 ± 4.6	20.0 ± 2.8	15.9 ± 1.8	11.3 ± 5.1$^{\#\#}$	8.5 ± 1.1$^{\#}$	84.3 ± 13.1	4.3 ± 1.3$^{\#}$	6.5 ± 2.3	13.7 ± 11.5
5.5 ∼ <6.0	73	115.4 ± 5.0	21.4 ± 3.6	16.0 ± 2.2	11.5 ± 4.8$^{\#\#}$	8.4 ± 0.9$^{\#\#}$	87.6 ± 16.5$^{\#\#}$	4.6 ± 1.3$^{\#\#}$	6.1 ± 1.8	13.0 ± 10.2
6.0 ∼ <6.5	25	118.1 ± 4.7	22.5 ± 3.4	16.2 ± 3.2	12.7 ± 3.7$^{\#\#}$	8.1 ± 0.7	93.6 ± 12.3	5.4 ± 1.5	5.7 ± 1.2	10.3 ± 9.1
One-way ANOVA		**	**	ns	ns	**	**	**	**	**

$^{**}p < 0.01$. $^{\#}$Female vs. Male, $p < 0.05$, $^{\#\#}$Female vs. Male, $p < 0.01$.
BMI, body mass index; SRT, shuttle run test; ns, no significance.

TABLE 2 | Correlations and partial correlations between skeletal age, chronological age, and body size, physical fitness in children aged 3–6 years old.

	SA		CA		Height (cm)	Weight (kg)	BMI (kg/m^2)
	r	$r_{partial\text{-}H\&W}$	r	$r_{partial\text{-}H\&W}$			
Male ($n = 509$)							
Height (cm)	0.735**	–	0.777**	–	–	–	–
Weight (kg)	0.629**	–	0.621**	–	0.778**	–	–
BMI (kg/m^2)	0.096*	0.078	−0.046	0.112*	0.069	0.672**	–
Sit and reach (cm)	−0.0193**	0.012	−0.244**	−0.063	−0.259**	−0.138**	0.084
2 × 10 m SRT (s)	−0.427**	−0.062	−0.640**	−0.419**	−0.514**	−0.341**	0.047
Standing long jump (cm)	0.508**	0.137**	0.641**	0.405**	0.553**	0.363**	−0.057
Tennis ball throw (m)	0.382**	−0.006	0.580**	0.287**	0.524**	0.411**	0.044
5 m jump on both feet (s)	−0.306**	−0.033	−0.513**	−0.306**	−0.368**	−0.288**	−0.035
Balance beam walk (s)	−0.266**	−0.039	−0.479**	−0.303**	−0.319**	−0.209**	0.034
Female ($n = 436$)							
Height (cm)	0.668**	–	0.801**	–	–	–	–
Weight (kg)	0.606**	–	0.652**	–	0.764**	–	–
BMI (kg/m^2)	0.153*	0.04	0.016	0.129*	0.014	0.651**	–
Sit and reach (cm)	−0.013	−0.065	0.043	0.002	0.026	0.05	0.050
2 × 10 m SRT (s)	−0.486**	−0.118*	−0.622**	−0.348**	−0.565**	−0.419**	0.002
Standing long jump (cm)	0.458**	0.125**	0.645**	0.416**	0.576**	0.396**	−0.047
Tennis ball throw (m)	0.428**	−0.011	0.659**	0.345**	0.579**	0.457**	0.031
5 m jump on both feet (s)	−0.225**	0.000	−0.405**	−0.232**	−0.305**	−0.239**	−0.010
Balance beam walk (s)	−0.269**	−0.027	−0.467**	−0.220**	−0.310**	−0.248**	−0.013

CA, chronological age; SA, skeletal age; BMI, body mass index; SRT, shuttle run test; partial-H&W, partial-Height & Weight.
$^*p < 0.05$, $^{**}p < 0.01$.

with relative chronological age (male, $r = 0.210$, $p < 0.01$, female, $r = 0.157$, $p < 0.05$).

DISCUSSION

The main purpose of this study was to demonstrate the associations between skeletal age/relative skeletal age and chronological age/relative chronological age and physical fitness performance in preschool children, especially independent of height and weight. Overall, the main finding was that skill-related physical fitness correlated with relative chronological age rather than relative skeletal age, contrary to the findings of previous studies that suggested that the skeletal maturation status has a much stronger influence on motor performance than the birth quarter and should be used in the selection and competition of young athletes (19, 20, 28). Additionally, both skeletal age and chronological age are associated with skill-related rather than health-related physical fitness performance, and after adjusting the height and weight, the chronological age was weakly-moderately correlated with skill-related physical fitness and skeletal age was not or very weakly correlated with skill-related physical fitness. This result might provide evidence to support the speculation from previous studies that skeletal age influences physical fitness performance mainly through height and weight (29). There are several possible explanations for the results obtained in this study that we try to discuss from three perspectives.

Firstly, the characteristic of the physical fitness item may affect the relationships between chronological age, skeletal age, and physical fitness performance. The physical fitness test includes a series of standardized motor tasks for children (14, 27), and it is more complex than specific motor acts executed in motor competence measuring. An early study (30) showed that correlations between skeletal age and isometric strength measured in the cable tension method are higher than those between skeletal age and motor performance. In this study, two health-related indicators (BMI reflecting body composition and sit and reach reflecting flexibility), reflecting a single physical ability and a simple test method, showed very weak or no correlation with skeletal and chronological age and relative age. However, other skill-related physical fitness test items were weakly-moderately associated with skeletal age and moderately-strongly associated with chronological age (as shown in **Table 2**), which is consistent with the finding of a previous study (29) that indicated a greater effect of skeletal age on motor fitness than handgrip performance (health-related fitness). Skill-related physical fitness measures more than one component, such as the motor components of coordination and lower limb strength that are assessed in the 5 m jump on both feet test. The early childhood stage is a crucial period for the development of basic motor skills, and significant changes might occur in a short time during this stage (8), which might explain the existence of a relationship between age and skill-related physical fitness performance. Additionally, physical fitness is related to intellectual maturity in preschool children (31), and the complexity of the test

TABLE 3 | Correlations and partial correlations between relative skeletal age, relative chronological age, and body size, physical fitness in children aged 3–6 years old.

	RSA		RCA		RSA		RCA	
	r	$r_{partial\text{-}H\&W}$	r	$r_{partial\text{-}H\&W}$	r	$r_{partial\text{-}H\&W}$	r	$r_{partial\text{-}H\&W}$
Grade 1		**Male (n = 118)**				**Female (n = 108)**		
Height (cm)	0.333**	–	0.492**	–	0.219*	–	0.449**	–
Weight (kg)	0.334**	–	0.344**	–	0.281**	–	0.175	–
BMI (kg/m^2)	0.181	0.049	0.049	0.066	0.175	0.041	−0.177	−0.075
Sit and reach (cm)	0.035	0.05	−0.189*	−0.194*	0.219*	0.165	−0.160	−0.216*
2 × 10 m SRT (s)	0.094	0.155	−0.343**	−0.302**	0.020	0.091	−0.324**	−0.246*
Standing long jump (cm)	−0.133	−0.225*	0.358**	0.287**	0.042	−0.051	0.464**	0.362**
Tennis ball throw (m)	0.012	−0.102	0.365**	0.271**	−0.173	−0.254**	0.433**	0.383**
5 m jump on both feet (s)	0.044	0.106	−0.227*	−0.186*	−0.052	−0.040	−0.237*	−0.194*
Balance beam walk (s)	0.036	0.093	−0.187*	−0.138	0.104	0.051	−0.143	−0.149
Grade 2		**Male (n = 186)**				**Female (n = 167)**		
Height (cm)	0.367**	–	0.246**	–	0.227**	–	0.451**	–
Weight (kg)	0.360**	–	0.013	–	0.237**	–	0.297**	–
BMI (kg/m^2)	0.169*	0.009	−.0207**	0.055	0.133	0.002	0.020	0.112
Sit and reach (cm)	−0.042	−0.010	−0.153*	−0.096	−0.064	−0.068	0.095	0.120
2 × 10 m SRT (s)	0.012	0.041	−0.210**	−0.154*	−0.047	−0.030	−0.142	−0.107
Standing long jump (cm)	0.205**	0.159*	0.265**	0.186*	−0.034	−0.078	0.265**	0.213**
Tennis ball throw (m)	−0.030	−0.087	0.180*	0.139	−0.085	−0.155*	0.285**	0.199**
5 m jump on both feet (s)	0.003	0.014	−0.111	−0.091	0.087	0.094	−0.091	−0.100
Balance beam walk (s)	−0.007	−0.024	−0.226**	−0.216**	0.041	0.080	−0.281**	−0.262**
Grade 3		**Male (n = 205)**				**Female (n = 161)**		
Height (cm)	0.451**	–	0.389**	–	0.251**	–	0.262**	–
Weight (kg)	0.355**	–	0.252**	–	0.331**	–	0.171*	–
BMI (kg/m^2)	0.138*	0.060	0.054	0.088	0.218**	0.011	0.039	0.148
Sit and reach (cm)	−0.008	0.064	−0.011	0.058	−0.109	−0.126	0.068	0.063
2 × 10 m SRT (s)	0.050	0.063	0.006	0.010	−0.107	−0.057	−0.009	0.048
Standing long jump (cm)	0.015	−0.03	0.210**	0.188**	0.006	0.029	0.157*	0.154
Tennis ball throw (m)	0.050	−0.068	0.085	−0.008	−0.061	−0.135	0.170*	0.115
5 m jump on both feet (s)	0.066	0.061	−0.030	−0.055	0.156*	0.199*	−0.028	−0.014
Balance beam walk (s)	0.121	0.133	−0.135	−0.147*	0.022	0.073	0.044	0.090

RSA, relative skeletal age; RCA, relative chronological age; BMI, body mass index; SRT, shuttle run test; partial-H&W, partial-Height & Weight.
$^*p < 0.05$, $^{**}p < 0.01$.

method might affect the understanding and mastery of various test methods, which may affect the demonstration of actual competence. This speculation is supported by the findings of previous studies that moderate-to-strong positive correlations exist between actual motor competence and physical fitness in preschool children (32, 33).

Secondly, physical fitness performance is not only decided by growth and maturation but also by adaptation, which is a form of motor learning in virtually all movements (34). Most of the young children are not specifically trained, and the experience of daily learning is crucial to improve motor skills. Consistent with this view, the importance of participation has similarly been highlighted in previous studies, indicating that an increased physical activity contributes to an improved physical fitness performance (32, 35, 36). Additionally, the effect of relative chronological age can be explained from the same perspective. A previous study emphasized the impact of relative chronological age (the difference in birth month) on the physical fitness performance of preschool children (15), and similar results were also obtained in our study (**Table 3**). Thus, we can speculate that chronological age not only reflects growth and maturation but also implies survival duration in the society, which indicates the opportunity to improve adaptation through participation and experience. On the contrary, skeletal age mainly reflects the growth and maturation status. However, this situation might be gradually altered with an increased time of living and studying in a similar environment. This is because, as shown in **Table 3**, the effect of relative chronological age seemed to be greater in grade 1 than in grade 3. In addition, previous studies have shown that there are similar correlation coefficients between skeletal age, chronological age and physical fitness in adolescent males (8, 30, 37).

Thirdly, the skeletal maturity status might determine the entire extent of motor skills, such as youth athlete's achievement in a competition after intensive training; however, it does not directly determine the performance of motor tasks in

children and adolescents without practice. Hence, skeletal age is used more in competitive sports. It has been suggested that skeletal maturation influences competition performance, which strengthens the importance of skeletal age in selecting young athletes (19, 20, 38). Consequently, much attention is not given to general physical education.

There are a few limitations to this study. Several factors influence physical fitness performance in preschool children; however, this study failed to consider other main influencing factors, physical activity lifestyles, and environmental factors (1) and only comparatively analyzed the effects of chronological age and skeletal age on physical fitness. Hence, we could not quantitatively explain the impact of each factor on physical fitness, and, therefore, could not provide direct and strong evidence for formulating measures to improve children's physical fitness. Secondly, although some test items included muscular strength components, the direct measurement of strength (e.g., handgrip, knee extension, and muscle mass) was not considered. This led to the failure to prove whether the relationship between preschool children's muscle strength and skeletal age and chronological age is different from that among other physical fitness performance. However, there are relatively few general methods for direct measurement of muscle mass and muscle strength in preschool children.

Nevertheless, this study has several strengths. To the best of our knowledge, this is the first study that clarified the correlation coefficients between skeletal age/relative skeletal age, chronological age/relative chronological age and physical fitness, especially adjusting the height and weight. The evidence from this study suggests that (1) both skeletal age and chronological age are associated with skill-related rather than health-related physical fitness performance, and after adjusting height and weight, chronological age, rather than skeletal age, is associated with skill-related physical fitness performance; (2) for preschool children, skill-related physical fitness performance is influenced by relative chronological age rather than individual differences in skeletal maturation, especially in the lower grades.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Shanghai Nutrition Society Medical Ethics Committee (No. 2019–007). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

DK and DL designed this study. DK, JZ, GC, and XW carried out the experiments. DK and KS analyzed experimental data. DK was responsible for manuscript writing. KS revised the manuscript. All authors were involved in writing the paper, and had final approval of the submitted and published versions.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fped.2021.641353/full#supplementary-material

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An Effective Life–Sex–Emotions Course for Taiwanese Adolescents on Health Perceptions: A Cohort Study

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Aim: Adolescence is a time of transition from childhood to adulthood, when young people go through a number of vital physical and psychological developments. It is surprising yet unfortunate that the number of teenage suicide deaths and teenage infections of gonorrhea have increased over the years, becoming serious public health concerns in Taiwan. The aim of this study was to investigate the effect of an education course on teenagers' understanding of adolescence and their attitudes toward life, sex, gender equality, and mental health.

Material and Methods: Participants were comprised of Taiwanese students in Grades 5 to 9 who completed a Life–Sex–Emotions course, titled "Sailing through Adolescence." The effect of the course was measured using pre- and post-test scores on the Perception Index of Life–Sex–Emotions Education (PILSEE) instrument. Qualitative data included subjective responses to questions before and after the course. Data were collected between September 2017 and June 2020.

Results: A total of 10,506 completed questionnaires were collected. The mean PILSEE pretest scores for each subscale ranged from 8.71 to 13.37 (SD = 1.499–1.99); posttest subscale scores ranged from 9.30 to 13.95 (SD range = 1.490–2.288). The mean overall pretest score was 86.86 (SD = 10.83); the mean posttest score was 92.62 (SD = 10.30). The paired *t*-test demonstrated that post-test scores were significantly higher than pretest scores ($t = 55.46$; $p < 0.01$). Qualitative feedback indicated that the course improved students' self-esteem, their understanding adolescence, and awareness of influences of the media.

Conclusion: Our findings indicate that an educational course about life, sex, and emotions during adolescence can be an effective intervention to help teenagers understand the impact of adolescence on attitudes toward life, sex, mental health, and gender equality.

Keywords: adolescence, life-sex-emotions course, perception index of life-sex-emotions education, life value, sex

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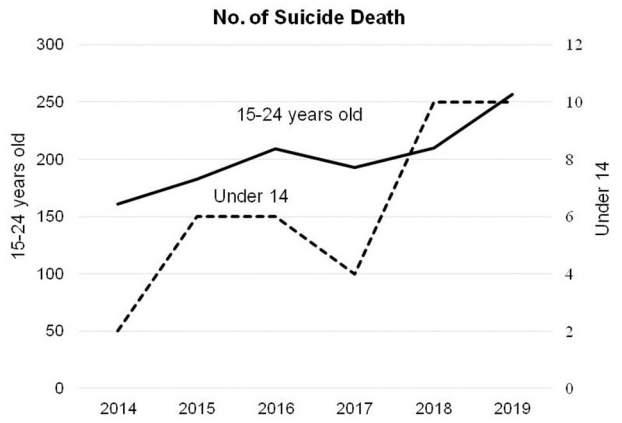

FIGURE 1 | Suicide deaths in adolescents during 2014–2019 in Taiwan.

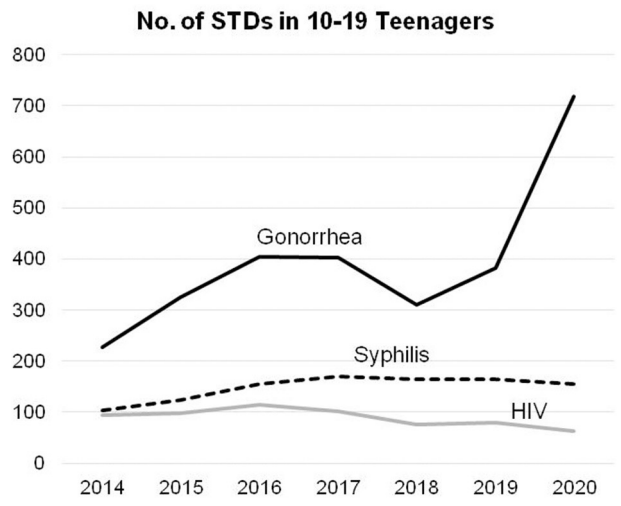

FIGURE 2 | Teenage infections of syphilis, gonorrhea, and HIV during 2014–2020 in Taiwan.

INTRODUCTION

Adolescence is a significant transitional stage between childhood and adulthood (1). Teenagers face many challenges during adolescence including the development of secondary sex characteristics, struggles between dependence and independence, hormone-related mood swings, annoying acne (2), and uncertainty about self-esteem and identity (3).

Teenage suicides have risen in Taiwan at an alarming rate. As shown in **Figure 1**, the number of suicide deaths among adolescents under the age of 14 years has increased from 2 to 10 per year between 2014 and 2019, and for adolescents between the ages of 15 and 24 years it increased from 161 to 257 during the same period (4). The suicide death rate of adolescents in 2019 reached a 10-year high. The common causes for teenage suicides in Taiwan were "a lack of meaning or value of life" and "to escape from or avoid pain" (5, 6).

Curiosity about sex is a natural and significant component of adolescence, which is often regarded as a topic that is taboo in Chinese society (7). Misconceptions of sex have also been spread by the media, increasing misunderstandings for teenagers and leading to infections from sexual transmitted diseases (STDs) and unwanted teenage pregnancies (8). Teenage infections with STDs have long been a concern in Taiwan, especially from gonorrhea (**Figure 2**) (9). In 2020, the number of teenagers infected with gonorrhea increased by almost 90%, yet the infection rate for adults only increased by 50% (9).

The importance of gender equality has become more significant, and social awareness has increased for adolescents. The Taiwanese government enacted the Gender Equity Education Act (GEEA) in 2004, which endeavors to promote gender equality (10). However, many of the changes that have been incorporated into textbooks have been considered by parents to be inappropriate for certain age groups. These have more recently been addressed by the Control Yuan, which is an independent investigatory and auditory agency of the government in Taiwan (11).

Issues considered to be important regarding the topic of sex education may differ between girls and boys. It was reported that boys showed positive interest in visits and discussions with nurses on sexual health (12) and sex life (13). In contrast, girls are likely to be more interested in topics of a responsible approach to sex life, sexual abuse, parenting, contraception, and gender equality (13).

To help teenagers smoothly transition through adolescence and develop positive and healthy attitudes toward life, sex, and gender equality, a course promoting Life–Sex–Emotions entitled "Sailing through Adolescence" has been offered in Taiwan since 2014 to students in grades 5 to 9. However, the impact of this course has not been quantitatively or qualitatively examined.

Therefore, the aim of this study was to investigate the effect of the "Sailing through Adolescence" course on perceptions of students in grades 5 to 9 regarding their understanding of adolescence and its impact on life, sex, emotions, and other associated issues. A pretest–posttest design examined students' perceptions using a Perception Index of Life–Sex–Emotions Education questionnaire (PILSEE) for quantitative measures and seven questions about students' subjective perceptions for qualitative measures.

METHODS

Design

This retrospective cohort study used a pretest–posttest design to examine the effect of an educational course entitled "Sailing through Adolescence" on students' perceptions of life, sex, and emotions.

Participants

Students in grades 5 to 9 enrolled in were selected by purposive sampling to ensure representation of diverse characteristics relevant to our study. Inclusion criteria for students were as

follows: (1) enrolled in the "Sailing through Adolescence" course and (2) had demonstrated the ability to read and write. Exclusion criteria for students were (1) absent from four or more classes of the "Sailing through Adolescence" course and (2) had been identified as having a mental disorder. In this survey, sample size calculation for ±1% precision levels, a confidence interval of 95%, and $P = 0.5$ was determined to be 9,604 (14). Considering the 10% churn rate, 10,564 participants were needed.

Ethical Considerations

This study was approved by the Ethics Committee of Taipei Hospital, Ministry of Health and Welfare (TH-IRB-0021-0001). All procedures performed were in accordance with the ethical standards of the Ethics Committee of Taipei Hospital, Ministry of Health and Welfare and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The PILSEE Instrument

The 20-item PILSEE instrument was developed to assess students' attitudes about aspects of adolescent life. The PILSEE was designed by the same three experts that developed the education course and is comprised of seven subscales: value of Life (three items), Secrets of Adolescence (three items), Gender Roles (three items), Friendship and Love (three items), Myths of the Media (two items), Adolescent Sexuality (three items), and Views of Marriage and Sex (three items). Each item is scored on a Likert scale from 1 to 5; item scores range from 1 to 5. Subscale scores are the sum of the item scores; the total score ranges from 20 to 100. Higher scores indicate a more positive attitude toward adolescence. Data collected from students in 2014 ($n = 8,693$) examined validity and reliability of the scale. The face validity was 4.86–4.98; the CVI for content validity was good (81.67%). The Cronbach's alpha assessing for internal consistence for each of the seven subscales was from 0.733 to 0.898; the Cronbach's alpha for overall was 0.956. For confirmatory factor analysis, the factor loadings for 18 out of 20 questions were over 0.7, and the remaining two questions were 0.692 and 0.591. GFI was 0.953, AGFI was 0.933, and both NFI and NNFI were over 0.9. Overall, this questionnaire had good reliability and validity and could serve as an evaluation tool. Details of the PILSEE instrument are shown in **Supplementary Table 1**.

The "Sailing Through Adolescence" Course

The "Sailing through Adolescence" course was offered in 12 weekly lessons over a period of 2–3 months and approved by the "Committee of School Curriculum Development" of all participating schools. The course was developed by three experts in sex education, gender equality education, and life-skills education for adolescents, which was based on cognition, affection, and behavior. Each lesson focuses on one specific topic. At the beginning of the course, students completed the PILSEE questionnaire for pre-test scores. Students were then presented with a "Treasure Map," and stickers were pasted on areas of the map as a means of recording the contents of each lesson. A "Learning sheet" was also distributed to the students as a guide for reinforcing knowledge related to each lesson. Students summarized knowledge gained from each lesson with an activity called "Brother Parrot has something to say." Students were encouraged to record and share their thoughts and impressions at the conclusion of each lesson. Details of the "Sailing through Adolescence" course are shown in **Supplementary Table 2**. After completing the 12 lessons, students filled out the PILSEE questionnaire for posttest data.

Data Collection

Data were collected from 2017 to 2020. Pretest and posttest data were collected with the PILSEE questionnaire before and at the conclusion of the education course (**Supplementary Table 2**).

Data Analysis

Quantitative data were analyzed using SPSS version 22.0 for Windows (Armonk, NY: IBM Corp). Descriptive statistics were used for frequency (n, %), and mean and standard deviations (SD) were used for total scores and subscale scores. Pair t tests assessed differences between pretest and posttest scores. Significance was set at $p < 0.05$ for statistical comparisons. Qualitative data were collected using from the learning sheets at the conclusion of each lesson.

RESULTS

Participant Characteristics

A total of 10,558 students enrolled in the course from September 2017 to June 2020. However, 52 participants only completed 20% of the questions. Thus, pre- and post-test data were analyzed for 10,506 students. The remaining missing data was replaced by the mode. The sample loss rate was 0.49%. In terms of gender distribution of the participants, 5,402 were boys (51.4%) and 5,104 were girls (48.6%). In terms of age distribution, 10,200 (97.0%) were grade 5 to 6 pupils (aged 10–12) in elementary schools, and 306 (3.0%) were grade 7 to 9 pupils (aged 13–15) in junior high schools.

PILSEE Scores

The mean PILSEE pretest scores for each subscale ranged from 8.71 to 13.37 (SD = 1.499–1.99); posttest subscale scores ranged from 9.30 to 13.95 (SD range = 1.490–2.288). The mean overall pretest score was 86.86 (SD = 10.83); the mean posttest score was and 92.62 (SD = 10.30). The paired t test indicated that posttest total scores and subscale scores were significantly higher than pretest scores ($p < 0.001$). Therefore, the significant improvement in posttest scores on the PILSEE suggests that the course on "Sailing through Adolescence" was effective in increasing students' attitudes toward adolescence. Details are shown in **Table 1**.

Difference Between Pre-test and Post-test PILSEE Scores for Boys and Girls

To examine if there were any differences in improvements in PILSEE scores between boys and girls following completion of the "Sailing through Adolescence" course, we used the difference between the mean posttest and pretest scores (**Table 2**). Boys scores were significantly greater for the total score ($p < 0.01$) as well as the subscales for Secrets of Adolescence ($p < 0.001$),

TABLE 1 | Pretest and posttest scores for students and differences between scores on the PILSEE ($N = 10,506$).

	Pre-test	Post-test		
	Mean ± SD	**Mean ± SD**	***t***	***P***
Total PILSEE score (range = 20–100)	86.86 ± 10.83	92.62 ± 10.30	55.46***	<0.001
PILSEE subscale scores				
Value of life (range = 3–15)	12.69 ± 2.25	13.83 ± 1.90	54.28***	<0.001
Secrets of adolescence (range = 3–15)	12.86 ± 2.28	13.89 ± 1.86	44.75***	<0.001
Gender roles (range = 3–15)	13.37 ± 1.99	13.94 ± 1.77	28.56***	<0.001
Friendship and love (range = 3–15)	13.33 ± 1.90	13.95 ± 1.73	31.47***	<0.001
Myths of the media (range = 2–10)	8.71 ± 1.49	9.30 ± 1.22	38.30***	<0.001
Adolescent sexuality (range = 3–15)	13.00 ± 2.15	13.91 ± 1.79	40.43***	<0.001
Views of marriage and sex (range = 3–15)	12.89 ± 2.13	13.80 ± 1.84	41.83***	<0.001

SD, standard deviation.
****$p < 0.001$.*

TABLE 2 | Amount of improvement between pretest and posttest for total score and subscale scores for boys ($n = 5,402$) and girls ($n = 5,104$) in grades 5–9 on the PILSEE.

	Boys	Girls		
	Mean ± SD	**Mean ± SD**	***t***	***P*-value**
Total score	6.02 ± 11.98	5.49 ± 9.01	2.60**	0.009
Subscale scores				
Value of Life	1.15 ± 2.33	1.14 ± 1.96	0.25	0.805
Secrets of adolescence	1.17 ± 2.59	0.87 ± 2.03	6.52***	<0.001
Gender roles	0.62 ± 2.26	0.52 ± 1.78	2.53*	0.011
Friendship and love	0.68 ± 2.25	0.55 ± 1.72	3.32**	0.001
Myths of the media	0.58 ± 1.69	0.60 ± 1.45	−0.73	0.468
Adolescent sexuality	0.91 ± 2.46	0.90 ± 2.13	0.29	0.771
Views of marriage and sex	0.91 ± 2.44	0.91 ± 1.99	0.21	0.836

SD, standard deviation.
**$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.*

TABLE 3 | Difference in pretest and posttest scores on the PILSEE between elementary school students ($n = 10,200$) and junior high school students ($n = 306$).

	Elementary	Junior high		
	Mean ± SD	**Mean ± SD**	***t***	***P*-value**
Total score	5.80 ± 10.66	4.59 ± 10.00	1.95	0.051
Subscale scores				
Value of life	1.15 ± 2.17	1.03 ± 1.91	0.91	0.364
Secrets of adolescence	1.03 ± 2.35	0.71 ± 1.89	2.88**	0.004
Gender roles	0.57 ± 2.05	0.42 ± 1.68	1.55	0.121
Friendship and love	0.62 ± 2.02	0.64 ± 1.91	−0.20	0.844
Myths of media	0.59 ± 1.58	0.50 ± 1.50	0.97	0.331
Adolescent sexuality	0.92 ± 2.31	0.65 ± 2.12	1.96	0.050
Views of marriage and sex	0.92 ± 2.24	0.62 ± 1.88	2.68**	0.008

SD, Standard deviation.
***$p < 0.01$.*

Gender Role ($p < 0.05$), and Friendship and Love ($p < 0.01$). These findings indicate that the education course had a more significant effect on boys' attitudes toward adolescence in these three areas.

Difference Between Pre-test and Post-test PILSEE Scores for Elementary School and Junior High School Students

The overall score of improvement for elementary pupils was 5.80 points (SD = 10.66), and that for junior high school students was 4.59 (SD = 10.00), which did not differ significantly between the two cohorts. However, two subscale scores increased significantly more for elementary school students: secrets of Adolescence ($t = 2.88$, $p < 0.01$) and Views of Marriage and Sex ($t = 2.68$, $p < 0.01$) (**Table 3**).

Qualitative Findings

Qualitative and descriptive studies allow researchers to gain an understanding of the experiences of participants closer to the truth (15). We also collected some anonymous feedback on the seven subscales for further analyses. This feedback about the seven subscales suggested that students' self-esteem, understanding of adolescence, the role of gender, the ability to analyze the influence of the media, and sexuality all improved after the education course.

Two students provided the following response to their personal perspective on *Value of Life*. One student (Student A) said, "I learned what sex is, and I also understood myself better. I am willing to accept who I am. I will not care about others' comments and I will live for myself." Student B offered the following perspective:

> *The course is over, but I wish I could take it again. I am particularly impressed by the lesson of "Rainbow Island." I learned that our lives are meaningful and useful. It is just like everything in nature. I used to think my life was worthless when I encountered difficulties, but I've learned to cherish my precious life.*

Adolescence is a period for a person to go through dramatic changes, both inside and outside. There are physical, psychological, and emotional changes of young persons during this time. Two students provided the following feedback on *Secrets of Adolescence*. Student C stated, "There are physical changes of boys and girls in adolescence, and I think it's important to know about these changes. I find this course useful, and I will concentrate more on this course," while Student D said,

> *I think this course has helped me understand myself better as well as the changes during adolescence, and how to prepare for them. It also helped me to know that those changes are normal and there's nothing wrong with me. We should be thankful that we are healthy. We must cherish and accept ourselves, and we need to be more confident and accept challenges in adolescence and in life.*

The importance of not having specific expectations for behaviors that are associated with gender was an important lesson for Student E, who shared the following feedback about one of the videos:

> *The boy liked to play house so his classmates bullied and laughed at him in the film. He was very unhappy and sad. However, his teacher found that he was a responsible boy and would help his mother. We should not have gender stereotypes of traits or hobbies. For example, my dad is a sushi chef and a cook. We should respect the hobbies and traits of others.*

Friendship and love are vital relationships that people cultivate and cherish in their lives and are some of the most valuable treasures a person can possess. Student G said, "Love is like sailing a boat. It is fun but can be dangerous," while a Student F shared the following:

> *I think confession should be from one's heart and should be sincere. We should not judge others by their looks, but instead, we shall focus on the beauty of peoples' personalities. We should not make friends with people only for their good looks, as some good-looking people could be rude. There are many kinds of people on the Internet. Don't talk to anyone you are not familiar with on the internet, because you don't know him/her quite well.*

Myths of the Media is the force exerted by the media, resulting in either a change of or reinforcement of beliefs, views, and perceptions in audience. Student H had the following opinion:

> *Everyone has a mobile phone today. We should learn how to distinguish all the online information. There are some pornographic, exaggerated and shocking advertisings on TV, and they are not worth learning about. Therefore, it's a must to learn how to filter unwanted and misleading information in the media in order to grow up healthily. We should be cautious in this diverse society.*

Adolescent sexuality is a stage of human development when adolescents experience and explore sexual feelings (16). Student I had a strong opinion about this subscale:

> *It is not proper to have sex when we are teenagers. We could scream or run into shops for help if we encounter sexual harassment or assaults. The most important thing is to protect ourselves and be safe. Each of us is unique. We should work hard and never give up.*

Marriage is a long-term commitment to spend your life with someone. Two students provided the following feedback:

> *You must think twice before doing things so that you will not regret. We shall do the right things rather than do the bad things. (You should have sex) only if you really want to have children. I saw news about many children losing lives due to child abuse, and this really made me very sad.* (Student J)
>
> *In marriage, I will not leave my husband for someone richer or better. I just want to love my husband and accompany him through all the difficulties.* (Student K)

DISCUSSION

Our study results showed that the "Sailing through Adolescence" course for Life–Sex–Emotions was effective for improving the perceptions of students in grades 5 to 9 about adolescence, attitudes toward life, sex, mental health, and gender equality. These attitudes might also enhance adolescents' self-awareness, attitudes toward physical changes during adolescence, and sexual health.

Regarding the prevention of teenage suicides, the Ministry of Education (MOE) in Taiwan established the "Three-level Prevention Program for Students Self-harm on Campus" (17). The first-level prevention is enhancing students' mental health through courses to protect students from self-harm. The second-level prevention is about early detection of students of high suicide risks and offering intervening counseling. The third level of prevention is to establish a crisis management system, which combines community resources to prevent further incidents of suicide. The course of "Sailing through Adolescence" improved students' self-esteem, which might also be included in first-level prevention of teenage suicide.

Regarding the increasing cases of STD among teenagers, it is vital to have quality sex education, so that it would help young people understand how pressure from family, peer, and media could impact their health (18). They would also then learn how to access valid and reliable health information about HIV/STDs and to make informed decisions about their health (19). As to gender equality, the goal of the course was to promote awareness of gender equality and eliminate gender discrimination (20). This course was therefore effective in sexual education and gender equality education according to participants' responses.

Topics such as "Secrets of Adolescence," "Friendship and Love," and "Gender Roles" would be more interesting for the boys, which were similar to the findings of other groups that boys would discuss sex life the most (13). Therefore, the strategies of the sex education should be more flexible in teaching boys and girls.

The most exciting message of the feedback was that the teenagers learned that their lives are precious and meaningful, and they should not give up no matter how hard the life is.

They also learned the physical, psychological, and emotional changes caused by hormone changes in the adolescence; the sexual knowledge and protection in sexual relationships and activities; the alertness about media; and the responsibilities in the marriage from this course.

In addition, the effects of this course could also be compared to the results of other studies on improving cognition. For example, in one study about children's cognitions of HIV, only 17.85% of children before taking the lesson "Sex Island" (one lesson in this course) answered HIV-related questions correctly, yet from the lesson, children learned that "they would not be infected with HIV if they ate, hugged or swam with HIV carriers" in the lesson (21).

The "Sailing through Adolescence" course incorporated interactions of affect, behavior, and cognition (ABC) (22) in order to improve students attitudes toward adolescence. Affective states may also influence the decision-making process even when the source of the affect is not directly related to the choices under evaluation. Incidental affects also impact on perception, memory, judgment, and behavior (23). Therefore, the affective states may influence the teenagers' behavioral strategies.

LIMITATIONS

The results of our study are limited by the lack of a control group, which would help reduce confounding biases. Additional studies should compare scores on the PILSEE for students in similar grades who did not enroll in the course on "Sailing through Adolescence." This course was introduced to schools in 2014, and the validity or reliability of the questionnaire was not fully accomplished at that time. Due to the increasing attention to these issues from teachers and parents over the years, the retrospective validity and reliability of the questionnaire were amended, and some statistics were not measured. The last two questions of PILSEE were slightly revised in the new version after 2017. Although this course has potential to improve teenagers' attitudes toward adolescence, the course has only been offered for 6 years. A longitudinal study with follow-ups in adulthood will be needed to better assess the effects of "Sailing through Adolescence."

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 "Sailing through Adolescence" course was approved by the "Committee of School Curriculum Development" of all participating schools, and was supervised by the teachers. The studies involving human participants were reviewed and approved by Ethics Committee of Taipei Hospital, Ministry of Health and Welfare (TH-IRB-0021-0001) in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

K-YC collected the data and processed further analyses. WC conceived the present idea, wrote the manuscript, and took primary responsibility for communication with the journal and editorial office during the submission process, throughout peer review, and during publication. Both authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.660229/full#supplementary-material

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Dietary Patterns and Weight Status of Primary School Children in Serbia

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The purpose of the present cross-sectional study was to examine dietary patterns and the prevalence of underweight, overweight, and obesity among Serbian children. Furthermore, the study analyzed the association between dietary patterns and weight status. A nationally representative sample of 6–9-year-old children (n = 3,067) was evaluated as part of the Fifth Round World Health Organization European Childhood Obesity Surveillance Initiative. The children's height and weight were measured by trained field examiners, while their parents or guardians filled paper versions of the food frequency questionnaire to collect information related to the child's breakfast habits and food and beverage intake. According to the International Obesity Task Force cut-off points, the overall prevalence of overweight (including obesity) and underweight were 28.9 and 8.1%, respectively. The majority of parents reported that their children (84.5%) had breakfast every day, while only 39.5 and 37% of children had daily fruit and vegetable consumption, respectively. The children who do not eat breakfast every day are more likely to be obese (OR = 1.50), while a higher intake frequency of nutrient-poor beverages such as soft drinks increases the risk of being not only overweight (OR = 1.32) but also underweight (OR = 1.39). Regular monitoring and understanding of dietary patterns and weight status is crucial to inform, design, and implement strategies to reduce national and global diet and obesity-related diseases. Urgent actions need to be taken from public policymakers to stop and reverse the increasing trend of overweight (including obesity) among Serbian children.

Keywords: obesity, overweight, underweight, WHO childhood obesity surveillance initiative, food habits, breakfast

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INTRODUCTION

Overweight and obesity in children are among the most severe public health problems that have increased dramatically during the last decades at the global and European levels (1). According to estimates from the World Health Organization (WHO), around 1 in 3 children in Europe aged 6–9 years old were overweight or obese (2), while reports from eight European countries suggest varied prevalence for underweight, from 5.7% in Italian boys to 16.6% for girls in Hungary (3, 4). Being overweight during childhood is associated with obesity and adverse health consequences throughout the life-span (5), reducing the average age at which non-communicable diseases and disabilities or the likelihood of mortality become apparent (6). Although it has

received less scientific scrutiny and is not regularly monitored, thinness or underweight could also harmfully affect child health, growth, and well-being in various ways, including nutritional deficiencies, menstrual irregularity, impaired immune system, osteoporosis, anemia, anorexia nervosa, hypotension, and decreased cognitive and work capacity (7–10).

Among all the behavioral factors, dietary patterns in childhood are considered one of the most important contributors to childhood malnutrition (stunting, wasting, micronutrient deficiencies, obesity) (11–13) and non-communicable diseases (14). Low-quality diets are believed to be the biggest and modifiable behavioral risk factors for the global burden and disease (15). The average dietary patterns among children and adolescents are shifted to more prepared and processed fast-foods and diets high in fat, sugar, and salt (16, 17). Unhealthy habits, such as skipping breakfast (18) and eating outside the home more frequently (1), increase the consumption of high energy-dense and nutrition poor foods. It further decreases the intake of key food groups such as fruit, vegetable, dairy, and dietary fiber and reduces the likelihood of meeting the recommendations for micronutrients (19). Dietary habits acquired during childhood tend to persist into adulthood (20), making nutrition in childhood an essential public health issue.

Regular monitoring of weight status and dietary habits would ideally be part of a nationally representative surveillance system (21) that could provide comparable data among children necessary for evaluating the effectiveness of obesity prevention efforts (22). As a response to the need for a European-wide harmonized surveillance system, WHO Regional Office for Europe initiated in 2006 the Childhood Obesity Surveillance Initiative (COSI) for children aged 6–9 years. Over 40 European countries participated in the five rounds of COSI so far. However, many of them provided reports only on mandatory measurements such as the prevalence of overweight and obesity, not including data on lifestyle behaviors such as food consumption frequency (23). Serbia joined COSI in the fourth round and reported an overall prevalence of overweight (including obesity) and underweight of 23.1 and 9.6%, respectively, in data collected from a nationally representative sample of 6–9-year-old school children (3, 24). However, regular reports on the weight status and dietary patterns of Serbia's schoolchildren are lacking. In addition, although dietary factors have been considered as one of the most important contributors to childhood obesity, overweight and underweight, this relationship is complex and not fully understood (25). Therefore, research on the issues of factors associated with overweight and underweight in schoolchildren deserves further attention.

Given the importance of nutrition and weight status in childhood, the present study aimed to explore (i) the prevalence of underweight, overweight, and obesity in a nationally representative sample of 6–9-year-old Serbian children, (ii) the parental reports of frequency of breakfast, selected food, and beverages intake, as well as (iii) investigate whether there is an association between dietary patterns and weight status.

TABLE 1 | Anthropometric characteristics with prevalence of thinness, normal weight, overweight, and obesity for a representative sample of Serbian children.

	Total mean (SD)	Girls mean (SD)	Boys mean (SD)
General information	***n* = 3,067**	***n* = 1,440**	***n* = 1,627**
Age (years)	8.5 (0.8)	8.5 (0.8)	8.5 (0.8)
Height (cm)	134.0 (7.8)	133.6 (7.8)**	134.4 (7.7)
Weight (kg)	31.7 (7.9)	31.3 (7.7)*	32.0 (8.0)
BMI (kg/m^2)	17.4 (3.0)	17.3 (3.0)	17.5 (3.0)
Body weight status (IOTF)	***n* (%)**	***n* (%)**	***n* (%)**
Thinness	247 (8.1)	125 (8.7)	122 (7.5)
Normal	1,935 (63.1)	898 (62.7)	1,037 (63.7)
Owerweight	635 (20.7)	287 (19.9)	348 (21.4)
Obesity	250 (8.2)	130 (9.0)	120 (7.4)

*$p < 0.05$, **$p < 0.01$.

METHODS

Following the COSI protocol (26), a cross-sectional design was employed in the present study selecting primary school children aged 6–9.9 years (**Table 1**). A nationally representative sample was selected through cluster sampling, with the primary school as the primary sampling unit. The minimal planned sample size consisted of 2,400 children as recommended by the WHO European Office. Primary schools were selected randomly from the list of public primary schools provided by the Serbian Ministry of Education. Since < 1% of the target children were enrolled in private or special schools, these schools were excluded from the sampling frame. The selection process employed proportional sampling procedures based on NUTS levels 2 and 3 (statistical regions and districts) and level of urbanization. Two criteria were used to ascribe a settlement to an urban/rural category: (1) administrative classification and (2) population size. Eventually, three categories were defined: (1) urban—more than 100,000 inhabitants, (2) semiurban—up to 100,000 inhabitants, and categorized as towns by administrative classification; and (3) rural—small towns and villages, not categorized as towns by administrative classification. All children registered in the sampled classes were invited to take part in the study. Those children who returned a signed parental consent and accepted to participate in the study on the survey day were examined and received the food frequency questionnaire. All data were collected during the spring of 2019 as a part of COSI round five. The study is conducted in accordance with the Declaration of Helsinki, and all procedures were approved by the World Health Organization (No. 2018/873491-0). Parents, teachers, and school administrators were fully informed about all study procedures, while signed informed consent for the measurements and data treatment was obtained voluntarily before the child's enrollment in the study. Verbal consent from the child to participate in the study was obtained on the measurement day.

During the data collection period, 3,397 children from 57 public elementary schools were recruited. Only two schools

refused to participate and 55 schools from all 5 statistical regions (NUTS level 2) in Serbia and 26 out of 29 districts (NUTS level 3) participated in the study. After initial checking, 162 children were excluded due to missing or inaccurate data and 168 due to age outside the limits acceptable for the study (6–9.99). The final sample consisted of 3,067 children (47% girls). The final sample consisted of 68.3% urban/semiurban schools and 32.7% rural schools.

The height and weight of the children were measured by five trained field examiners (physical education teachers). Children were measured in everyday clothes without their shoes and heavy objects like wallets, mobile phones, key chains, belts, and hair ornaments. Body weight was measured to the nearest 0.1 kg with portable digital scales (Omron BF214, Kyoto, Japan) and was corrected for the average weight of the clothes worn (gym clothes −0.15 kg, light clothing −0.35 kg, heavy clothing −0.5 kg). Body height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 213, Hamburg, Germany). Age and gender-specific body mass index (BMI, kg/m^2) cut-off points for different categories of body weight status (thinness, normal weight, overweight, and obesity) were applied according to widely used classification, the International Obesity Task Force (IOTF) (27).

The food frequency questionnaire was used to collect information related to the child's breakfast habits and food and beverage intake. The food frequency items are part of the Family Record Form, a questionnaire designed within the WHO COSI project and widely used in many international studies (28). The food frequency items had been adapted from the 2001/2002 questionnaire of the Health Behavior in School-aged Children study (HBSC study) validated on adolescent samples (29). The development of the national version followed the COSI Protocol and the original form (food frequency items included) was translated into the Serbian language and back-translated into English by a professional translator. To provide further information on the clarity and validity of the questionnaire, it was pilot tested on a small sample of the parents ($n = 40$). The meaning and clarity of the items were discussed with the pilot study participants after completing the questionnaires. The principal investigator approved the final version of the questionnaire (the questionnaire is available upon the request to the corresponding author). Paper versions of the questionnaire were presented to the parents and children during the measurements or given to the children to bring home to be filled by their parents or guardians. The question relating to breakfast habits was formulated as follows: over a typical week, how often does your child have breakfast? The allowed options for answers were "never," "some days (1–3 days)," "most days (4–6 days)," and "every day." Seventeen items were contained in the food and beverage part of the questionnaire (**Table 2**), and the question was: How often does your child eat or drink the following kinds of foods or beverages? The options for food items and beverages were "never," "less than once a week," "some days (1–3 days)," "most days (4–6 days)," and "every day." For the purpose of inferential statistics, the response for the breakfast intake, fruit and vegetable consumption were dichotomized to "every day" and "<7 days a week," while the responses for soft drink, savory snacks, and sweets were dichotomized into "<1 days a week" and "one or more days a week."

Descriptive statistics, mean and standard deviation (SD), were calculated for all anthropometric variables. In addition, the frequency of breakfast and food consumption was calculated according to gender and the weight status category. The gender differences in the prevalence of child thinness, overweight, and obesity as well as in the distribution of responses obtained for breakfast and selected food and beverage consumption, were assessed using the chi-square test with Bonferroni correction (30). The same tests were also applied to identify significant independent variables between the different weight status categories and the distribution of responses obtained for breakfast and food/beverage consumption. Odds ratios (ORs) with 95% confidence intervals (CIs) were computed to estimate the association between variables. The data were analyzed using the statistical package (SPSS Statistics 21.0, IBM Corporation, Chicago, IL, USA).

RESULTS

The mean and SD for age, weight, height, and prevalence rate for thinness, normal weight, overweight, and obesity are presented in **Table 1**. We found lower values in girls for body height ($p < 0.01$) and weight ($p < 0.05$) but not for BMI or neither for distribution in the IOTF body weight status categories. The total percentage of overweight children, including obesity, was 28.9%.

Breakfast, food and beverages frequency of consumption for Serbian children during a regular week were presented in **Table 2**. We did not find any gender differences except for vegetable consumption ($p < 0.05$); girls more commonly were reported as having vegetables more than 4 days a week.

Differences among weight status categories (thinness, normal, overweight, obesity) and reported frequency for breakfast and food/beverages consumption are presented in **Table 3**. A lower frequency of consumption of savory snacks was reported in the normal group ($p < 0.01$). The risk of being obese was higher if the child was reported not to have breakfast every day [OR = 1.50 (1.05–2.14), $p = 0.03$] or have a higher intake frequency of soft drinks more than 1 day a week [OR = 1.38 (1.01–1.88), $p = 0.04$]. The risk of being overweight [OR = 1.32 (1.08–1.61), $p = 0.01$] or underweight [OR = 1.39 (1.02–1.88), $p = 0.04$] was also higher if the child was reported to have a higher intake frequency of soft drinks more than 1 day a week.

DISCUSSION

The present study investigated the weight status and dietary patterns of 6–9-year-old Serbian children. Our findings showed that the overall prevalence of overweight (including obesity) and underweight was 28.9 and 8.1%, respectively, without differences between genders. Regarding the dietary patterns, a high level of daily breakfast intake has been observed among Serbian children (84.5%). At the same time, consumption of some healthy food items, such as fruits and vegetables, were below

TABLE 2 | Breakfast, food, and beverages frequency of consumption for Serbian children during a regular week.

	Girls n (%)					Boys n (%)					Total n (%)				
	Never	**Less than once a week**	**Some days (1–3 days)**	**Most days (4–6 days)**	**Every day**	**Never**	**Less than once a week**	**Some days (1–3 days)**	**Most days (4–6 days)**	**Every day**	**Never**	**Less than once a week**	**Some days (1–3 days)**	**Most days (4–6 days)**	**Every day**
Breakfast frequency	22 (1.7)		87 (6.7)	100 (7.7)	1,082 (83.8)	27 (1.9)		87 (6)	101 (7)	1,228 (85.1)	49 (1.8)		174 (6.4)	201 (7.4)	2,310 (84.5)
Food and beverages frequancy															
Fresh_fruit	8 (0.6)	35 (2.7)	304 (23.5)	407 (31.5)	537 (41.6)	13 (0.9)	67 (4.7)	344 (24.1)	467 (32.7)	536 (37.6)	21 (0.8)	102 (3.8)	648 (23.8)	874 (32.2)	1,073 (39.5)
Vegetables (excluding potatos)*	12 (0.9)	33 (2.6)	264 (20.6)	484 (37.8)	487 (38)	18 (1.3)	42 (3)	338 (23.8)	510 (35.9)	511 (36)	30 (1.1)	75 (2.8)	602 (22.3)	994 (36.8)	998 (37)
Cereals	374 (33.5)	292 (26.2)	334 (29.9)	70 (6.3)	46 (4.1)	500 (39.5)	315 (24.9)	342 (27)	61 (4.8)	48 (3.8)	874 (36.7)	607 (25.5)	676 (28.4)	131 (5.5)	94 (3.9)
Legumes	38 (3)	326 (25.7)	750 (59.1)	128 (10.1)	27 (2.1)	67 (4.7)	346 (24.5)	837 (59.2)	131 (9.3)	32 (2.3)	105 (3.9)	672 (25.1)	1,587 (59.2)	259 (9.7)	59 (2.2)
Egg dishes	14 (1.1)	127 (10)	765 (60.3)	296 (23.3)	66 (5.2)	18 (1.3)	130 (9.3)	827 (58.9)	345 (24.6)	83 (5.9)	32 (1.2)	257 (9.6)	1,592 (59.6)	641 (24)	149 (5.6)
Fish	113 (8.9)	665 (52.5)	455 (35.9)	28 (2.2)	6 (0.5)	138 (9.8)	723 (51.5)	509 (36.3)	26 (1.9)	7 (0.5)	251 (9.4)	1,388 (52)	964 (36.1)	54 (2.0)	13 (0.5)
Meat	8 (0.6)	24 (1.9)	372 (29.1)	599 (46.9)	274 (21.5)	12 (0.9)	22 (1.6)	387 (27.5)	690 (49)	298 (21.1)	20 (0.7)	46 (1.7)	759 (28.3)	1,289 (48)	572 (21.3)
Skimmed/semi-skimmed milk	244 (19.8)	162 (13.1)	281 (22.8)	253 (20.5)	292 (23.7)	314 (23.3)	156 (11.6)	290 (21.5)	252 (18.7)	338 (25)	558 (21.6)	318 (12.3)	571 (22.1)	505 (19.6)	630 (24.4)
Whole fat milk	262 (22.1)	222 (18.8)	274 (23.1)	218 (18.4)	208 (17.6)	299 (22.5)	220 (16.5)	305 (22.9)	246 (18.5)	261 (19.6)	561 (22.3)	442 (17.6)	579 (23)	464 (18.4)	469 (18.6)
Flavored milk	453 (36.9)	355 (28.9)	264 (21.5)	86 (7.0)	69 (5.6)	520 (38.1)	374 (27.4)	318 (23.3)	81 (5.9)	71 (5.2)	973 (37.6)	729 (28.1)	582 (22.5)	167 (6.4)	140 (5.4)
Cheese	112 (8.9)	252 (20.1)	490 (39)	273 (21.8)	128 (10.2)	175 (12.6)	265 (19.1)	553 (39.8)	254 (18.3)	144 (10.4)	287 (10.8)	517 (19.5)	1,043 (39.4)	527 (19.9)	272 (10.3)
Yogurt and other dairy products[a]	13 (1.0)	68 (5.3)	352 (27.6)	422 (33.1)	421 (33)	26 (1.8)	73 (5.1)	379 (26.7)	424 (29.9)	517 (36.4)	39 (1.4)	141 (5.2)	731 (27.1)	846 (31.4)	938 (34.8)
Fuit juice (100%)	84 (6.7)	306 (24.3)	425 (33.8)	261 (20.7)	183 (14.5)	83 (5.9)	311 (22.2)	497 (35.4)	297 (21.2)	214 (15.3)	167 (6.3)	617 (23.2)	922 (34.6)	558 (21)	397 (14.9)
Soft drinks that contain sugar	131 (10.4)	354 (28.1)	432 (34.3)	177 (14)	166 (13.2)	142 (10.2)	344 (24.6)	496 (35.5)	226 (16.2)	191 (13.7)	273 (10.3)	698 (26.3)	928 (34.9)	403 (15.2)	357 (13.4)
Diet drinks	941 (76.9)	157 (12.8)	79 (6.5)	20 (1.6)	26 (2.1)	1,057 (77.9)	187 (13.8)	79 (5.8)	17 (1.3)	17 (1.3)	1,998 (77.4)	344 (13.3)	158 (6.1)	37 (1.4)	43 (1.7)
Savory snacks[b]	32 (2.5)	310 (24.1)	551 (42.9)	230 (17.9)	161 (12.5)	50 (3.5)	312 (22)	634 (44.8)	247 (17.4)	173 (12.2)	82 (3.0)	622 (23)	1,185 (43.9)	477 (17.7)	334 (12.4)
Sweets[c]	13 (1.0)	119 (9.3)	521 (40.7)	362 (28.3)	264 (20.6)	15 (1.1)	122 (8.6)	587 (41.5)	410 (29)	279 (19.7)	28 (1.0)	241 (9)	1,108 (41.2)	772 (28.7)	543 (20.2)

[a] *Yogurt, milk pudding, cream cheese, or other dairy products.*

[b] *Potato crisps, corn crisps, popcorn, or peanuts.*

[c] *Candy bars or chocolates.*

**Girls more frequently were reported to consume vegetables more than 4 days a week.*

TABLE 3 | Breakfast, selected food, and beverages frequency of consumption for children with different weight status.

	Weight status				
	Thinness *n* (%)	**Normal weight *n* (%)**	**Overweight *n* (%)**	**Obesity *n* (%)**	**Total *n* (%)**
Breakfast					
Every day	184 (82.1)	1,461 (85.2)	496 (85.2)	169 (79.3)	2,310 (84.5)
<7 days a week	40 (17.9)	254 (14.8)	86 (14.8)	44 (20.7)	424 (15.5)
Fresh_fruit					
Every day	82 (36.9)	695 (40.9)	217 (37.3)	79 (36.7)	1,073 (39.5)
<7 days a week	140 (63.1)	1,005 (59.1)	364 (62.7)	136 (63.3)	1,645 (60.5)
Vegetables (excluding potatos)					
Every day	85 (38.8)	632 (37.4)	203 (35)	78 (37)	998 (37)
<7 days a week	134 (61.2)	1,057 (62.6)	377 (65)	133 (63)	1,701 (63)
Soft drinks					
<1 days a week	68 (31.6)	649 (39.1)**	188 (32.7)	66 (31.7)	971 (36.5)
>1 days a week	147 (68.4)	1,012 (60.9)**	387 (67.3)	142 (68.3)	1,688 (63.5)
Savory snacks[a]					
<1 days a week	49 (22.1)	432 (25.6)	167 (29)	56 (26.4)	704 (26.1)
>1 days a week	173 (77.9)	1,258 (74.4)	409 (71)	156 (73.6)	1,996 (73.9)
Sweets[b]					
<1 days a week	19 (8.5)	182 (10.8)	45 (7.8)	23 (10.9)	269 (10)
>1 days a week	204 (91.5)	1,498 (89.2)	533 (92.2)	188 (89.1)	2,423 (90)

[a] *Potato crisps, corn crisps, popcorn, or peanuts.*
[b] *Candy bars or chocolates.*
*** $p < 0.01$.*

the recommended level, while daily consumption of nutrient-poor foods such as savory snacks, sweets, and soft drinks was higher than the pooled estimates observed on the European level. The children who do not eat breakfast every day are more likely to be overweight and obese, while a higher intake frequency of nutrient-poor beverages such as soft drinks increases the risk of being not only overweight but also underweight.

The present study represents the second survey that employed a standardized COSI protocol to assess Serbian children's weight status. According to the IOTF cut-off points, the findings suggest the overall prevalence of overweight 20.7%, obesity 8.2%, and underweight 8.1% in the country representative sample of primary-school children. Although significant differences have been found in body height and weight, no significant gender differences were identified for BMI or prevalence in any weight status categories. The findings from the present study seem to be comparable to relatively high rates of overweight previously reported in other countries participating in the COSI program (23). Compared to other European countries, Serbia seems to fit the Central and Eastern Europe overweight/obesity profiles in children (11, 23). At the same time, the prevalence rates are generally higher compared to the rates in Western, Baltic, and Nordic regions and considerably lower than overweight ratios in Southern Europe (Spain, Cypar, Greece, Italy) (11, 23). In comparison to thinness prevalence, it seems that findings from our study do not differ from ones observed in eight European countries (4). Our previous research performed as a part of the fourth round of COSI revealed lower values of overweight and obesity (16.2 and 6.9%, respectively) (24) and slightly higher underweight values (9.6%) (3). The relatively higher overall prevalence of overweight (including obesity) observed in the fifth COSI round (28.9%) compared to the fourth round (23.1%) should be interpreted as a red alarm to trigger urgent actions focused on stopping obesity pandemic present in Serbian children.

Regarding the dietary patterns, we found some positive sides but also many areas that require improvements. A wealth of research suggests a significant role of breakfast in attaining an optimal nutritional profile (31). The positive side of dietary pattern includes a high level of daily breakfast intake among Serbian children (84.5%), which is higher than our previous findings on Serbian adolescents (78.2%) (32). It is also slightly higher than the pooled average reports from European countries (80% of children); however, it is still lower than reports from Nordic countries, Portugal, Spain, Russian Federation, Ireland, and Montenegro (90% of children) (33–35). There is evidence that breakfast consumption is generally related to children's age, where higher breakfast skipping has been increasing as children get older, particularly in girls (36, 37). Several prospective studies support the association between breakfast consumption and a lower risk of obesity in adults (38, 39). In line with those findings, the current study also suggests an increased risk of being obese among children who were reported not to have breakfast every day [OR = 1.50 (1.05–2.14)].

The area that requires improvement relates to increasing fruit and vegetable consumption. Although global recommendation for a healthy diet suggests a daily intake of fruit and vegetables

(40), the parents reported that 39.5 and 37% of Serbian children had daily fruit and vegetable consumption, respectively. The observed percentages are slightly below (42.5%) and above the average (22.6%) for daily fruit and vegetable intake, respectively, observed for 6–9-year-old children in 23 European countries (23, 33). However, our data are still far from reports that come from Nordic countries where consumption of fruit and vegetables are more than 52% (33, 35). We found a significant gender difference in vegetable consumption, with girls more frequently having vegetables more than 4 days a week. The same gender difference in consumption of vegetables was also observed in a study of Swedish 11-year-old children (35). Although we did not find any association between fruit and vegetable consumption and overweight and obesity, some studies suggested lower consumption of fruit and vegetables in overweight than normal-weight children (41).

The findings of the present study highlight the need for actions to decrease the consumption of nutrient-poor foods high in salt, sugar, and saturated fats. Our data suggest that 12.4, 20.2, and 13.4% of Serbian children consume daily savory snacks, sweets, and soft drinks, respectively, which is higher than pooled estimates observed on the European level (33). In addition, we found that children who were reported having a higher frequency of consumption of soft drinks have a higher risk of being overweight and obese. These results are consistent with studies that reported a positive association of soft drink consumption with overweight and obesity (42, 43). Interestingly, we also found a positive association between soft drink consumption and underweight. Although we did not find similar reports from the literature, unhealthy dietary behaviors could be associated with a lower frequency of consumption of nutrient-rich food (35) that could lead to some forms of malnutrition, including underweight (40).

Using a standardized WHO COSI protocol to monitor weight status and dietary patterns on the nationally representative sample is one of the present study's significant strengths. Standardized and accurate data on children's weight status and dietary habits allows comparisons within European countries and will be updated in future years. There are several limitations to be noted. The cross-sectional study design did not allow inferring a causal relation. The present study used a self-reported dietary questionnaire that had not been validated and may have limited accuracy. We did not collect information on foods' portion sizes to identify chilren's prevalence meeting specific nutrition recommendations. Our study identified a negative trend of underweight, overweight, and obesity pandemic among Serbian children compared to our previous reports (3, 24). We found some bright spots in dietary habits, such as the high prevalence of Serbian children that regularly consume breakfast and some areas that require improvements, including low fruit and vegetable and high nutrition-poor food consumption. Urgent actions are needed to ensure children consume healthy diets, including adequate quantities and appropriate proportions of fruit, vegetables (44), limiting the intake of free sugars (45), salt (46), saturated fats, and highly processed foods (47). The present findings could provide vital support for government actions to implement and evaluate effective and appropriate strategies to combat underweight and overweight.

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 World Health Organization (No. 2018/873491-0). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

PB participated in acquiring data, statistical analysis, and wrote the initial manuscript. SO contributed to the conception and design of the study, participated in statistical analyses, and reviewed and revised the manuscript. VD contributed to the conception and design of the study, coordinated and supervised data collection, and reviewed literature and critically reviewed the manuscript. LM participated in acquiring data, organized the database, contributed in statistical analysis, reviewed literature, and contribute in writing the introduction. DC participated in acquiring data and contributed in writing the methods. NT participated in acquiring data and contributed in writing the results. SH participated in acquiring data and contributed in writing the method and the results. All authors contributed to the article and approved the submitted version.

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Geographical Variation in Physical Fitness Among Chinese Children and Adolescents From 2005 to 2014

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Introduction: To examine the geographical variation in change in the levels of physical fitness from 2005 to 2014 among Chinese children and adolescents.

Methods: A total of 663,813 children 7 to 18 years of age with physical fitness data in 2005, 2010 and 2014, participated in the study. Physical fitness was assessed using six components, and their standardized scores were aggregated to form a summary physical fitness indicator (PFI).

Results: Over the study period, there was an increase in the proportion of high PFI (from 15.3% in 2005 to 19.0% in 2014, $P_{trend} < 0.05$) and a decrease in the proportion of low PFI (from 30.6 to 29.8%, $P_{trend} < 0.05$). Children and adolescents in the eastern provinces of China showed a high proportion of high PFI with an increasing trend over time, while those in the western provinces had a high proportion of low PFI with a decreasing trend over time ($P < 0.05$).

Conclusions: The comprehensive physical fitness among Chinese children showed an improved trend from 2005 to 2014. Region-specific interventions with priority policies could be useful to sustainably narrow geographical variation in Chinese children, especially in the western provinces.

Keywords: physical fitness, geographical variation, children and adolescents, China, trend analysis

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INTRODUCTION

Physical fitness is the body's ability to perform activities or motions effectively and efficiently. Usually, physical fitness is a comprehensive concept that combines various abilities together, such as muscular strength and endurance, cardiorespiratory endurance, and motor ability (1). Thus, a universal comprehensive physical fitness indicator (PFI) is used to define composite fitness among children and adults (2, 3). Previous studies have physical fitness was associated with the development of cardiovascular diseases (CVD) in both children and adults (4–6).

Physical fitness is considered to be a reflection of outcomes of physical activity (PA), so many physical exercise related factors were considered to affect physical fitness (7–9). Previous study found that the physical fitness among children and adolescents has been a world-wide decline since the late 1950s, especially in the maximal long-distance running performance of Asian children and adolescents, including China (10). One study using a national study in Chinese children and adolescents demonstrated that China has followed global trends in exhibiting a steadily deterioration in the levels of physical fitness, particularly in the domain of cardiorespiratory fitness (11–13).

With the increasing number of factors that contribute to physical fitness deterioration among Chinese children and adolescents, such as the increased prevalence in obesity, lack of physical exercise, increased academic burden and use of electronic devices, more public health measures need to be focused on priority areas and regions. However, there has been a lack of systematic research in examining changes in geographic variations of comprehensive physical fitness using population-level prevalence data. Therefore, the objective of this study is to examine geographical variation in the levels of physical fitness among Chinese school-aged children and adolescents using three successive national cross-sectional surveys from 2005 to 2014.

METHOD

Study Design and Participants

Data were extracted from CNSSCH in 2005, 2010 and 2014. The CNSSCH was the largest nationally representative surveys comprising multiple core components of physical fitness among Chinese children and adolescents aged 7–18 years, and the CNSSCH was jointly launched by the Ministry of Education, the Ministry of Health, the Ministry of Science and Technology, the State of Nation Affairs, and the State Sports General Administration of People's Republic of China in order to investigate the constitution and health of children and adolescents. The details of the design of CNSSCH have been described in the previous studies (14). The CNSSCH used a multistage stratified cluster sampling design and included 31 Chinese provinces but did not cover Hong Kong, Macau and Taiwan. Initially, children and adolescents in each province, except Tibet, were stratified by three levels of prefecture cities (i.e., upper, moderate, low) based on their socioeconomic status. Then, in each city of three sub-provincial levels, children and adolescents were also stratified by urban and rural areas based on their residence location. Within these stratified areas since 1985, schools covering students aged 7–18 years including primary, middle and high schools were randomly selected, and the sampling procedure has remained uniform in each subsequent survey year. From these schools, all students in the randomly selected classes were included in the survey. Following inclusion and exclusion criteria and obtaining informed consent (as shown in previous studies) (14, 15), at least 50 Han students in each age group from 7–18 years of boys or girls in urban and rural areas were included in the survey. As participants in Tibet were minority students, only children in Lasa city were surveyed for feasibility reasons. At last, a total of 663,813 children and adolescents aged 7–18 years (234,289 in 2005, 215,223 in 2010, and 214,301 in 2014) were collected for the geographical variations trends analyses of physical fitness.

Physical Fitness Measurements and Categories

Participants in the survey underwent a complete physical fitness test according to the same protocol at all survey sites. All physical fitness tests were implemented in PE classes by special trained PE teachers who have passed the measurement examination. A school doctor was present to prevent children and adolescents from being injured during the physical fitness test, and a project supervisor was present to monitor whether the physical fitness test was carried out as required and to provide necessary guidance. Six physical fitness components (forced vital capacity (FVC), standing long jump (SLJ), sit-and-reach (SR), body muscle strength (BMS), 50 meter dash and endurance running) were included in our study and were measured by a team of trained technicians following a standardized procedure. FVC, SLJ, SR, and 50 meter dash were measured at each age from 7–18 years. According to the changing physical capabilities with age and sex, BMS was evaluated by oblique body pull-ups (boys aged 7–12 years), pull-ups (boys aged 13–18 years) and 1 min sit-ups (girls aged 7–18 years). Speed and speed endurance were evaluated by interval 50 m dash time and time for long distance running (50 m × 8 shuttle run for both boys and girls aged 7–12 years; 1,000 m endurance running for boys aged 13–18 years; and 800 m endurance running for girls aged 13–18 years). All the measuring instruments were consistent at each survey site and calibrated before use. All the students in the final analysis took each test simultaneously. Almost 100% of the students took all tests on the same day. The sample sizes and proportion of participants in each item test in each survey year are shown in the **Supplementary Table 1**. A total of 234,289, 215,223, and 214,301 chidlren and adolescents participated the physical fitness tests, and total valid participants for each physical fitness component tests in 2005 and 2010 exceeded 99.0% and even reached at 100% in 2014.

Allowing for the different items in boys and girls of different age groups and difficulties of comparison, sex- and age-specific standardized values were calculated for each physical fitness component. Based on the reference population with median values and standard deviation (SD) of each physical fitness component that was defined in previous studies (2, 12). Z scores of each component were calculated as an individuals' item value minus the median, divided by the SD for that child's age and sex in the reference population. PFI was calculated by summing the standard values for each of the six items: $PFI = standardized\ values\ of\ FVC + SLJ + SR + BMS + (-50\ m\ dash) + (-endurance\ running)$. Based on the percentile of the PFI in the reference population in 1985, we categorized the PFI into five levels: low level (<20th), low-middle level (≥20th and <40th), middle level (≥40th and <60th), middle-high level (≥60th and <80th), high level (≥80th).

Statistical Analysis

Descriptive statistics were used to describe the demographic characteristics of the study population in CNSSCH. Chi-square tests were used to examine between group differences in categorical variables. Stacking scales diagrams were employed to examine trends in the levels of physical fitness across the study period. To analyze geographical variation, we compared the proportion of different levels of physical fitness in each province (excluding Hong Kong, Macau, and Taiwan) across the three survey years. To examine geographical variation, the thirty-one mainland Chinese provinces were divided into four regions: East, Central, West, and Northeast, in accordance with the geographical standard division from the Chinese National

TABLE 1 | The sample size and distribution of each physical fitness component from 2005 to 2014 in CNSSCH.

Survey year	2005	2010	2014
Total sample size, n	234,289	215,223	214,301
Physical fitness measurement			
Forced vital capacity, *n* (%)	234,003 (99.88)	215,171 (99.98)	214,301 (100.00)
Original values (Mean (SD), ml)	2,017.1 (923.0)	2,095.4 (947.1)	2,210.0 (1,001.8)
Standardized values, Mean (SD)	−0.88 (1.27)	−0.66 (1.33)	−0.41 (1.41)
Standing Long Jump, *n* (%)	234,229 (99.97)	215,001 (99.90)	214,301 (100.00)
Original values (Mean (SD), cm)	165.9 (37.0)	166.4 (37.5)	163.5 (38.1)
Standardized values, Mean (SD)	0.25 (1.09)	0.28 (1.13)	0.12 (1.17)
Sit and Reach, *n* (%)	234,241 (99.98)	214,983 (99.89)	214,301 (100.00)
Original values (Mean (SD), cm)	9.2 (6.8)	9.4 (6.7)	9.1 (7.1)
Standardized values, Mean (SD)	0.14 (1.19)	0.19 (1.17)	0.14 (1.23)
Body Muscle Strength, *n* (%)	234,086 (99.91)	214,741 (99.78)	214,301 (100.00)
Original values, Mean (SD):			
Oblique Body Pull-ups (Boys aged 7–12 years)	30.8 (22.6)	26.2 (18.4)	23.8 (16.0)
Pull-Ups (Boys aged 13–18 years)	3.9 (4.1)	4.0 (5.1)	3.4 (3.6)
1-min Sit-Ups (Girls aged 7–18 years)	26.3 (10.8)	25.3 (10.8)	27.8 (10.8)
Standardized values, Mean (SD)	0.39 (1.33)	0.27 (1.24)	0.32 (1.22)
50 Meter Dash, *n* (%)	234,164 (99.95)	214,884 (99.84)	214,301 (100.00)
Original values (Mean (SD), s)	9.5 (1.5)	9.6 (1.5)	9.5 (1.5)
Standardized values, Mean (SD)	−0.02 (1.24)	0.01 (1.26)	−0.07 (1.28)
Endurance running, *n* (%)	233,301 (99.58)	213,719 (99.30)	214,301 (100.00)
Original values (Mean (SD), s)			
50 m × 8 shuttle run (Students aged 7–12 years)	126.7 (19.3)	127.1 (17.3)	126.7 (17.3)
1,000 m run (Boys aged 13–18 years)	272.1 (38.3)	271.5 (39.0)	274.3 (41.2)
800 m run (Girls aged 13–18 years)	261.7 (32.4)	260.9 (32.8)	261.5 (34.2)
Standardized values, Mean (SD)	1.00 (1.52)	1.03 (1.56)	1.02 (1.55)

n (%), the sample size and percentage completing each physical fitness measurement.

Bureau of Statistics (NBS) (**Supplementary Figure 1**) (16). We used the Cochran-Armitage trend test to calculate the P_{trend} values. Statistical analyses were conducted with Stata (version 15.0) statistical software. Two-sided $P < 0.05$ was considered statistically significant.

RESULTS

Study Population Characteristics

The characteristics of the study population of CNSSCH are presented in **Supplementary Table 1**. The proportion of sample sizes for physical fitness from 2005 to 2014 and questionnaire survey in 2014 were balanced across sex, age, provinces, and urban and rural areas. The mean of original and standardized values of FVC got improvement, but other five physical fitness components among children and adolescents presented a fluctuating tends from 2005 to 2014 (**Table 1**).

Trend in Physical Fitness

Physical fitness, as indexed by PFI, improved with an increased proportion of children and adolescents who performed at above middle-high levels of PFI ($P_{trend} < 0.05$), and a decreased proportion of those who scored below low-middle levels of PFI ($P_{trend} < 0.05$). Boys and girls showed a similar increasing trend in the proportion of their physical fitness from 2005 to 2014 with both girls and boys showing a significant increase in the proportion of high levels of PFI (13.5% in 2005 to 19.8% in 2014, $P_{trend} < 0.05$) for girls, 17.1% in 2005 to 18.2% in 2014, $P_{trend} < 0.05$ for boys, respectively). The proportion of low levels of PFI decreased in girls, but increased in boys (30.9–27.0% in girls, $P_{trend} < 0.05$, and 30.4–32.6% in boys, $P_{trend} < 0.05$, respectively). With respect to residence, results from urban and rural students revealed a similar trend, showing an increased proportion of those who performed above middle-high levels of PFI and a decreased proportion of those who performed below low-middle levels of PFI ($P_{trend} < 0.05$) (**Figure 1**). Among the four age groups, the proportion of the high levels of PFI showed an increased trend from 2005 to 2014, particular for those aged 13–15 years from 13.4 to 22.1% during the 10 years ($P_{trend} < 0.05$). Also, children and adolescents aged 13–15 years witnessed the largest decrease for low levels of PFI from 33.3% in 2005 to 28.5% in 2014 ($P_{trend} < 0.05$) (**Figure 2**).

Geographical variations

With regard to the level of PFI (data shown in **Figure 3**), over the study period, children living in eastern Chinese provinces showed a relatively higher proportion of physical fitness compared to those living in western provinces. For example, children in the

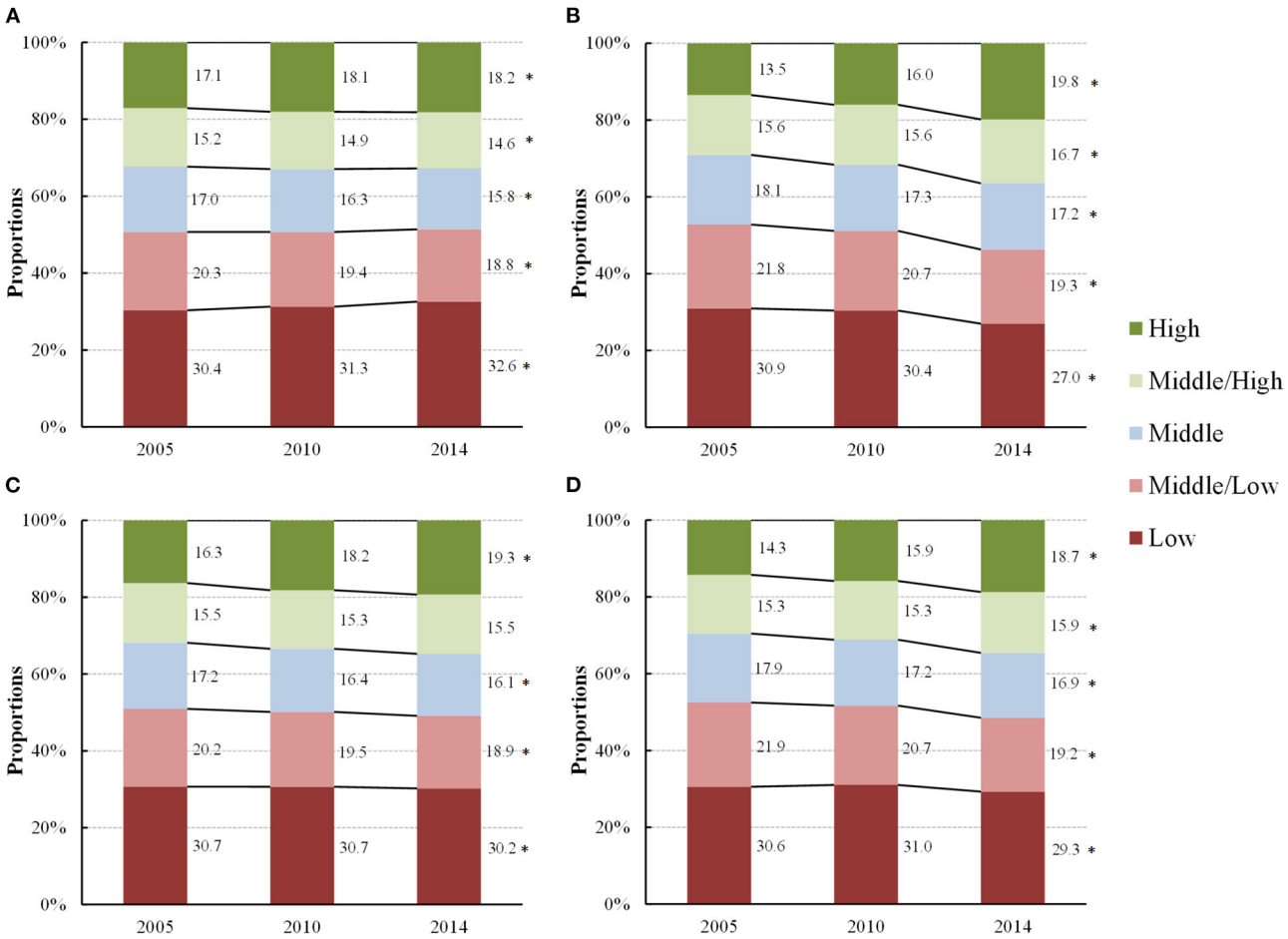

FIGURE 1 | Proportions of change in different levels of physical fitness, as indexed by physical fitness index, in children and adolescents by sex and residence [**(A)** Boys, **(B)** Girls, **(C)** Urban and **(D)** Rural] from 2005 to 2014 (2005–2014, China). *A statistically significant increased trend or decreased trend in the proportions of each level of physical fitness from 2005 to 2014 ($P_{trend} < 0.05$) using Cochran-Armitage trend test.

eastern coastal provinces, such as Jiangsu, Zhejiang, Shanghai, Beijing, and Fujian, exhibited the largest proportion of high level of PFI. Up to 2014, the proportions of high level of PFI in the eastern, central, western and northeastern regions were 28.5, 16.4, 12.5, and 16.5%, respectively (**Table 2**). Students living in the eastern regions also witnessed a largest increase in the proportion of high level of PFI (6.7 percent point from 2005 to 2014), followed by those living in the western and central regions (2.8 and 2.0 percent point from 2005 to 2014), but those from northeastern regions even showed a decrease in high level of PFI from 17.8% in 2005 to 16.5% in 2014 with 1.3 percent point decreases.

On the contrary, children and adolescents in the western and northeastern provinces showed a high proportion of low levels of PFI, followed those living in the central and eastern provinces. The proportions of low levels of PFI in the eastern, central, western and northeastern provinces in 2005 were 21.0, 30.8, 38.7, and 33.2% respectively. In 2014, their estimates were changed to 21.6, 28.6, 36.0, and 36.4%, respectively. Across the four geographic regions, children and adolescents in the western provinces showed the largest decrease (by 2.7 percentage points) in the proportion of low levels of PFI from 2005 to 2014, though there was also an increase, between 2005 and 2014, for those living in the eastern and northeastern provinces. Specifically, children and adolescents in Gansu, Qinghai, and Tibet were shown to have the largest decrease in the proportion of low levels of PFI (by 15.7, 15.4, and 15.1% points). In contrast, children and adolescents in Guangxi and Ningxia exhibited the largest increase in the proportion of low levels of PFI (by 15.0 and 14.7% points, respectively (**Figure 4** and **Supplementary Table 2**). The standardized values of each physical fitness components were also showed in the **Supplementary Table 3**. The FVC, 50 meter dash, and endurance running among children and adolescents got improvement from 2005 to 2014 in four regions, particularly in central and western regions, but the standing long jump, sit and reach

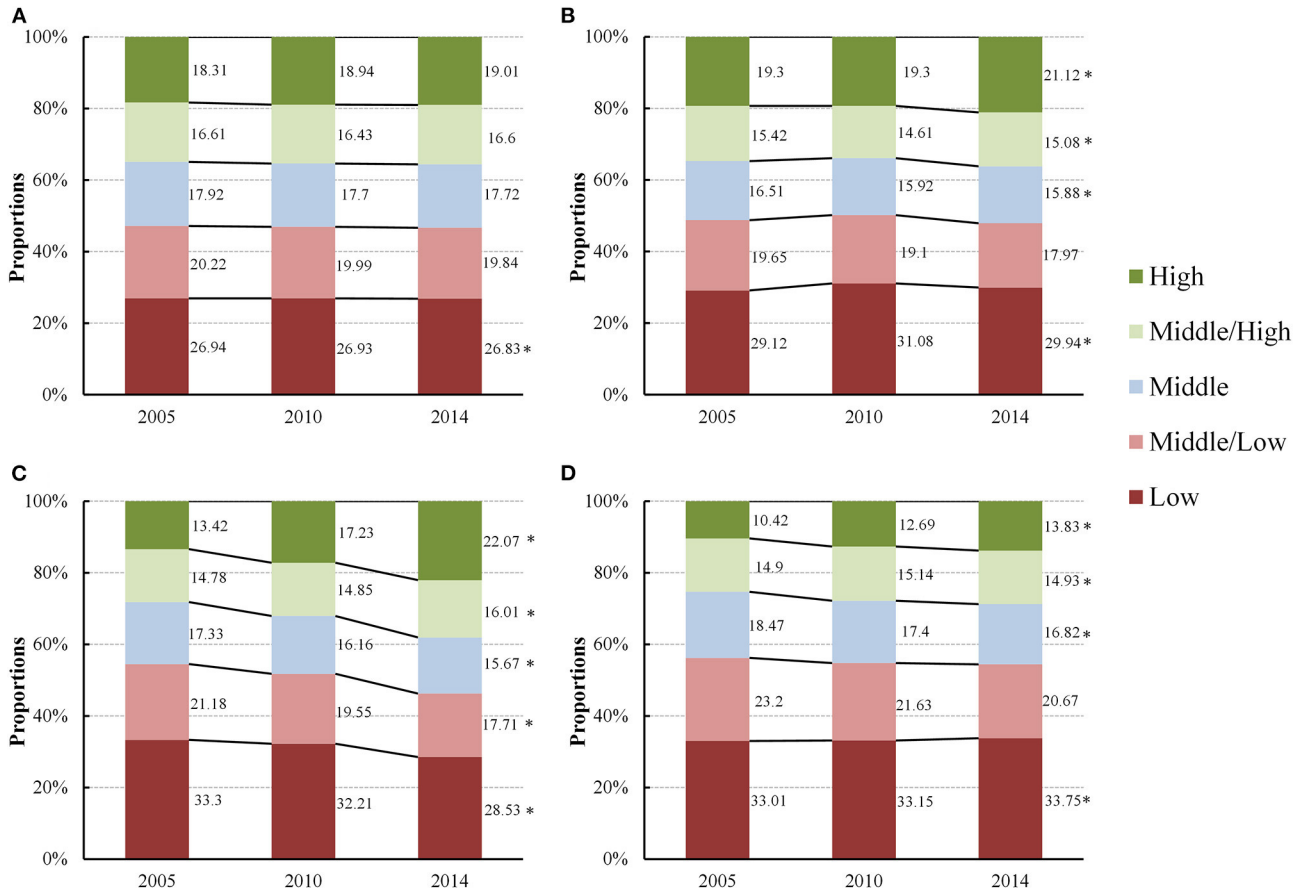

FIGURE 2 | Proportions of change in different levels of physical fitness, as indexed by physical fitness index, in children and adolescents by age groups [**(A)** 7–9 years, **(B)** 10–12 years, **(C)** 13–15 years and **(D)** 16–18 years] from 2005 to 2014 (2005–2014, China). *A statistically significant increased trend or decreased trend in the proportions of each level of physical fitness from 2005 to 2014 ($P_{trend} < 0.05$) using Cochran-Armitage trend test.

and body muscle strength deteriorated in 2014 than they were in 2005.

DISCUSSION

To our knowledge, this is the first study that used three successive national cross-sectional surveys between 2005 and 2014 that assessed the geographic variations in comprehensive physical fitness among Chinese school-aged children and adolescents. From 2005 to 2014, there was an increase in the proportion of high PFI and a decrease in the proportion of low PFI among Chinese children and adolescents, especially among girls, and those living in rural areas and in middle-school stage. These trends were observed with notable geographic variability showing that children and adolescents in the eastern provinces having a higher proportion of PFI compared with a higher proportion of low PFI in children and adolescents living in the western provinces. During the study period, the levels of physical fitness among children and adolescents in both eastern and western provinces showed an upward (in the direction of improvement) trend.

Actually, there has been an increase in health-promotion policies at national and local levels. In 2007, the State Council of the Chinese government issued a strategic policy aimed at strengthening and enhancing physical fitness for school-aged children and adolescents (17). In the years followed, the government issued a total of 88 multisectoral measures and policies involving promotion of sport, reductions in academic burden through curriculum reform, and development of public facilities to promote students' physical fitness (12, 18). Although there has been an increase in health-promotion policies in China, our findings highlight notable geographic variations in the levels of children's physical fitness across regions with children living in the eastern provinces experiencing high levels of fitness compared to those living in the western provinces. These geographic disparities may reflect an uneven development and implementation of nationwide policies. In order to promote physical fitness among children and adolescents, China initiated its Healthy China 2030 blueprint in 2016 (19). It set out specific requirements on physical activities for children and puts them

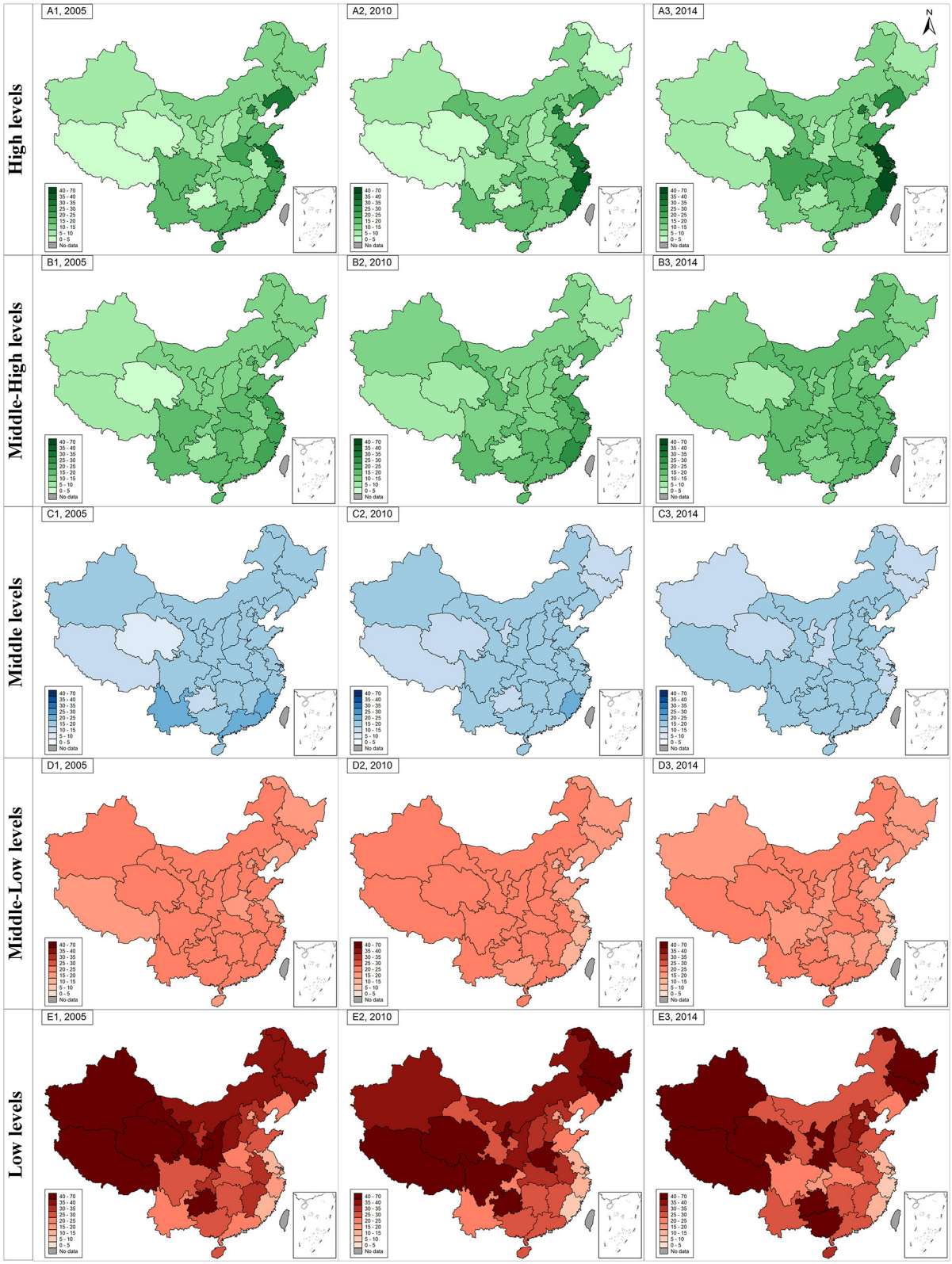

FIGURE 3 | The geographical distribution and changes of different levels of physical fitness index from 2005 to 2014 (2005–2014, China). The green graph in subfigure (**A1**, **A2**, and **A3** for 2005, 2010, and 2014) and (**B1**, **B2**, and **B3** for 2005, 2010, and 2014) represents geographical distribution of high levels of PFI and middle-high levels of PFI in 2005, 2010, and 2014. The blue graph in subfigure (**C1**, **C2**, and **C3** for 2005, 2010, and 2014) represents geographical distribution of middle levels of PFI in 2005, 2010, and 2014. The red graph in subfigure (**D1**, **D2**, and **D3** for 2005, 2010, and 2014) and (**E1**, **E2**, and **E3** for 2005, 2010, and 2014) represents geographical distribution of low levels of PFI and middle-low levels of PFI in 2005, 2010, and 2014. The gradient of each color series in each subfigure was used to show the exact proportions of the specific PFI levels (exact number showed in **Supplementary Table 2**).

TABLE 2 | The geographical changes of different levels of physical fitness index from 2005 to 2014.

Categories	2005, %	2010, %	2014, %	2005-2014 Changes (Percent point, *P* values) *
High Level				
East	21.8	27.0	28.5	6.7 (<0.001)
Central	13.4	12.0	16.4	3.0 (<0.001)
West	9.6	11.7	12.5	2.8 (<0.001)
Northeast	17.8	13.7	16.5	−1.3 (0.001)
Middle-High level				
East	18.7	19.3	17.6	−1.2 (<0.001)
Central	15.5	14.4	16.4	0.9 (0.001)
West	12.7	13.1	14.0	1.3 (<0.001)
Northeast	14.2	11.7	14.0	−0.1 (0.739)
Middle Level				
East	18.9	17.7	16.0	−3.0 (<0.001)
Central	18.2	18.1	18.1	−0.1 (0.701)
West	16.6	16.2	16.7	0.1 (0.634)
Northeast	15.5	13.5	14.8	−0.7 (0.053)
Low-Middle Level				
East	19.6	17.2	16.3	−3.3 (<0.001)
Central	22.2	22.8	20.6	−1.6 (<0.001)
West	22.4	21.7	20.9	−1.5 (<0.001)
Northeast	19.4	18.0	18.2	−1.2 (0.002)
Low Level				
East	21.0	18.8	21.6	0.7 (0.002)
Central	30.8	32.8	28.6	−2.2 (<0.001)
West	38.7	37.4	36.0	−2.7 (<0.001)
Northeast	33.2	43.1	36.4	3.2 (<0.001)

**The difference of proportions of each level of PFI in different survey years between 2005 and 2014 years was evaluated by the Chi-square test.*

into action, which makes school-aged children achieve at least 1 h of physical activity daily and have more than 25% of them achieve an "excellent" rating in physical fitness. Thus, the geographic variations in physical fitness in this study will clarify the disadvantaged areas and the priority of public health resources investment under the national Healthy China 2030 strategy.

Findings from this study highlight significant geographic variations in the levels of fitness among children and adolescents living between economically developed regions (e.g., eastern provinces) and those that are less well-developed (e.g., western provinces). It is conceivable that such variation may reflect geographic disparities in economic development, investment in physical activity or sport facilities, and inherent uneven resources. As such, in order to narrow these disparities, targeted physical fitness interventions or programs should be directed toward school children living in those under developed areas (e.g., western provinces). From the health promotion perspective, priority areas in physical fitness programs need to be identified across regions of a wide socioeconomic spectrum and be targeted at the province, district, school and classroom levels, through policy and practice recommendations, periodical physical fitness and health surveillance, and implementation of evidence-based health-related school PE curricula (20–22).

Apart from those nationwide efforts, reductions in academic pressures, breaking of sedentary time, and engagement in sporting activities should also be encouraged to narrow these regional disparities in children and adolescents' physical fitness (23). For example, since obesity and undernutrition were both important causes of physical fitness deterioration, the background of rapid increase in obesity and persistent undernutrition among children and adolescents suggested that the differentiated improvement measures were needed in different regions of China (24, 25). Thus, as suggested in the previous study, the control of over-nutrition should be emphasized among eastern developed provinces with policies that encourage taxation on unhealthy foods and promotion of moderate-to-vigorous PA. In the less developed western provinces, emphasis should be placed on improving malnutrition with promotion of rural nutrition improvement programs and dietary diversity (12).

Our study has several strengths, derived from its comprehensive assessment of physical fitness combining respiratory function, strength, flexibility, explosive power, and

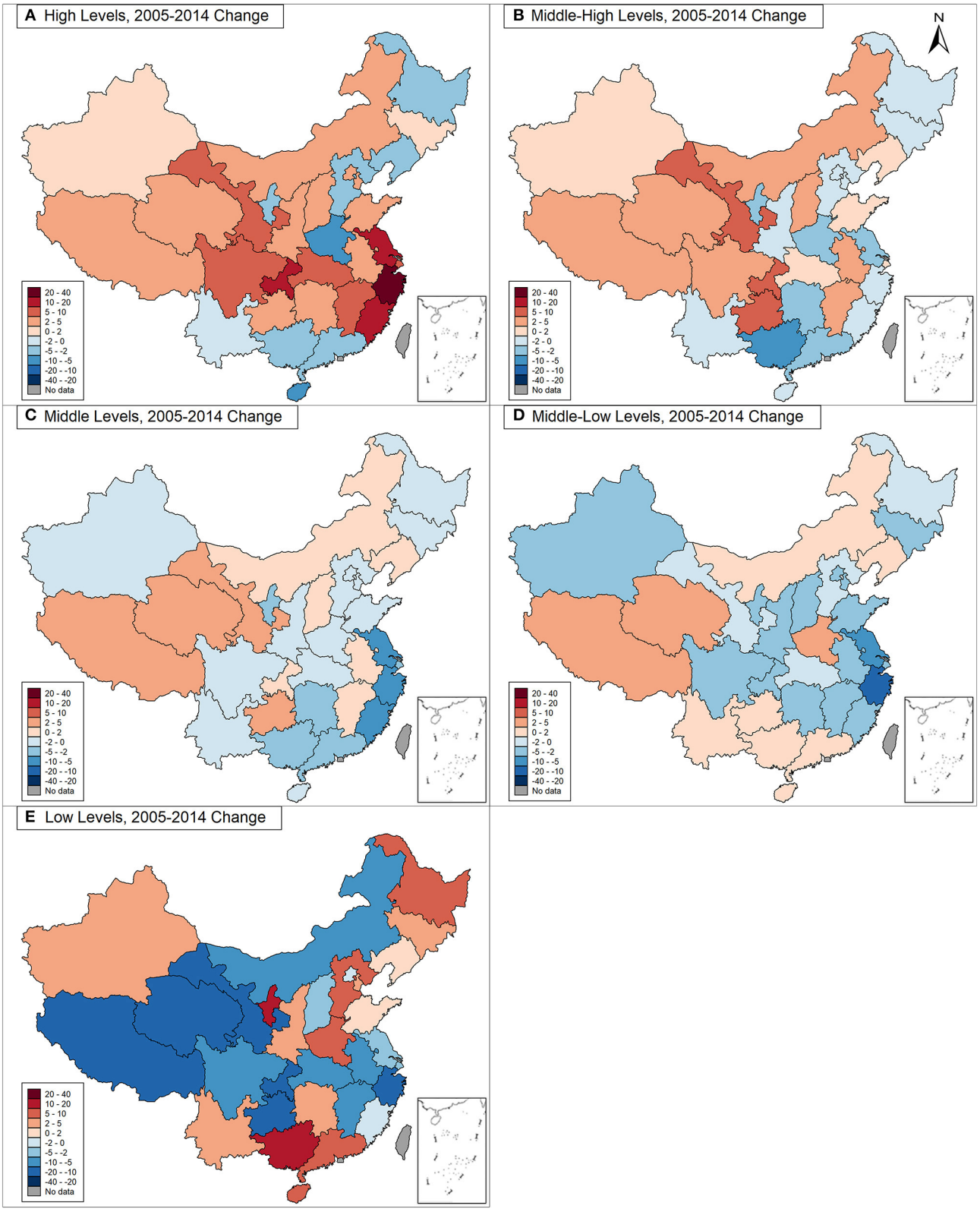

FIGURE 4 | The changes of different levels of physical fitness from 2005 to 2014 (2005–2014, China). **(A)** For high levels of PFI; **(B)** for middle-high levels of PFI; **(C)** for middle levels of PFI; **(D)** for middle-low levels PFI; **(E)** for low levels PFI. The red-colored item in subfigure represents an increased percentage point of each level physical fitness index from 2005 to 2014. The blue-colored item in subfigure represents a decreased percentage point of each level physical fitness index from 2005 to 2014. The color gradient of red and blue series was used to show the proportions' changes of each level of PFI (exact number showed in **Supplementary Table 2**).

cardiorespiratory endurance factions, with a large nationally-representative sample size and repeated measures with geographic variations across a 10-year period. Our study also has several limitations that should be noted. First, since this study used original data on subnational changes from three cross-sectional surveys, the data cannot be used to infer causality, and merely ecological analyses were adopted in this study. However, the CNSSCH collected nationally representative data with a large sample size and compelling evidence, and the comprehensive physical fitness estimated in CNSSCH could meet our purpose of secular trend, geographical and influencing factors analyses. Second, our study adopted the PFI assessing the comprehensive physical fitness, and did not use the national fitness standard, and also some characteristics of six components of PFI might be ignored. The scope of PFI could be not as broad as the national fitness standard in the use of the individual evaluation of physical fitness. But it has other advantages, for example, it was helpful to observe the different levels of physical fitness, including the low, low-middle, middle, middle-high, and high levels of PFI analyzed in this study, and extend the application scope in the use of PFI in terms of trend analysis and intra-data comparison. In addition, the national fitness standards were calculated based on grade rather than age, which did not apply to our data.

CONCLUSIONS

Findings from this study showed an improved trend, from 2005 to 2014, in the overall level of physical fitness among Chinese children and adolescents. However, notable geographic variations in the levels of fitness were observed with high prevalence of healthy fit children and adolescents living in the eastern region and unhealthy or low-fit children and adolescents living in the western region of the country. These findings suggest that national and regional school fitness health-enhancing strategies and initiatives should aim to reduce geographic disparities by targeting evidence-based interventions in geographical regions that have a high prevalence of unhealthy physical fitness in school children and adolescents across the country from diverse regions.

DATA AVAILABILITY STATEMENT

All the individual (de-identified) participant data collected in the surveys can be shared with investigators whose proposed use of the data has been approved by an independent review committee identified for this purpose by contacting the corresponding author. Proposals should be directed to majunt@bjmu.edu.cn and songyi@bjmu.edu.cn.

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

YD conceptualized and designed the study, completed the statistical analyses, drafted the initial manuscript, and reviewed and revised the manuscript. JM and YS contributed to the conceptualization and design of the study, supervised the data collection, the statistical analyses and initial drafting of the manuscript, and reviewed and revised the manuscript. PL participated in conceiving the study design and critically reviewed and revised the manuscript from preliminary draft to submission. MC assisted with the data interpretation, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agreed to be accountable for all aspects of the work.

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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.2021.694070/full#supplementary-material

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