Physical activity and sedentary behaviors among Chinese children: recent trends and correlates

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Research

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Abstract

Background

With the progress of urbanization and technology advancement in China, this study aimed to examine the trends in and correlates of PA and sedentary behaviors among Chinese children.

Methods

Self-reported physical activity data were extracted from the “China Health and Nutrition Survey” project. A total of 6,936 observations (4341 subjects) aged 6–17 years old who participated in at least one round of follow-up surveys from 2004 to 2015 were included. Random-effects ordinal regression models were applied to investigate the trends in the levels of PA, and repeated measures mixed models were applied to examine the trends in and distribution characteristics of PA and sedentary behaviors, controlling for the random effect of communities and adjusting for socio-demographic differences. Quantile regression models were applied to explore the influencing factors at each quartile of PA volume and time spent in sedentary behaviors.

Results

The prevalence of physical inactivity among Chinese Children aged 6–17 years increased from 76.0% in 2004 to 81.5% in 2015 (OR = 1.51, 95% CI: 1.19 ~ 1.90, $p < 0.001$). The average weekly volume of PA declined from 41.7 ± 1.6 to 35.9 ± 1.7 MET-hrs/week ($P < 0.001$) from 2004 to 2015, of which, in-school PA declined significantly by 4.6 MET-hrs/week ($P < 0.001$). The time spent in sedentary behaviors rose from 23.9 ± 0.6 hrs/week in 2004 to 25.7 ± 0.6 hrs/week in 2015 ($p < 0.001$), with more profound increases observed for the time on screen-based entertainment (increased by 2.9 hrs/week, $P < 0.001$). Age, ethnicity, and region showed significant effects on the volume of PA across quartiles ($p < 0.001$). Compared with children residing in rural area or with low urbanization level, sedentary time was significantly higher than those residing in urban areas ($p < 0.001$) or with high urbanization level ($p \leq 0.005$) across quartiles.

Conclusions

To improve PA and curb sedentary behaviors among Chinese children aged 6–17 years old, urgent actions should be taken to promote in-school PA and to reduce their screen time. The findings also suggest certain subgroups and geographical areas that are at higher risk of physical inactivity, which warrants more attention when designing and implementing physical activity-promoting policy and action.

Background

Physical activity (PA) offers a number of health benefits for children including improved physical fitness (aerobic fitness, muscle strength and endurance), promoting bone health, maintaining healthy weight, improving blood pressure and cholesterol levels[1-3]. Furthermore, PA habits developed during childhood and the associated health benefits may carry forward into adulthood[4]. However, data from the 2016 World Health Organization (WHO) survey suggests that globally, 81% of the adolescents aged 11-17 years did not meet the recommended PA level [5]. Further, the report from Active Healthy Kids Global Alliance (AHKGA), which created the most comprehensive assessments of global variation in PA level among children, concludes that there was a persistent global trend towards low PA and high sedentary behaviors among children using the data gathered from 49 countries[6]. Recently, WHO has launched a global action plan to reduce physical inactivity by 10% and 15% among adolescents by 2025 and 2030, respectively. This is also documented as one of the nine global Noncommunicable Disease (NCD) targets[7]. Globally, there is a consensus to actively advocate healthy lifestyle, including increase in PA and reduction in sedentary behaviors, to mitigate the obesity trend in children and adolescents, which in turn helps to prevent obesity related chronic disease in adulthood[8-10].

With the rapid advancement of science and technology and increased social productivity, there have been substantial changes in agricultural production, lifestyle behaviors, and living environment in the Chinese population. Children’s physical activity has been impacted by these changes. Meanwhile, there is a global call for monitoring PA among children, especially in developing countries[11]. In a recent commentary published in Lancet Global Health, Ding highlighted that research on trends in PA plays a fundamental role in the development, implementation, and evaluation of PA-enhancing interventions at the global, national, and regional levels[12] . To date, there is a paucity of evidence on the long-term trend in PA among children in China as a comprehensive surveillance system was only established in early 2000s. Data from the CHNS revealed that there was little change in PA and sedentary behaviors among children between 2004 and 2011[13]. What is not yet clear is the recent changes and correlates of PA and sedentary behaviors among Chinese children. Therefore, there is a pressing need to explore these issues. As China is considered as a representative of developing countries, investigating the trend in PA and sedentary behaviors among children also provide valuable data that enables cross-sectional and longitudinal comparisons across countries.

In 2016, a paper published in Lancet reviewed and analyzed global policies and action plans to increase PA. The authors proposed that effective policy should align with local culture, religious value, geographical location, and economic development[14]. As China is undergoing rapid urbanization, there is an urgent need to identify the factors influencing PA and sedentary behaviors among children aged 6-17 years.

This study aims to: 1) examine the trends in PA and sedentary behaviors among Chinese children aged 6 to 17 years over an 11-year time period (2004 – 2015); and 2) explore the correlates of the volume of PA and time spent in sedentary behaviors.

Methods

Participants

This study utilized the data from (China Health and Nutrition Survey, CHNS)[15], which is an ongoing cohort study jointly conducted by the China Center for Disease Control and Prevention (China CDC) and Carolina Population Center at the University of North Carolina. The project started in 1989 and a multistage, random cluster process was employed to draw samples from 9 provinces including Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, and Guizhou. Thereafter, nine rounds of follow-up surveys were conducted in 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011 and 2015. Since 2011, samples from three megacities (Beijing, Shanghai and Chongqing) have been added. The recruitment efforts and sampling strategies have been described previously [13]. To facilitate comprehensive assessment of PA, questions related to sedentary behaviors were added since 2004. For this reason, we only included children aged 6-17 years who participated in at least one round of follow-up surveys from 2004 to 2015. Records with illogical or missing data were excluded. A total of 298 primary sampling units, commonly known as “communities”, were included. This study was approved by the Medical Ethics Committee of the National Institute for Nutrition and Health, China CDC and University of North Carolina.

Data Collection

Data on PA, sedentary behaviors and socio-demographic characteristics were collected using structured questionnaires.

PA outcome measures comprises PA level, the average daily time spent in PA (min/day) and average weekly volume of PA (MET-hrs/week). To estimate the average weekly volume of PA, the average weekly time spent in various PA was multiplied by the corresponding metabolic equivalent of task (MET) values based on the “Youth Compendium of Physical Activities” developed by the US Center for Chronic Disease Prevention and Health Promotion in 2017[16]. In the compendium, MET values of 196 activities are presented for four age-groups: 6–9, 10–12, 13–15, and 16–18 years. With reference to the Physical Activity Guidelines for Chinese Children[17], moderate- and vigorous-intensity PA (MVPA) were identified, and the average time spent in MVPA per day (min/d) were estimated. Using the 60 minutes of accumulated MVPA per day proposed by WHO as cut off point, we defined less than 60 minutes of accumulated MVPA per day as physical inactivity. PA was categorized into three levels based on the average time spent in MVPA per day: <60 min, 60-120 min and > 120 min for low, medium and high levels of PA, respectively. PA was classified into four domains: active leisure, in-school PA, active travel and domestic PA. Active leisure and in-school PA included strolling, gymnastics, track and field, martial arts, ball games and others; active travel included walking and cycling; domestic PA included cleaning the house, doing laundry, cooking and buying food.

Sedentary behaviors were measured as the average weekly time (hrs/week) spent in sedentary behaviors before school, after school and during weekends. Sedentary activities were grouped into four categories: education, screen-based entertainment, transportation, and Arts&Play. Activities in the education category included extracurricular reading, writing, and painting; Activities in the screen-based entertainment category included TV (watching TV, videos, video discs), games (playing computer or smartphone games, playing game consoles), and internet (chatting online, watching programs online or on smartphones); Activities in the transportation category included traveling as passenger by bicycles, buses, subways, cars, taxis, motorcycles; Activities in the Arts&Play category included chess, toy cars, puppets etc.

Socio-demographic characteristics included age, gender, ethnicity, annual family income, parental education levels and geographical factors. Since the average of 12 years old is the beginning of the development of puberty and the secondary study, age was stratified into 6-11 year-old and 12-17 year-old groups. The annual family income was stratified into low (<50,000 yuan) and high (>50,000 yuan) income groups. Parental education was stratified into low (primary or below), middle (secondary completed), and high (college or higher) education levels. Geographical factors included residential areas (urban / rural), region (north / south) and urbanization level of community. Urbanization level of community was assessed using an urbanization index developed by Jones Smith and Barry Popkin. The index was produced from a comprehensive evaluation of 12 dimensions such as population density, education, and transportation infrastructure[18]. In this study, the urbanization index for each survey year was compiled and stratified into three groups: low, medium and high levels of urbanization.

Data Analysis

All data analyses were performed using SAS 9.4 software and p-value < 0.05 was considered as statistically significant. Categorical data were presented as frequency (percentage). The Cochran-Armitage trend test was used to analyse the trends in proportion of gender, residential areas and region over time. The Fisher’s exact test was used for ethnicity as the expected count of cells in this group was less than 5. As paternal education levels and maternal education levels are ordinal multilevel variables, the Mantel-Haenszel chi-square test was used. As age, annual family income and urbanization index of community are continuous variables, the mean ± standard deviation was presented and the multiple linear model was used to test the trends after adjusting other socio-demographic characteristics.

The random-effects ordinal regression model was conducted to examine the trends in PA levels across survey years. The Newton-Raphson Ridge optimization method was used to optimize parameter estimation, controlling for the random effect of communities and adjusting for socio-demographic factors including gender, age, ethnicity, paternal education level, maternal education level, annual family income, urbanization index of community, residential area and region. The trends were further analysed after applying stratification on gender.

Repeated measures mixed models were conducted using volume of PA and time spent in sedentary behaviors as dependent variables, survey year as an independent variable, controlling for all socio-demographic characteristics. Community was included as random effect in the models. The adjusted means of volume of PA and time spent in sedentary behaviors was reported. The trends in both outcomes were examined and the differences across survey years were compared using Bonferroni method. The trends were further analysed after applying stratification on gender, age, urbanization level of community, residential area and region. The repeated measures mixed effects model considers the internal connection of the observations in different survey years, and the aggregation of the observations in the community level. The hypothesis test showed that the change of the -2log-likelihood value of the random intercept

model and the random slope model is statistically significant ($p < 0.001$), indicating that the fitting of the random slope model was better than the random intercept model, so the random slope model was adopted.

Quantile regression models were used to examine trends and the differential effects of correlates at different quantiles of volume of PA and time spent in sedentary behaviors. Quantile regression uses conditional quantile modelling of the dependent variable to estimate the regression parameters by minimizing the weighted sum of the absolute values of the residuals. Since there is no special requirement for the distribution of the dependent variable or the homogeneity of variance, it is not affected by outliers. This is a robust method that can reflect the influence of independent variables on dependent variables at different levels[19].

Results

Characteristics of participants

A total of 6,936 observations of children aged 6-17 years in 12 provinces and cities, comprising 4,341 subjects and 298 communities were included. The mean age was 11.0 ± 3.3, and the gender composition was consistent across all survey years. The proportions of the children who participated in the survey once, twice, three times, four times and five times were 59.0%, 26.1%, 11.2%, 3.5% and 0.2%, respectively. Over the 11 years, there were a decrease of 1.7 years old in the average age of children, and an increases of 50 thousands yuan in the annual family income and an increase of 13.5 of the urbanization index of community ($p < 0.001$). Furthermore, significant increase in the proportion of children residing in the south was observed ($p = 0.030$) (Table 1).

Trend in PA levels

The proportion of children with low PA level (i.e. physical inactivity) increased from 76.0% in 2004 to 81.5% in 2015 (*OR* = 1.51, 95% *CI*: 1.19 ~ 1.90, $p < 0.001$); while the proportion of children with high PA level decreased from 9.0% in 2004 to 5.8% in 2015(*OR* = 0.66, 95% *CI*: 0.53 ~ 0.84, $p < 0.001$). The random-effects ordinal regression model shows that there was a significant difference in the PA levels among communities ($p = 0.042$), but no significant difference was observed in the trends in PA levels among communities over time. Gender stratification analysis shows that the prevalence of physical inactivity among boys increased from 70.0% to 80.0% (*OR* = 1.75, 95% *CI*: 1.30 ~ 2.34, $p < 0.001$) while the proportion of boys with high PA level decreased from 12.0% to 7.0% (*OR* = 0.57, 95% *CI*: 0.43 ~ 0.77, $p < 0.001$) from 2004 to 2015. No significance differences were observed among girls. In 2015, the prevalence of physical inactivity among girls was 83.3%, and the proportion of girls was 4.3% (Figure 1).

Trends in volume of PA, time spent in PA and MVPA

From 2004 to 2015, there was no evidence of a change in the average time spent in PA per day, but the average time spent in MVPA per day declined by 26.9%, from 47.2±2.3 min/d to 34.5±2.1 min/d ($F = 9.29$, $p < 0.001$). Over the 11 years, the average weekly volume of PA declined by 13.9%, from 41.7±1.6 to 35.9±1.7 MET-hrs/week ($F = 5.16$, $p < 0.001$). Of the four types of PA, active leisure contributed to the largest proportion of the volume of PA. In particular, in-school PA declined by 39.7%, from 11.6±0.6 METs hrs/week in 2004 to 7.0±0.5 METs hrs/week in 2015 ($F = 25.04$, $p <0.001$). More profound decreases in PA were observed between 2011 and 2015, with PA decreased by 15.3% ($p = 0.004$), MVPA decreased by 24.8% ($p < 0.001$) and the volume of PA decreased by 17.5% ($p = 0.002$). In addition, the volume of in-school PA, active travel PA and domestic PA were decreased by 42.1%, 10.3% and 44.4% ($p < 0.001$), respectively. See Figure 2.

Trends in time spent in sedentary behaviors

The time spent in sedentary behaviors among children rose by 7.5%, from 23.9±0.6 hrs/week in 2004 to 25.7±0.6 hrs/week in 2015($F = 15.17$, $p < 0.001$). The education and screen-based entertainment categories were the predominant contributors to sedentary behaviors. Over 11 years, the time spent in activities under the screen-based entertainment and transportation categories increased by 2.9 hrs/week ($F = 20.37$, $p < 0.001$) and 1.3 hrs/week ($F = 5.45$, $p < 0.001$), respectively, while the time spent in recreational activities decreased by 0.4 hrs/week ($F = 8.83$, $p = 0.024$) and educational sedentary behaviors remained stable. Among the activities under the screen-based entertainment category, more profound increases were observed for the time spent in the internet and games sub-categories, with the increases of 2.5 hrs/week ($F = 50.69$, $p < 0.001$) and 1.3 hrs/week ($F = 25.37$, $p < 0.001$), respectively, from 2004 to 2015; in contrast, the time spent in activities under the TV sub-category decreased by 0.8 hrs/week ($F = 8.23$, $p < 0.001$) over the 11-year period. See Figure 3.

Correlates of PA

As shown in Table 2, the repeated measures mixed model analysis shows that variation among communities and observations accounted for 2.6% and 97.4% of the total variation in volume of PA among children, respectively. In each survey year, the volume of PA differed among communities ($p < 0.001$). Likewise, the changes in volume of PA over time differed among communities ($p < 0.001$). The volume of PA was 5.7 MET-hrs/week lower in 2015 than in 2004 ($p = 0.003$), but there were no significant differences in the volume of PA between 2004 and other survey years. Regarding the results of the quantile regression analyses, the volume of PA in 2006 was 1.3 MET-hrs/week lower than that in 2004 at the 25th quartile ($p = 0.048$); the volume of PA in 2011 was 3.6 MET-hrs/week ($p = 0.001$) and 4.3 MET-hrs/week ($p = 0.029$) higher than that in 2004 at the 50th and 75th quartiles; and the volume of PA in 2015 was 5.4 to 6.5 MET-hrs/week higher than that in 2004 at all quartiles ($p \leq 0.018$).

The results of repeated measures mixed effect model and quantile regression models indicate that age, ethnicity, and region affected the volume of PA ($p \leq 0.003$), and with differences were observed across quartiles ($p < 0.001$). Specifically, the volume of PA among children aged 6-11 years was 5.9 to 22.3 MET-hrs/week lower than that among children aged 12-17 years ($p < 0.001$); the volume of PA among Han Chinese children was 2.4 to 11.3 MET-hrs/week lower than that of ethnic minorities children ($p < 0.001$); the volume of PA among those in the north was 4.0 to 7.4 MET-hrs/week lower than those in the south ($p < 0.001$). As the quartile increases, the differences became larger. Repeated measures mixed model further shows that the volume of PA among boys and urban

children were 9.1 MET-hrs/week higher and 6.1 MET-hrs/week higher than that among girls and rural children, respectively (p <0.001). The effect of gender and region were significant at the 50th and 75th quartiles of the volume of PA, with greater differences observed at the 75th quartile (p <0.001), but there was no statistical significance at the 25th quartile. As regards family income, children in low-income families had 5.6 MET-hrs/week lower volume of PA than those in high-income families (p <0.001). Quantile regression analyses revealed that the effect of income was only significant at the 75th quartile (p = 0.003). No significant effects were observed for either parental or maternal education levels. Considering the aggregation effect of community, the impact of urbanization level of community on volume of PA was not statistically significant. However, quantile regression analyses show that the effect of urbanization level of community was significant at the 25th and 50th quartiles of the volume of PA, in which children residing in area with low urbanization level had 1.8 MET-hrs/week (p =0.006) and 2.4 MET-hrs/week (p = 0.013) lower volume of PA than those residing in area with high urbanization level.

Correlates of sedentary behaviors

As shown in Table 3, the repeated measures mixed model analysis shows that variation among communities and observations accounted for 3.6% and 96.4% of the total variation in sedentary time among children, respectively. In each survey year, the sedentary time significantly differed among communities (p < 0.001). Likewise, the changes in sedentary time over time significantly differed among communities (p <0.001). Compared with 2004, the sedentary time among children was significantly higher in other survey years (p < 0.001). The results of quantile regression analyses suggest that, in each survey year, the increase in sedentary time was greater at higher quartiles than lower quartiles. At each quartile level, sedentary time increased significantly between 2004 and other survey years (p < 0.001) except in 2015 that significant increase was only observed at the 75th quartile (p < 0.001).

The results of the repeated measures mixed effect model and quantile regression models indicate that the sedentary time in urban children was 2.6 to 3.6 hrs/week higher than that in rural children (p <0.001) and those residing in areas with high urbanization level reported 1.3 to 2.6 hrs/week higher sedentary time than those residing in areas with low urbanization level ($p \leq 0.050$). As the quartile increases, the effect of residential area became larger. Repeated measures mixed model analysis shows that the effects of ethnicity, parental education level and region on sedentary time were not statistically significant. However, significant effects were observed in quantile regression analyses. At the 75th quartile, the sedentary time among ethnic minorities children was 2.3 hrs/week higher than that of Han Chinese children (p < 0.001); children with fathers educated to middle education level reported 1.0 hrs/week higher sedentary time than those with fathers educated to high education level (p = 0.043); and those with mothers educated to middle education level reported 1.8 hrs/week lower sedentary time than those with mothers educated to high education level (p = 0.016). At the 25th quartile, the sedentary time in children residing in the south was 0.8 hrs/week higher than those residing in the north (p = 0.031); children with fathers educated to high education level reported 4.9 hrs/week higher sedentary time than those with fathers educated to low education level (p = 0.045). Gender was not significant in all models.

Discussion

In this study, we examined the trends and correlates in PA and sedentary behaviors among children aged 6-17 years in China from 2004 to 2015. Overall, there was a gradual decline in PA and steady increase in sedentary behaviors in Chinese children over the 11-year period, and socio-demographic factors were associated with PA and sedentary behaviors.

From 2004 to 2015, the prevalence of physical inactivity among Chinese children aged 6-17 years increased from 70.0% to 81.5%. This figure is similar to the global estimate of 81.0% adolescents with physical inactivity in 2016[5]. While the global trend in physical inactivity among adolescents started to fall, the momentum in China is still on the rise. If effective strategies are not in place to ameliorate these trends, it is impossible to achieve the WHO target of 10% reduction in physical inactivity among children in China by 2025.

In this study we found downward trend for in-school PA among Chinese children aged 6-17 years, which was the major contributor to the decrease in the volume of PA. This finding is consistent with a systematic review of global PA trends indicated that there was a decline in youth PA seems over the 20 years before and after the early 21st century, particularly in the domain of in-school PA[20]. The review also identified the gap that there were fewer studies on PA trends in children than in adults, and studies on children's PA trends were mainly conducted in the Western countries, such as United States, Canada, and Switzerland. Our study adds to existing literature by providing data on Chinese children's PA trends. In view of the prominent decreasing trend in in-school PA, urgent actions should be taken to increase the volume of in-school PA to promote PA among Chinese children aged 6-17 years old.

|In this study the time spent in screen-based entertainment increased significantly from 2004 to 2015, which was mainly contributed by activities under the internet and games sub-categories. In contrast, time spent in activities under the TV subcategory decreased gradually. A study comparing the international trends in children screen-time behaviors among 30 countries found that TV viewing decreased slightly from 2002 to 2010, which was offset by a sharp increase of the time spent on internet and video games. This trend was consistently observed in all surveying countries[21].These changes illustrate that new technologies have replaced old technologies in children's' daily lives and result in more time spent in sedentary behaviors. The profound increase in time spent in transport-related sedentary behaviors from 2011 to 2015 may reflect the impact of increasing popularity of modern and convenient means of transportation during the rapid urbanization process. In 2015, the time spent in screen-based entertainment among Chinese children was as high as 1.8h/day, which is far higher than the target of less than one hour screen time per day documented in the Healthy China Action Plan (2019-2030). Taken together, there is an urgent need for effective interventions and policies to curb the rising trend of time spent in screen-based entertainment in order to decrease sedentary time among children in China.

PA volume and sedentary time differed by socio-demographic factors. After controlling for other factors, girls had lower volume of PA than boys. The gender difference was more prominent at 50th and 75th quartiles. A global survey of 1.6 million adolescents shows that the age- standardized prevalence of physical inactivity among boys has dropped from 80% to 78% while that among girls held study at roughly 85% over 15 years since 2001[5]. Our findings suggest a similar trend among Chinese girls, but the prevalence of physical inactivity among Chinese boys increased from 76.0% in 2004 to 80.0% in 2015. In this regard,

gender-specific interventions or polices are warranted to eliminate barriers to PA and promote PA among children in China. Interventions targeting girls should focus on increasing the volume of PA while that targeting boys should focus on reducing physical inactivity.

This study shows that age was positively associated with PA volume and sedentary time. A review of systematic reviews conducted by the Lancet Physical Activity Series Working Group concluded that an inversely relationship was noted for age with PA in children and adolescents; however, the included studies were mostly conducted in middle and high income countries[22]. In 2012, a study collected accelerometer data from 2163 grade 4-11 students in 11 cities in China found that older students had higher levels of sedentary behaviors and lower levels of MVPA than younger students[23]. The findings of a recent systematic review of Chinese studies show that the effect of age on PA among children aged 3-18 years was inconsistent[24]. In this study, the positive correlates of PA volume with age may be due to the higher basic metabolic rate and relative larger METs for the same PA in older than younger children. The mixed findings suggest a need to further monitor and track PA among Chinese children at different age stages to enhance the sensitivity of PA interventions.

There were differences among communities were observed for both volume of PA and sedentary time across all survey years and over time. This finding supports the development of interventions targeted at the community level to promote PA and reduce sedentary behaviors among children in China. Children residing in area with high urbanization level reported significantly higher PA volume and sedentary time than those residing in area with low urbanization level indicating that urbanization promoted both of PA and sedentary behaviors among Chinese children. Similarly, PA volume and sedentary time in urban children were both higher than those in rural children. A possible explanation is that the rapid economic growth and urbanization in China have brought tremendous changes in transportation mode, communication systems, cultural practices, and infrastructure, which in turn influenced the lifestyle behaviors of children. Our finding on residential area corroborates the findings of CHNS from 2010 to 2012, which indicate that the sedentary time among Chinese primary and secondary school students residing in big cities and urban areas were higher than those residing in medium-small cities and rural areas, respectively[25]. As regards region, children from the north reported significantly lower volume of PA than those from the south. Other region-related factors such as topography, climate, and cultural differences may also influence PA.

This study has several strengths. First, this study covered the longest time span and the widest survey coverage among studies of similar topics. Second, the analyses of PA trends were controlling for the random effect of communities and adjusting for socio-demographic differences across survey years, using the repeated measures mixed models. Third, in this study, the random-effects ordinal regression models were applied to show the trends of low, medium and high level of PA in Chinese children, which were rarely been studied before. Last but not least, the quantile regression models that is a robust method were used to test the different effects of the influencing factors at different quantiles of PA and sedentary behaviors.

Several limitations to this study need to be acknowledged. First, the samples drawn in CHNS were not nationally representative, but previous findings were consistent with the findings obtained from the Chinese Nutrition and Health Surveillance project. Second, the data from all survey years were treated as cross-sectional data. The significant relationships reported in this study can only be interpreted as correlational relationships, but not as causal relationships. Third, this study included only socio-demographic factors, the influence of other factors such as other family factors and environmental factors needs to be further explored. Fourth, PA and sedentary behaviors outcomes were based on self-report, which may be subject to recall bias. Finally, the metabolic equivalent coding system for PA used in this study was developed based in the Western countries, which may not be applicable to Chinese children.

Conclusion

This study highlighted that physical inactivity among children in China is a public health problem in China and warrants urgent actions to increase PA and curb the rising trend in sedentary behaviors. In particular, more concerted and focused efforts are needed to develop effective strategies to increase in-school PA and reduce screen-based sedentary behaviors among children. Age, family income, urbanization level of community and residential area were common correlates of PA and sedentary behaviors, and gender, ethnicity and region differences were also observed in the volume of PA among Chinese children aged 6-17 years old. Urbanization development are "double-edged swords", which could promote PA, as well as sedentary behaviors. As China is undergoing rapid urbanization and economic development, monitoring the trend and correlates of PA and sedentary behaviors has the potential to promote PA interventions and strategies among children, ultimately improving children's health in the future.

Abbreviations

China CDC: China Center for Disease Control and Prevention; CHNS: China Health and Nutrition Survey; MET: Metabolic equivalent of task; MVPA: Moderate- and vigorous-intensity physical activity; PA: Physical activity

Declarations

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Availability of data and materials

The datasets generated and/or analyzed during the current study are availablefrom the Carolina Population Center, http://www.cpc.unc.edu/projects/china.

Authors' contributions

All authors were involved in the conception of the review and the revision of the manuscript. XY contributed to the conception, design, analysis and interpretation of data and drafted the manuscript. AL designed the study and drafted the manuscript. RJ contributed intellectual input into the main ideas of this paper and assisted with writing of the manuscript. SY contributed to study analyses. WZ directed all aspects of the study, including the design of the study, administration of analyses and interpretation of the results. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The study was approved by the Institutional Review Boards of the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety, China Center for Disease Control and Prevention.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1 Demographic characteristic of the participants

	CHNS year					Statistics
	2004	2006	2009	2011	2015	(*p*-value)
N	1593	1267	1141	1544	1391	
Gender (%)[a]						
Boys	854(53.6)	677(53.4)	644(56.4)	791(51.2)	728(52.3)	*Z*=-0.304 (Unilateral *P*=0.381)
Girls	739(46.4)	590(46.6)	497(43.6)	753(48.8)	663(47.7)	
Age, years(SD)[d]	11.9(3.3)	11.3(3.4)	11.0(3.2)	10.8(3.3)	10.2(3.1)	*F*=64.5 (*P*<0.001)
Ethnicity (%)[b]						
Han	1374(86.3)	1065(84.1)	957(83.9)	1353(87.6)	1212(87.1)	*Z*=-0.458 (Unilateral *P*=0.323)
Minority	219(13.7)	202(15.9)	182(16.0)	189(12.2)	169(12.2)	
Unknown	0	0	2(0.2)	2(0.1)	10(0.7)	
Annual family income(Thousands, SD)[d]	0.4(0.9)	0.7(1.2)	1.2(3.0)	2.1(3.9)	5.4(20.8)	*F*=44.0 (*P*<0.001)
Paternal education levels (%)[c]						
Low(primary or below)	204(12.8)	198(15.6)	153(13.4)	225(14.6)	195(14.0)	X^2=0.000 (*P*=0.995)
Middle(secondary completed)	1203(75.5)	938(74.0)	871(76.3)	1122(72.7)	1041(74.8)	
High(college or higher)	186(11.7)	131(10.3)	117(10.3)	197(12.8)	155(11.1)	
Maternal education levels (%)[c]						
Low(primary or below)	307(19.3)	271(21.4)	225(19.7)	315(20.4)	283(20.3)	X^2=0.002 (*P*=0.966)
Middle(secondary completed)	1102(69.2)	870(68.7)	805(70.6)	1040(67.4)	960(69.0)	
High(college or higher)	184(11.6)	126(9.9)	111(9.7)	189(12.2)	148(10.6)	
Urbanization index(SD)[d]	58.6(19.9)	61.7(20.1)	64.6(18.9)	70.5(19.6)	72.1(17.3)	*F*=110.8 (*P*<0.001)
Residential areas (%)[a]						
Urban	444(27.9)	370(29.2)	308(27.0)	583(37.8)	486(34.9)	*Z*=1.540 (Unilateral *P*=0.062)
Rural	1149(72.1)	897(70.8)	833(73.0)	961(62.2)	905(65.1)	
Region (%)[a]						
North	679(42.6)	500(39.5)	402(35.2)	494(32.0)	446(32.1)	*Z*=-1.88 (Unilateral *P*=0.03)
South	914(57.4)	767(60.5)	739(64.8)	1050(68.0)	945(67.9)	

[a] Using Cochran-Armitage trend test; [b] Using Fisher's exact test; [c] Using Mantel-Haenszel chi-square test; [d] Using the multiple linear model to test the trends after adjusting other socio-demographic characteristics.

Table 2 Results of repeated measures mixed effect model and quantile regression model analyses of factors associated with the volume of physical activity among Chinese children from 2004-2015

	Repeated measures mixed effect models		Quantile regression models						
			25th quantile		50th quantile		75th quantile		Tren tests
	β-value(SE)	*p- value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	*p-valu*
CHNS year									
2015	-5.7(1.9)	0.003	-5.4(-6.6,-4.2)	<0.001	-6.5(-8.6,-4.4)	<0.001	-5.8(-10.6,-1)	0.018	<0.0
2011	2.1(1.8)	0.245	0.4(-0.9,1.8)	0.531	3.6(1.4,5.8)	0.001	4.3(0.4,8.2)	0.029	
2009	1.4(1.9)	0.467	0.1(-1.4,1.7)	0.869	1.2(-0.9,3.2)	0.279	1.2(-2.7,5.1)	0.547	
2006	-1.2(1.8)	0.514	-1.3(-2.6,0)	0.048	-0.8(-2.9,1.3)	0.476	-2.4(-6.4,1.6)	0.233	
2004	0		0		0		0		
Gender									
Boys	9.1(1)	<0.001	0.1(-0.8,1)	0.777	4.0(2.6,5.5)	<0.001	12.8(10.1,15.6)	<0.001	<0.0
Girls	0		0		0		0		
Age									
6-11y	-16.9(1)	<0.001	-5.9(-7.2,-4.5)	<0.001	-14.2(-16.2,-12.3)	<0.001	-22.3(-25.3,-19.3)	<0.001	<0.0
12-17y	0		0		0		0		
Ethnicity									
Han	-6.9(1.9)	<0.001	-2.4(-3.6,-1.1)	<0.001	-3.6(-5.9,-1.2)	0.003	-11.3(-15.9,-6.8)	<0.001	<0.0
Minority	0		0		0		0		
Family income level									
low (<50,000 yuan)	-5.6(1.8)	0.002	-1.1(-3,0.8)	0.256	-1.9(-4.8,0.9)	0.181	-11.0(-18.3,-3.7)	0.003	0.01
high (>50,000 yuan)	0		0		0		0		
Paternal education levels									
Low(primary or below)	4.1(7.8)	0.599	-0.6(-3,1.7)	0.598	1.1(-10.3,12.5)	0.848	-4.7(-12.5,3.1)	0.239	0.70
Middle(secondary completed)	6.1(7.5)	0.415	-0.4(-1.9,1.1)	0.642	2.6(-8.4,13.6)	0.647	-0.3(-4.7,4.1)	0.906	
High(college or higher)	0		0		0		0		
Maternal education levels									
Low(primary or below)	-4.7(7.9)	0.548	0.1(-2.2,2.3)	0.957	-1.9(-13.3,9.6)	0.747	3.3(-4.7,11.4)	0.421	0.61
Middle(secondary completed)	-5.4(7.6)	0.478	0.2(-1.6,1.9)	0.845	-2.3(-13.5,8.9)	0.689	-0.6(-6.6,5.4)	0.848	
High(college or higher)	0		0		0		0		
Urbanization level of community									
Low	-2.7(1.9)	0.145	-1.8(-3.1,-0.5)	0.006	-2.4(-4.3,-0.5)	0.013	-3.2(-6.8,0.5)	0.092	0.41
Middle	-0.8(1.7)	0.633	-0.8(-1.9,0.4)	0.203	-2.1(-3.9,-0.3)	0.023	-2(-5.5,1.6)	0.275	
High	0		0		0		0		
Residential areas									
Urban	6.1(1.7)	<0.001	0.4(-0.7,1.5)	0.434	3.6(1.6,5.5)	<0.001	11(7.4,14.6)	<0.001	<0.0
Rural	0		0		0		0		
Region									
North	-4.5(1.4)	0.002	-4.0(-4.8,-3.1)	<0.001	-6.7(-8.0,-5.3)	<0.001	-7.4(-10.2,-4.7)	<0.001	<0.0
South	0		0		0		0		
Random effects*									

	Repeated measures mixed effect models		Quantile regression models						
			25th quantile		50th quantile		75th quantile		Tren tests
	β-value(SE)	*p- value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	*p-valu*
$\sigma^2_{\mu 0}$(intercept)	39.0(12.9)	0.001							
$\sigma^2_{\mu 01}$(covariance)	102.4(18.1)	<0.001							
$\sigma^2_{\mu 1}$	1469.5(27.0)	<0.001							

* These were the random effects of communities in repeated measures mixed effect models on the volume of physical activity. Interclass variance: 39.0/(39.0+1469.5)=2.6%. Intraclass variance: 1-2.6%=97.4%. CHNS: China Health and Nutrition Survey; CI: Confidence Interval.

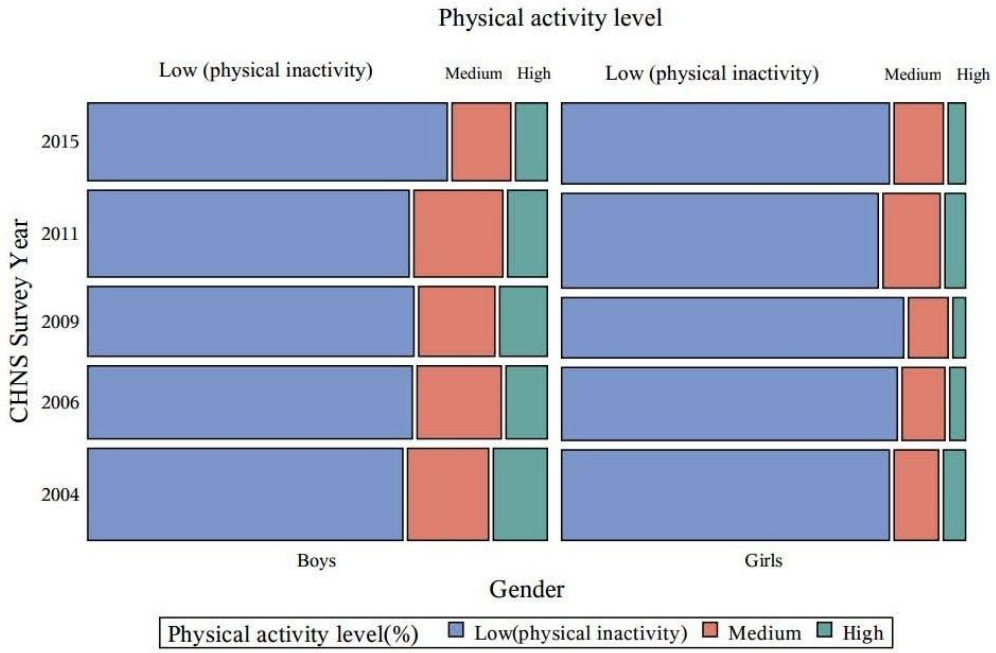
Table 3 Results of repeated measures mixed effect model and quantile regression model analyses of factors associated with the time spent in sedentary behaviors among Chinese children from 2004-2015

	Repeated measures mixed effect models		Quantile regression models						
			25th quantile		50th quantile		75th quantile		Trend tests
	β-value(SE)	*p- value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	*p-value*
CHNS year									
2015	1.9(0.6)	0.003	-0.4(-1.5,0.6)	0.432	1.1(-0.2,2.4)	0.088	4(2.4,5.6)	<0.001	<0.001
2011	4.1(0.6)	<0.001	3.8(3,4.7)	<0.001	4.2(3.1,5.3)	<0.001	4.6(3.4,5.8)	<0.001	
2009	3.2(0.6)	<0.001	2.9(1.9,3.9)	<0.001	3.5(2.5,4.6)	<0.001	3.5(2.3,4.6)	<0.001	
2006	3(0.6)	<0.001	2.5(1.6,3.4)	<0.001	2.9(1.9,4)	<0.001	3.1(2.1,4.2)	<0.001	
2004	0		0		0		0		
Gender									
Boys	0.5(0.3)	0.098	-0.2(-0.8,0.4)	0.592	-0.3(-1,0.4)	0.413	0.5(-0.2,1.3)	0.170	0.060
Girls	0		0		0		0		
Age									
6-11y	-1.2(0.3)	<0.001	-0.1(-0.8,0.6)	0.812	-1.1(-1.9,-0.3)	0.007	-2.6(-3.5,-1.8)	<0.001	<0.001
12-17y	0		0		0		0		
Ethnicity									
Han	-0.9(0.6)	0.157	-0.6(-1.4,0.2)	0.153	-1.2(-2.4,0)	0.041	-2.3(-3.4,-1.3)	<0.001	0.007
Minority	0		0		0		0		
Family income level									
low (<50,000 yuan)	-1.7(0.6)	0.004	-1.3(-2.8,0.3)	0.119	-2.9(-4.4,-1.4)	<0.001	-3.7(-5.7,-1.7)	<0.001	0.040
high (>50,000 yuan)	0		0		0		0		
Paternal education levels									
Low(primary or below)	-0.9(2.5)	0.737	-4.9(-9.7,-0.1)	0.045	-0.9(-4.3,2.5)	0.590	0.5(-1.6,2.6)	0.643	0.285
Middle(secondary completed)	0.2(2.4)	0.920	-3.9(-8.4,0.6)	0.092	-0.4(-3.3,2.6)	0.797	1.0(0,2.0)	0.043	
High(college or higher)			0		0		0		
Maternal education levels									
Low(primary or below)	-0.5(2.6)	0.854	3.6(-1.2,8.4)	0.137	-1.4(-4.8,2)	0.425	-2(-4.1,0.1)	0.058	0.049
Middle(secondary completed)	-1(2.5)	0.682	2.7(-1.9,7.3)	0.245	-0.8(-3.9,2.3)	0.607	-1.8(-3.2,-0.3)	0.016	
High(college or higher)	0		0		0		0		
Urbanization level of community									
Low	-1.3(0.6)	0.050	-2.6(-3.4,-1.8)	<0.001	-1.4(-2.4,-0.4)	0.005	-1.5(-2.5,-0.5)	0.003	0.038
Middle	-0.3(0.6)	0.628	-1.1(-1.9,-0.2)	0.013	0.1(-0.9,1)	0.914	-0.2(-1.2,0.8)	0.674	
High	0		0		0		0		
Residential areas									
Urban	3.2(0.6)	<0.001	2.6(1.8,3.3)	<0.001	3.3(2.5,4.2)	<0.001	3.6(2.6,4.6)	<0.001	0.100
Rural	0		0		0		0		
Region									
North	-0.3(0.5)	0.538	-0.8(-1.4,-0.1)	0.031	-0.4(-1.1,0.4)	0.346	0.4(-0.5,1.3)	0.403	0.058
South	0		0		0		0		
Random effects*									
$\sigma^2_{\mu 0}$(intercept)	**5.7□1.4□**	**0.001**							

	Repeated measures mixed effect models		Quantile regression models						
			25th quantile		50th quantile		75th quantile		Trend tests
	β-value(SE)	*p- value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	β-value(95%CI)	*p-value*	*p-value*
$\sigma^2_{\mu 01}$(covariance)	13.1□2.0□	<0.001							
$\sigma^2_{\mu 1}$	153.3□2.8□	<0.001							

* These were the random effects of communities in repeated measures mixed effect models on the time spent in sedentary behaviors. Interclass variance: 5.7/(5.7+153.3)=3.6%. Intraclass variance: 1-3.6%=96.4%. CHNS: China Health and Nutrition Survey; CI: Confidence Interval.

Figures

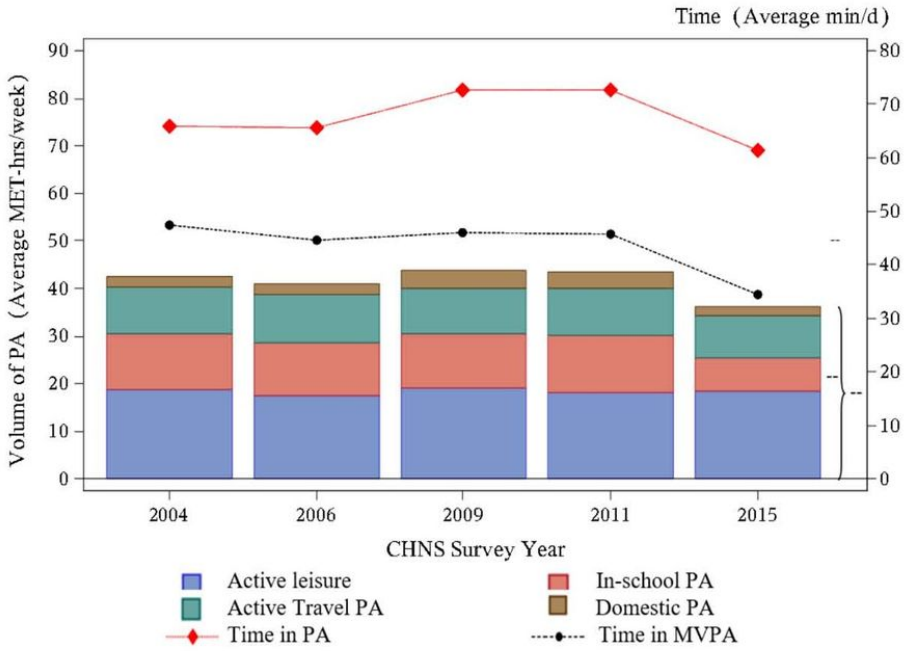


* The random-effects ordinal regression model was conducted to examine the trends in PA levels across CHNS survey years, controlling for the random effect of communities and adjusting for socio-demographic factors including gender, age, ethnicity, paternal education level, maternal education level, annual family income, urbanization index of community, residential area and region. CHNS: China Health and Nutrition Survey.

Figure 1 Trends of physical activity level among Chinese children from 2004 to 2015

Figure 1

Trends of physical activity level among Chinese children from 2004 to 2015

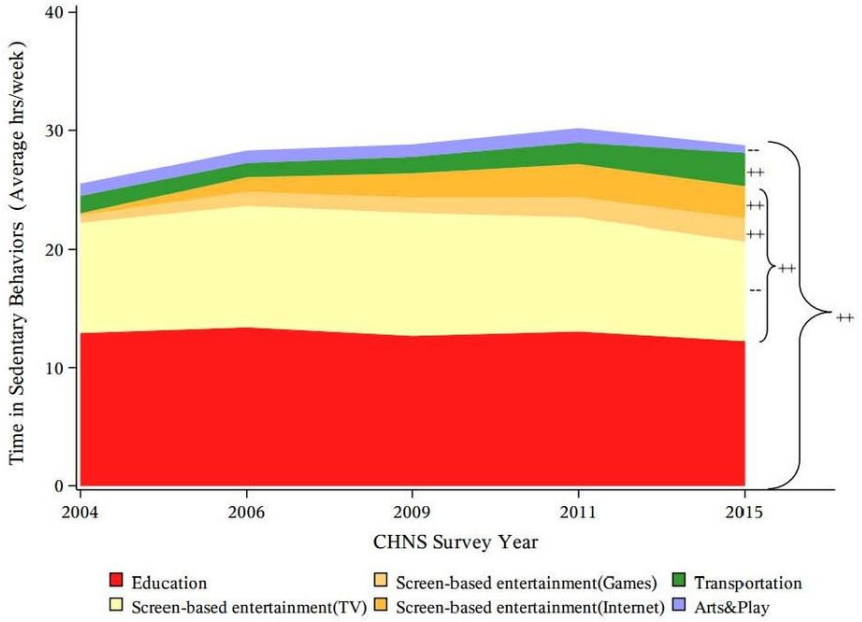


* Repeated measures mixed effect models were conducted to examine the trends of PA across CHNS survey years, controlling for the random effect of communities and adjusting for socio-demographic factors including gender, age, ethnicity, paternal education level, maternal education level, annual family income, urbanization index of community, residential area and region. "--"indicates a significant decrease in the overall trend ($p <$ 0.001). PA: Physical Activity; MVPA: Moderate- to Vigorous-intensity Physical Activity. CHNS: China Health and Nutrition Survey.

Figure 2 Trends of physical activity among Chinese children from 2004 to 2015

Figure 2

Trends of physical activity among Chinese children from 2004 to 2015



* Repeated measures mixed effect models were conducted to examine the trends of sedentary behaviors across CHNS survey years, controlling for the random effect of communities and adjusting for socio-demographic factors including gender, age, ethnicity, paternal education level, maternal education level, annual family income, urbanization index of community, residential area and region. "++"indicates a significant increase in the overall trend ($p < 0.001$); "+" indicates an increase in the overall trend ($p < 0.05$); "--"indicates a significant decrease in the overall trend ($p < 0.001$). CHNS: China Health and Nutrition Survey.

Figure 3 Trends of sedentary behaviors among Chinese children from 2004 to 2015

Figure 3

Trends of sedentary behaviors among Chinese children from 2004 to 2015