ORIGINAL ARTICLE

Physical activity, motor skills and sedentary time in China adolescents: A cross-lagged analysis

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Abstract

Background and study Aim: Physical activity, motor skills and sedentary time are important to adolescents' development, the longitudinal relationship between them is unclear. The aim of this study was knowledge about the associations between moderate to vigorous physical activity (MVPA), sedentary time, motor skills in China adolescents. We hypothesize that MVPA is positively linked with motor skills and negatively with sedentary time.

Material and Methods: A total of 124 participants (64 boys, age 12.48 ±0.21 years) completed two tests. Accelerometer was used to measure MVPA and sedentary time. Movement Assessment Battery for children, Second Edition (MABC-2) was used to measure motor skills. Cross-lagged structural equation modelling was conducted to evaluate the associations between MVPA, sedentary time, and motor skills at 7th grade and 8th grade students.

Results: (1) MVPA at both time points was negatively associated with sedentary time in 7th grade (r = −0.311 and −0.610); (2) there was a significant positive correlation between MVPA in 7th grade and object control skills at both time points (r = 0.306 and 0.444); (3) sedentary time at both time points was negatively associated with the object control skills at the 8th grade (r = −0.365 to 0.452). The cross-lagged analysis showed that: (4) the MVPA in 7th grade was positively correlated with object control skills in 8th grade (β = 0.27, p = 0.003); (5) balance skills in 7th grade were positively associated with object control skills in 8th grade (β = 0.15, p = 0.036).

Conclusions: Object control skills are positively associated with MVPA, and negatively associated with sedentary time, reducing sedentary time and increasing MVPA are essential to promote the development of adolescents' object control skills.

Key words: Movement Assessment Battery for children • risk of cardiovascular diseases • WHO recommendation

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INTRODUCTION

Physical activity – is defined as any bodily movement produced by skeletal muscle that requires energy expenditure [1]; alternative definition: **physical activity** – ***noun*** exercise and general movement that a person carries out as part of their day [23].

Motor skills – *plural noun* the ability of a person to make movements to achieve a goal, with stages including processing the information in the brain, transmitting neural signals and coordinating the relevant muscles to achieve the desired effect [23].

Performance – ***noun*** the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [23].

Physical activity is defined as any bodily movement produced by skeletal muscle that requires energy expenditure [1]. The World Health Organization recommends that children and adolescents should engage in no less than 60 minutes of moderate to vigorous intensity physical activity (MVPA) every day. However, more than 80% of children and adolescents around the world still do not meet the standard of WHO. Meta-analysis showed that the average daily MVPA time of children and adolescents in China is 41.11 min/day, and the sedentary time is 529.83 min/day [2]. So, there is still a gap between the physical activity of children and adolescents in China and the recommended by the WHO. Physical inactivity may cause serious harm to children and adolescent's physical fitness and health, not only obesity but also increasing the risk of cardiovascular diseases [3]. Also, the relationship between adolescents' sedentary behaviour and poor health condition has received increasing attention [4]. Therefore, encouraging adolescents to participate in MVPA and reducing sedentary time has become an urgent problem to be solved.

Motor skills are specific performance of various human body action behaviours, and, like basic concepts such as physical fitness and physical function, it is one of the important elements that constitute human motor competence. If children cannot proficiently run, jump, catch, throw, then they will have limited opportunities for engagement in physical activities later in their lives, because they will not have the prerequisite skills to be active. Stodden's et al. [5] motor skills and physical activity model assumes that the relationship between them is mutually reinforcing and dynamic. In early childhood, physical activity is important to the development of motor skills, and the relationship is weak, but in adolescence, motor skills are more important for participation in physical activities, and the relationship is strengthened.

Mastering proficient motor skills are a crucial factor to encourage adolescents to participate in physical activities [5]. After a one-year motor skills intervention for Finnish 7th-grade students, it was found that the motor skills score of the experimental group increased, and the physical activity level remained, while the motor skills and physical activity of the control group decreased. These results also show that the acquisition of proficient motor skills in adolescents is an important factor in preventing the decline of physical activity. Research also shows that when focusing on balance skills, it will have a more significant effect [6]. The study of Barnett was an early longitudinal study of children and adolescents' physical activity and motor skills, results showed that physical activity in childhood was positively correlated with the control objects skills. After 6-7 years, children with better object control skills were more likely to participate in moderate to vigorous physical activity [7]. A longitudinal study by Nilsen et al. [8] showed that MVPA of preschool children can predict motor skills after two years, while motor skills cannot predict physical activity. The population of this study is preschool children and cannot represent adolescents. The developmental period may also moderate the association. Due to the differences in the correlation and causality between physical activity and motor skills in a different period, it is necessary to research Chinese adolescents.

The seventh grade is the beginning stage of middle school. At this time, the influence of physical activity, motor skills, and sedentary time on the eighth grade is still unknown. Research design and statistical methods are essential for exploring the relationship among them. This study uses a longitudinal research design to objectively measure physical activity, sedentary time (ST), and motor skills (MS) at two-time points, the cross-lag model is used to analyse the relationship among the three factors, to provide a basis for promoting the development of adolescents' physical activity and motor skills.

The aim of this study was knowledge about the associations between moderate to vigorous physical activity (MVPA), sedentary time, motor skills in China adolescents. We hypothesize that MVPA is positively linked with motor skills and negatively with sedentary time.

MATERIAL AND METHODS

Participants

The method of was used random cluster sampling to select 136 7th grade students from a middle school in Beijing as research objects, and conduct a one-year follow-up. The first test was conducted in October 2019, and there were 132 data of students obtained. Following test time was in October 2020, 124 students (64 boys and 60 girls) were included in the study.

The average age of the two tests was 12.38 **±0.21 years and 13.38 ±0.2**2 years. All students and their parents provided written consent to participate and the methods used with the ethical standard of the Declaration of Helsinki. Individuals with physical disabilities, severe cardiovascular diseases, and exercise contraindications were excluded.

The study was approved by the Beijing sport university Ethics Review Board (2019101H).

Measurement of physical activity and sedentary time

Physical activity and sedentary time are measured objectively using an accelerometer (Actigraph GT3X+). Accelerometers are considered objective devices as their assessment of acceleration is independent of human-related factors and provides more reliable and valid estimates when compared with self-report measures, such as questionnaires [9]. Students wear the accelerometer on the right hip for 7 consecutive days and take it off when sleeping and participating in water sports. The sampling frequency of the accelerometer is 60HZ. Screening criteria for valid data [10]: include 2 weekdays and 1 weekend day at least; Each valid day must include 10 hours of wearing time at least; A valid wearing hours must include at least 40 minutes of non-zero data. The Counts value is divided into [11]: Sedentary: 0-100counts/min; Light Physical Activity; LPA: 101-2295counts/min; Moderate Physical Activity; MPA: 2296-4411counts/min Vigorous Physical Activity: VPA: above 4012 counts/min. Moderate to Vigorous Physical Activity; MVPA: above 2296 counts/min.

Motor skills measurement

The Movement Assessment Battery for children, Second Edition (MABC-2) is used to measure motor skills. MABC-2 evaluates the fine motor, gross motor, and balance skills of children and adolescents. It is currently translated into multiple languages and is widely used worldwide [12]. The battery is suitable for measuring the motor skills of children and adolescents aged 3-16. Two test modules are used for the object control and balance skills of the 11-16 years parts. There are two tests for object control skills, which are divided into one-handed throwing and catching and hitting the target. Balance skills include 3 test items: standing on one foot, walking backward, and zigzag jumping. Record the subjects' original scores during the test, and convert into standard scores according to the MABC-2 standard score conversion table. The testers were trained before the test to ensure that each tester is proficient in the test method. Each method is tested twice and the optimal value is selected.

Morphological measurement

Height is measured with a height meter, accurate to 0.1cm. Weight is measured with an electronic scale, accurate to 0.1kg. The calculation method is the body mass index (BMI): the weight (kg) / height (m^2). Variables such as gender and age were collected during the first test.

Statistical analysis

Before conducting statistical analyses, we imputed missing values, removed outliers, and checked the normality of the data. Descriptive statistics are expressed as mean, standard deviation (SD or ±) aspect ratio (%). An independent sample t-test was applied for analysis gender differences in the study variables.

Pearson correlation (for pairs of empirical variables, each n = 124) was used to analyse the correlation between MVPA, ST, object control skills, balance skills. In order to study cross-lagged associations among objectively measured MVPA, ST, object control skills, balance skills, a cross-lagged Structural Equation Modelling (SEM) was conducted. The proportion of variance in each outcome explained by the model was evaluated by using squared multiple correlations (R^2). SPSS 26.0 and Amos 25.0 software were used to conduct statistical analyses. Significance was set at $p<0.05$.

RESULTS

Descriptive statistics of physical activity, motor skills and sedentary time

There is no statistically significant difference in the accelerometers wearing time of boys and girls at the two-time points. In the 8th grade, boys spend significantly more time participating in MVPA than girls ($p<0.05$), and there is no statistical significance in the 7th grade. The MVPA time of 8th grade tends to be higher than that of 7th grade. Girls' sedentary time is statistically higher ($p<0.001$) than boys in 7th grade. The object control skills of boys are higher than girls in the 8th grade, and the boy's BMI is higher than girls', the difference was statistically significant $p<0.001$ (Table 1).

Table 1. Descriptive statistics of physical activity, motor skills and sedentary time.

Variable	Boys (n = 64)	Girls (n = 60)	T	p
	Mean & SD	Mean & SD		
T1 wearing time (min/day)	742 ±153.1	752.4 ±151	0.004	0.996
T2 wearing time (min/day)	805 ±103.8	814. 4±124.1	0.474	0.626
T1 MVPA (min/day)	46.2 ±13.5	39.6 ±13.6	−1.786	0.077
T2 MVPA (min/day)	62.5 ±31.2	48.1 ±15.4	−2.25	**0.031**
T1 sedentary time (%/day)	61.3 ±6.5	64.6 ±4.3	3.82	**0.001**
T2 sedentary time (%/day)	65.2 ±11.7	68.2 ±12.4	0.037	0.971
T1 object control (point)	12.5 ±3.3	11.2 ±3.5	−1.435	0.165
T2 object control (point)	12.6 ±3.1	10.3 ±3.2	2.6	**0.012**
T1 balance skills (point)	10.2 ±2.8	10.5 ±2.4	−0.106	0.917
T2 balance skills (point)	10.9 ±2.3	10.8 ±2.7	0.085	0.936
BMI (kg/m2)	21.5 ±4.3	17.1 ±2.4	−3.35	**0.001**

Note: **T1** grade seven; **T2** grade eight

Correlation analysis of physical activity, motor skills and sedentary time

MVPA at the 7th grade is negatively strongly correlated with the sedentary time in 7th grade ($r = -0.610$, $p<0.01$) but not statistically significantly negative averagely with sedentary time in the 8th grade. MVPA in 7th grade is significantly positively averagely correlated with object control skills at two time points ($r = 0.306$, $p<0.05$ with 7th grade and 0.444 $p<0.01$ with 8th grade). MVPA 8th grade is positive significantly weak correlated with object control skills ($r = 0.279$, $p<0.05$). The balance skills in the 7th grade is positively strongly correlated with the object control skills in the 8th grade ($r = 0.668$, $p<0.01$). The strongest statistically significant positive correlation ($r = 0.670$, $p<0.01$) occurs between object control 7th grade and 8th grade (Table 2).

Cross-lag analysis of physical activity, motor skills and sedentary time

The model shows two pathways about object control skills: (1) MVPA of the seventh grade can significantly predict the object control skills of the 8th grade ($\beta = 0.27$, $p=0.003$); (2) The balance skills of the seventh grade can predict the object control skills of the eighth grade ($\beta = 0.15$, $p = 0.036$). Use AMOS 25.0 maximum likelihood method to test the fit of the model, results show that the model fitting index is good: $\chi2 = 24.065$, $df = 16$, $\chi2/df = 1.504$, $p = 0.088$, CFI = 0.946, TLI = 0.906, RMSEA = 0.092. The model explained 18% of the variation sedentary time, 34% in MVPA, 53% in object control skills, and 45% in balance skills in eighth grade (Figure 1).

Table 2. Correlation analysis of physical activity, motor skills and sedentary time (n = 124).

Variable	1	2	3	4	5	6	7
1 MVPA (T1)	—						
2 MVPA (T2)	**0.584****	—					
3 sedentary time (T1)	**−0.610****	**−0.336***	—				
4 sedentary time (T2)	−0.427	−0.311*	**0.424****	—			
5 object control (T1)	**0.306***	0.150	−0.249	−0.199	—		
6 object control (T2)	**0.444****	**0.279***	**−0.365****	**−0.452****	**0.670****	—	
7 balance skills (T1)	0.043	−0.024	0.002	−0.087	0.182	**0.259***	—
8 balance skills (T2)	0.080	−0.148	0.032	0.127	0.173	0.136	**0.668****

Note: **T1** grade seven; **T2** grade eight; *p<0.05; **p<0.01

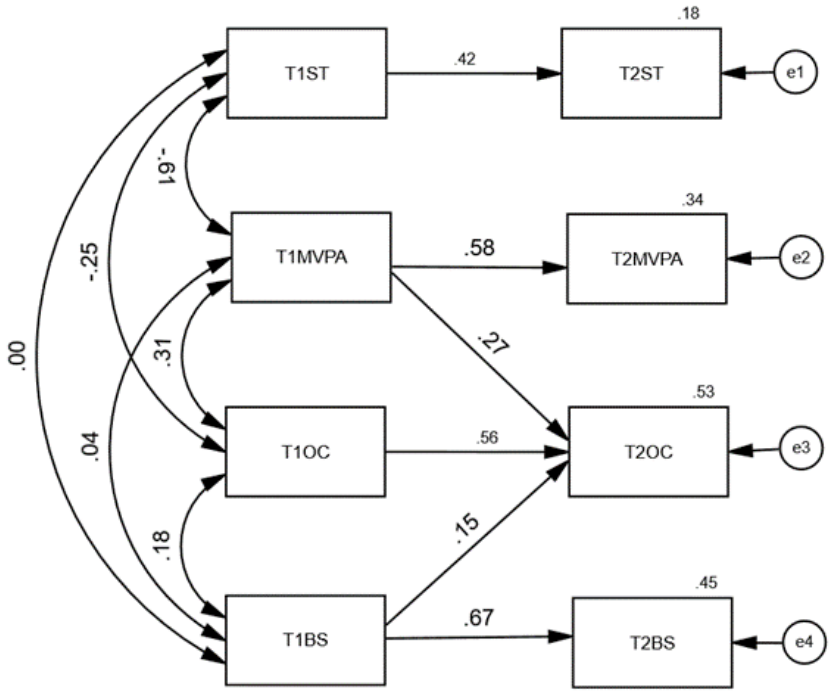

Figure 1. Cross-lagged analysis of MVPA, sedentary time, object control skills, and balance skills.

Note **ST** sedentary time; **MVPA** moderate and vigorous physical activity; **OC** object control skill; **BS** balance skills. The figure shows the standardized cross-lag regression coefficient ($p<0.05$). BMI and gender are controlled. **T1**grade seven; **T2** grade eight.

DISCUSSION

Results indicate that: (1) MVPA in 7th grade is positively correlated with object control skills in 8th grade; (2) Balance skills in the seventh are positively correlated object control skills in 8th grade, cross-lag analysis among other variables is not statistically significant. This is the first research to explore the cross-lag relationship between MVPA, sedentary time, object control skills, and balance skills among Chinese adolescents.

Descriptive statistics show that there is no statistically significant difference in the time of boys and girls participating in MVPA in the 7th grade. Boys spend more time in MVPA than girls in the 8th grade, and the MVPA time in the 8th grade tends to be higher than that in the 7th grade. Studies have shown that physical activity decreases with age, and the most obvious decline in puberty occurs between the ages of 13 and 18 [13, 14]. This study demonstrates that physical activity does not decrease with age. This may be due to reports and recommendations subjects received after the baseline test, which had a positive impact on the subjects. Girls' object control skills are lower than that of boys, which also supports previous research results [15], object control skills are important motor skills, which are included in many sports, such as basketball, soccer, and volleyball. Compared with girls, boys are more involved in ball games. This may be the reason why boys have better object control skills than girls. Therefore, it is necessary to develop a targeted plan to improve girls' object control skills.

MVPA in the 7th grade can predict the object control skills in the 8th grade, this is an important result. This is consistent with previous studies. For example, Lima et al. [16] conducted a 7-year follow-up study on children, from 6.75 to 14.35 years old, during which three follow-ups were conducted. The results showed that in children and adolescents Period, VPA can predict the development of motor skills. This shows that children's participation in vigorous intensity physical activities can promote motor skills.

Barnett et al. [17] conducted a follow-up study on preschool children, and measurement time at 19 months, 3.5 years, and 5 years old. The results showed that MVPA at 3.5 years old can predict locomotion at age 5. In addition, Jaakkola et al. [18] conducted a study on 336 12-year-old adolescents entering middle school. There was no statistically significant correlation between MVPA in primary school and motor skills in middle school but was significantly correlated with the jumping skills of girls. The reason for the inconsistency with the results of this study may be related to the type of physical activity that adolescents participate in, Studies have shown that the type of physical activity is closely related to the development of motor skills. This is a study of Finnish adolescents, the physical activities that Finnish girls like include dancing, aerobics, and other rhythmic sports, which include different forms of jumping skills [19]. Stodden's et al.[5] motor skills and physical activity model assumes that the relationship between them is mutually reinforcing and dynamic.

In early childhood, physical activity is important to the development of motor skills, and the relationship is weak, but in adolescence, motor skills are more important for participation in physical activities, and the relationship is strengthened. this research is inconsistent with the hypothesis. The motor skills of early childhood are affected by the type of physical activity. Increasing physical activity promotes the development of motor nerves, which in turn promotes the development of motor skills [20].

It can also be understood that the age of 12 is still in the later stages of childhood, and the time of MVPA contributes to the development of the object control skills until the later stages of childhood. Another reason may be related with the degree of developing motor skills.

Base on Stodden's et al. [5] dynamic theoretical model, teenagers should have mastered sufficient motor skills, however, the motor skills development of Chinese children and adolescents is relatively lagging, this may affect the relationship between motor skills and physical activity. Therefore, it is recommended that children and adolescents participate in more MVPA.

This study also shows that there is a positive correlation between the balance skills in the seventh grade and the object control skills in the eighth grade. In other words, mastering balance skills in seventh grade can promote the development of object control skills in eighth grade. The longitudinal relationship between balance skills and object control skills can be explained as the need to control objects under the premise of maintaining balance during sports, such as boys' three-step layups, girls' dances, all need to be supported on one leg to maintain body balance. Its physiological mechanism may be related to neuromuscular control [21].

This study has shown that there is no longitudinal correlation between MVPA, balance skills, and sedentary time. The reason may be related to the growth spurt of adolescents. Adolescents develop faster at the age of 12, and rapid changes in time of developmental spurts may affect adolescents' coordination [22]. Therefore, this effect may confuse the longitudinal correlation between them.

The results of this study indicate that MVPA, sedentary time, object control skills, balance skills measured at grade seven associated strongly with MVPA, sedentary time, object control skills, balance skills measured at grade eight. These results are in line with the results of previous suggestions [14] and demonstrate that the primary school years are an important period for adopting patterns of PA and ST, and motor skills. Therefore, all contexts that contribute to children's healthy PA patterns and developing motor skills are considered crucial. These include, increase the number of physical education classes, reduce sedentary time, set up the courseware game, active commuting to and from school, and extracurricular activities.

The strength of this study lies in the longitudinal research design and the objective measurement of MVPA and sedentary time. Use the cross-lag model to explore two-way causality. The limitation is that only the object control skills and balance skills are measured in the motor skills. Future research should analyse the relationship between physical activity, sedentary time, and a greater range of motor skills to determine the relationship between other motor skills and physical activity and sedentary time. Additionally, it would be necessary to investigate the relationship among type and duration of physical activity engagement and the development of motor skills.

CONCLUSIONS

Object control skills is positively correlated with MVPA, and negatively correlated with sedentary time. The results of this study also indicate that MVPA, sedentary time, object control skills, balance skills are associated in adolescent between 7th grade and 8th grade students. Reducing the sedentary time and increasing MVPA are essential to promote the development of adolescents' object control skills.

HIGHLIGHTS

Object control skills are positively associated with MVPA, and negatively associated with sedentary time, reducing sedentary time and increasing MVPA are essential to promote the development of adolescents' object control skills.

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