

Accelerometry-measured Physical Activity and Determinants in PE classes of Fourth-Grade Primary school students in China

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Abstract

Purpose

Physical education (PE) classes provide opportunities for students to meet recommended daily moderate-to-vigorous physical activity (MVPA). This study aimed to explore PA levels and determinants in PE among Chinese fourth-grade primary school students.

Methods

This cross-sectional study recruited 195 Grade 4 children (49.2% boys; aged 12 to 13 years). Accelerometers (ActiGraph GT3X) were used to measure PA in PE. Physical fitness (PF) was measured by professional PE teachers during PE lessons from October 10 to October 20, 2020, following the Chinese National Student Physical Fitness Standard (CNSPFS) guidelines, as established by the Ministry of Education. Students' body mass index (BMI) and fitness scores were calculated and evaluated from their PF test. We observed 10 PE lessons and recorded lesson contents. Independent samples t-tests and analysis of variance (ANOVA) were applied to compare the differences in PA between genders, weight statuses, and PF scores among the students. The multiple linear regression model (MLR) was developed to identify the influencing factors that influence the PA levels of boys and girls enrolled in PE classes.

Results

Within 40 minutes of each PE class, children averagely accumulated 6.69 ± 4.05 minutes MVPA, equaling 16.73% of PE time. Boys were more active than girls (%MVPA: Boys 18.95%, Girls 14.56%; %*Sedentary Behaviour*. Boys 42.44%, Girls 49.29%; $P < 0.01$). MVPA was significantly affected by teaching content (Boys $\beta = 0.613$, $P < 0.001$; Girls $\beta = 0.837$, $P < 0.001$). PF (Boys $\beta = 0.113$, $P = 0.246$; Girls $\beta = 0.093$, $P = 0.196$) and BMI (Boys $\beta = -0.069$, $P = 0.474$; Girls $\beta = -0.029$, $P = 0.690$) did not significantly affect MVPA in PE.

Conclusion

The percentage of MVPA in PE was much lower than the proposed standards (50%). Teaching content significantly affects the MVPA level of elementary school students, especially for girls. PF and BMI did not significantly affect MVPA in PE. In China, there is an urgent need to design contents for improving MVPA in PE.

Introduction

Physical inactivity is an alarming global issue [1]. The World Health Organization (2020) recommends that children and adolescents should engage in a minimum of 60 minutes of Moderate to Vigorous Physical Activity (MVPA) daily to achieve essential health benefits [2]. However, currently, more than 80% of children and adolescents do not meet the recommended PA levels [3–6], contributing to the decline in children and adolescents' physical and mental health as well as the development of many severe chronic diseases like obesity and metabolic syndrome [7–9].

School physical education (PE) has great potential to increase physical activity (PA) levels and help meet the PA guidelines among children [10]. Structured PE classes are the most promising opportunity to promote MVPA in school children [11]. According to the WHO's 2013–2020 Global Action Plan, PE presents a significant opportunity to promote MVPA in children [12]. The U.S. Department of Health and Human Services (USDHHS, 2010) [13] and the U.K. Association of Physical Education (AFPE, 2017) [14] suggested that children and adolescents should engage in MVPA for 50% of their PE class time. However, many studies found that elementary school students do not meet the recommended MVPA time in many countries [15, 16]. Wood and Hall (2015) even found that elementary school students aged 8–9 years in the U.K. only spent 9.5% of class time in MVPA [17]. In China, where a large number of school-aged children receive compulsory education [18], PE is mandatory. It typically occurs four times a week, lasting for 40–45 minutes each session, and is usually taught by certified physical education specialists in most elementary schools. Therefore, PA in PE classes plays a crucial role in meeting the daily recommendation of ≥ 60 minutes of MVPA, especially for students in China.

Given the potential significance of PE in promoting PA, numerous scholars have investigated PA levels and influencing factors within PE settings. Reasons for PA levels in PE classes are complex, including gender [15, 19], grade levels [20, 21], BMI [22, 23], teacher influence [23, 24], and teaching contents [20, 25, 26], and so on. However, there is a lack of recent research on the effect of teaching contents on PA levels in PE classes, and it is not clear whether content makes the same difference in PA levels in PE classes for boys and girls. Consequently, this study aims to: 1) objectively measure PA levels in Chinese fourth-grade elementary school PE using accelerometers, and 2) identify whether teaching content has the same effect on PA levels in boys' and girls' physical education classes.

Methods

Study Design and participants

This cross-sectional study employed convenience sampling to recruit fourth-grade students from a single public school in Xi'an, China, spanning from the Autumn semester of 2020 to the Summer semester of 2021. The primary school featured coeducational settings with 2,100 students across 42 classes. Each student in fourth grade in this school was invited to participate, while those with conditions potentially affecting the measurement of physical activity and fitness were excluded. A total of 195 fourth-grade students participated in our study. Before data collection, parental written consent and child verbal assent were secured from 195 children. Approval for all procedures was granted by the Institutional Review Board at Xi'an University of Architecture and Technology.

Anthropometrics Measures

Children's standing height and weight were measured by the trained researcher. Children's height was measured to the nearest 0.1 cm using a portable stadiometer (Shorr Productions, Olney, MD). Weight was measured to the nearest 0.1 kg using an electronic scale (Model 770; Seca GmbH & Co. KG, Hamburg, Germany). All anthropometric data were recorded as the average of two measurements for both height and weight. BMI (kg/m^2) was calculated from the average measures of height and weight. Children's Weight Status (WS) was classified on BMI according to the Chinese National Student Physical Fitness Standard (CNSPFS, Revised 2014) [27]. For boys, classifications included normal weight (14.2–20.1), low weight (≤ 14.1), overweight (20.2–22.6),

and obese (≥ 22.7). Similarly, girls were categorized into normal weight (13.7–19.4), low weight (≤ 13.6), overweight (19.5–22.0), and obese (≥ 22.1).

Assessment of Physical Fitness

Physical fitness was measured and assessed by PE teachers during PE lessons from October 10 to October 20, 2020, following the guidelines outlined in CNSPFS, as established by the Ministry of Education. The measurement consisted of six fitness indicators: vital capacity, 50m running, sit and reach, 1-minute rope skipping, 1-minute sit-ups, and 50m×8 round-trip running. Each indicator was scored 100 points. The total physical fitness score was calculated from the above fitness test indicators, considering the weighting of each indicator. The physical fitness level was then classified as follows: excellent (≥ 90 points), good (80–89.9 points), qualified (60–79.9 points), and failed (< 60 points).

Assessment of PA and SB

PA was assessed using accelerometers (ActiGraph GT3X + Activity monitors, Pensacola, Florida, USA) from the Autumn semester of 2020 to the Summer semester of 2021 (September 2020 to June 2021). PA intensity was categorized into sedentary behavior (SB), low-intensity physical activity (LPA), moderate physical activity (MPA), vigorous physical activity (VPA), and moderate-to-vigorous physical activity (MVPA). The day before the test, the accelerometer was configured with a sampling frequency of 30 Hz and an epoch of 1 second. The objective was to monitor all brief MVPAs performed by elementary school students. Evenson's thresholds were used to classify physical activity intensity, with ≥ 2296 counts per minute (CPM) for MVPA, and ≤ 100 CPM for SB [28]. Each student was provided with an accelerometer to collect PA data. The accelerometers were assigned codes corresponding to the roll book order, and it was ensured that they were worn correctly throughout the assessment period. The accelerometers were affixed to elastic belts and positioned on the right side of the waist and abdomen of the children upon arrival at the PE class, and removed just before they concluded the lesson. A researcher and a professional PE teacher were present during every PE session. The researcher observed and documented the class context, as well as verified the appropriate placement of the accelerometers on the right hip throughout the PE lesson.

Assessment of Teaching Contents

During each physical education class, a trained researcher, in a position that does not disturb the students and the teacher in class, carefully observes the content of the lesson and takes notes. We observed and documented the teaching contents of all physical education classes. A topic was documented as the lesson content if it occupied more than half of the physical education lesson. After observing all PE classes, the content was categorized into four distinct groups: indoor dance, balls, fitness training, and games to process the data.

Statistical analysis

All statistical analyses were conducted using SPSS software, version 26.0 (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics, including frequencies and percentages, summarized categorical data, while means and standard deviations (SD) were utilized for continuous data presentation. The percentage of PE lessons spent in moderate-to-vigorous physical activity (%MVPA), sedentary behavior (%SB), low-intensity physical activity (%LPA), and vigorous physical activity (%VPA) was estimated based on the cut-point established by Evenson et

al. [28]. Independent two-sample t-tests were employed to explore gender differences (Boys vs. Girls) in SB, LPA, and MVPA. Analysis of variance (ANOVA) was utilized to assess differences in SB, LPA, and MVPA among children with varying weight statuses and fitness levels. Additionally, a multiple linear regression model (MLR) was constructed to identify determining factors such as gender, teacher, weight status, and physical fitness level influencing children's accumulated MVPA during PE lessons. The significance level was set at 0.05 ($\alpha = 0.05$).

Results

Descriptive Characteristics

The descriptive characteristics of the study sample are detailed in Table 1. A total of 195 children, comprising 96 boys and 99 girls, with valid accelerometer data were included in the analysis. The mean height of the participants was 140.3 ± 6.73 cm, while the mean weight was 34.9 ± 7.69 kg. The majority (77.44%) of the children were in the normal weight range, with over one-fifth (20.51%) classified as overweight or obese based on BMI. Surprisingly, most (65.13%) of the children attained only a qualified level of Physical Fitness score. There were no significant differences in participant characteristics concerning height and fitness score, however, boys exhibited significantly higher weight and BMI levels compared to girls (Table 1).

Physical activity levels during physical education

Table 2 displays the average time and proportion spent in each category of PA during PE classes. Each PE lesson had a duration of 40 minutes. On average, children accumulated only 6.69 ± 4.05 minutes MVPA of each class, accounting for merely 16.73% of a single PE lesson time. Boys (18.95%) significantly accumulated more MVPA in PE than girls (14.56%). Conversely, girls (49.29%) significantly accumulated more sedentary behavior (SB) in PE than boys (42.44%). In comparison with students at failed, qualified, and good fitness levels, those at excellent fitness level exhibited significantly more MVPA and less SB in PE classes; however, the difference was not statistically significant ($P \geq 0.05$). Furthermore, there was no significant difference in MVPA during PE lessons either between normal weight and low weight or overweight and obese students (data not shown). Among the four teaching contents, students at indoor dance classes exhibited significantly more sedentary behavior and less MVPA than those in balls, fitness, and games classes.

Regression Analysis for Prediction of MVPA in Physical Education

The results of the regression analyses are shown in Table 3. In terms of the boys' MVPA levels, in model 1, including teacher, fitness score, and BMI, accounted for 6.4% of the variance in physical activity. Teaching content was a significant predictor of MVPA. For girls' MVPA, teachers and teaching content were significant influencing factors. The addition of the teaching content in model 2 dramatically improved the prediction of MVPA, accounting for an additional 42.7% of the variance (Table 3).

Table 1 Characteristics of the Study Population

	Total(n=195)	Boys(n=96)	Girls(n=99)
Height(cm)	140.3(6.73)	140.6 (6.94)	140.0 (6.55)
Weight(Kg)	34.9 (7.69)	36.0 (8.50)*	33.8 (6.66)
BMI(kg/m ²)	17.6(2.84)	18.1(3.14)*	17.1(2.44)
Normal	151(77.44)	74(77.08)	77(77.78)
low weight	4(2.05)	2(2.08)	2(2.02)
Overweight	30(15.38)	14(14.58)	16(16.16)
Obese	10(5.13)	6(6.25)	4(4.04)
Physical Fitness Level	76.34(7.22)	76.27(7.92)	76.41(6.51)
Excellent	4(2.05)	3(3.13)	1(1.01)
Good	60(30.77)	29(30.21)	31(3.44)
Qualified	127(65.13)	61(63.54)	66(66.67)
Failed	4(2.05)	3(3.13)	1(1.01)

Abbreviations: BMI, body mass index. Significant difference* (p < 0.05)

Table 2 Physical activity levels during physical education

		No.	SB			LPA			MVPA	
			M[SD]	%PE			M[SD]	%PE	M[SD]	%PE
Total		195	18.37(5.74)	45.93	14.94(3.10)		37.35	6.69(4.05)	16.73	
Genders	Boys	96	16.98(5.98)**	42.44	15.44(2.90)*		38.61	7.58(4.56)**	18.95	
	Girls	99	19.72(5.18)	49.29	14.46(3.22)		36.15	5.82(3.28)	14.56	
Weight status	Low weight	5	24.23(3.70)	60.58	12.53(3.28)		31.33	3.23(1.58)	8.08	
	Normal weight	147	18.05(5.75)	45.13	15.18(3.02)		37.95	6.77(4.15)	16.92	
	Overweight	30	18.59(5.44)	46.49	14.41(3.16)		36.03	6.99(3.80)	17.49	
	Obese	13	19.14(6.18)	47.85	14.45(3.52)		36.12	6.41(3.72)	16.03	
Fitness level	Excellent	2	14.92(9.07)	37.29	14.67(0.00)		36.67	10.42(9.07)	26.04	
	Good	60	18.86(5.77)	47.16	14.96(2.98)		37.40	6.18(4.21)	15.44	
	Qualified	117	18.20(5.62)	45.49	14.91(3.19)		37.27	6.90(3.86)	17.25	
	Failed	4	19.38(7.77)	48.44	14.25(5.16)		35.63	6.37(2.94)	15.94	
Teaching content	Indoor Dance	80	23.17(3.42)***	57.93	13.78(2.97)***		34.45	3.05(1.18)***	7.62	
	Balls	40	13.38(4.60)	33.45	17.15(2.94)		42.88	9.47(4.54)	23.68	
	Fitness Training	15	12.13(3.59)	30.33	16.59(2.14)		41.47	11.28(2.70)	28.19	
	Games	60	16.85(3.90)	42.12	14.61(2.64)		36.53	8.54(2.13)	21.35	

Abbreviations: SB, Sedentary behavior; LPA, light physical activity; MVPA, moderate-to-vigorous physical activity.

Note: * P<0.05, ** P<0.01, *** P<0.001.

Table 3 Results of Regression Analysis for Prediction of MVPA in Physical Education Among Fourth-Grades by Gender

Independent Variables	Girls				Boys			
	β	T-value	P-value	Adjusted r^2	β	T-value	P-value	Adjusted r^2
Model 1								
Intercept		-1.628	0.107	0.123				0.064
Teacher	0.374	3.810	<0.001		0.296	2.923	0.004	
Fitness score	-0.028	-0.287	0.775		0.074	0.694	0.489	
BMI	0.028	0.278	0.781		-0.045	-0.424	0.673	
Model 2				0.550				0.229
Intercept		0.627	0.532					
Teacher	-0.107	-1.235	0.220		-0.155	-1.147	0.254	
Fitness score	0.093	1.302	0.196		0.113	1.168	0.246	
BMI	-0.029	-0.400	0.690		-0.069	-0.718	0.474	
Teaching content	0.837	9.536	<0.001		0.613	4.546	<0.001	

Abbreviations: BMI, body mass index; Fitness score, total physical fitness score. Significant difference* ($p < 0.05$)

Discussion

Physical Education (PE) in schools presents a significant opportunity for promoting MVPA among children [10, 29, 30]. Globally, guidelines recommend that at least 50% of PE class time be dedicated to MVPA. However, the MVPA percentage in this study was a mere 16.73% (18.95% for boys, and 14.56% for girls), which is significantly below the recommended standard and previous research findings utilizing accelerometers [15, 31-35]. Notably, our findings indicate that MVPA accounted for only 6–7 minutes of a PE class session among Chinese fourth-grade students, which is even lower than one-sixth of the daily PA guidelines (60 minutes) and recommended MVPA levels. In a populous country like China, promoting MVPA in PE classes could help achieve PA guidelines. Exploring interventions to increase MVPA levels in Chinese PE classes could serve as a reasonable reference for other similar countries, potentially reducing the global prevalence of physical inactivity.

The key finding of this study was that teaching content accounted for a much larger fraction of the variance in MVPA for girls than for boys. After teaching content is added to the regression model, boys' %MVPA ranged from 6.4% to 22.9%, and girls' %MVPA from 12.3% to 55.0% (Table 3). This demonstrates that %MVPA in PE for girls is much more significantly influenced by the teaching content. Scholars have consistently found that girls are less likely than boys to be active in school [22, 36, 37]. However, our findings show that by carefully crafting the content of physical education classes to encourage MVPA in girls, it is possible to reduce the imbalance in PA between girls and boys. Therefore, PE classes in schools could potentially serve as a crucial "window of opportunity" for girls to be more active. It is particularly important to develop teaching content that fit the interests of girls in order to improve the MVPA level of girls in PE.

In our study, we investigate four teaching contents that include indoor dance, balls, fitness training, and games. The mean minutes of MVPA in different teaching contents varied from 3.05 to 11.28 (Table 2). Fitness training classes had the highest MVPA, which was consistent with a previous study [25]. Children at indoor dance classes had the least MVPA, probably because in these kinds of lessons, they had to learn some skills or orders in quiet, resulting in fewer MVPA. Tanaka et al. [38] also found that children in gymnastic lessons accumulated the highest time in SB. However, it has been demonstrated that improving children's skills while increasing physical activity can be accomplished simultaneously [39]. So what really matters is that teachers should carefully construct the content structure of each PE lesson to promote more PA, rather than only focusing on some kinds of teaching content.

The relationships between BMI, fitness levels and PA have been widely explored in settings besides PE classes, and researchers agree that overweight or obese children are not as active as normal-weight children [40-42], and similarly, children with poorer fitness levels have less PA than children with better fitness levels [43-45]. However, the data from this study showed that there was no statistically significant difference between the MVPA levels of overweight and obese children or those with lower fitness scores and those with normal weight or higher fitness scores. This may be attributed to elementary school PE classes providing equal opportunities for all students among different weight statuses and fitness levels. Consequently, children with lower BMI levels or fitness levels exert similar efforts to participate in MVPA to achieve teachers' requirements during PE classes as students with higher BMI levels or fitness levels. Therefore, we firmly believe that high-quality PE has the essential potential to promote MVPA equally among students regardless of their weight statuses or physical fitness levels. Encouragingly, there is a growing advocacy for schools to provide realistic and equal opportunities for children to promote participation in MVPA, thereby for educational equity.

Strengths and limitations

The exploration of teaching content as a determinant of physical activity levels in physical education primarily took place in the early 20th century, predominantly relying on observational data collection methods. Consequently, the primary strength of our present study lies in its utilization of accelerometers to quantify physical activity (PA) levels and assess the impact of various teaching contents on boys' and girls' MVPA in PE classes. By using ActiGraph GT3X accelerometers, we enabled an objective evaluation of PA and SB in children, capturing activity intensity at a 1-second interval. Moreover, the obligation of PE in China, scheduled four times weekly, presents a significant opportunity for promoting MVPA levels. However, there is a dearth of research data of PA levels and the determinants of PE classes in China. Consequently, our study holds the potential to shed light on the level and influencing factors of MVPA in PE classes within this context, thereby furnishing policymakers and researchers with comparative data to inform the design and refinement of PA interventions.

Several limitations should be acknowledged when interpreting the findings of this study. Firstly, the investigation was conducted solely within one elementary school, thus caution is warranted when generalizing the findings to other schools across China. Future research endeavors should aim to include a larger and more diverse sample comprising multiple schools to enhance the generalizability of the results. Secondly, the analysis focused exclusively on MVPA within the fourth-grade level. Expanding the scope to include a broader age range in future studies would bolster the universality of the findings. Thirdly, this study solely examined the effects of four types of teaching contents on MVPA in PE classes. Subsequent research efforts should encompass a more

comprehensive array of teaching content to discern which strategies most effectively promote physical activity engagement within PE.

Conclusion

On average, only less than one-sixth (6.69 ± 4.05 minutes, 16.73%) of each PE lesson time was spent in MVPA. The percentage of MVPA was very low in Chinese PE classes. There were significant gender differences in %MVPA. Teaching content significantly affects the MVPA in PE classes, especially for girls. PF and BMI did not significantly affect MVPA in PE. The potential for PE to contribute to public health goals is extremely important because students of any weight status and fitness level can realize an increase in MVPA through PE classes.

Declarations

Ethics approval and consent to participate

The Ethical Committee of Xi'an University of Architecture and Technology approved the study protocol. Written informed consent was obtained from all participants and their parents to participate in this study.

Consent for publication

All authors provided their consent for publication.

Availability of data and materials

The dataset supporting the conclusions of this article are currently not available in the public domain but may be shared upon request. For further information on the data and materials used in this study, please contact the corresponding author.

Competing interests

All authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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Contributions

MeiBing L: data processing, drafting the initial manuscript, revision the manuscript, and final approval; ZhangZhi Q: data collecting, data cleaning, and discussed the manuscript; Chong T, XiaoYan H, and HaoNan G: discussed the manuscript with suggestions for revisions; HaiXia G: study design, supervision, revision critically, and final approval; HongJuan L: revision critically, and final approval. All authors reviewed and approved the final manuscript.

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