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Are preschool children active enough in Shanghai—An accelerometer-based cross-sectional study

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ABSTRACT

Objective: Engaging in physical activity (PA) play an important roles in promoting physical and mental health, but the PA data for Chinese preschool children are lacking. This study is aim to objectively assess the PA levels of preschool children in Shanghai, China and to evaluate their PA levels relative to age-specific recommendations.

Design, Setting and Participants: A cross-sectional study was conducted among preschool children in Shanghai city of China. There were a total of 303 preschool children (boys, 174; girls, 129) were recruited from eight kindergarten classes in the Yangpu and Baoshan Districts of Shanghai.

Main outcome measures: Daily PA was assessed using ActiGraph GT3X^{+} accelerometers for seven consecutive days. children were required to have data from at least two weekdays and one weekend day, with a minimum daily wear time of 480 min to be included in the analysis.

Results: Preschool children in Shanghai accumulated, on average, 70.9 minutes (min) of moderate-to-vigorous PA (MVPA) and 168.0 min of total PA (TPA) per day (d). Boys engaged in more MVPA and TPA than girls (72.8 min/d *vs.* 68.3 min/d and 171.9 min/d *vs.* 162.9 min/d, respectively). Overall, 72.9% of the participants met the age-specific recommendations of MVPA, while 35.3% met TPA recommendations.

Conclusions: Findings of this study warn of the insufficiency of PA in Shanghai preschool children, suggesting there is substantial room to improve their PA.

Key words: accelerometry, physical activity, preschool children.

Strength and limitation of this study

- Objective measures of daily physical activity were obtained by accelerometers in a sample of preschool children from Shanghai, China.
- Daily physical activity levels in Shanghai preschool children were evaluated by both moderate to vigorous physical activity and activity at any intensity recommended guidelines.
- For feasibility, this study sample was not a random sample recruited from the population.

INTRODUCTION

Engaging in physical activity (PA) and minimizing sedentary time play important roles in promoting physical, psychological, and cognitive health.[1] Moreover, establishing robust PA habits in childhood has positive long-term effects on lifestyle that persist into adulthood,[2] including reducing the risk of chronic diseases, such as coronary artery disease, diabetes, stroke, and hypertension. [3 4] Accordingly, US and Canadian PA guidelines for preschoolers suggest that, to achieve health benefits, children aged 3 to 6 years old should participate in at least 60 minutes (min) of moderate-to-vigorous PA (MVPA) or 180 min of activity at any intensity level per day (d), cumulatively.[5 6]

Researchers and public health professionals are interested in establishing what percentage of preschool children meet the aforementioned PA recommendations. Accelerometers can be used as an objective tool to facilitate and improve the accuracy of PA monitoring, overcoming the limitations of self-reported data from children and the potential for recall bias in proxy reports from parents or teachers.[7] Thus, accelerometers have become increasingly popular as a feasible strategy for capturing preschoolers' movement behavior accurately.[8]

Although there is a perception that preschool children are constantly active,[9] accelerometer-based evidence does not support this presumption for all children. In a sample of 3–5-year-old Canadian children, only 13.7% of participants met the PA recommendation for at least 60 min per day of MVPA.[10] In a similar study of Australian preschool aged children, 22% of the sample met this guideline.[11] Moreover,

a meta-analysis of 29 reports encompassing 6,309 preschool children in Canada and Australia yielded an average daily MVPA of only 42.8 (95% CI: 28.9–56.8) min.[12] As of yet, accelerometer-based PA data for Chinese preschool children are lacking.

The aim of this study was to assess PA levels quantitatively in a sample of preschool aged children in Shanghai, China with accelerometers and to determine the proportion of children meeting the aforementioned age-specific PA recommendations.

MATERIALS AND METHODS

Participants

This cross-sectional study forms a baseline dataset for The Physical Activity and Cognitive Function Study (Trial registration: ChiCTR-OOC-15007439), in which a total of 346 preschool children (boys, 201; girls, 145) were recruited from eight kindergarten classes in the Yangpu and Baoshan Districts of Shanghai, China. The aims and procedures of this study were explained comprehensively to the parents/guardians of all potential participants, including the right to withdraw from the study at any time. Signed informed consent forms were obtained from the participants' parents/guardians. This study was approved by the Ethics Advisory Committee of Shanghai University of Sport.

Measures and procedures

PA was assessed with GT3X$^+$ accelerometers (ActiGraph, Pensacola, FL), worn on the right hip attached to an elastic adjustable belt for seven consecutive days.

Parents or guardians agreed to have their children wear the accelerometers during all waking, including water-based activities such as bathing and swimming. They were instructed on the proper way to wear and remove the accelerometers, and asked to encourage their children to wear them as much as possible during their school hours. The accelerometers were collected at the end of a 7-d study period, and the accelerometer data were transferred to a computer via ActiLife version 6.11.6 software. Non-wear time was determined by the Choi algorithm;[13] children were required to have data from at least two weekdays and one weekend day, with a minimum daily wear time of 480 min to be included in the analysis. Based on these criteria, 43 participants were excluded from the final analysis.

Body mass index (BMI) was calculated with the formula weight/height^2 (kg/m^2). Based on his or her BMI, each child was categorized as normal, overweight, or obese based on the International Obesity Task Force scale.[14]

Interpretation of accelerometer data

Data were collected in 1-second epochs, because short epochs have been recommended for capturing movement behavior in this age group.[15] Raw output was expressed as counts per minute (CPM), and cut-off count levels previously developed for preschool children by Pate and colleagues were used to analyze MVPA time.[7] We classified PA into three levels: light (LPA), 101–1679 CPMs; moderate (MPA), 1680–3367 CPMs; and vigorous (VPA), ≥3368 CPMs. Total physical activity (TPA) was calculated as the sum of LPA, MPA, and VPA time periods. TPA values were

compared to the established recommendations of ≥60 min of MVPA or ≥180 min of PA at any intensity to evaluate the proportion of participants meeting these recommendations.

Data analysis

The data are reported as means ± standard deviations (SDs) for normally distributed variables or as medians with interquartile ranges (IQRs) for non-normally distributed variables. Independent *t* tests, Mann-Whitney *U* tests, and chi-square tests were used to assess gender differences in characteristics for normally distributed, non-normally distributed, and categorical variables, respectively. When necessary, PA data were normalized by a log or square root methods prior to analysis. Differences in PA by gender and day were determined with independent *t* tests, and differences in PA by BMI category were determined by one-way analysis of variance (ANOVA) with Bonferroni *post hoc* tests. Analyses were performed in SPSS version 22.0 (IBM Inc., Armonk, NY). A two-sided *P* value ≤ .05 was considered statistically significant.

RESULTS

Characteristics of participants

The descriptive characteristics of the 303 participants included in the present cohort analysis are shown in **Table 1.** Weight, BMI, and the proportion of overweight/obese children were significantly higher in boys than in girls.

The amount of different intensities of PA

On average, the number of valid accelerometer days among participants was 6.3 days (95%CI = 6.2–6.4 d), and the mean duration of wear time across all valid days was 748.7 min/d (95%CI = 740.3–756.7 min/d). The absolute and relative time spent engaged in CPM and each PA intensity level are presented in **Table 2**. On average, participants in this study accumulated 168.0 min/d of TPA, and spent 13.0% (~97.2 min) of their daily waking time engaged in LPA and 9.5% (~70.9 min) of their days was spent engaged in MVPA. In general, boys were more active than girls, and participants engaged in more PA on weekend days than on week days. No significant difference in PA was identified with respect to BMI category.

Meeting the current PA recommendations

Almost three quarters of the participants spent at least 60 min/d engaged in MVPA across all valid days, while only a little more than a third accumulated at least 180 min/d of PA at any intensity. Boys met the PA recommendations more frequently than girls (**Table 3**).

DISCUSSION

In this accelerometer-based cross-sectional study of preschool children in Shanghai, we found that, on average, boys accumulated 72.8 min/d of MVPA and 171.9 min/d of TPA, while girls accumulated 68.3 min/d of MVPA and 162.9 min/d of TPA. At least 27% of the participants did not meet the established PA guidelines.

Strengths and limitations

To the best of our knowledge, this is the first study to evaluate PA in Chinese preschool children with accelerometers, which eliminating the recall bias associated with other PA measurements. Additionally, our PA data were evaluated relative to both MVPA and TPA recommended guidelines.

This study had two noteworthy limitations. First, for sampling feasibility, all participants were recruited from Northeast Shanghai. Thus, it remains to be determined whether similar findings would be obtained for children in other regions of Shanghai. Second, the accelerometer was worn over the right hip limited to capture activities with little displacement of the body, such as cycling. However, hip was probably the best placement to capture whole-body movements and on the side of the hip was also the most often site by various studies.[16]

PA status of Shanghai preschoolers

Approximately 73% of participants in our Shanghai cohort met the recommendation of spending more than 60 min/d engaged in MVPA. However, less than 36% accumulated at least 180 min/d of TPA. The gap between these proportions is due largely to the shift from intensity to volume. The short 1-second sampling intervals used in this study may have resulted in an underestimation of LPA time, which would then yield an underestimation of TPA time, relative to, for example, a 15-second epoch. A longer epoch is more likely to result in an underestimation of MVPA and an overestimation of LPA in young children.[17] Notably, a Canadian study

with a much longer 60-second epoch found that 83.8% of young children met the 180 min/d TPA guideline,[10] while only 13.7% engaged in at least 60 min/d of MVPA. This methodological inconsistency makes it quite difficult to conduct reliable inter-study comparisons. Here, we chose a shorter epoch because it has been recommended for capturing movement in young children owing to the particularly sporadic and intermittent nature of activity exhibited by children in this age group.[18]

Differences in PA by gender, BMI category, and date

Our empirical findings that boys spent 6.6% more time engaged in MVPA and had 5.5% more TPA time than girls are consistent with our meta-analysis results. Trost et al. suggested that a similar gender gap in PA was attributed to a VPA difference, with boys spending approximately 45% more time engaged in VPA than girls in their study.[19] Meanwhile, Crespo et al. found that familial, social, and environmental characteristics correlated with higher MVPA in boys than in girls.[20] Possible factors in this gender gap to explore in future studies include parental modeling and location.

Our finding of similar PA data across normal-weight and overweight/obesity groups was somewhat surprising. Although we commonly thought that normal-weight children must be more active than those who overweight/obese, accelerometer-based evidence does not support this presumption for all studies.[21] Furthermore, the opposite findings are more likely to be ture in some studies.[22 23] These negative findings suggest that other factors, such as diet and genetic background, play more important roles in body weight. Future studies are needed to identify the relative importance of

and interactions among PA, diet, and genetics for weight status.

Our observation of greater PA on weekend days than on weekdays may be explained by participants having more opportunities to engage in PA on non-school days. Further studies should investigate and compare the specific activities engaged in on school days versus weekend days.

PA in Shanghai preschool children versus children elsewhere

Given the important of PA for physical, psychological, and cognitive health,[1] there is an increasing body of research focusing on the PA levels on preschool children from different population. Findings from a meta-analysis identified 29 studies indicated preschoolers' accelerometer-derived PA ranged from 19 min/d to 281 min/d.[24] However, the amounts of PA across different intensity levels varied widely depending upon the assessment methodology selected, with MVPA cut-off CPM levels having a particularly large effect on PA results.[25] Therefore, it is more reasonable to compare the results that using the same cut-off value for PA levels. Unfortunately, the amount of time spent engaged in MVPA in Shanghai preschool children lower than data for the most prior populations assessed with the same cut-off CPM levels by Pate (Range: 35.3-100.0 min/d; Median: 94.9 min/d).[21 26-34] The pattern of our TPA results was comparable to that of the MVPA results (Range: 73.7-394.0 min/d; Median: 348.0 min/d).[26-34]

Obviously, the results of this cross-sectional study indicate that Shanghai preschool children tend to have insufficient PA, and less PA than other populations

examined with the same cut-off CPM levels. Based on these data, we suggest that interventions may be needed to promote PA in Shanghai preschool children.

CONCLUSIONS

At least 27% of preschool children in Shanghai did not meet current age-specific PA recommendations and preschool children in Shanghai were less active than most of the populations assessed in comparable studies. These findings suggest that interventions should be explored to promote PA in Shanghai preschoolers given that the development of active lifestyle behaviors early in life are believed to yield health benefits that extend into adulthood.

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Author Contributions

Minghui Quan conceived and designed the study, analyzed the data and drafted the manuscript. Hanbin Zhang, Jiayi Zhang, Tang Zhou, Jinming Zhang, Guanggao Zhao, Hui Fang and Shunli Sun conducted the experiments and collected the data. Minghui Quan and Guanggao Zhao performed the literature search. Ru Wang and Peijie Chen advised on analysis and interpretation of the data, and critically revised the manuscript.

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Potential conflicts of interest

The authors declare that they have no conflicts to report.

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Table 1 Characteristics of participants with valid accelerometer data.

Characteristic	Boys (N = 174; 57.4%)	Girls (N = 129; 42.6%)	All (N = 303)
Mean age ± SD, months	58.3 ± 5.6	57.1 ± 5.3	57.8 ± 5.5
Mean height ± SD, cm	111.4 ± 5.0	110.3 ± 4.9	111.0 ± 5.0
Median weight (IQR), kg	20.6 (20.1–21.1)*	19.3 (18.8–19.8)	20.0 (19.7–20.4)
Median BMI (IQR), kg/m^2	16.5 (16.2–16.8)*	15.8 (15.5–16.1)	16.2 (16.0–16.4)
BMI category, %			
Normal	76.4*	86.8	80.9
Overweight	15.5*	10.1	13.2
Obesity	8.0*	3.1	5.9

Note: *$p < .05$, boys *vs.* girls.

Table 2 Analysis of time spent engaged in PA categories by gender, BMI category, and day.

Factor	Mean CPM ± SD (95% CI)	Mean PA by category ± SD, min/d (95%CI)				
		LPA	MPA	VPA	MVPA	TPA
Gender						
Boys	**498.3 ± 120.3***	**99.2 ± 18.4***	40.9 ± 9.7	**31.9 ± 10.7***	**72.8 ± 18.8***	**171.9 ± 34.0***
(N = 174)	(478.7–516.7)	(96.8–102.0)	(39.5–42.3)	(30.4–33.4)	(70.1–75.4)	(167.1–176.8)
Girls	468.0 ± 109.3	94.6 ± 15.9	38.8 ± 8.0	29.6 ± 8.6	68.3 ± 15.1	162.9 ± 27.6
(N = 129)	(447.3–486.2)	(91.8–97.3)	(37.3–40.1)	(28.0–31.1)	(65.7–70.9)	(158.0–167.6)
BMI						
Normal	484.7 ± 113.6	96.9 ± 17.4	39.8 ± 8.8	30.9 ± 9.6	70.7 ± 17.0	167.6 ± 31.1
(N = 245)	(470.0–501.4)	(94.7–99.1)	(38.7–41.0)	(29.7–32.0)	(68.7–72.9)	(163.8–171.5)
Overweight	476.0 ± 121.5	99.0 ± 18.2	40.0 ± 9.7	30.3 ± 10.9	70.3 ± 19.7	169.3 ± 35.5
(N = 40)	(437.3–514.6)	(93.5–104.9)	(37.1–43.4)	(27.1–34.0)	(64.4–76.9)	(158.2–181.2)
Obesity	509.9 ± 144.2	97.7 ± 16.9	42.1 ± 11.1	32.3 ± 12.1	74.4 ± 19.0	171.0 ± 32.4
(N= 18)	(444.0–580.5)	(89.3–105.2)	(37.4–47.2)	(26.7–37.9)	(65.7–83.0)	(156.0–186.4)
Type of day						
Week	**471.0 ± 117.4**†	96.4 ± 17.9	**39.3 ± 9.3**†	30.9 ± 9.9	70.2 ± 17.5	**166.6 ± 32.3**†
(N = 303)	(457.8–484.6)	(94.5–98.3)	(38.3-40.4)	(29.9–32.1)	(68.4–72.1)	(163.2–170.1)
Weekend	517.4 ± 166.2	98.6 ± 24.8	41.6 ± 12.0	30.6 ± 13.3	72.1 ± 24.0	170.6 ± 44.3
(N = 303)	(497.4–536.5)	(95.8–101.4)	(40.1-43.1)	(29.2–32.2)	(69.6–75.0)	(165.8–175.6)
ALL	485.0 ± 116.4	97.2 ± 17.5	40.0 ± 9.1	30.9 ± 9.9	70.9 ± 17.5	168.0 ± 31.7
(N = 303)	(472.6–500.0)	(95.2-–99.2)	(39.0-40.1)	(29.8–32.0)	(68.9–72.9)	(164.6–171.6)
Relative time, %	-----	13.1 ± 2.1	5.4 ± 1.1	4.2 ± 1.3	9.5 ± 2.2	22.6 ± 3.7
		(12.8–13.3)	(5.2–5.5)	(4.0–4.3)	(9.3–9.8)	(22.1–23.0)

Note: Mean ± SD and 95% CI are reported for normally distributed variables; Significant data are shown in bold; $^{*}p < .05$, boys *vs.* girls; $^{\dagger}p < .05$, weekdays *vs.* weekend days.

Table 3 Adherence to common established PA recommendations for preschool aged children.*

PA metric	Guideline target	Subjects, % (95%CI)		
		Boys (N = 174)	Girls (N = 129)	All (N = 303)
MVPA	≥60 min/d accumulated, averaged across valid d	74.1 (67.2–79.9)	71.3 (63.6–79.1)	72.9 (68.3–77.9)
TPA	≥180 min/d accumulated, averaged across valid d	42.0 (34.5–48.9)	26.4 (19.4–34.1)	35.3 (30.0–40.9)

Note: * $p < .05$, boys *vs.* girls.

Reporting checklist for cross sectional study.

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		Reporting Item	Page Number
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	#3	State specific objectives, including any prespecified hypotheses	5
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	6

	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	5-6
Bias	#9	Describe any efforts to address potential sources of bias	6
Study size	#10	Explain how the study size was arrived at	none
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	7
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	7
	#12b	Describe any methods used to examine subgroups and interactions	none
	#12c	Explain how missing data were addressed	none
	#12d	If applicable, describe analytical methods taking account of sampling strategy	none
	#12e	Describe any sensitivity analyses	none
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	7
	#13b	Give reasons for non-participation at each stage	6
	#13c	Consider use of a flow diagram	none
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	7

	#14b	Indicate number of participants with missing data for each variable of interest	6
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	8
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8
	#16b	Report category boundaries when continuous variables were categorized	None
	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	none
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	none
Key results	#18	Summarise key results with reference to study objectives	8
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	9
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	11-12
Generalisability	#21	Discuss the generalisability (external validity) of the study results	9-11
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

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Are preschool children active enough in Shanghai—An accelerometer-based cross-sectional study

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Are preschool children active enough in Shanghai—An accelerometer-based cross-sectional study

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ABSTRACT

Objective: Engaging in physical activity (PA) play an important roles in promoting physical and mental health, but the PA data for Chinese preschool children are lacking. This study is aim to objectively assess the PA levels of preschool children in Shanghai, China and to evaluate their PA levels relative to age-specific recommendations.

Design, Setting and Participants: A cross-sectional study was conducted among preschool children in Shanghai city of China. There were a total of 303 preschool children (boys, 174; girls, 129) were recruited from eight kindergarten classes in the Yangpu and Baoshan Districts of Shanghai.

Main outcome measures: Daily PA was assessed using ActiGraph GT3X^{+} accelerometers for seven consecutive days. children were required to have data from at least two weekdays and one weekend day, with a minimum daily wear time of 480 min to be included in the analysis.

Results: Preschool children in Shanghai accumulated, on average, 70.9 minutes (min) of moderate-to-vigorous PA (MVPA) and 168.0 min of total PA (TPA) per day (d). Boys engaged in more MVPA and TPA than girls (72.8 min/d *vs.* 68.3 min/d and 171.9 min/d *vs.* 162.9 min/d, respectively). Overall, 72.9% of the participants met the age-specific recommendations of MVPA, while 35.3% met TPA recommendations.

Conclusions: Findings of this study warn of the insufficiency of PA in Shanghai preschool children, suggesting there is substantial room to improve their PA.

Key words: accelerometry, physical activity, preschool children, meta-analysis.

Strength and limitation of this study

- Objective measures of daily physical activity were obtained by accelerometers in a sample of preschool children from Shanghai, China.
- Daily physical activity levels in Shanghai preschool children were evaluated by both moderate to vigorous physical activity and activity at any intensity recommended guidelines.
- For feasibility, this study sample was not a random sample recruited from the population.

INTRODUCTION

Engaging in physical activity (PA) play an important roles in promoting physical, psychological, and cognitive health.[1] Moreover, establishing robust PA habits in childhood has positive long-term effects on lifestyle that persist into adulthood,[2] including reducing the risk of chronic diseases, such as coronary artery disease, diabetes, stroke, and hypertension. [3 4] Accordingly, Canadian PA guideline for preschool children suggests that, to achieve health benefits, children aged 3 to 6 years old should participate in at least 180 minutes (min) of PA at any intensity and progression toward at least 60 min moderate-to-vigorous PA (MVPA) per day (d), cumulatively.[5]

Researchers and public health professionals are interested in establishing what percentage of preschool children meet the aforementioned PA recommendations. Accelerometers can be used as an objective tool to facilitate and improve the accuracy of PA monitoring, overcoming the limitations of self-reported data from children and the potential for recall bias in proxy reports from parents or teachers.[6] When compared with pedometer, accelerometer can provide the data not only about the total amount of daily activities, but also the pattern of daily activities,[7] which were considered to be more important to achieve health benefits based on the current PA guideline.[5] Thus, accelerometers have become increasingly popular as a feasible strategy for capturing preschoolers' movement behavior accurately.[8] Furthermore, accelerometer-based PA has become an important data source for examining the association between PA and health-related outcomes in recent years, even in the

national health survey with large sample size.[9 10]

Although there is a perception that preschool children are constantly active,[11] accelerometer-based evidence does not support this presumption for all children. In a sample of 3–5-year-old Canadian children, only 13.7% of participants met the PA recommendation for at least 60 min per day of MVPA.[12] In a similar study of Australian preschool aged children, 22% of the sample met this guideline.[13] Moreover, a meta-analysis of 29 reports encompassing 6,309 preschool children in Canada and Australia yielded an average daily MVPA of only 42.8 (95% CI: 28.9–56.8) min.[14] As of yet, accelerometer-based PA data for Chinese preschool children are lacking.

The aim of this study was to assess PA levels quantitatively in a sample of preschool aged children in Shanghai, China with accelerometers and to determine the proportion of children meeting the aforementioned age-specific PA recommendations. Findings of this study will help us to understand the PA levels from a sample of Shanghai, which may serve as a foundation for making strategies to maintain and promote PA for preschool children.

MATERIALS AND METHODS

Participants

This cross-sectional study forms a baseline dataset for The Physical Activity and Cognitive Function Study (Trial registration: ChiCTR-OOC-15007439), in which a convenience sample of 346participants (boys, 201; girls, 145) were recruited from eight kindergarten classes in the Yangpu and Baoshan Districts of Shanghai, China.

After contacting the kindergarten director by phone and interested in this study, the aims and procedures of this study were to explain comprehensively to the parents/guardians of all potential participants by parents' meeting held in the kindergarten, including the right to withdraw from the study at any time. Parents interested in having their children participate subsequently signed an informed consent document. The inclusion criteria for the participants in this study were: (1) aged 3-6 years; (2) without a diagnosed physical and mental disability; and (3) with signed informed consent from the participants' parents/guardians. This study was approved by the Ethics Advisory Committee of Shanghai University of Sport.

Procedures

Before accelerometer data collection, parents or guardians were instructed on the proper way to wear and remove the accelerometers by well-trained research staff. Parents or guardians agreed to have their children wear the accelerometers during all waking, including water-based activities such as bathing and swimming. And, Parents or guardians asked to encourage their children to wear them as much as possible during their school hours. The accelerometers were collected at the end of a consecutive 7-d study period, and the accelerometer data were transferred to a computer via ActiLife version 6.11.6 software.

Measures

Anthropometric data

Height and weight were measured with participants dressed in light clothing. Height was measured to the nearest 0.1 cm using a freestanding portable stadiometer, and weight was measured to the nearest 0.1 kg with an electronic weighting scale (HN-358, Omron, Tokyo, Japan). Body mass index (BMI) was calculated with the formula weight/height^2 (kg/m^2). Based on his or her BMI, each child was categorized as normal, overweight, or obese based on the International Obesity Task Force scale.[15]

Physical activity data

PA was assessed with GT3X$^+$ accelerometers (ActiGraph, Pensacola, FL), worn on the right hip attached to an elastic adjustable belt from 7 am to 11 pm every day for seven consecutive days. Non-wear time was determined by the Choi algorithm;[16] children were required to have data from at least two weekdays and one weekend day, with a minimum daily wear time of 480 min to be included in the analysis. Based on these criteria, 43 participants were excluded from the final analysis.

Data were collected in 1-second epochs, because short epochs have been recommended for capturing movement behavior in this age group.[17] Raw output was expressed as counts per minute (CPM), and cut-off count levels previously developed for preschool children by Pate and colleagues were used to analyze MVPA time.[6] We classified PA into three levels: light (LPA), 101–1679 CPMs; moderate (MPA), 1680–3367 CPMs; and vigorous (VPA), ≥3368 CPMs. Total physical activity (TPA) was calculated as the sum of LPA, MPA, and VPA time periods. PA values were compared to the established recommendations of ≥60 min of MVPA or ≥180 min of PA at any intensity to evaluate the proportion of participants meeting these

recommendations.

Data analysis

Assuming the coefficient of variation (CV) of MVPA ($CV = 0.28$) based on the previous study,[18] confidence level as 95%, and 5% level of precision, the required sample size was at least 125 in this study. The data are reported as means ± standard deviations (SDs) for normally distributed variables or as medians with interquartile ranges (IQRs) for non-normally distributed variables. Independent *t* tests, Mann-Whitney *U* tests, and chi-square tests were used to assess gender differences in characteristics for normally distributed, non- normally distributed, and categorical variables, respectively. When necessary, PA data were normalized by a log or square root methods prior to analysis. Differences in PA by gender and day were determined with independent *t* tests, and differences in PA by BMI category were determined by one-way analysis of variance (ANOVA) with Bonferroni *post hoc* tests. Analyses were performed in SPSS version 22.0 (IBM Inc., Armonk, NY). A two-sided *P* value $\leq .05$ was considered statistically significant.

Patient and public involvement

No patients or public were involved in this study.

RESULTS

Characteristics of participants

The descriptive characteristics of the 303 participants included in the present cohort analysis are shown in **Table 1.** Weight, BMI, and the proportion of overweight/obese children were significantly higher in boys than in girls.

The amount of different intensities of PA

On average, the number of valid accelerometer days among participants was 6.3 days (95%CI = 6.2–6.4 d), and the mean duration of wear time across all valid days was 748.7 min/d (95%CI = 740.3–756.7 min/d). The actual and percent time spent engaged in CPM and each PA intensity level are presented in **Table 2**. On average, participants in this study accumulated 168.0 min/d of TPA, and spent 13.0% (~97.2 min) of their daily waking time engaged in LPA and 9.5% (~70.9 min) of their days was spent engaged in MVPA. In general, boys were more active than girls, and participants engaged in more PA on weekend days than on week days. No significant difference in PA was identified with respect to BMI category.

Meeting the current PA recommendations

There were 72.9% of the participants met the MVPA recommendation that spent at least 60 min/d engaged in MVPA across all valid days, while only 35.3% of the participants met the TPA recommendation that accumulated at least 180 min/d of PA at any intensity. Boys met the PA recommendations more frequently than girls (**Table 3**).

DISCUSSION

In this accelerometer-based cross-sectional study of preschool children in Shanghai, we found that, on average, boys accumulated 72.8 min/d of MVPA and 171.9 min/d of TPA, while girls accumulated 68.3 min/d of MVPA and 162.9 min/d of TPA. At least 27% of the participants did not meet the established PA guidelines.

PA status of Shanghai preschoolers

Approximately 73% of participants in our Shanghai cohort met the recommendation of spending more than 60 min/d engaged in MVPA. However, less than 36% accumulated at least 180 min/d of TPA. The gap between these proportions is due largely to the shift from intensity to volume. The short 1-second sampling intervals used in this study may have resulted in an underestimation of LPA time, which would then yield an underestimation of TPA time, relative to, for example, a 15-second epoch. A longer epoch is more likely to result in an underestimation of MVPA and an overestimation of LPA in young children.[19] Notably, a Canadian study with a much longer 60-second epoch found that 83.8% of young children met the 180 min/d TPA guideline,[12] while only 13.7% engaged in at least 60 min/d of MVPA. This methodological inconsistency makes it quite difficult to conduct reliable inter-study comparisons. Here, we chose a shorter epoch because it has been recommended for capturing movement in young children owing to the particularly sporadic and intermittent nature of activity exhibited by children in this age group.[20]

Differences in PA by gender, BMI category, and date

Our empirical findings that boys spent 6.6% more time engaged in MVPA and had 5.5% more TPA time than girls are consistent with our meta-analysis results. Trost et al. suggested that a similar gender gap in PA was attributed to a VPA difference, with boys spending approximately 45% more time engaged in VPA than girls in their study.[21] Meanwhile, Crespo et al. found that familial, social, and environmental characteristics correlated with higher MVPA in boys than in girls.[22] Possible factors in this gender gap to explore in future studies include parental modeling and location.

Our finding of similar PA data across normal-weight and overweight/obesity groups was somewhat surprising. Although we commonly thought that normal-weight children must be more active than those who overweight/obese, accelerometer-based evidence does not support this presumption for all studies.[23] Furthermore, the opposite findings are more likely to be true in some studies.[24,25] These negative findings suggest that other factors, such as diet and genetic background, play more important roles in body weight. Future studies are needed to identify the relative importance of and interactions among PA, diet, and genetics for weight status.

Our observation of greater PA on weekend days than on weekdays may be explained by participants having more opportunities to engage in PA on non-school days. Further studies should investigate and compare the specific activities engaged in on school days versus weekend days.

PA in Shanghai preschool children versus children elsewhere

Given the important of PA for physical, psychological, and cognitive health,[1] there is an increasing body of research focusing on the PA levels on preschool children from different population. Findings from a meta-analysis identified 29 studies indicated preschoolers' accelerometer-derived PA ranged from 19 min/d to 281 min/d.[26] However, the amounts of PA across different intensity levels varied widely depending upon the assessment methodology selected, with MVPA cut-off CPM levels having a particularly large effect on PA results.[27] Therefore, it is more reasonable to compare the results that using the same cut-off value for PA levels. Unfortunately, the amount of time spent engaged in MVPA in Shanghai preschool children lower than data for the most prior populations assessed with the same cut-off CPM levels by Pate (Range: 35.3-100.0 min/d; Median: 94.9 min/d).[18 23 28-35] The pattern of our TPA results was comparable to that of the MVPA results (Range: 73.7-394.0 min/d; Median: 348.0 min/d).[18 28-35]

Obviously, the results of this cross-sectional study indicate that Shanghai preschool children tend to have insufficient PA, and less PA than other populations examined with the same cut-off CPM levels. Although the current Shanghai Preschool Education Curriculum Guide requires daily outdoor activities for preschool children to be no less than two hours,[36] we also suggest that interventions and policies may need to promote PA in Shanghai preschool children based on the data in this study. Similar to children, adolescents and adults, a variety of settings can promote the level of PA in children aged 3-5. However, in the early childhood stage, preschool is an

important settings for the promotion of PA.[37] Although the findings of PA intervention on preschool setting are inconsistent,[38-41] the extant literatures also provide us with some strategies that may be useful for promoting young children's PA levels. These included: (1) increasing time of outdoor activities, (2) providing materials that are easy to get and play, such as balls and hula hoops, and (3) activities held both indoor and outdoor by teacher-planned.[42] Furthermore, there was a growing evidence that technology applications, such as exergaming, seemed to be an effective approach to promote PA levels in children.[43-45] It should be noted that technology applications may be a viable supplemental way to promote PA levels in young children in preschool-based setting.

Strengths and limitations

To the best of our knowledge, this is the first study to evaluate PA in Chinese preschool children using accelerometers, which eliminating the recall bias associated with other PA measurements. Additionally, our PA data were evaluated relative to both MVPA and TPA recommended guidelines.

This study had some limitations. First, for sampling feasibility, all participants were recruited from Northeast Shanghai. Thus, it remains to be determined whether similar findings would be obtained for children in other regions of Shanghai. Second, the accelerometer was worn over the right hip limited to capture activities with little displacement of the body, such as cycling. However, hip was probably the best placement to capture whole-body movements and on the side of the hip was also the

most often site by various studies.[46] Third, the accelerometer-based PA collection process spans different seasons that may have an impact on the result, although the seasonal variation in accelerometer-determined PA was not always observed in different region's studies.[47]

CONCLUSIONS

At least 27% of preschool children in Shanghai did not meet current age-specific PA recommendations, and preschool children in Shanghai were less active than most of the populations assessed in comparable studies. Findings of this study implication that there remains a lot of room for improvement in PA behaviors among preschool children in Shanghai, particular in girls and weekday period. It was suggesting that public health interventions and policies regarding PA should be explored to promote PA levels in Shanghai preschoolers, given that the development of active lifestyle behaviors early in life are believed to yield health benefits that extend into adulthood.

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Author Contributions

Minghui Quan conceived and designed the study, analyzed the data and drafted the manuscript. Hanbin Zhang, Jiayi Zhang, Tang Zhou, Jinming Zhang, Guanggao Zhao, Hui Fang and Shunli Sun conducted the experiments and collected the data. Minghui Quan and Guanggao Zhao performed the literature search. Ru Wang and Peijie Chen advised on analysis and interpretation of the data, and critically revised the manuscript.

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Potential conflicts of interest

The authors declare that they have no conflicts to report.

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Table 1 Characteristics of participants with valid accelerometer data.

Characteristic	Boys (N = 174; 57.4%)	Girls (N = 129; 42.6%)	All (N = 303)
Mean age ± SD, months	58.3 ± 5.6	57.1 ± 5.3	57.8 ± 5.5
Mean height ± SD, cm	111.4 ± 5.0	110.3 ± 4.9	111.0 ± 5.0
Median weight (IQR), kg	20.6 (20.1–21.1)*	19.3 (18.8–19.8)	20.0 (19.7–20.4)
Median BMI (IQR), kg/m^2	16.5 (16.2–16.8)*	15.8 (15.5–16.1)	16.2 (16.0–16.4)
BMI category, %			
Normal	76.4*	86.8	80.9
Overweight	15.5*	10.1	13.2
Obesity	8.1*	3.1	5.9

Note: *$p < .05$, boys *vs.* girls.

Table 2 Analysis of time spent engaged in PA categories by gender, BMI category, and day.

Factor	Mean CPM ± SD (95% CI)	Mean PA by category ± SD, min/d (95%CI)				
		LPA	MPA	VPA	MVPA	TPA
Gender						
Boys	**498.3 ± 120.3***	**99.2 ± 18.4***	40.9 ± 9.7	**31.9 ± 10.7***	**72.8 ± 18.8***	**171.9 ± 34.0***
(N = 174)	(478.7–516.7)	(96.8–102.0)	(39.5–42.3)	(30.4–33.4)	(70.1–75.4)	(167.1–176.8)
Girls	468.0 ± 109.3	94.6 ± 15.9	38.8 ± 8.0	29.6 ± 8.6	68.3 ± 15.1	162.9 ± 27.6
(N = 129)	(447.3–486.2)	(91.8–97.3)	(37.3–40.1)	(28.0–31.1)	(65.7–70.9)	(158.0–167.6)
BMI						
Normal	484.7 ± 113.6	96.9 ± 17.4	39.8 ± 8.8	30.9 ± 9.6	70.7 ± 17.0	167.6 ± 31.1
(N = 245)	(470.0–501.4)	(94.7–99.1)	(38.7–41.0)	(29.7–32.0)	(68.7–72.9)	(163.8–171.5)
Overweight	476.0 ± 121.5	99.0 ± 18.2	40.0 ± 9.7	30.3 ± 10.9	70.3 ± 19.7	169.3 ± 35.5
(N = 40)	(437.3–514.6)	(93.5–104.9)	(37.1–43.4)	(27.1–34.0)	(64.4–76.9)	(158.2–181.2)
Obesity	509.9 ± 144.2	97.7 ± 16.9	42.1 ± 11.1	32.3 ± 12.1	74.4 ± 19.0	171.0 ± 32.4
(N= 18)	(444.0–580.5)	(89.3–105.2)	(37.4–47.2)	(26.7–37.9)	(65.7–83.0)	(156.0–186.4)
Type of day						
Week	**471.0 ± 117.4†**	96.4 ± 17.9	**39.3 ± 9.3†**	30.9 ± 9.9	70.2 ± 17.5	**166.6 ± 32.3†**
(N = 303)	(457.8–484.6)	(94.5–98.3)	(38.3-40.4)	(29.9–32.1)	(68.4–72.1)	(163.2–170.1)
Weekend	517.4 ± 166.2	98.6 ± 24.8	41.6 ± 12.0	30.6 ± 13.3	72.1 ± 24.0	170.6 ± 44.3
(N = 303)	(497.4–536.5)	(95.8–101.4)	(40.1-43.1)	(29.2–32.2)	(69.6–75.0)	(165.8–175.6)
ALL	485.0 ± 116.4	97.2 ± 17.5	40.0 ± 9.1	30.9 ± 9.9	70.9 ± 17.5	168.0 ± 31.7
(N = 303)	(472.6–500.0)	(95.2-–99.2)	(39.0-40.1)	(29.8–32.0)	(68.9–72.9)	(164.6–171.6)
Percentage time spent in different intensities of PA, %	-----	13.1 ± 2.1 (12.8–13.3)	5.4 ± 1.1 (5.2–5.5)	4.2 ± 1.3 (4.0–4.3)	9.5 ± 2.2 (9.3–9.8)	22.6 ± 3.7 (22.1–23.0)

Note: LPA, light physical activity; MPA, moderate physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; TPA, total physical activity; VPA, vigorous physical activity; Mean ± SD and 95% CI are reported for normally distributed variables; Significant data are shown in bold; *$p < .05$, boys *vs.* girls; †$p < .05$, weekdays *vs.* weekend days.

Table 3 Adherence to common established PA recommendations for preschool aged children.*

PA metric	Guideline target	Participants, % (95%CI)		
		Boys (N = 174)	Girls (N = 129)	All (N = 303)
MVPA	≥60 min/d accumulated, averaged across valid d	74.1 (67.2–79.9)	71.3 (63.6–79.1)	72.9 (68.3–77.9)
TPA	≥180 min/d accumulated, averaged across valid d	42.0 (34.5–48.9)	26.4 (19.4–34.1)	35.3 (30.0–40.9)

Note: MVPA, moderate to vigorous physical activity; PA, physical activity; TPA, total physical activity;

* $p < .05$, boys *vs.* girls.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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		Reporting Item	Page Number
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	#3	State specific objectives, including any prespecified hypotheses	5
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	6

	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-7
Bias	#9	Describe any efforts to address potential sources of bias	6
Study size	#10	Explain how the study size was arrived at	8
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	8
	#12b	Describe any methods used to examine subgroups and interactions	none
	#12c	Explain how missing data were addressed	none
	#12d	If applicable, describe analytical methods taking account of sampling strategy	8
	#12e	Describe any sensitivity analyses	none
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	8
	#13b	Give reasons for non-participation at each stage	8
	#13c	Consider use of a flow diagram	none
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	8

	#14b	Indicate number of participants with missing data for each variable of interest	9
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	9
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-10
	#16b	Report category boundaries when continuous variables were categorized	10-11
	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	none
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	none
Key results	#18	Summarise key results with reference to study objectives	12-13
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	10-13
Generalisability	#21	Discuss the generalisability (external validity) of the study results	14
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

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Are preschool children active enough in Shanghai—An accelerometer-based cross-sectional study

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Are preschool children active enough in Shanghai—An accelerometer-based cross-sectional study

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ABSTRACT

Objective: Engaging in physical activity (PA) play an important role in promoting physical and mental health, but the PA data for Chinese preschool children are lacking. This study is aims to objectively assess the PA levels of preschool children in Shanghai, China and to evaluate their PA levels relative to age-specific recommendations.

Design, Setting and Participants: A cross-sectional study was conducted among preschool children in Shanghai city of China. There were a total of 303 preschool children (boys, 174; girls, 129) were recruited from eight kindergarten classes in the Yangpu and Baoshan Districts of Shanghai.

Main outcome measures: Daily PA was assessed using ActiGraph GT3X^{+} accelerometers for seven consecutive days. children were required to have data from at least two weekdays and one weekend day, with a minimum daily wear time of 480 min to be included in the analysis.

Results: Preschool children in Shanghai accumulated, on average, 70.9 minutes (min) of moderate-to-vigorous PA (MVPA) and 168.0 min of total PA (TPA) per day (d). Boys engaged in more MVPA and TPA than girls (72.8 min/d *vs.* 68.3 min/d and 171.9 min/d *vs.* 162.9 min/d, respectively). Overall, 72.9% of the participants met the age-specific recommendations of MVPA, while 35.3% met TPA recommendations.

Conclusions: Findings of this study warn of the insufficiency of PA in Shanghai preschool children, suggesting there is substantial room to improve their PA.

Key words: accelerometry, physical activity, preschool children.

Strength and limitation of this study

- Objective measures of daily physical activity were obtained by accelerometers in a sample of preschool children from Shanghai, China.
- Daily physical activity levels in Shanghai preschool children were evaluated by both moderate to vigorous physical activity and activity at any intensity recommended guidelines.
- For feasibility, this study sample was not a random sample recruited from the population.

INTRODUCTION

Engaging in physical activity (PA) play an important role in promoting physical, psychological, and cognitive health.[1] Moreover, establishing robust PA habits in childhood has positive long-term effects on lifestyle that persist into adulthood,[2] including reducing the risk of chronic diseases, such as coronary artery disease, diabetes, stroke, and hypertension. [3 4] Accordingly, Canadian PA guideline for preschool children suggests that, to achieve health benefits, children aged 3 to 6 years old should participate in at least 180 minutes (min) of PA at any intensity and progression toward at least 60 min moderate-to-vigorous PA (MVPA) per day (d), cumulatively.[5]

Researchers and public health professionals are interested in establishing what percentage of preschool children meet the aforementioned PA recommendations. Accelerometers can be used as an objective tool to facilitate and improve the accuracy of PA monitoring, overcoming the limitations of self-reported data from children and the potential for recall bias in proxy reports from parents or teachers.[6] When compared with pedometer, accelerometer can provide the data not only about the total amount of daily activities, but also the pattern of daily activities,[7] which were considered to be more important to achieve health benefits based on the current PA guideline.[5] Thus, accelerometers have become increasingly popular as a feasible strategy for capturing preschoolers' movement behavior accurately.[8] Furthermore, accelerometer-based PA has become an important data source for examining the association between PA and health-related outcomes in recent years, even in the

national health survey with large sample size.[9 10]

Although there is a perception that preschool children are constantly active,[11] accelerometer-based evidence does not support this presumption for all children. In a sample of 3–5-year-old Canadian children, only 13.7% of participants met the PA recommendation for at least 60 min per day of MVPA.[12] In a similar study of Australian preschool aged children, 22% of the sample met this guideline.[13] Moreover, a meta-analysis of 29 reports encompassing 6,309 preschool children in Canada and Australia yielded an average daily MVPA of only 42.8 (95% CI: 28.9–56.8) min.[14] As of yet, objectively-measured PA data for Chinese preschool children are lacking. However, a questionnaire-based national survey in China reported that only 29.9% of the children and youth met the guideline of PA.[15] This phenomenon of lack of PA in children and youth may be more pronounced in the developed region. Take Shanghai, a highly-developed city in China, for example, it was only 18.4% of children and youth met the PA guideline in a representative sample.[16] Considered accelerometer-based PA data for Chinese preschool children are lacking so far, and the facts that many health-related benefits are achieved by regular PA. There is urgent need to objectively assess the PA levels in Chinese preschool children, especially in the developed regions like Shanghai.

Therefore, the aim of this study was to assess PA levels objectively in a sample of preschool aged children in Shanghai, China with accelerometers and to determine the proportion of children meeting the aforementioned age-specific PA recommendations. Findings of this study will help us to understand the levels of PA

from a sample of Shanghai, which may serve as a foundation for making strategies to maintain or promote PA for preschool children.

MATERIALS AND METHODS

Participants

This cross-sectional study forms a baseline dataset for The Physical Activity and Cognitive Function Study (Trial registration: ChiCTR-OOC-15007439), in which a convenience sample of 346participants (boys, 201; girls, 145) were recruited from eight kindergarten classes in the Yangpu and Baoshan Districts of Shanghai, China.

After contacting the kindergarten director by phone and interested in this study, the aims and procedures of this study were explained comprehensively to the parents/guardians of all potential participants by parents' meeting held in the kindergarten, including the right to withdraw from the study at any time. Parents interested in having their child participate subsequently signed an informed consent document. The inclusion criteria for the participants in this study were: (1) aged 3-6 years; (2) without a diagnosed physical and mental disability; and (3) with signed informed consent from the participants' parents/guardians. This study was approved by the Ethics Advisory Committee of Shanghai University of Sport.

Procedures

Before accelerometer data collection, parents or guardians were instructed on the proper way to wear and remove the accelerometers by trained research staff. Parents

or guardians agreed to have their children wear the accelerometers during all waking, including water-based activities such as bathing and swimming. And, Parents or guardians asked to encourage their children to wear them as much as possible during their school hours. The accelerometers were collected at the end of a consecutive 7-d study period, and the accelerometer data were transferred to a computer via ActiLife version 6.11.6 software.

Measures

Anthropometric data

Height and weight were measured with participants dressed in light clothing. Height was measured to the nearest 0.1 cm using a freestanding portable stadiometer, and weight was measured to the nearest 0.1 kg with an electronic weighting scale (HN-358, Omron, Tokyo, Japan). Body mass index (BMI) was calculated with the formula weight/height^2 (kg/m^2). Based on his or her BMI, each child was categorized as normal, overweight, or obese based on the International Obesity Task Force scale.[17]

Physical activity data

PA was assessed with GT3X$^+$ accelerometers (ActiGraph, Pensacola, FL), worn on the right hip attached to an elastic adjustable belt from 7 am to 11 pm every day for seven consecutive days. Non-wear time was determined by the Choi algorithm;[18] children were required to have data from at least two weekdays and one weekend day, with a minimum daily wear time of 480 min to be included in the analysis. Based on

these criteria, 43 participants were excluded from the final analysis.

Data were collected in 1-second epochs, because short epochs have been recommended for capturing movement behavior in this age group.[19] Raw output was expressed as counts per minute (CPM), and cut-off count levels previously developed for preschool children by Pate and colleagues were used to analyze MVPA time.[6] We classified PA into three levels: light (LPA), 101–1679 CPMs; moderate (MPA), 1680–3367 CPMs; and vigorous (VPA), ≥3368 CPMs. Total physical activity (TPA) was calculated as the sum of LPA, MPA, and VPA time periods. PA values were compared to the established recommendations of ≥60 min of MVPA or ≥180 min of PA at any intensity to evaluate the proportion of participants meeting these recommendations.

Data analysis

Assuming the coefficient of variation (CV) of MVPA ($CV = 0.28$) based on the previous study,[20] confidence level as 95%, and 5% level of precision, the required sample size was at least 125 in this study. The data are reported as means ± standard deviations (SDs) for normally distributed variables or as medians with interquartile ranges (IQRs) for non-normally distributed variables. Independent *t* tests, Mann-Whitney *U* tests, and chi-square tests were used to assess gender differences in characteristics for normally distributed, non- normally distributed, and categorical variables, respectively. When necessary, PA data were normalized by a log or square root methods prior to analysis. Differences in PA by gender and day were determined

with independent *t* tests, and differences in PA by BMI category were determined by one-way analysis of variance (ANOVA) with Bonferroni *post hoc* tests. Analyses were performed in SPSS version 22.0 (IBM Inc., Armonk, NY). A two-sided *P* value ≤ .05 was considered statistically significant.

Patient and public involvement

No patients or public were involved in this study.

RESULTS

Characteristics of participants

The descriptive characteristics of the 303 participants included in the present cohort analysis are shown in **Table 1.** Weight, BMI, and the proportion of overweight/obese children were significantly higher in boys than in girls.

The amount of different intensities of PA

On average, the number of valid accelerometer days among participants was 6.3 days (95%CI = 6.2–6.4 d), and the mean duration of wear time across all valid days was 748.7 min/d (95%CI = 740.3–756.7 min/d). The actual and percent time spent engaged in CPM and each PA intensity level are presented in **Table 2**. On average, participants in this study accumulated 168.0 min/d of TPA, and spent 13.0% (~97.2 min) of their daily waking time engaged in LPA and 9.5% (~70.9 min) of their days was spent engaged in MVPA. In general, boys were more active than girls, and participants engaged in more PA on weekend days than on week days. No significant

difference in PA was identified with respect to BMI category.

Meeting the current PA recommendations

There were 72.9% of the participants met the MVPA recommendation that spent at least 60 min/d engaged in MVPA across all valid days, while only 35.3% of the participants met the TPA recommendation that accumulated at least 180 min/d of PA at any intensity. Boys met the PA recommendations more frequently than girls (**Table 3**).

DISCUSSION

In this accelerometer-based cross-sectional study of preschool children in Shanghai, we found that, on average, boys accumulated 72.8 min/d of MVPA and 171.9 min/d of TPA, while girls accumulated 68.3 min/d of MVPA and 162.9 min/d of TPA. At least 27% of the participants did not meet the established PA guidelines.

PA status of Shanghai preschoolers

Approximately 73% of participants in our Shanghai cohort met the recommendation of spending more than 60 min/d engaged in MVPA. However, less than 36% accumulated at least 180 min/d of TPA. The gap between these proportions is due largely to the shift from intensity to volume. The short 1-second sampling intervals used in this study may have resulted in an underestimation of LPA time, which would then yield an underestimation of TPA time, relative to, for example, a

15-second epoch. A longer epoch is more likely to result in an underestimation of MVPA and an overestimation of LPA in young children.[21] Notably, a Canadian study with a much longer 60-second epoch found that 83.8% of young children met the 180 min/d TPA guideline,[12] while only 13.7% engaged in at least 60 min/d of MVPA. This methodological inconsistency makes it quite difficult to conduct reliable inter-study comparisons. Here, we chose a shorter epoch because it has been recommended for capturing movement in young children owing to the particularly sporadic and intermittent nature of activity exhibited by children in this age group.[22]

Differences in PA by gender, BMI category, and date

Our empirical findings that boys spent 6.6% more time engaged in MVPA and had 5.5% more TPA time than girls are consistent with meta-analysis results.[14] Trost et al. suggested that a similar gender gap in PA was attributed to a VPA difference, with boys spending approximately 45% more time engaged in VPA than girls in their study.[23] Meanwhile, Crespo et al. found that familial, social, and environmental characteristics correlated with higher MVPA in boys than in girls.[24] Possible factors in this gender gap to explore in future studies include parental modeling and location.

Our finding of similar PA data across normal-weight and overweight/obesity groups was somewhat surprising. Although we commonly thought that normal-weight children must be more active than those who overweight/obese, accelerometer-based evidence does not support this presumption for all studies.[25] Furthermore, the opposite findings are more likely to be true in some studies.[26 27] These negative findings

suggest that other factors, such as diet and genetic background, play more important roles in body weight. Future studies are needed to identify the relative importance of and interactions among PA, diet, and genetics for weight status.

Our observation of greater PA on weekend days than on weekdays may be explained by participants having more opportunities to engage in PA on non-school days. Further studies should investigate and compare the specific activities engaged in on school days versus weekend days.

PA in Shanghai preschool children versus children elsewhere

Given the important of PA for physical, psychological, and cognitive health,[1] there is an increasing body of research focusing on the PA levels on preschool children from different population. Findings from a meta-analysis identified 29 studies indicated preschoolers' accelerometer-derived PA ranged from 19 min/d to 281 min/d.[28] However, the amounts of PA across different intensity levels varied widely depending upon the assessment methodology selected, with MVPA cut-off CPM levels having a particularly large effect on PA results.[29] Therefore, it is more reasonable to compare the results that using the same cut-off value for PA levels. Unfortunately, the amount of time spent engaged in MVPA in Shanghai preschool children lower than data for the most prior populations assessed with the same cut-off CPM levels by Pate (Range: 35.3-100.0 min/d; Median: 94.9 min/d).[20 25 30-37] The pattern of our TPA results was comparable to that of the MVPA results (Range: 73.7-394.0 min/d; Median: 348.0 min/d).[20 30-37]

Obviously, the results of this cross-sectional study indicate that Shanghai preschool children tend to have insufficient PA, and less PA than other populations examined with the same cut-off CPM levels. Although the current Shanghai Preschool Education Curriculum Guide requires daily outdoor activities for preschool children to be no less than two hours,[38] we also suggest that interventions and policies may be needed to promote PA in Shanghai preschool children based on the data in this study. Similar to children, adolescents and adults, a variety of settings can promote the level of PA in children aged 3-5. However, in the early childhood stage, preschool is an important settings for the promotion of PA.[39] Although the findings of PA intervention on preschool setting are inconsistent,[40-43] the extant literatures also provide us with some strategies that may be useful for promoting PA levels of young children. These included: (1) increasing time of outdoor activities, (2) providing materials that are easy to get and play, such as balls and hula hoops, and (3) activities held both indoor and outdoor by teacher-planned.[44] Furthermore, there was a growing evidence that technology applications, such as exergaming, seem to be an effective approach to promote PA levels in children.[45-47] It should be noted that technology applications may be a viable supplemental way to promote PA levels in young children in preschool-based setting.

Strengths and limitations

To the best of our knowledge, this is the first study to evaluate PA in Chinese preschool children with accelerometers, which eliminating the recall bias associated

with other PA measurements. Additionally, our PA data were evaluated relative to both MVPA and TPA recommended guidelines.

This study had some limitations. First, for sampling feasibility, all participants were recruited from Northeast Shanghai. Thus, it remains to be determined whether similar findings would be obtained for children in other regions of Shanghai. Second, the accelerometer was worn over the right hip limited to capture activities with little displacement of the body, such as cycling. However, hip was probably the best placement to capture whole-body movements and on the side of the hip was also the most often site by various studies.[48] Third, the accelerometer-based PA collection process spans different seasons that may have an impact on the result, although the seasonal variation in accelerometer-determined PA was not always observed in different region's studies.[49]

CONCLUSIONS

At least 27% of preschool children in Shanghai did not meet current age-specific PA recommendations and preschool children in Shanghai were less active than most of the populations assessed in comparable studies. Findings of this study implication that there remains a lot of room for improvement in PA behaviors among preschool children in Shanghai, suggesting that public health interventions and policies regarding PA should be explored to promote PA levels in Shanghai preschoolers given that the development of active lifestyle behaviors early in life are believed to yield health benefits that extend into adulthood.

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Author Contributions

Minghui Quan conceived and designed the study, analyzed the data and drafted the manuscript. Hanbin Zhang, Jiayi Zhang, Tang Zhou, Jinming Zhang, Guanggao Zhao, Hui Fang and Shunli Sun conducted the experiments and collected the data. Minghui Quan and Guanggao Zhao performed the literature search. Ru Wang and Peijie Chen advised on analysis and interpretation of the data, and critically revised the manuscript.

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Potential conflicts of interest

The authors declare that they have no conflicts to report.

Data sharing statement

No additional data are available.

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Table 1 Characteristics of participants with valid accelerometer data.

Characteristic	Boys (N = 174; 57.4%)	Girls (N = 129; 42.6%)	All (N = 303)
Mean age ± SD, months	58.3 ± 5.6	57.1 ± 5.3	57.8 ± 5.5
Mean height ± SD, cm	111.4 ± 5.0	110.3 ± 4.9	111.0 ± 5.0
Median weight (IQR), kg	20.6 (20.1–21.1)*	19.3 (18.8–19.8)	20.0 (19.7–20.4)
Median BMI (IQR), kg/m^2	16.5 (16.2–16.8)*	15.8 (15.5–16.1)	16.2 (16.0–16.4)
BMI category, %			
Normal	76.4*	86.8	80.9
Overweight	15.5*	10.1	13.2
Obesity	8.1*	3.1	5.9

Note: $^*p < .05$, boys *vs.* girls.

Table 2 Analysis of time spent engaged in PA categories by gender, BMI category, and day.

Factor	Mean CPM ± SD (95% CI)	Mean PA by category ± SD, min/d (95%CI)				
		LPA	MPA	VPA	MVPA	TPA
Gender						
Boys (N = 174)	**498.3 ± 120.3*** (478.7–516.7)	**99.2 ± 18.4*** (96.8–102.0)	40.9 ± 9.7 (39.5–42.3)	**31.9 ± 10.7*** (30.4–33.4)	**72.8 ± 18.8*** (70.1–75.4)	**171.9 ± 34.0*** (167.1–176.8)
Girls (N = 129)	468.0 ± 109.3 (447.3–486.2)	94.6 ± 15.9 (91.8–97.3)	38.8 ± 8.0 (37.3–40.1)	29.6 ± 8.6 (28.0–31.1)	68.3 ± 15.1 (65.7–70.9)	162.9 ± 27.6 (158.0–167.6)
BMI						
Normal (N = 245)	484.7 ± 113.6 (470.0–501.4)	96.9 ± 17.4 (94.7–99.1)	39.8 ± 8.8 (38.7–41.0)	30.9 ± 9.6 (29.7–32.0)	70.7 ± 17.0 (68.7–72.9)	167.6 ± 31.1 (163.8–171.5)
Overweight (N = 40)	476.0 ± 121.5 (437.3–514.6)	99.0 ± 18.2 (93.5–104.9)	40.0 ± 9.7 (37.1–43.4)	30.3 ± 10.9 (27.1–34.0)	70.3 ± 19.7 (64.4–76.9)	169.3 ± 35.5 (158.2–181.2)
Obesity (N= 18)	509.9 ± 144.2 (444.0–580.5)	97.7 ± 16.9 (89.3–105.2)	42.1 ± 11.1 (37.4–47.2)	32.3 ± 12.1 (26.7–37.9)	74.4 ± 19.0 (65.7–83.0)	171.0 ± 32.4 (156.0–186.4)
Type of day						
Week (N = 303)	**471.0 ± 117.4†** (457.8–484.6)	96.4 ± 17.9 (94.5–98.3)	**39.3 ± 9.3†** (38.3-40.4)	30.9 ± 9.9 (29.9–32.1)	70.2 ± 17.5 (68.4–72.1)	**166.6 ± 32.3†** (163.2–170.1)
Weekend (N = 303)	517.4 ± 166.2 (497.4–536.5)	98.6 ± 24.8 (95.8–101.4)	41.6 ± 12.0 (40.1-43.1)	30.6 ± 13.3 (29.2–32.2)	72.1 ± 24.0 (69.6–75.0)	170.6 ± 44.3 (165.8–175.6)
ALL (N = 303)	485.0 ± 116.4 (472.6–500.0)	97.2 ± 17.5 (95.2-–99.2)	40.0 ± 9.1 (39.0-40.1)	30.9 ± 9.9 (29.8–32.0)	70.9 ± 17.5 (68.9–72.9)	168.0 ± 31.7 (164.6–171.6)
Percentage time spent in different intensities of PA, %	-----	13.1 ± 2.1 (12.8–13.3)	5.4 ± 1.1 (5.2–5.5)	4.2 ± 1.3 (4.0–4.3)	9.5 ± 2.2 (9.3–9.8)	22.6 ± 3.7 (22.1–23.0)

Note: LPA, light physical activity; MPA, moderate physical activity; MVPA, moderate to vigorous physical activity; PA, physical activity; TPA, total physical activity; VPA, vigorous physical activity; Mean ± SD and 95% CI are reported for normally distributed variables; Significant data are shown in bold; *$p < .05$, boys *vs.* girls; †$p < .05$, weekdays *vs.* weekend days.

Table 3 Adherence to common established PA recommendations for preschool aged children.*

PA metric	Guideline target	Participants, % (95%CI)		
		Boys (N = 174)	Girls (N = 129)	All (N = 303)
MVPA	≥60 min/d accumulated, averaged across valid d	74.1 (67.2–79.9)	71.3 (63.6–79.1)	72.9 (68.3–77.9)
TPA	≥180 min/d accumulated, averaged across valid d	42.0 (34.5–48.9)	26.4 (19.4–34.1)	35.3 (30.0–40.9)

Note: MVPA, moderate to vigorous physical activity; PA, physical activity; TPA, total physical activity; * $p < .05$, boys *vs.* girls.

Reporting checklist for cross sectional study.

Based on the STROBE cross sectional guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

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In your methods section, say that you used the STROBE cross sectional reporting guidelines, and cite them as:

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		Reporting Item	Page Number
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1
Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	#3	State specific objectives, including any prespecified hypotheses	5
Study design	#4	Present key elements of study design early in the paper	5
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants.	6

	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group. Give information separately for for exposed and unexposed groups if applicable.	6-7
Bias	#9	Describe any efforts to address potential sources of bias	6
Study size	#10	Explain how the study size was arrived at	8
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	8
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	8
	#12b	Describe any methods used to examine subgroups and interactions	none
	#12c	Explain how missing data were addressed	none
	#12d	If applicable, describe analytical methods taking account of sampling strategy	8
	#12e	Describe any sensitivity analyses	none
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	8
	#13b	Give reasons for non-participation at each stage	8
	#13c	Consider use of a flow diagram	none
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	8

	#14b	Indicate number of participants with missing data for each variable of interest	9
Outcome data	#15	Report numbers of outcome events or summary measures. Give information separately for exposed and unexposed groups if applicable.	9
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9-10
	#16b	Report category boundaries when continuous variables were categorized	10-11
	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	none
Other analyses	#17	Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses	none
Key results	#18	Summarise key results with reference to study objectives	12-13
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	13
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	10-13
Generalisability	#21	Discuss the generalisability (external validity) of the study results	14
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15