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Accelerometer-measured sedentary volume and bouts during the segmented school day among Chinese school students

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ABSTRACT

Background: This study examined sedentary volume and bouts of Chinese primary and middle school students during different segments of a school day and determined whether gender and school level are associated with their sedentary volume and bouts.

Methods: A total of 472 students participated in this study. Accelerometers were used to measure the sedentary volume and sedentary bouts of different durations (i.e., 1–4 min, 5–9 min and ≥10 min) during all segments.

Results: The participants spent the majority of their time in sitting (61.7%) and sitting bouts of ≥10 min (37.3%). They spent higher percentages of time in sitting during regular classes (76.7%) and out-of-school time (54.5%), and lower during physical education (PE) classes (32.2%), lunch break (35.4%) and recess (38.0%). The highest proportions of time were in sedentary bouts of ≥10 min during regular classes (50.2%), out-of-school time (28.0%) and lunch break (18.8%), while the greatest percentages occurred in sitting bouts of 1–4 min during PE class (16.4%) and recess (18.6%). Girls and middle school students had higher percentages of sedentary volume than boys and primary school students during most segments. They spent greater proportions of time in sitting bouts of ≥10 min during regular classes, lunch break, and out-of-school time, and higher proportions in sedentary bouts of 1–4 min than boys and primary students during PE classes.

Conclusion: Regular class and out-of-school time were identified as key segments for reducing sedentary volume and breaking up prolonged sitting. Interventions on interrupting prolonged sitting during lunch break should also be explored. Girls and middle school students should receive more attention in future interventions.

1. Introduction

Sedentary behaviour refers to any waking behaviour with an energy expenditure ≤1.5 METs (metabolic equivalent of tasks) when in a sitting or reclining posture.[1] School students exhibit a high prevalence of sedentary behaviour in many countries.[2] Sedentary volume (i.e., total amount of sedentary time) and bouts (i.e., a continuous period of sedentary time) are associated with health outcomes in school students.[3,4] Considerable evidence has shown that sitting for long periods is a risk factor for physical, social and mental health of school students.[5] However, the relationships between sedentary bouts and their health outcomes are less clear.[6]

A school day offers several segments for students to be sedentary. School is identified as a key setting contributing to their sedentary time. Students attend regular classes while mostly sitting for long periods to perform academic activities.[7] However, they may have opportunities to break up their prolonged sitting through different levels of physical activities during recess, lunch break and physical education (PE) classes.[8] Out-of-school time may also be a setting for students to accumulate sedentary time through doing homework, attending tutorial classes, reading books, watching television and surfing the Internet. Different segments may involve different amounts and bouts of sedentary time for students. Hence, detailed and objective description of their sedentary volume and bouts during different segments of a school day is necessary to understand how and when daily sitting time is accumulated.

Several studies have used accelerometers to quantify sedentary volume of school students in different segments across a school day.[8–16] Bailey et al. examined the distribution of sedentary time of 135 school children during different segments each day.[9] They found that the majority of sedentary time occurred during class and after-school time and less during morning recess, lunch break and school transport.[9] Gao et al. reported that elementary school students were sedentary for the majority of time.[12] After-school hours contributed the most sedentary time and PE/exergaming contributed the least.[12] da Costa et al. indicated that

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Grades 1–6 students spent most of time sitting during instructional time, recess and PE classes.[11] da Costa et al. identified class time as the segment with the most sitting time, followed by recess and PE classes.[8]

Limited studies have examined the sedentary bouts of school students during different periods in a school day.[17–20] Harrington et al. investigated the number of sedentary bouts of different durations (i.e., from less than 1 min to more than 40 min) during and after school hours in 15–18-year-old girls in Ireland.[19] The findings indicated that girls engaged in a greater number of longer sedentary bouts (> 20 min) during school than after-school hours.[19] Carson et al. longitudinally examined sedentary bouts lasting at least 10, 20, and 30 min during school hours, after-school hours and evening periods among 655 adolescent girls from Australia.[18] Almost all sedentary bouts were more prevalent during evening period than during school and after-school periods at both baseline and follow-up.[18] Verloigne et al. also examined the frequency and time spent in bouts of different durations (2–5, 5–10, 10–20, 20–30 and ≥ 30 min) during school, after school and evening period in Belgium.[20] The study found that students engaged in fewer sedentary bouts of nearly all durations during after-school hours compared to during school hours and evening period.[20] Arundell et al. compared sitting volume and sitting bouts of 297 adolescents from Australia during different periods of the day (i.e., early morning, mid-morning, morning break, late morning, lunch, early afternoon, late-afternoon, evening, school time, class time, and out-of-school time).[17] Findings showed that students spent the majority of their waking time sitting and much of this occurs in prolonged bouts.[17] Class time, school breaks, and evening are identified as periods that students spent the most time in prolonged sitting (≥10 min).[17] The above-mentioned studies compared sedentary bouts between school and out-of-school time but they did not consider specific in-school contexts (e.g., regular class, PE class and recess time). However, it is necessary to gain insights into what in-school settings are prone or resistant to prolonged sitting and which segments of the day may benefit from strategies to reduce prolonged sitting. Such details are important in forming more effective interventions and policies to reduce sedentary time of school students.

In addition to the need to better understand the distribution of sedentary volume and bouts across different segments of the school day, understanding the potential demographic differences across these segments to develop more supportive strategies to reduce sedentary time and break up prolonged sedentary bouts for specific subgroups of school students is also important. Differences in segmented sedentary volume by gender and age have been explored by several studies.[8,9,11,13,14] They have consistently reported that girls accumulated significantly more sedentary time than boys during most segments such as class time, recess, and lunch time.[8,9,11,13,14] Age was positively associated with sedentary time in most segments.[8,11] However, only one study, Arundell et al., examined gender differences in sedentary bouts across different periods and showed that girls had more prolonged sitting (≥10 min) than boys during school breaks and school hours.[17] More empirical evidence is required to explore the influence of some demographic factors on sedentary bouts across different segments.

Although the sedentary volume and bouts of students during different segments in school days has been explored in Western countries, the extension of these findings to Asian countries (e.g., China), which have different educational systems, remains unclear. Therefore, the primary purpose of this study is to explore sedentary volume and bouts of primary and middle school students in China during different segments of the school day such as regular class, PE class, recess, lunch break and out-of-school time. The secondary purpose is to determine whether there are gender and school-level differences exist in sedentary volume and bouts across different segments of the school day.

2. Research method

2.1. Participants and settings

This study was approved by the Institutional Review Board of Shanghai University of Sport (102772023RT090). A convenience sample of a primary (i.e., Grades 1–6 with students aged 6–12 years) and a middle school (i.e., Grades 7–8 with students aged 13–15 years) were selected from Wuhan, a city in the central part of China. Two classes were randomly selected from Grades 1–8. Grade 9 students were excluded because of their intensive study schedules. All students (n = 792) from the 16 selected classes were invited to participate in this study. Informed consent was sent to the students before data collection and eventually 641 students agreed to participate.

A school day consisted of five segments (i.e., regular class, PE class, recess, lunch break and out-of-school time) according to the timetables of two schools. The first four segments belong to in-school period. Regular classes include Chinese, mathematics, English, history, geography and politics classes, ranging from 240 to 380 min across a school day. Students generally sit in classroom and listen to teachers during regular class time. Recess refers to the break between two classes and comprises one long period (25–30 min) and five to six shorter periods (10 min each time). Students perform broadcast gymnastics in the playground or participate in sports activities organized by school teachers during the long recess but they are free to engage in different activities such as playing games, chatting with others or just sitting during the short recesses. Lunch break, ranging from 120 to 130 min, is arranged for lunch, break, napping and self-study. Students have lunch for 30 min, and then have a short break and 40–65 min nap time. Then, they read books or do assignments in the classrooms by themselves for 20–40 min. Each PE class lasts 40–45 min and has three parts: warm-up (5 min), sports skill teaching and practicing (30–35 min) and cool-down (5 min). Sports skills are taught by PE teachers in PE classes. Out-of-school time is defined as periods between waking time and the beginning of the school day, and between the end of the school day and bedtime, ranging from 365 to 525 min. Students spend some time in transport when going to school or return home. After school, they must do their homework and may participate in tutorial classes, recreational activities, reading books, watching television and so on if they have available spare time.

2.2. Measures of sedentary volume and bouts

Data were collected by the first author and two research assistants in June 2023. Sedentary volume and bouts were measured by using Actigraph wGT3X-BT accelerometer (Pensacola, FL, USA), secured on the right hip by an elastic band during waking hours for five consecutive school days except water-based activities. The sampling interval (epoch) in the present study was set at 60 s because it was reported to have better validity in measuring sedentary behaviour than a 5- and 15-s epoch.[21] Non-wear time was defined as a period of 20 consecutive minutes of zero counts from the vertical axis of the accelerometer.[22] Only participants with a minimum of 10 h of wear time per day for at least three days were included in the analyses.[23] The original sedentary data were extracted and processed using the ActiLife 6.13.4 software (Pensacola, FL, USA) and were truncated and matched to the time frames for each of the five segments per day based on the schools' timetables. A cut point of ≤100 counts per minute was used to define sedentary time because it exhibited excellent classification accuracy in the evaluation of sedentary behaviour in children and adolescents.[24] Nap time was excluded from sedentary time. The percentage of sedentary time per day and each segment was calculated as the minutes of daily and segmented sitting, divided by daily and segmented wear time, multiplied by 100.

Sedentary bouts in sedentary behaviour were also measured and calculated. Based on previous studies[3,25,26] and preliminary exploration of the samples' sedentary bouts, three sedentary bouts lasting 1–4 min,

5–9 min, and ≥10 min were identified. Longer bout durations (i.e., ≥20 and ≥ 30 min) were not included because low proportion of the participants engaged in these bouts during PE class and recess time (i.e., 10% of the sample or less) (see Table S1). A sedentary bout was defined as a continuous period (≥60 consecutive seconds) of sedentary time (≤100 cpm).[27,28] No tolerance was allowed in the sedentary bouts because previous studies have shown that interruptions can attenuate the inverse health effects of prolonged sedentary behaviour in children and adolescents.[29] Altenburg and colleagues examined the associations between different sedentary bouts lasting 0, 30 or 60 s and health indicators in children and found that a greater number of associations became significant when no tolerance was allowed within sedentary bouts.[30] The percentage of time spent in sedentary bouts per day and segment was calculated as sedentary time accumulated in different bouts per day and segment, divided by wear time per day and segment, multiplied by 100.

2.3. Covariates

Parental education, family income, BMI and accelerometer wear time were potential confounders. Questionnaires were distributed to collect information on students' gender, age, parental education, and family income. The height and weight of participants were measured by a portable instrument (GMCS-IV; Jianmin, Beijing, China). The values were accurate to 1 decimal place. BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Accelerometer wear time was extracted and calculated by the ActiLife software.

2.4. Data analysis

The data were analyzed using IBM SPSS 26.0 (IBM Corporation, Armonk, NY). Descriptive analyses were conducted to describe sedentary volume and bouts during all periods. Multilevel modelling was used to test for gender and school-level differences in sedentary variables during five segments, and because data were collected from only two schools, limiting variation between schools, a two-level model was used, with student as level one and class as level two. Two models were run for analyses. Model 1 included gender and school level as fixed effects. Model 2 additionally adjusted for parental education, family income, BMI, and accelerometer wear time. Class was added in all models as a random effect to account for the clustering of students within classes. Sedentary time, sedentary bouts of 1–4 min, 5–9 min and ≥10 min were dependent variables in separate models during each segment. Coefficients, 95% confidence intervals (CI) and *P*-values were calculated to assess gender and school-level differences in sedentary variables. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Descriptive statistics of participants

Among 641 participating students, two lost accelerometers and 169 did not cover three valid school days. The percentages of three, four, and five valid days were 22%, 32%, and 46%, respectively. Removal of these data resulted in a total of 472 participants aged 6–15 years included in the current analyses (257 boys and 215 girls, 198 primary and 274 middle school students). No significant differences were observed in the general characteristics between included and excluded participants. The mean wear time of students was 802.6 (SD = 72.3) min on a school day. On average, participants accumulated 493.9 min (61.7% of wear time) being sedentary for an entire school day. They spent the highest percentage of time in sedentary bouts lasting ≥10 min, with an average of 297.2 min (37.3% of wear time) in these bouts, and lower proportion in sedentary bouts of 1–4 min (104.2 min and 12.9% of segmented wear time) and 5–9 min (92.6 min and 11.5% of segmented wear time). The characteristics of the total sample, boys and girls, and primary and middle school students are tabulated in Table 1.

3.2. Sedentary volume and bouts during different segments

Fig. 1 shows the percentages of sedentary volume and sedentary bouts of different durations during specific segments of a school day. Students spent 13.0–238.2 min sitting in all segments, with higher percentage of sitting occurring during regular classes (76.7%) and out-of-school time (54.5%), and lower percentage occurring during PE classes (32.2%), lunch break (35.4%) and recess time (38.0%). In terms of sedentary bouts, students spent the greatest percentage of segmented wear time in sedentary bouts of ≥10 min during regular classes (50.2%), out-of-school time (28.0%) and lunch break (18.8%), and the highest percentage in sedentary bouts of 1–4 min during PE classes (16.4%) and recess time (18.6%).

3.3. Gender and school-level differences in sedentary volume and bouts during different segments

Table 2 shows multilevel modelling of gender and school-level differences in proportions of sedentary volume and sedentary bouts in each segment. Results showed that after adjusting for parental education, family income, BMI and accelerometer wear time, girls spent significantly higher percentage of segmented wear time in sedentary volume than boys during all segments such as regular classes (b = 5.1; 95% CI = 3.3, 7.0; $p < 0.001$), PE classes (b = 9.7; 95% CI = 7.1, 12.2; $p < 0.001$), recess (b = 10.2; 95% CI = 8.1, 12.3; $p < 0.001$), lunch break (b = 3.7; 95% CI = 2.2, 5.3; $p < 0.001$), and out-of-school time (b = 4.7; 95% CI = 3.2, 6.2; $p < 0.001$). Girls accumulated significantly higher percentage of segmented wear time in bouts of ≥10 min during regular classes (b = 7.8; 95% CI = 4.6, 10.9; $p < 0.001$), lunch break (b = 3.2; 95% CI = 1.6,

Table 1
Descriptive statistics of total sample, boys and girls, and primary and middle school students (M, SD).

	Total sample	Gender		School level	
		Boys	Girls	Primary-school students	Middle-school students
Age (years)	12.1 (2.4)	12.1 (2.5)	12.0 (2.3)	9.7 (1.9)	13.8 (0.7)
Height (cm)	153.9 (13.9)	155.4 (14.9)	152.0 (12.4)	142.1 (12.3)	162.4 (7.3)
Weight (kg)	47.6 (16.4)	48.9 (18.0)	45.8 (14.0)	34.7 (10.6)	56.9 (13.3)
BMI (kg/m^2)	20.4 (4.7)	20.5 (5.1)	20.2 (4.2)	18.9 (4.9)	21.5 (4.3)
Sedentary time					
Min (per day)	493.9 (109.6)	479.4 (110.2)	512.3 (105.6)	412.7 (80.3)	552.7 (88.4)
% (per day)	61.7 (13.2)	59.4 (12.9)	64.5 (12.9)	50.6 (9.0)	69.7 (9.3)
Sedentary bout 1–4 min					
Min (per day)	104.2 (34.7)	107.0 (32.4)	100.6 (36.9)	125.0 (23.8)	89.1 (33.5)
% (per day)	12.9 (4.0)	13.2 (3.7)	12.5 (4.2)	15.3 (2.7)	11.2 (3.8)
Sedentary bout 5–9 min					
Min (per day)	92.6 (23.0)	93.3 (23.1)	91.8 (22.8)	97.4 (17.4)	89.0 (25.7)
% (per day)	11.5 (2.6)	11.5 (2.6)	11.5 (2.5)	12.0 (2.0)	11.2 (2.9)
Sedentary bout≥10 min					
Min (per day)	297.2 (137.1)	279.0 (132.0)	320.0 (139.3)	190.3 (85.7)	374.5 (113.2)
% (per day)	37.3 (17.3)	34.7 (16.4)	40.5 (17.8)	23.3 (10.3)	47.4 (14.0)
Wear time (per day)	802.6 (72.3)	807.5 (71.7)	796.9 (72.9)	815.1 (59.5)	793.7 (79.1)

Note: % represents the proportion of wear time per day. Abbreviations: M, mean; SD, standard deviation.

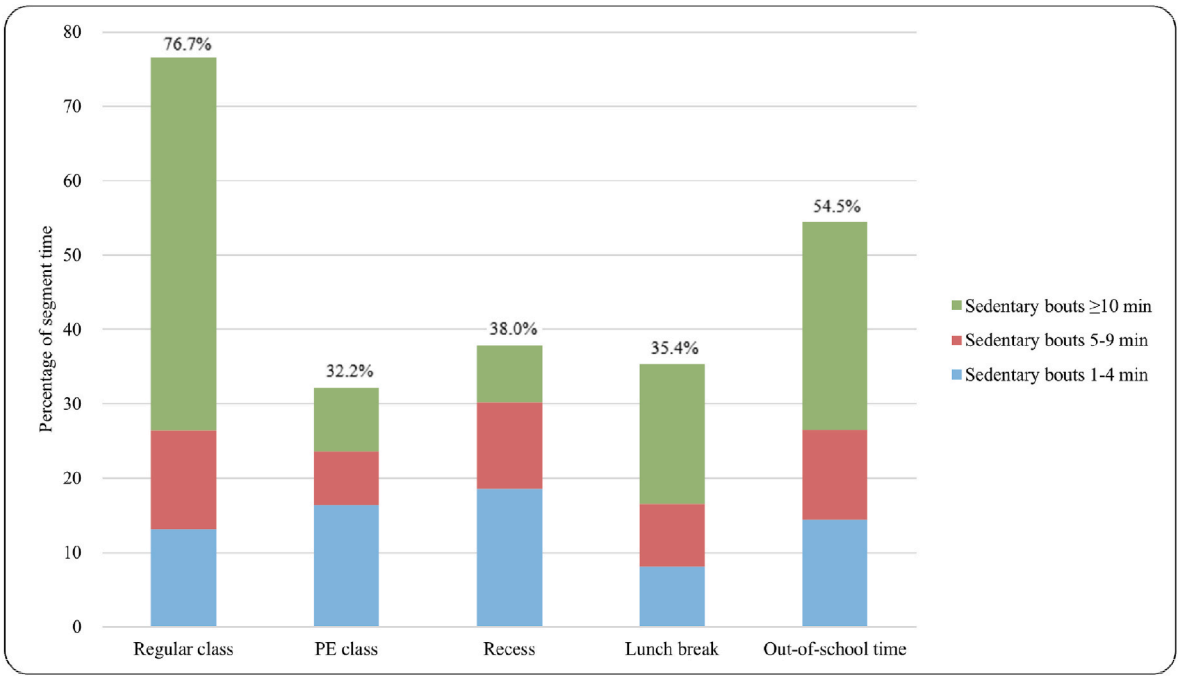

Fig. 1. Percentages of sedentary volume and bouts of different durations during specific segments on a school day.
Note: The percentage above each column represents the proportion of total sedentary time during each segment.

Table 2
Proportions of sedentary time and sedentary bouts in each segment of a school day by gender and school level (Coefficient, 95% CI).

	SED time		SED bout 1–4 min		SED bout 5–9 min		SED bout ≥10 min	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Regular class								
Gender[a]	6.1 (4.3, 7.9) **	5.1 (3.3, 7.0) **	−2.6 (−3.6, −1.6) **	−2.0 (−3.0, −1.0) **	−1.2 (−2.0, −0.3) *	−0.7 (−1.6, 0.2)	9.9 (6.7, 13.0) **	7.8 (4.6, 10.9) **
School level[b]	20.0 (15.3, 24.8) **	29.1 (22.3, 36.0) **	−9.0 (−11.3, −6.6) **	−15.1 (−18.6, −11.5) **	−4.3 (−5.5, −3.1) **	−8.5 (−11.0, −6.0) **	33.3 (25.5, 41.1) **	52.7 (41.3, 64.1) **
PE class								
Gender[a]	9.8 (7.3, 12.4) **	9.7 (7.1, 12.2) **	5.5 (4.0, 7.1) **	5.5 (3.9, 7.0) **	2.1 (0.6, 3.6) **	2.1 (0.5, 3.6) **	2.2 (0.0, 4.5) *	2.2 (−0.1, 4.4)
School level[b]	6.2 (−9.5, 22.0)	5.2 (−10.5, 20.8)	4.7 (0.8, 8.7) *	5.0 (1.1, 8.9) *	1.9 (−2.0, 5.8)	−1.7 (−2.3, 5.6)	−0.5 (−15.4, 14.4)	−1.5 (−16.5, 13.6)
Recess								
Gender[a]	10.5 (8.4, 12.6) **	10.2 (8.1, 12.3) **	3.0 (2.2, 3.8) **	3.1 (2.2, 3.9) **	4.0 (2.9, 5.1) **	3.8 (2.7, 4.9) **	3.3 (2.0, 4.5) **	3.1 (1.9, 4.3) **
School level[b]	20.6 (12.6, 28.6) **	31.9 (20.1, 43.6) **	6.0 (3.6, 8.4) **	5.1 (1.4, 8.7) **	7.2 (4.2, 10.2) **	16.1 (10.9, 21.3) **	7.7 (4.6, 10.8) **	13.4 (7.8, 19.0) **
Lunch break								
Gender[a]	4.2 (2.6, 5.7) **	3.7 (2.2, 5.3) **	0,1 (−0.4, 0.7)	0.1 (−0.5, 0.6)	0.7 (−0.1, 1.4)	0.4 (−0.3,1.2)	3.4 (1.7, 5.0) **	3.2 (1.6, 4.9) **
School level[b]	25.4 (23.0, 27.7) **	28.4 (24.7, 32.0) **	1.3 (−0.1, 2.8)	2.2 (0.3, 4.1) *	3.6 (2.4, 4.9) **	6.0 (4.1, 7.9) **	20.4 (17.4, 23.4) **	20.4 (16.1, 24.6) **
Out-of-school time								
Gender[a]	5.2 (3.6, 6.7) **	4.7 (3.2, 6.2) **	−0.3 (−1.0, 0.3)	−0.3 (−0.9, 0.4)	0.5 (−0.1, 1.1)	0.5 (−0.1, 1.0)	5.0 (3.1, 6.9)	4.5 (2.7, 6.4) **
School level[b]	13.7 (8.8, 18.6) **	8.1 (2.8, 13.3) **	−1.3 (−2.4, −0.2) *	−1.7 (−3.1, −0.3) *	1.3 (0.6, 2.1) **	−0.2 (−1.4, 0.9)	13.7 (8.4, 19.1) **	9.9 (3.9, 15.8) **

Note: [a] Boys are the referent group, [b] Primary school students are the referent group.
Model 1 included gender and school level as fixed factors, Model 2 included additional adjustment for parental education, family income, BMI and accelerometer wear time. Abbreviations: CI, confidence interval; SED, sedentary. *$p < 0.05$; **$p < 0.01$.

4.9; $p < 0.001$) and out-of-school time (b = 4.5; 95% CI = 2.7, 6.4; $p < 0.001$), which contributed to more sedentary time of girls than boys during these segments. Girls spent significantly higher percentage of segmented wear time in bouts of 1–4 min (b = 5.5; 95% CI = 3.9, 7.0; $p < 0.001$) and 5–9 min (b = 2.1; 95% CI = 0.5, 3.6; $p = 0.008$) compared with boys, leading to the girls having more sedentary time than boys in PE classes. In addition, girls spent significantly greater percentage of segmented wear time in all three sedentary bouts including 1–4 min (b = 3.1; 95% CI = 2.2, 3.9; $p < 0.001$), 5–9 min (b = 3.8; 95% CI = 2.7, 4.9; $p < 0.001$), and ≥10 min (b = 3.1; 95% CI = 1.9, 4.3; $p < 0.001$) than boys during recess time.

Significant school-level differences in sedentary volume and bouts were found among all segments except PE classes. Middle school students spent significantly higher percentage of segmented wear time in

sedentary volume than primary school students during regular classes (b = 29.1; 95% CI = 22.3, 36.0; $p < 0.001$), recess (b = 31.9; 95% CI = 20.1, 43.6; $p < 0.001$), lunch break (b = 28.4; 95% CI = 24.7, 32.0; $p < 0.001$) and out-of-school time (b = 8.1; 95% CI = 2.8, 13.3; $p = 0.005$), but no significant difference was observed during PE classes (b = 5.2; 95% CI = −10.5, 20.8; $p = 0.486$). Middle school students spent higher percentage of segmented wear time in sedentary bouts of ≥10 min than primary school students during regular classes (b = 52.7; 95% CI = 41.3, 64.1; $p < 0.001$), lunch break (b = 20.4; 95% CI = 16.1, 24.6; $p < 0.001$) and out-of-school time (b = 9.9; 95% CI = 3.9, 15.8; $p = 0.002$), which contributed to more sedentary time of middle school students than primary school students during these segments. Middle school students had higher percentage of segment time in all sedentary bouts, such as bouts of 1–4 min (b = 5.1; 95% CI = 1.4, 8.7; $p = 0.008$), 5–9 min (b = 16.1; 95% CI = 10.9, 21.3; $p < 0.001$) and ≥10 min (b = 13.4; 95% CI = 7.8, 19.0; $p < 0.001$) than primary school students during recess time. Additionally, middle school students spent higher percentage of segmented wear time in sedentary bouts of 1–4 min (b = 5.0; 95% CI = 1.1, 8.9; $p = 0.016$) than primary school students in PE classes, but it did not result in more sedentary time of middle school students than primary school students during this segment.

4. Discussion

This study examined objectively measured volume and bouts of sedentary behaviour among school students during different segments of a school day. Findings showed that students spent the majority (61.7%) of their daily accelerometer-wear time in sedentary behaviour during a school day. It is consistent with previous studies that showed 55%–75% of daily time in accelerometer measured sedentary behaviour during weekdays.[17,18,20,31] Moreover, sedentary bouts lasting more than 10 min were more common among students (37.3% of wear time) compared with sitting bouts of 1–4 min (12.9%) and 5–9 min (11.5%), indicating that students were generally engaged in prolonged sitting in the current study. The results differ from those of Carson et al. and Verlogine et al. who reported that students in Canada and Belgium accumulated 6% and 25% of daily accelerometer wear time in ≥10 min sitting bouts, respectively.[20,32] Interventions are necessary to reduce daily sedentary time of school students and break up their prolonged sitting behaviour in China.

Findings showed that regular class and out-of-school time are the two key settings contributing most to daily sedentary time. Moreover, students spent the highest percentage of segmented wear time in prolonged sedentary bouts (≥10 min) under these two settings. In the current study, students are the most physically inactive in regular classes, which is consistent with previous research reporting that children spent more than 70% of class time in sedentary behaviour[9,14,33–37] and much of this occurred in prolonged sitting bouts.[36] This finding is understandable because students are restricted in sitting for most of the class time.[38] Moreover, teachers in China are used to adopting teacher-centred instructional approaches in their classes characterized by few teacher-student and student-student interactions.[39] Classroom discipline is also addressed in Chinese schools which requires students to continuously sit still and listen to teachers' lecture in classes.[39] These distinctive instructional approaches and classroom requirements may deprive students of possible opportunities to break up sitting (e.g., standing up to interact with teachers, moving to discuss with classmates and walking around to engage in group work) during regular classes.

Out-of-school time is unstructured, and students are free to arrange their activities. However, considerable prolonged sedentary behaviour was also observed, possibly due to the change of commute mode, high academic learning burden, and involvement in screen-based activities. First, private vehicles are widely used by Chinese urban families, replacing students' active commuting time with continuous sitting in the car.[40] Second, students spend a considerable amount of out-of-school time on academic learning because of high academic burden, which requires them to sit for continuous learning.[41] Third, the popularization of electronic products (e.g., televisions, mobile phones and digital tablets) has resulted in more screen-based prolonged sedentary time of students out of school.[42]

These findings suggest that the total volume of sedentary time that students engage in and how this sedentary time is spent during regular classes and out-of-school time are considerable problems that need to be addressed. Therefore, future interventions that aim to reduce and break up prolonged sitting in school and family settings should be considered, such as standing classroom, active breaks during class time, incorporating family walks or active games into family daily routine with their children by parents and reminding children of interrupting their continuous sitting at home by parents.

Findings in PE class, lunch break and recess time are more optimistic. Students are the most active during PE classes compared to other segments, achieving the lowest percentage of segmented wear time (32.2%) spent in sitting with the highest percentage (16.4%) accumulated in shorter bouts (1–4 min). It is unsurprising because PE classes are designed for students to be physically active.[11] Moreover, the sedentary proportion in PE classes in the current study is generally lower than other Western studies which showed 41%–76% of PE class time in sedentary behaviour.[8,14,43] A group of factors may influence their sedentary volume and bouts in PE classes, such as, PE class environment, teaching experience, expertise and teaching behaviours of PE teachers, class size, PE activities, students' PE motivation, class organization and so on.[44,45] Future studies are needed to identify factors determining students' sedentary volume and bouts in PE classes in China. Additionally, students spent low percentage of segmented wear time (38.0% and 35.4%) in sitting during recess and lunch break. Meanwhile, students had the highest proportion of time (18.6%) in shorter bouts (1–4 min) during recess time, while the greatest percentage of time (18.8%) was spent in longer bouts (≥10 min) during lunch break. Recess time is unstructured, and children can spontaneously choose their activities. It provides opportunities to keep them physically active and break up their prolonged sitting. However, the possible reason for low proportion of sedentary time during lunch break is that almost half of lunch time was spent in napping. Therefore, it cannot be concluded that students are physically active during lunch time. The greatest percentage of sedentary time being spent in prolonged sitting bouts (≥10 min) confirmed that students are not active during this segment. Students in China eat lunch and study in the classroom during their lunch breaks confining them to unbroken sitting. As a result, encouraging students to break up prolonged sitting with physical activities during lunch time should also be taken seriously.

The current study shows that girls had significantly more sedentary time than boys during all segments, which is in line with previous studies.[8,9,11,13,14] Girls are expected to be gentle and quiet while boys are supposed to be active and aggressive in China influenced by Chinese traditional culture, which may result in the gender difference in their sedentary time.[46] Meanwhile, middle school students spent more time sitting than primary school students during all segments except PE classes. Upon entering middle schools, students face more challenges, including preparing for the high school entrance examinations in China. They must study harder than primary school students to obtain academic achievements, which could possibly lead to more sedentary time in learning during regular classes, out-of-school time and even in recess and lunch break.[41,47] The current study also found that girls and middle school students spent higher proportions of time in sedentary bouts of ≥10 min than boys and primary school students during regular classes, lunch break and out-of-school time. This finding is consistent with the characteristics of sedentary bouts in these segments, in which students presented longer and uninterrupted sedentary bouts. However, no significant school-level difference in sitting time during PE classes was observed. This finding is not unexpected because the teaching content, teaching approach and students' activities in PE classes are not affected by the increased academic burden of students from primary to middle

school. These findings suggested girls and middle school students should receive more attention and consideration in interventions to reduce sedentary volume and interrupt prolonged sitting during regular classes, lunch break and out-of-school time and decrease total sedentary time during recess.

5. Strength and limitations

This study is the first to objectively measure sedentary volume and bouts during specific segments of school days in China. However, it has some limitations that need to be acknowledged. First, the limited number of schools and our sample only including primary and middle school students restricts the generalizability of the results. Accordingly, a larger sample of multiple school sites and a broader age-range sample including high school students should be targeted in future research. Second, no consensus on how to define sedentary bouts in sedentary time exists, making it more difficult to compare studies. Third, the current study only examined students' sedentary behaviours during the school day. Future research should target their sedentary behaviours on school days and weekends because their sedentary behaviours may differ between these days. Last, the lack of health markers did not allow conclusions on the relationship with sedentary volume and bouts to be drawn. Further research may focus on the influence of sedentary volume and bouts during different segments on the health of school students.

6. Conclusions

The current study examined how and when Chinese primary and middle school students accumulate their sedentary time in school days. Students spent the majority of time in sitting, especially in prolonged sitting during a school day. Regular class and out-of-school time are identified as key segments for students to reduce total sedentary time and break up prolonged sitting. Interventions on interrupting prolonged sitting during lunch break should be also explored. Girls and middle school students should receive more attention than boys and primary school students in future interventions to reduce sedentary volume and break up prolonged sitting during regular class, lunch break, and out-of-school time but only decrease total sedentary time during recess.

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Availability of data and materials

The dataset analyzed during the current study are available from the corresponding author on reasonable request.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest.

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Appendix A. Supplementary data

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