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Original article

Pedometer-determined physical activity patterns in a segmented school day among Hong Kong primary school children

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Abstract

Background/Objective: This study aimed to characterize pedometer-determined physical activity (PA) patterns in segmented school days among Hong Kong primary school children.
Methods: Participants were instructed to wear pedometers for 4 consecutive days. The overall step counts and counts at specific periods (e.g., after school, recess, and lunch) during the test days were recorded.
Results: Of the 74 recruited participants, 68 (41.2% boys, aged 10 and 11 years old) provided valid data. The mean total daily steps over the 4 test days ranged from 9064 to 9714 (standard deviation = 3140–3471 steps). The periods that contributed most toward total daily steps were after school (34.2%), recess (14.0%), and physical education (PE) classes (12.3%). Overall, Student *t* tests revealed that boys were more active than girls. More active children (daily step average above the sex-specific median value) accumulated significantly more steps during recess and after school than less active children (daily step average below the sex-specific median value) in both sexes (mean differences ranged from 507 steps to 1977 steps). A mixed model analysis of variance (ANOVA) revealed that students accumulated 914 steps more on days that included PE classes than on days without PE classes. A three-way ANOVA found no significant differences in body weight status (normal weight vs. overweight and obesity) and travel mode (active vs. passive modes).
Conclusion: The findings provide a better understanding of PA patterns and the contribution of the distinct segments within a school day to children's PA. This information may assist in developing more effective, appropriate, and timely school-based PA interventions for children in Hong Kong.

Keywords: Child; Pedometer; Physical activity patterns; Segmented school day

Introduction

Physical activity (PA) is defined as any bodily movement produced by skeletal muscles that require energy expenditure.[1] Conclusive evidence confirms that frequent PA substantially enhances the physical fitness and health status of children. The well-documented health benefits of PA include reduced body fat, more favorable cardiovascular and metabolic disease risk profiles, enhanced bone health, and reduced symptoms of anxiety and depression.[1,2] In addition, physically active children have higher levels of cardiorespiratory fitness, muscular endurance, and muscular strength. By contrast, physical inactivity has been identified as the fourth leading risk factor for global mortality causing an estimated 3.2 million, or 6%, deaths worldwide.[1] The World Health Organization (WHO) has recommended that children aged 5–17 years should accumulate at least 60 minutes of moderate-to vigorous-intensity PA (MVPA) daily.[1] However, a population-based study in Hong Kong revealed that only 8.3% of children (aged 7–12 years) meet the

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WHO recommendations, suggesting that Hong Kong children may be one of the most inactive child populations in the world.[3] As such, it is of utmost importance to improve PA levels among children in Hong Kong.

However, the improvement of PA in school children is difficult to achieve without first understanding PA patterns.[4] Many studies that have attempted to address this issue have been over-reliant on self-report methods due to their practicality and ease of administration.[5] However, research conducted with self-report methods has revealed problems in quantifying overall PA trends.[5] As such, researchers have been encouraged to adopt objective PA measures. The pedometer is one such objective measure, which is a low-cost, unobtrusive, reliable, and valid tool, and has been used in recent studies assessing children's PA.[6,7]

The school day offers distinct periods, or segments, within a structured environment namely, the school commute, recess, lunchtime, physical education (PE) class time, and after school. The PA conducted within these periods can be used to understand the contribution of each segment to children's daily PA, and to highlight which of those may have the most potential for effective PA interventions. However, only limited data are available on PA during specific segments of the school day, and such data are even more limited among Chinese children.

The present study primarily aimed to characterize Chinese children's pedometer-determined PA levels (daily steps) during the segmented school day. Differences, according to the segmented day, in daily steps were also explored across sex, age, body weight status, travel mode, and PE class groups. In addition, the contribution of each distinct time segment to the daily step count was examined. Findings from this study may help in designing effective, tailored, school-based interventions to enhance children's PA levels and provide useful options for the treatment of childhood obesity.

Methods

Participants

Seventy-four students (aged 10- and 11-years) were recruited from four Grade 5 classes in one Hong Kong primary school. All participants were under the instruction of the same PE teacher, and there were no interclass differences in PE class frequency, duration, content, or other PA-related programs offered by the school. Thus, the class was not regarded as a factor, and therefore was not controlled for in the data analysis. The participants were from similar middle-class, socioeconomic backgrounds, and represented typical Hong Kong middle-class families in housing type, amount of leisure time, and family income. The majority of students lived in private residential estates, and had free time after school for engaging in various activities. Informed written consent was obtained from all parents (or guardians) prior to data collection. Participants were also informed that their participation in the study was voluntary and they could withdraw from the study at any time. Ethical approval was obtained from the Ethics Committee of Hong Kong Baptist University, Kowloon Tong, Hong Kong.

Data collection

Participants' PA levels were assessed using YAMAX pedometers (SW 700; YAMAX Corporation, Tokyo, Japan) over 4 consecutive school days. YAMAX pedometers have been validated elsewhere in the literature among children.[8] The 4-day evaluation period is recommended as a sufficient length of time for determining children's PA levels.[9] In this study, only pedometers passing the shake test with a measurement error of <5% were used to collect data.[10]

The study school had three 20-minute recess sessions (2 in the morning and 1 in the afternoon) and one 60-minute lunch break in a typical school day, as well as two 35-minute PE classes every week. The school day was segmented according to the school timetable and step counts were collected during each segment. The segments are as follows: (1) before school (the period from waking up to arriving at school, accounting for potential active commuting or walking to school); (2) first session (from arriving at school to the start of the 1st recess); (3) first recess; (4) second session (from the end of the 1st recess to the start of the 2nd recess); (5) second recess; (6) third session (from the end of the 2nd recess to the start of lunch break); (7) lunch break; (8) fourth session (from the end of the lunch break to the start of the 3rd recess); (9) third recess; (10) fifth session (from the end of the 3rd recess to the end of school); and (11) after school (from leaving school to going to sleep, accounting for potential active commuting and after-school activities). Step counts during PE classes were separately recorded if a PE class was attended on that day. Steps from each segment were combined to generate the following variables, which are used for data analysis: (1) total daily steps (sum of all segments); (2) total daily steps without a PE class (only school days without PE class were counted); (3) total daily steps including a PE class (only school days including a PE class were counted); (4) step counts in school (sum of all segments from 2 to 10); (5) step counts out of school (sum of segments 1 and 11); and (6) step counts during recess (sum of segments 3, 5, and 9).

A study briefing was provided to the participants the day prior to data collection, in which they were instructed about the correct wearing position of the pedometer (at their right waist), nonwear recording periods (i.e., during showering, bathing, swimming, or sleeping), checking step counts at specific times during the measuring days, resetting the pedometer every night, and reattaching it before going to school. Participants were also instructed to accurately record their total daily steps and to return their data logs to the investigators at school the following morning. They were requested not to tamper with the pedometers and to go about their normal activities during the entire period of investigation. After the briefing, 2 consecutive trial days were conducted to familiarize the participants with the required procedure. Immediately following the trial days, the 4 consecutive data-collection days (from Tuesday to Friday) began. One research assistant was present at school for each class throughout the school day, with the school teachers, to check the resetting of pedometers and to record step counts in children's logs at the required time points. Parents (or guardians) were asked to help their children complete the segments after school and to sign their logs.

In accordance with standard anthropometric methods, the children's height and weight were measured, during a PE class, using a FISCO measuring tape (CMS Weighing Equipment Ltd., London, UK) and a Tanita electronic digital scale (Model No. HD305, Tanita Inc., Tokyo, Japan).[11] Height was measured to the nearest 0.1 cm and weight was measured to the nearest 0.1 kg. Subsequently, body mass index (BMI, kg/m^2) was calculated. According to international BMI cutoff points for childhood overweight and obesity, the children were classified into the normal, overweight, and obese groups based on their BMI values.[12] Children's age, sex, and travel modes (between home and school) were also collected using a self-administered questionnaire in the PE class. Travel modes of the participants were classified as either active (including on foot and by bike) or passive (including public transport and private car).

Statistical analysis

Students with missing data (more than 1 segment in a measuring day) for > 2 days were excluded from data analysis.[13] For the remaining students, an individual-centered data-replacement procedure was performed to deal with missing step counts.[13] The Kolmogorov–Smirnov analysis was performed to test the normality of daily step counts.[14] Step counts (each day/segment) beyond three standard deviations (SDs) of the mean were omitted to avoid potential influences from outliers.[15] A repeated measures analysis of variance (ANOVA) was used to compare the difference in total daily steps across the 4 monitoring days. Because there was no significant difference across the test days, the means for daily and segmental steps were calculated for each child (individual means for qualified days) and used in subsequent data analysis.

Percentages, means, and SDs were calculated to describe the distribution of the categorical and continuous variables, respectively. Age in this study was treated as a binary variable as the study included only children aged 10- and 11-years. A student *t* test was performed to determine whether there are any between-group differences in daily and segmental step counts. In the multivariable analysis, a three-way ANOVA was performed to estimate the marginal means and standard errors (SEs) for daily and segmental step counts according to sex (2 levels), age (2 levels), body weight status (2 levels), and travel mode (2 levels). A mixed model ANOVA was performed to test the differences in daily steps by PE class (2 levels), sex (2 levels), and age (2 levels). All possible two-way and three-way interactions were entered into the initial models and only significant interactions were included in the final models.

To examine the contribution of segmental steps to the total daily counts, participants were divided into the high- and low-activity groups according to their average daily steps, which were defined as either above or below the sex-specific daily step median values (11,200 steps for boys and 8900 steps for girls). A student *t* test was performed to compare the differences in segmental steps between the two groups. All statistical analyses were performed using IBM SPSS Statistics 21.0 (IBM Corp., Armonk, NY, USA) and a two-tailed $p < 0.05$ was considered statistically significant.

Results

Of the 74 recruited participants, 68 (28 males and 40 females) completed their activity logs with an adherence rate of 92%. Table 1 shows the participant characteristics. Of these participants, 54.4% were aged 10 years, and 45.6% were aged 11 years. The means for height, weight, and BMI were 144.9 cm (SD = 7.98 cm), 35.9 kg (SD = 8.4 kg), and 17.2 kg/m^2 (SD = 3.9 kg/m^2), respectively. Of all the children, 17.6% were overweight or obese. Three of 10 children (33.8%) engaged in active travel (on foot), and none traveled by bike. Boys were more likely to engage in active travel than girls (42.9% vs. 27.5%, $p = 0.048$). There were no other significant differences between boys and girls in other characteristics ($p > 0.05$).

The means for total daily steps in all test days ranged from 9064 to 9714 steps (SDs = 3140–3471 steps), and results from the repeated measures ANOVA showed no significant

Table 1
Participant characteristics.[a]

	Overall ($n = 68$)		Male ($n = 28$)		Female ($n = 40$)		*p*
	Mean	SD	Mean	SD	Mean	SD	
Height (cm)	144.9	8.0	143.5	6.8	145.9	8.6	0.136
Weight (kg)	35.9	8.4	36.9	8.5	35.2	8.3	0.338
BMI (kg/m^2)	17.2	3.9	16.9	3.6	17.3	4.1	0.700
Age	*n*	%	*n*	%	*n*	%	
10 y	37	54.4	15	53.6	21	53.8	0.589
11 y	31	45.6	13	46.4	18	46.2	
Weight status	*n*	%	*n*	%	*n*	%	
Normal	56	82.4	25	89.3	31	77.5	0.210
Overweight + obesity	12	17.6	3	10.7	9	22.5	
Travel mode[b]	*n*	%	*n*	%	*n*	%	
Active	23	33.8	12	42.9	11	27.5	0.048
Passive	45	66.2	16	57.1	29	72.5	

BMI = body mass index; SD = standard deviation.

[a] Student *t* tests and Chi-square tests were used to test differences in continuous and categorical variables, respectively.

[b] Active travel mode included travel on foot (none of our participants traveled by bike). Passive travel mode included travel by public transport and by private car.

Table 2
Means and SDs for daily/segmental steps by sex and age.[a]

	Overall (n = 68)		Sex					Age				
			Male (n = 28)		Female (n = 40)		p	10 y (n = 37)		11 y (n = 31)		p
	Mean	SD	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Total daily steps	9341	2478	10,706	2505	8382	1982	<0.001	9505	2520	9136	2455	0.561
Total daily steps by PE class												
Total daily steps (without PE class)	8844	3008	9870	3091	8126	2764	0.017	9093	3024	8548	3011	0.460
Total daily steps (with PE class)	9715	3032	11,268	3262	8627	2343	<0.001	10,093	3156	9263	2863	0.264
Steps by site												
Steps in school	5110	1546	5734	1706	4672	1270	0.004	5225	1674	4972	1392	0.506
Steps in recess	1304	645	1467	771	1189	521	0.081	1370	703	1224	570	0.356
Steps in lunch break	250	170	283	175	226	166	0.177	233	174	269	167	0.392
Steps in PE class	1150	566	1290	601	1052	525	0.088	1193	615	1099	506	0.497
Steps out of school	4146	1772	4842	2030	3660	1397	0.006	4259	1727	4012	1844	0.572
Steps before school	955	546	1211	604	777	424	0.001	986	612	919	461	0.617
Steps after school	3191	1595	3631	1906	2884	1273	0.057	3274	1530	3093	1691	0.646

PE = physical education; SD = standard deviation.
[a] Student t tests were performed to test differences by sex and age. Age in this study was treated as a binary variable as there were only two age groups—10- and 11-year-old children.

difference across the 4 days [$F(3,65) = 0.669$; $p = 0.574$]. Thus, daily and segmental steps were averaged for each individual and the differences were compared by sex and age (Table 2). The top three segments contributing to total daily steps were steps after school (34.2%), steps during recess (14.0%), and steps during PE class (12.3%). Step counts for all segments during school accounted for more than half of the total daily steps (54.7%). In each segment, boys were more active than girls. Compared with girls, significantly higher total daily step counts were found for boys for steps in school, steps out of school, and steps before school ($p < 0.05$). In addition, differences in steps between boys and girls in recess, in PE class, and after school reached marginal significance ($0.05 < p < 0.10$), with higher values being observed in boys. No significant age difference was found in step counts ($p > 0.05$).

Table 3 summarizes marginal means and SEs for daily and segmental step counts by body weight status and travel mode drawn from the three-way ANOVAs. None of the two-way or three-way interactions reached significance, and thus none was included in the final models. Compared with normal weight children, overweight and obese children had slightly lower but insignificant values for daily steps, steps in school, and steps before school; however, for these children, slightly higher but insignificant values for steps out of school and steps after school were noted. This suggests that overweight and obese children may be less active in school but more active after school. There were no consistent findings between the active and passive travel groups in step counts across different time segments. The findings from the three-way ANOVA between daily and segmental step counts and sex and age were similar to the results of the t tests, as shown in Table 2.

In the mixed model ANOVA, the influence of PE class on daily step counts was estimated in consideration of sex and age. Daily steps on PE class days (marginal mean = 9930 steps; SE = 342 steps) were 914 (SE = 375 steps), and this

Table 3
Marginal means and SEs for steps/day/segment of the participants by body weight status and travel mode.[a]

	Weight status					Travel mode[b]				
	Normal weight (n = 56)		Overweight + obesity (n = 12)		p	Active (n = 23)		Passive (n = 45)		p
	Mean	SE	Mean	SE		Mean	SE	Mean	SE	
Total daily steps	9466	312	9005	726	0.566	9612	502	9286	346	0.596
Total daily steps by PE class										
Total daily step (without PE class)	9051	391	8162	906	0.377	9547	606	8569	436	0.197
Total daily step (with PE class)	9770	374	9647	867	0.898	9141	576	10,068	415	0.198
Steps by site										
Steps in school	5281	194	4414	451	0.086	5043	310	5188	224	0.707
Steps in recess	1364	85	1047	197	0.150	1169	133	1387	96	0.190
Steps in lunch break	257	23	227	54	0.613	226	36	266	26	0.371
Steps in PE class	1180	76	997	176	0.349	1051	118	1202	85	0.309
Steps out of school	4125	231	4358	535	0.694	4322	360	4080	259	0.590
Steps before school	969	69	932	160	0.836	848	107	1023	77	0.190
Steps after school	3157	214	3425	497	0.625	3474	333	3058	240	0.317

PE = physical education; SE = standard error.
[a] Three-way analysis of variance was performed by sex, age, and body weight (or travel mode). The main effects of sex and age were similar to the results from Student t tests. No two-way and three-way interactions were significant, and therefore not included in the final models.
[b] Active travel mode included travel on foot (none of our participants traveled by bike). Passive travel mode included travel by public transport and by private car.

Table 4
Means and SDs for segmental steps by daily activity level.[a]

	Boys					Girls				
	Low activity[a] (n = 14)		High activity[a] (n = 14)		p	Low activity[a] (n = 20)		High activity[b] (n = 20)		p
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Steps in school										
Steps in recess	1106	462	1819	906	0.019	984	365	1491	653	0.007
Steps in lunch break	284	195	290	156	0.930	251	193	240	231	0.874
Steps in PE class	1187	519	1499	626	0.180	981	468	1148	511	0.307
Steps out of school										
Steps before school	953	385	1341	481	0.033	717	374	860	451	0.301
Steps after school	2722	1414	4699	1785	0.005	2242	1147	3608	1104	0.001

PE = physical education; SD = standard deviation.
[a] Student t tests were used to compare mean differences in segmental steps between the low- and high-activity groups after stratification by sex.
[b] Low- and high-activity levels were defined according to students' mean daily steps being below or above their sex-specific median values (11,200 for boys and 8900 for girls).

count is higher than on days without PE classes [marginal mean = 9016 steps, SE = 35 steps, $F(1,67) = 5.96$, $p = 0.017$]. Sex, age, and daily step differences were similar to the previous t tests.

Table 4 presents mean differences in segmental step counts between children with low- and high-activity levels. Step counts of more active children (daily steps above the sex-specific medians) in recess and after school were significantly higher than less active children. The differences also emerged in both sexes by 28.2–72.6% (range of mean differences = 507–1977 steps), suggesting that the step accumulations in recess and after school contributed significantly to the daily counts. Furthermore, the difference in steps before school reached significance between more and less active boys (mean difference = 388 steps; 40.7% higher in more active boys compared with less active boys), suggesting that, for boys, the period before school is a major determinant of total daily steps.

Discussion

This study described pedometer-determined PA levels during school days and has provided specific time-segment information for 10- and 11-year-old Hong Kong Chinese children. The total daily step mean was 9341 steps (SD = 2478 steps), with boys having significantly higher value than girls (10,706 ± 2505 steps vs. 8382 ± 1982 steps; $p < 0.001$). Body weight status and travel mode were not significantly associated with daily and segmental step counts, although a marginally significant higher value was found for steps accrued in school for normal weight children compared with overweight or obese children (5281 steps vs. 4414 steps, $p = 0.086$). The top three time segments that contributed to total daily steps were steps after school (34.2%), steps in recess (14.0%), and steps in PE class (12.3%). The former two segments demonstrated the greatest contribution to daily steps for both sexes.

In this study, the mean daily steps of our sample was 10,706 steps (SD = 2505 steps) for boys, 8382 steps (SD = 1982 steps) for girls, and 9341 steps (SD = 2478 steps) overall, which is much lower than those observed in previous studies. In Western countries, 12,546–18,346 steps/d and 10,479–14,825 steps/d have been reported for boys and girls, respectively,[16–25] which is 17.1–76.9% higher than that observed in the current study. Beets and colleagues[26] reviewed 43 articles, which were published before April 2009, and found considerable variation across 13 countries, with children from European and Western Pacific regions recording significantly more daily steps than their Northern American counterparts. Studies among Asian populations are scarce, although a recent Singaporean study reported daily mean steps of 12,830 for boys aged 7–12 years, which is 19.8% higher than the male participants in the current study.[27] Girls in the Singaporean study had a mean for daily step counts of 8767, which is also lower than that reported by girls in the current study. This variation across these studies cannot be explained by variations in data-collection procedures alone.[26] Furthermore, previous studies using PA measures other than pedometers, such as questionnaires, observation techniques, and accelerometers, have also revealed lower PA levels among Hong Kong children compared with other countries and regions.[28–30] This suggests that Hong Kong children may be one of the least-active child populations in the world. It is, therefore, imperative to improve PA levels in this population.

Globally, physical inactivity is the fourth leading risk factor of death, after high blood pressure, tobacco use, and high blood glucose.[1] PA levels have been continually decreasing in many countries, due to urbanization and modernization, and this decline has major implications, such as the growing prevalence of noncommunicable diseases as well as for the general health of the population. Recently, WHO revised the PA for health recommendations and suggested that children aged 5–17 years should engage in at least 60 minutes of MVPA every day. Because pedometers cannot directly measure the time spent in MVPA, attempts have been made to link the pedometer-based daily step counts with the WHO recommendations.[31] Tudor-Locke et al[32] conducted secondary analysis on an international data set, collected from the United States, Australia, and Sweden, and recommended a PA cutoff point of 15,000 steps/d for boys and 12,000 steps/d for girls, respectively. Using these criteria, the daily mean steps in the current sample fell short by 28.6% for boys and 30.2% for girls. At an individual level, only one girl in the current study averaged 12,012 steps/d; however, none of the boys met the recommended step counts. Considering that the recommended daily steps are based on white child populations, it may not be suitable to directly apply these criteria to the Chinese participants in our study.[32] Therefore, it is suggested that future studies should determine the appropriate pedometer-based, PA cutoff points for Asian children to recommend the correct level of health-promoting PA.

Consistent with most previous studies, boys in the current study accrued significantly more daily steps in all distinct periods than girls.[16−25] Steps accrued after school, in recess, and in PE classes were major sources of daily PA levels, which is in line with other studies.[22,33,34] After school, a period of about 6−8 hours is a free-living period, which provides an important opportunity to encourage children to participate in more activities. In this study, the absolute contributions of PE classes and recess to the daily steps counts (12.3% and 14.0%, respectively) were similar to previous studies (18.0% and 13.0%, respectively). Therefore, educators may utilize this period during school to focus on modifying children's PA behaviors.[19,35] However, the participants in the current study took fewer steps during lunch break [283 steps (2.6% of daily steps) for boys and 226 steps (2.7% of daily steps) for girls]. This is inconsistent with previous studies, which found a contribution of up to 68% of children's recommended daily MVPA for this period.[23,33,34,36] School culture and school policy may play a role in this marked difference. For example, in most Hong Kong primary schools, including the school in this current study, students are requested to stay in their classrooms during the lunch break, and running or even fast walking is regarded as misconduct.[37] In addition, the relatively short lunch break in local Hong Kong schools (i.e., 30 minutes from 12:30 PM to 13:00 PM in the study school) may also partly account for the fewer step counts.[37]

Although overweight and obese children accrued fewer steps than those with normal weight during most of the segments, no significance was found among these comparisons, which may be, at least partly, due to the small sample size ($n = 68$), resulting in insufficient power. Interestingly, overweight and obese children accrued 10% more steps than their normal weight counterparts after school (3425 steps vs. 3157 steps; Table 3), suggesting that overweight and obese children may be more active after school. One possibility could be that parents of overweight or obese children may be aware of the importance of PA for their children's health and may have made attempts to improve their children's PA levels. However, further large-scale studies are needed to confirm this finding. Hohepa et al[38] found that active travel to and from school significantly contributed to more daily steps in high-school students in Auckland (13,308 steps in walkers vs. 10,986 steps in car transit users). However, the current study failed to observe a similar relationship (Table 3). Besides the small sample size, a possible explanation is that the travel mode may not be a major determinant of PA levels in our sample. The majority of primary school children in Hong Kong travel by school bus rather than walking unless their homes are located in close proximity to school. In general, children taking the school bus (as well as those taking other public transport) have to walk to the neighborhood pick-up stations. Thus, the steps taken between school and home may not differ much between children taking either active or passive travel modes. Unfortunately, children were not asked how long they walked to or from school, and therefore this study was unable to answer this particular hypothesis. Further studies should collect such information to confirm the relationship between transport mode and daily steps.

We compared steps across the measured time segments between children with low- and high-activity levels. This was done according to their daily steps being lower or higher than the sex-specific medians. Based on this analysis, it was found that recess and after school were the two critical periods in which the children were more active. For example, more active boys accrued 76.9% more steps after school than their less active counterparts (4699 steps vs. 2722 steps; Table 4). This finding may have important implications for improving PA levels in less active children. Further studies should identify the determinants of the discrepancies in recess and after school to provide scientific evidence for the development of effective interventions to improve children's PA levels.

The current findings should be interpreted with caution. First of all, this study has encountered similar limitations to other investigations using pedometers to measure children's PA levels.[23,26,33] For example, pedometers cannot directly capture the intensity of PA. In addition, pedometers do not have the ability to measure time spent in MVPA, and therefore no firm conclusions can be made as to whether children reached the recommended daily PA levels or not. Second, this is a small-scale investigation ($n = 68$) and participants were selected from a single grade of one primary school. This population is, therefore, not representative of the wider child population, which may affect the generalizability of these findings. Selection bias may be another major threat to our results, as both age and school factors have been known to influence childhood PA levels. Further research should be conducted in larger representative samples across multiple schools, covering all grades to confirm the current findings. In addition, the step counts taken outside school were recorded by the parents of the participants instead of the well-trained researchers. Thus, measurement bias may exist and threaten our results. Finally, PA levels during the weekend days were not monitored, and in previous studies, significantly more daily steps have been found during the week compared with weekend days suggesting that our findings might have been upwardly biased.[21,26]

In conclusion, compared with other countries, children in Hong Kong are less active based on pedometer-determined PA levels. Boys accrue significantly more steps than girls in daily step counts and at most periods during the school day, with after-school step counts contributing most toward daily step counts. Recess and after school emerged as two critical windows of opportunity, which can be used to enhance PA levels in both boys and girls. Our findings provide a better understanding of PA patterns and the relative contribution of the distinct time segments within a school day to PA in Hong

Kong children. However, future large-scale studies should be conducted to confirm these findings.

Conflicts of interest

All contributing authors declare no conflicts of interests.

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References

1. World Health Organization (WHO). *Global Recommendations on Physical Activity for Health*. Geneva, Switzerland: WHO; 2010. Available from: http://www.who.int/dietphysicalactivity/publications/9789241599979/en/. Accessed 30.03.15.
2. Janssen I, LeBlanc AG. Review systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *Int J Behav Nutr Phys Act*. 2010;7:1–16.
3. Leisure and Cultural Services Department of Hong Kong (LCSD). *Health Exercise for All Campaign—Physical Fitness Test for Community: Final Summary Report*. Sha Tin, Hong Kong: LCSD; 2012. Available from: http://www.lcsd.gov.hk/healthy/physical_fitness/download/SummaryReport_en.pdf. Accessed 30.03.15.
4. Tudor-Locke C, Ainsworth BE, Adair LS, et al. Physical activity and inactivity in Chinese school-aged youth: the China Health and Nutrition Survey. *Int J Obes Relat Metab Disord*. 2003;27:1093–1099.
5. Tudor-Locke C, Ham SA, Macera CA, et al. Descriptive epidemiology of pedometer-determined physical activity. *Med Sci Sports Exerc*. 2004;36:1567–1573.
6. Tudor-Locke C, Williams JE, Reis JP, et al. Utility of pedometers for assessing physical activity: convergent validity. *Sports Med*. 2004;34:281–291.
7. Eston RG, Rowlands AV, Ingledew DK. Validity of heart rate, pedometry, and accelerometry for predicting the energy cost of children's activities. *J Appl Physiol (1985)*. 1998;84:362–371.
8. Barfield JP, Rowe DA, Michael TJ. Interinstrument consistency of the Yamax Digi-Walker pedometer in elementary school-aged children. *Meas Phys Educ Exerc Sci*. 2004;8:109–116.
9. Vincent SD, Pangrazi RP. Does reactivity exist in children when measuring activity levels with pedometers? *Pediatr Exerc Sci*. 2002;14:56–63.
10. Welk GJ, Differding JA, Thompson RW, et al. The utility of the Digi-walker step counter to assess daily physical activity patterns. *Med Sci Sports Exerc*. 2000;32:S481–S488.
11. Cameron N. The methods of axiological anthropometry. In: Falkner F, Tanner JM, eds. *Human Growth*. London: Plenum Press; 1978:1–42.
12. Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320:1240–1243.
13. Kang M, Zhu W, Tudor-Locke C, et al. Experimental determination of effectiveness of an individual information-centered approach in recovering step-count missing data. *Meas Phys Educ Exerc Sci*. 2005;9:233–250.
14. Lilliefors HW. On the Kolmogorov-Smirnov test for normality with mean and variance unknown. *J Am Stat Assoc*. 1967;62:399–402.
15. Rowe DA, Mahar MT, Raedeke TD, et al. Measuring physical activity in children with pedometers: reliability, reactivity, and replacement of missing data. *Pediatr Exerc Sci*. 2004;16:343–354.
16. Loucaides CA, Chedzoy SM, Bennett N. Differences in physical activity levels between urban and rural school children in Cyprus. *Health Educ Res*. 2004;19:138–147.
17. Le Masurier GC, Beighle A, Corbin CB, et al. Pedometer-determined physical activity levels of youth. *J Phys Act Health*. 2005;2:159–168.
18. Rowlands AV, Eston RG. Comparison of accelerometer and pedometer measures of physical activity in boys and girls, ages 8–10 years. *Res Q Exerc Sport*. 2005;76:251–257.
19. Beighle A, Pangrazi RP. Measuring children's activity levels: the association between step-counts and activity time. *J Phys Act Health*. 2006;3:221–229.
20. Cox M, Schofield G, Greasley N, et al. Pedometer steps in primary school-aged children: a comparison of school-based and out-of-school activity. *J Sci Med Sport*. 2006;9:91–97.
21. Duncan MJ, Al-Nakeeb Y, Woodfield L, et al. Pedometer determined physical activity levels in primary school children from central England. *Prev Med*. 2007;44:416–420.
22. Craig CL, Cameron C, Tudor-Locke C. CANPLAY pedometer normative reference data for 21,271 children and 12,956 adolescents. *Med Sci Sports Exerc*. 2013;45:123–129.
23. Tudor-Locke C, Lee SM, Morgan CF, et al. Children's pedometer-determined physical activity during the segmented school day. *Med Sci Sports Exerc*. 2006;38:1732–1738.
24. Ng C, Marshall D, Willows ND. Obesity, adiposity, physical fitness and activity levels in Cree children. *Int J Circumpolar Health*. 2006;65:322–330.
25. Loucaides CA, Jago R. Correlates of pedometer-assessed physical activity in Cypriot elementary school children. *J Phys Act Health*. 2006;3:267–276.
26. Beets MW, Bornstein D, Beighle A, et al. Pedometer-measured physical activity patterns of youth: a 13-country review. *Am J Prev Med*. 2010;38:208–216.
27. Chia M. Pedometer-assessed physical activity of Singaporean youths. *Prev Med*. 2010;50:262–264.
28. So HK, Sung RY, Li AM, et al. Higher exercise frequency associated with lower blood pressure in Hong Kong adolescents: a population-based study. *J Hum Hypertens*. 2010;24:646–651.
29. Mak KK, Day JR. Secular trends of sports participation, sedentary activity and physical self-perceptions in Hong Kong adolescents, 1995–2000. *Acta Paediatr*. 2010;99:1731–1734.
30. Macfarlane DJ. Some disturbing trends in the levels of habitual physical activity in Hong Kong primary school children: preliminary findings. *Hong Kong J Sports Med Sports Sci*. 1997;5:42–46.
31. Tudor-Locke C, Hatano Y, Pangrazi RP, et al. Revisiting "how many steps are enough?". *Med Sci Sports Exerc*. 2008;40:S537–S543.
32. Tudor-Locke C, Pangrazi RP, Corbin CB, et al. BMI-referenced standards for recommended pedometer-determined steps/day in children. *Prev Med*. 2004;38:857–864.
33. Tudor-Locke C, McClain JJ, Hart TL, et al. Expected values for pedometer-determined physical activity in youth. *Res Q Exerc Sport*. 2009;80:164–174.
34. Brockman R, Jago R, Fox KR. The contribution of active play to the physical activity of primary school children. *Prev Med*. 2010;51:144–147.
35. Flohr JA, Todd MK, Tudor-Locke C. Pedometer-assessed physical activity in young adolescents. *Res Q Exerc Sport*. 2006;77:309–315.
36. Verstraete SJ, Cardon GM, De Clercq DL, et al. Increasing children's physical activity levels during recess periods in elementary schools: the effects of providing game equipment. *Eur J Public Health*. 2006;16:415–419.
37. Chow BC, McKenzie TL, Louie L. Children's physical activity and environmental influences during elementary school physical education. *J Teach Phys Educ*. 2008;27:38–50.
38. Hohepa M, Schofield G, Kolt GS, et al. Pedometer-determined physical activity levels of adolescents: differences by age, sex, time of week, and transportation mode to school. *J Phys Act Health*. 2008;5:S140–S152.