Changes in physical activity and weight status of Chinese children: A retrospective longitudinal study

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Abstract The aims of this study were to describe longitudinal changes in objectively measured physical activity (PA) in Chinese children and to investigate the associations of such changes with weight status, gender, and day of the week. This study was conducted on 50 boys and 43 girls. Children underwent measurements in 2011 (age 7-8 years, 2nd grade) and in 2014 (age 10-11 years, 5th grade). The children were divided into: normal weight (NW) or overweight/obese (OW/OB) groups based on weight status recorded in 2014. PA was quantified by steps measured using a uniaxial accelerometer, then total PA time and time spent performing moderate to vigorous PA (≥ 3 METs) were analyzed separately for weekdays and weekends. The daily PA outcomes and normalized PA outcomes per hour (steps, total PA time, and moderate to vigorous PA) declined with age in the OW/OB group on weekends for boys and on both weekdays and weekends for girls ($p < 0.05$). But no change was observed in the NW group of boys and girls. The percentages of achieving the global recommendations by WHO also declined with age in the OW/OB group for boys on weekdays ($p < 0.05$). Moreover, they had significantly less percentages of achieving the WHO recommendations than that of the NW group for boys on both weekdays and weekends in 2014 ($p < 0.05$). Our findings suggest that longitudinal changes in PA, predominantly in the quantity and intensity of activity, are related to weight status in children. Prevention of this decline in PA among children in OW/OB children, particularly on weekends for boys and on both weekdays and weekends for girls may be a suitable health promotion target.

Keywords : accelerometer, MVPA, overweight, obese, WHO recommendations

Introduction

In recent decades, the prevalence of overweight/obesity has risen quickly worldwide¹⁾, not only in adults, but also in children and adolescents. Children who are overweight/obese are more likely to be overweight or obese as adults²⁾. Childhood obesity is a serious health problem linked to serious complications. Childhood obesity increases the risk for cardiovascular disease, diabetes, and other chronic diseases later in life³⁾.

Several epidemiological and intervention studies have identified the effects of physical activity (PA) on overweight and obese children^{4,5)}. During childhood and adolescence, regular PA helps to maintain a healthy weight, and is also associated with the development of healthy musculoskeletal and cardiovascular systems, as well as neuromuscular awareness. Thus, PA has been suggested as an important component of disease prevention. Moreover, consistent PA at a young age considerably increases

the probability of being active in adulthood⁶⁾. Therefore, assessing childhood PA is especially important, since increased PA in childhood seems to be essential for the development of a lifetime habit of PA⁷⁾. Current health-related PA recommendations for children include at least 60 minutes of moderate to vigorous PA (MVPA); these guidelines have recently been updated by the World Health Organization (WHO)⁸⁾ to incorporate activities of vigorous intensity.

The highest prevalence of childhood overweight and obesity has been observed in developed countries; however, prevalence is increasing in developing countries as well. Previous reports have suggested that the epidemic of childhood overweight and obesity in China has spread across the country since the end of the 20th century^{9,10)}. Compared with other age-specific groups, the highest prevalence of overweight and obesity was observed in 7- to 9-year-old children⁹⁾. To address this problem, the Chinese government released a new policy in 2007 calling for 1 hour of exercise every day¹¹⁾ to help children achieve the current Chinese exercise target levels (any

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kind of exercise for a total of 60 minutes or more per day). However, the Chinese National Physical Fitness and Health Survey (CNPFHS) to estimate the probabilities of children meeting the Chinese exercise target levels by questionnaire and found that only 22.7% of Chinese students aged 9-18 years achieved this standard in 2010¹²⁾.

In general, children's PA varies in frequency, duration, and intensity depending on the setting. Although children are given similar PA exposure and opportunities during weekdays and weekends, PA quantity and intensity also appear to vary according to the day of the week^{13,14)}. Until now, PA self-report questionnaires have been the most widely used instrument to assess PA, and these have been used extensively by researchers investigating PA in Chinese children and adolescents^{12,15)}. However, a single self-report may not address the broad range of PA intensity that might be reflected in children's actual PA¹⁶⁾. Furthermore, it is difficult to obtain precise descriptions of the type of PA performed and of differences between weekdays (school time and after school) and weekends in the quantity and intensity of PA using questionnaires. In recent years, the use of accelerometers (ACs) has permitted greater accuracy and reliability in the assessment of activity compared with questionnaires. Their validity has been demonstrated under daily-living conditions using the doubly labeled water (DLW) method, and they have the added merit of enabling measurement of the frequency, intensity, and duration of PA^{17,18)}. Moreover, ACs provide a tool for further investigation of the relationship between PA and weight status in children, a major factor in the interpretation of longitudinal studies on this relationship¹⁹⁾. Meta-analysis²⁰⁾ of percent body fat was used to measure adiposity in American children, and results suggested no prospective association between measured PA and changing fat mass. On the other hand, Remmers et al.²¹⁾ segmented AC data to explore 3-year changes in body mass index (BMI) and PA in Dutch children aged 4-5 years at baseline, and reported that changes in MVPA and BMI were significant in boys and girls. These results facilitate our understanding and ability to improve childhood obesity. However, these longitudinal characteristics have not been examined thoroughly in Chinese children, and their relationship with PA and weight status are unclear.

Therefore, the purpose of this longitudinal study was to describe changes in objectively measured PA during both weekdays and weekends in Chinese children over a 3-year period. In addition, because PA can play a major role in the development of weight status, we aimed to investigate how this developmental change is associated with weight status, gender, and day of the week (weekday vs. weekend). We also estimated the percentage of Chinese children achieving WHO recommendations.

Methods

Participants

All children enrolled in a primary school in Loudi, a city in south China, participated in this study with the permission of school officials. This school has 10 classes in each grade, and two 2nd grade classes were selected from the school to participate in this study in 2011 (72 boys and 70 girls, mean age 7.0 ± 0.2 years). The selection criteria for admission into the study were: attendance at this primary school, permission from parents to participate in this study, and no injuries or current illnesses. The subjects provided informed consent, in line with a research protocol adhering to the Declaration of Helsinki, which was approved by the ethics committee of Juntendo University. To control for seasonality, data were collected for all participants during the same season, namely, in September 2011 and 2014.

Data collection procedures

Participants underwent measurements at two separate times. We assessed children in 2nd grade in 2011 (7-8 years of age) on the first visit, and again in 5th grade in 2014 (10-11 years of age) on the second visit. Researchers visited the primary school to take measurements and distribute ACs to two classes of consenting students; each child wore an AC for 1 week and then returned it to school personnel. Children at the same school were asked to participate in the second part of the study. Of these, 30 children did not have proper consent from their parents to participate in the PA study, six were not available for follow up in 2014, and 13 were excluded due to incomplete accelerometer data in either 2011 or 2014. Finally, data were collected from 93 Chinese children (50 boys and 43 girls, mean age 10.3 ± 0.4 years) for subsequent analyses.

Anthropometrics data

All anthropometric data were collected by trained staff under supervision of the school nurse in 2011 and 2014. Height and body weight were measured using a portable stadiometer and portable digital scale (TCS-200-RT, YaoYi, Shanghai, China), respectively. Height was measured to the nearest 0.1 cm without shoes, and body weight was measured to the nearest 0.1 kg in light underwear. BMI was calculated by the following standard equation: $\text{BMI} = \text{weight in kg} / \text{height squared in meters}$. Weight status (i.e., normal weight and overweight/obese) was determined according to the age- and gender-specific cut-offs of the Working Group on Obesity in China (WGOC)²²⁾.

In this study, the sample consisted of 29 boys with normal weight and 21 overweight/obese. Girls included 27 with normal weight and 16 that were overweight/obese in 2011. The sample in 2014 consisted of 29 normal weight and 21 overweight/obese boys. For girls, it was 24 with normal weight and 19 who were overweight/obese. Since

we desired to look retrospectively at the PA situation three years ago of children both with normal weight and those who were overweight/obese, the children were divided into either the normal weight (NW) or overweight/obese (OW/OB) group according to weight status in 2014.

Physical activity

We measured PA using uniaxial Kenz EX AC (Lifecorder, Suzuken Co., Ltd., Nagoya, Japan; 60 g). Each child attached the AC to the waist and wore it from the time they got up in the morning until they went to bed. They were instructed to wear the AC from a Monday to Sunday, providing seven consecutive days of data. Previous studies examining the validity of AC data when the monitor was worn at the waist have reported good validity (correlation coefficients 0.66–0.89), and have proposed cutoff values for different activity intensities^{23–25}. Adachi et al. reported that PA energy expenditure using the doubly labeled water (DLW) method is significantly correlated ($r = 0.709$ – 0.828) with PA intensity among children using the AC²⁶. According to the scale, distinctions were made regarding degrees of intensity (intensity levels 1–3, 4–6, and 7–9), with light (LPA, AC intensity levels of 1–3 and 1.5–2.9 METs), moderate (MPA, AC intensity levels of 4–6 and 3–5.9 METs) and vigorous (VPA, AC intensity levels of 7–9 and ≥ 6 METs)^{27,28}. We recorded crude step counts to estimate activity levels, and the time spent in MVPA (≥ 3 METs) was calculated as the sum of the MPA and VPA minutes. Total PA (TPA) = LPA + MPA + VPA for each day. The number of children who achieved a minimum of 60 MVPA on weekdays and the weekends was calculated and compared to WHO recommendations.

Each AC was initialized (requires setting the start time and date, inputting participant height, weight, age, and gender, and selecting the display and keypad functions for subsequent data collection) and downloaded according to the manufacturer's instructions using Physical Activity Analysis software (Lifelyzer, ver. 2.04, Suzuken Co., Ltd., Nagoya, Japan). If the AC data were not detected for 1 h, this period was regarded as non-wear time. AC analyses were based on a minimum of 10 hours of data per day and at least 2 weekdays and 1 weekend day^{29,30}.

Data analysis

Boys and girls were each divided into two groups (NW and OW/OB) based on weight status in 2014. Differences in physical characteristics by weight status between 2011 and 2014 were evaluated by two-way analysis of variance (ANOVA). Three-way ANOVA was used to investigate differences in each daily PA outcome and normalized PA outcome per hour (steps, TPA, and MVPA) between the 2011 and 2014 assessments, weight status, and day of the week. If significant differences in physical characteristics, daily PA outcomes and normalized PA outcomes per hour, were identified by ANOVA, the Bonferroni post hoc test was used to determine their significance. Chi-square anal-

ysis was used to examine differences in percentages of achieving the WHO recommendations by weight status. Analysis was conducted using SPSS software version 20.0 (SPSS Inc., IBM, USA). The results are given as means $\pm$ SD, and the level of significance was set at $p < 0.05$.

Results

Participant characteristics

A total of 93 children (50 boys and 43 girls) met the inclusion criteria and were included in the analyses (Table 1). The mean ages of these children were 7.3 ± 0.4 years in 2011 and 10.3 ± 0.4 years in 2014. As shown in Table 1, boys and girls in the OW/OB group differed significantly from the NW group in all physical characteristics, except for height of boys in 2011. Regardless of gender, no difference was observed between 2011 and 2014 for BMI in NW group, while it was increased in OW/OB group. The prevalence of overweight/obese increased with age: 28.8% in 2011 to 29.6% for boys in 2014 and 24.6% to 26.0% for girls, respectively. A total of six children (two boys and four girls) who were normal weight in 2011 became overweight in 2014. On the other hand, three children (two boys and one girl) went from overweight to normal weight with increasing age.

Mean wear time per day and the mean number of days that children wore the AC were 13.9 hours and 5.2 days in 2011, and 14.1 hours and 5.5 days in 2014. No differences were observed in wear time or the number of valid days based on gender or weight status between 2011 and 2014.

Daily physical activity outcomes (Table 2)

Steps

Girls took significantly fewer steps than boys in 2011 and 2014 ($p < 0.05$). Both boys and girls took significantly fewer steps on weekends in 2014 than in 2011, and children took significantly fewer steps on weekends than weekdays in 2011 and 2014 ($p < 0.05$).

The OW/OB group of boys took significantly fewer steps than those by the NW group on weekdays in 2011. Boys and girls in the OW/OB group took significantly fewer steps than those in the NW group on weekdays and weekends in 2014 ($p < 0.05$). Regardless of gender, the number of steps taken by the NW group on weekdays or weekends did not differ between 2011 and 2014. However, the OW/OB group of boys took significantly fewer steps on the weekends in 2014 compared to those in 2011 ($p < 0.05$). The OW/OB group of girls took significantly fewer steps on both weekdays and weekends in 2014 compared to 2011 ($p < 0.05$).

Total physical activity (TPA)

Girls also engaged in significantly less time in TPA than boys in 2011 and 2014 ($p < 0.05$). Boys and girls engaged in significantly less time in TPA on weekdays and weekends in 2014 than in 2011, and children spent significant-

Table 1. Physical characteristics of children by weight status

Boys	ALL N=50		NW N=29		OW/OB N=21	
	2011	2014	2011	2014	2011	2014
Age (yr)	7.5 ± 0.4	10.5 ± 0.4	7.5 ± 0.5	10.5 ± 0.5	7.4 ± 0.3	10.4 ± 0.3
Height (cm)	128.1 ± 5.6	139.1 ± 6.0	127.0 ± 5.2	137.6 ± 5.5 *	129.6 ± 5.8	141.2 ± 6.1 ^{§*}
Weight (kg)	28.9 ± 5.2	36.1 ± 8.7	26.3 ± 2.5	30.7 ± 3.7 *	32.5 ± 5.9 [§]	43.7 ± 7.9 ^{§*}
BMI (kg/m ²)	17.5 ± 2.1	18.5 ± 3.4	16.3 ± 0.7	16.2 ± 1.4	19.2 ± 2.1 [§]	21.8 ± 2.5 ^{§*}
Girls	ALL N=43		NW N=24		OW/OB N=19	
	2011	2014	2011	2014	2011	2014
Age (yr)	7.2 ± 0.4	10.2 ± 0.4	7.1 ± 0.4	10.1 ± 0.4	7.2 ± 0.4	10.2 ± 0.4
Height (cm)	126.0 ± 5.3	139.1 ± 6.2	123.9 ± 5.5	137.0 ± 6.5 *	128.6 ± 3.7 [§]	141.9 ± 4.6 ^{§*}
Weight (kg)	26.8 ± 4.3	34.9 ± 6.7	24.1 ± 2.3	30.4 ± 4.3 *	30.3 ± 3.8 [§]	40.6 ± 4.4 ^{§*}
BMI (kg/m ²)	16.8 ± 1.9	17.9 ± 2.5	15.7 ± 1.0	16.2 ± 1.4	18.3 ± 1.9 [§]	20.1 ± 1.6 ^{§*}

NW: normal weight, OW/OB: overweight/obese; [§] vs. NW, * vs. 2011; p<0.05; Mean ± SD.

Table 2. Daily physical activity outcomes (steps, TPA, and MVPA) of children by weight status

Boys	ALL N=50		NW N=29		OW/OB N=21	
	2011	2014	2011	2014	2011	2014
Weekdays						
Steps (steps/day)	19110 ± 2386	18662 ± 4774	20124 ± 1907	20319 ± 3322	17710 ± 2303 [§]	16374 ± 5558 [§]
TPA (min/day)	183.1 ± 26.1	178.9 ± 43.9	192.2 ± 23.5	194.3 ± 29.4	170.5 ± 24.6 [§]	157.5 ± 51.8 [§]
MVPA (min/day)	77.2 ± 14.2	80.9 ± 27.2	81.2 ± 15.3	89.4 ± 21.6	71.7 ± 10.6	69.1 ± 30.1 [§]
Weekends						
Steps (steps/day)	14522 ± 4238 [#]	12304 ± 5034 ^{*#}	15218 ± 4656 [#]	13898 ± 4964 [#]	13562 ± 3461 [#]	10101 ± 4336 ^{§*#}
TPA (min/day)	141.9 ± 40.7 [#]	121.7 ± 47.8 ^{*#}	148.9 ± 45.4 [#]	136.7 ± 46.5 [#]	132.1 ± 31.6 [#]	101.1 ± 42.4 ^{§*#}
MVPA (min/day)	58.5 ± 22.3 [#]	48.3 ± 25.7 ^{*#}	61.6 ± 23.9 [#]	56.2 ± 26.6 [#]	54.2 ± 19.7 [#]	37.4 ± 20.3 ^{§*#}
Girls	ALL N=43		NW N=24		OW/OB N=19	
	2011	2014	2011	2014	2011	2014
Weekdays						
Steps (steps/day)	15302 ± 2760	14027 ± 3092 *	15170 ± 2322	14848 ± 2961	15468 ± 3292	12989 ± 3010 ^{§*}
TPA (min/day)	149.4 ± 28.6	139.6 ± 29.6 *	147.6 ± 23.8	147.2 ± 29.2	151.6 ± 34.4	129.9 ± 27.9 *
MVPA (min/day)	59.2 ± 15.3	54.0 ± 16.8 *	57.9 ± 15.1	57.0 ± 15.6	60.8 ± 15.9	50.3 ± 17.9 *
Weekends						
Steps (steps/day)	12138 ± 2390 [#]	10059 ± 3558 ^{*#}	12818 ± 2250 [#]	11557 ± 3806 [#]	11279 ± 2338 [#]	8166 ± 2062 ^{§*#}
TPA (min/day)	120.9 ± 22.3 [#]	103.2 ± 36.6 ^{*#}	127.5 ± 21.7 [#]	118.0 ± 39.9 [#]	112.6 ± 20.5 [#]	84.5 ± 20.9 ^{§*#}
MVPA (min/day)	48.83 ± 14.0 [#]	35.5 ± 18.3 ^{*#}	52.5 ± 15.1	43.2 ± 19.1 ^{*#}	42.9 ± 10.6 ^{§#}	25.8 ± 11.5 ^{§*#}

NW: normal weight, OW/OB: overweight/obese; TPA: total time spent in physical activity; MVPA: moderate-to-vigorous physical activity; [§] vs. NW, * vs. 2011, [#] vs. weekdays; p<0.05; Mean ± SD.

ly less time in TPA on weekends compared to weekdays in 2011 and 2014 ($p < 0.05$).

Similar to steps, the OW/OB group of boys spent significantly less time in TPA than that of the NW group on weekdays in 2011 and 2014. Boys and girls in the OW/OB group spent significantly less time in TPA than the NW group on weekends in 2014 ($p < 0.05$). Regardless of gender, the time in TPA did not change in the NW group between 2011 and 2014 during weekdays or weekends. In contrast, boys in the OW/OB group spent significantly less time in TPA on weekends in 2014 than in 2011 ($p < 0.05$). Girls in the OW/OB group spent significantly less time in TPA on both weekdays and weekends in 2014 than in 2011 ($p < 0.05$).

Moderate to vigorous physical activity (MVPA)

Girls recorded significantly less time in MVPA than boys in 2011 and 2014 ($p < 0.05$). Boys and girls also engaged in significantly less time in MVPA on weekdays and weekends in 2014 than in 2011, and they spent significantly less time in MVPA on weekends than on weekdays in 2011 and 2014 ($p < 0.05$).

The OW/OB group of boys spent significantly less time doing MVPA than that by the NW group on weekdays

and weekends in 2014. The OW/OB group of girls spent significantly less time doing MVPA than that by the NW group on weekends in 2011 and 2014 ($p < 0.05$). Boys in the OW/OB group spent significantly less time in MVPA on the weekends in 2014 than in 2011 ($p < 0.05$). Girls in the NW group spent significantly less time in MVPA on the weekends in 2014 than 2011, and the OW/OB group spent significantly less time in MVPA on both weekdays and weekends in 2014 than in 2011 ($p < 0.05$).

Normalized physical activity outcomes (Table 3)

The results of the normalized PA outcomes according to the wear time for individuals based on gender or weight status are discussed here, and denote the same tendency as the results of daily PA outcomes (steps, TPA and MVPA) in this study. Moreover, the OW/OB group of boys spent significantly less time doing MVPA per hour than the NW group on weekdays in 2011 ($p < 0.05$).

Percentage of children achieving WHO recommendations

The percentage of children achieving the WHO recommended levels for MVPA between 2011 and 2014 are shown in Fig. 1. A significantly lower percentage of boys in the OW/OB group achieved the WHO recommenda-

Table 3. Normalized physical activity outcomes (steps, TPA, and MVPA) of children by weight status (per hour)

Boys	ALL N=50		NW N=29		OW/OB N=21	
	2011	2014	2011	2014	2011	2014
Weekdays						
Steps (steps/h)	1366 ± 183	1312 ± 335	1433 ± 135	1421 ± 247	1274 ± 179 §	1162 ± 386 §
TPA (min/h)	13.1 ± 1.9	12.6 ± 3.1	13.7 ± 1.6	13.6 ± 2.2	12.3 ± 1.9 §	11.2 ± 3.6 §
MVPA (min/h)	5.5 ± 1.0	5.7 ± 1.9	5.8 ± 1.1	6.2 ± 1.5	5.2 ± 0.8 §	4.9 ± 2.1 §
Weekends						
Steps (steps/h)	1035 ± 299 #	878 ± 353 *#	1088 ± 332 #	994 ± 337 #	960 ± 234 #	719 ± 318 §*#
TPA (min/h)	10.1 ± 2.9 #	8.7 ± 3.3 *#	10.6 ± 3.2 #	9.8 ± 3.1 #	9.4 ± 2.2 #	7.2 ± 3.1 §*#
MVPA (min/h)	4.2 ± 1.6 #	3.4 ± 1.8 *#	4.4 ± 1.7 #	4.0 ± 1.9 #	3.8 ± 1.4 #	2.7 ± 1.5 §*#
Girls	ALL N=43		NW N=24		OW/OB N=19	
	2011	2014	2011	2014	2011	2014
Weekdays						
Steps (steps/h)	1085 ± 203	981 ± 222 *	1065 ± 176	1027 ± 207	1111 ± 235	922 ± 232 *
TPA (min/h)	10.6 ± 2.0	9.8 ± 2.1 *	10.4 ± 1.7	10.2 ± 2.0	10.9 ± 2.4	9.2 ± 2.2 *
MVPA (min/h)	4.2 ± 1.1	3.8 ± 1.2 *	4.0 ± 1.0	3.9 ± 1.1	4.4 ± 1.2	3.6 ± 1.4 *
Weekends						
Steps (steps/h)	896 ± 200 #	747 ± 281 *#	951 ± 207 #	863 ± 309 #	826 ± 172 §#	598 ± 144 §*#
TPA (min/h)	8.9 ± 1.9 #	7.7 ± 2.9 *#	9.5 ± 2.0 #	8.8 ± 3.3 #	8.2 ± 1.5 §#	6.2 ± 1.5 §*#
MVPA (min/h)	3.6 ± 1.1 #	2.6 ± 1.4 *#	3.9 ± 1.2	3.2 ± 1.5 #	3.2 ± 0.8 §#	1.9 ± 0.8 §*#

NW: normal weight, OW/OB: overweight/obese; TPA: total time spent in physical activity; MVPA: moderate-to-vigorous physical activity; § vs. NW, * vs. 2011, # vs. weekdays; $p < 0.05$; Mean ± SD.

Fig. 1 Percentages of children achieving World Health Organization (WHO) recommendations on both weekdays and weekends by weight status. NW: normal weight, OW/OB: overweight/obese, § vs. NW, * vs. 2011; $p < 0.05$.

tions on weekdays in 2014 than 2011 (90.5 vs. 61.9, $\chi^2 = 4.725$, $p < 0.05$), and a significantly lower percentage of boys in the OW/OB group achieved the WHO recommendations than the NW group on weekdays (61.9 vs. 93.1, $\chi^2 = 7.410$, $p < 0.05$) and weekends (14.3 vs. 48.3%, $\chi^2 = 6.271$, $p < 0.05$) in 2014.

Discussion

This study identified changes in PA and weight status over a 3-year period in Chinese children beginning from ages 7-8 and concluding at 10-11 years of age. The results suggest that objectively measured daily PA outcomes (steps, TPA, and MVPA) are related to weight status. Moreover, OW/OB children showed significant differences in the magnitude of PA change compared to NW controls.

To the authors' knowledge, this is the first longitudinal study using AC data and examining weekday and weekend activity to describe changes in PA during development in Chinese children. The average height and weight of participants were similar to the average national values in 2010, according to data from the China Health and Nu-

trition Survey³¹). Thus, it is reasonable to suggest that our results are applicable to the entire population. The prevalence rates of overweight (21.1% for boys, and 20.5% for girls in 2014) in this study were higher than those of the Chinese Survey (14.2% for boys and 7.7% for girls), but the prevalence rates of obesity (8.5% for boys and 5.5% for girls in 2014) was similar to the Chinese survey (9.4% for boys and 5.4% for girls) by the Working Group on Obesity in China (WGOC) in 2010³². Notably, because of differences in cut-off values for overweight and obesity among studies, the rate of overweight and obesity was not compared with rates in other countries.

A novel aspect of our study was its longitudinal approach, which followed participants over three years to understand developmental trends in PA among children classified by weight status. Particularly noteworthy was the finding that, independent of gender, NW participants maintained their steps and MVPA over time, whereas OW/OB children displayed a steep decline in PA with age, revealing an increasing disparity in activity levels during the transition to adolescence. A number of studies have reported that obese children engage in less PA compared to normal weight children. Berley et al.³³ explored 1-year changes in PA and BMI among 10-15-year-old children, and reported that increasing PA can decrease BMI in overweight boys and girls. The Chinese National Physical Fitness and Health Survey (CNPFFHS) investigated obesity-related behaviors and found that less PA and more sedentary behavior were closely related to overweight and obesity among Chinese students¹². Our findings indicate low levels of PA in OW/OB children; therefore, treatment of obese children should include increasing PA³⁴. This is consistent with the notion that PA is a key modifier of overweight and obesity in children and adolescence. Moreover, our findings support previous longitudinal studies showing a decline in PA with age³⁵⁻³⁷, except for the NW group of boys in this study. An association was reported between changes in PA and changes in body fat (higher levels of PA associated with lower levels of body fat) in 12 to 14-year-old children³⁸.

Similar to previous reports, our results show that the children engaged in more PA on weekdays than weekends, and boys engaged in more PA than girls on weekdays and weekends. The decline in PA by children on weekends concurs with previous research demonstrating that early adolescents are less active, and more sedentary on weekends regardless of age and gender¹⁴. Nyberg et al.³⁹ compared weekday and weekend PA between 6 and 10-year-old Swedish children and showed declines of 14-19% and 13-24% in PA on weekends in boys and girls, respectively. Moreover, in this study, it was clear that the OW/OB group had significantly less PA (steps, TPA and MVPA) on the weekends compared to weekdays. Several researchers have proposed that increasing outdoor time could be an effective strategy for limiting childhood obesity and increasing PA on weekends. Thus, family in-

fluences on PA (e.g., presence of siblings, social support, and modeling) may be more significant on weekends than at other times of the week, when more discretionary opportunities for PA usually exist^(40,41). Previous reviews have clearly shown important differences between boys and girls in the quantity, intensity, and patterns of PA^(13,42). Sherar et al.⁽⁴³⁾ suggested that the differences between genders in maturity (i.e., on average, girls mature earlier than boys do) may be one reason for lower PA in girls relative to boys. Further studies are needed to elucidate the cause of gender differences in PA in children.

According to Tudor-Locke and Myers^(44,45), boys aged 6-12 years should take at least 15,000 steps per day, and girls should take 12,000 steps to derive the health benefits from walking daily. The amount of average steps by children in this study was higher than Tudor-Locke's recommendation and that observed in Canadian and US children^(46,47), but similar to other pedometer data of Chinese children^(48,49). Possible reasons for this difference are as follows. In 2006, the Chinese government recommended that students do calisthenics between the second and third classes each morning, including taking 900-1,700 steps⁽⁴⁸⁾. Moreover, during the week after morning classes end, Chinese students return home for lunch rather than taking a lunch break at school. Our results suggest that these unique characteristics of the Chinese education system may contribute to the increased PA compared to levels observed in other countries.

In our study, children spent less time in TPA on weekdays and weekends in 2014 than in 2011, particularly the OW/OB group. The major reasons for the age-related decline in time spent in TPA are most likely related to increased student schoolwork load with age in China. Older students spend more time in general knowledge courses than younger students⁽¹²⁾. Incidentally, a strong association between MVPA and adiposity has been found in both cross-sectional and longitudinal studies⁽³⁸⁾. According to WHO and other published health guidelines on PA^(50,51), regardless of weight status, children and adolescents should engage in at least 60 min MVPA most days of the week to obtain health benefits. High-intensity activity, especially, is an important aspect of overweight and obesity prevention. In our results, in the OW/OB groups between 2011 and 2014, reductions of 2.6 ± 27.9 and 16.7 ± 25.7 min for boys and 10.5 ± 22.3 and 17.1 ± 16.1 min for girls during weekdays or weekends, respectively, were seen, which could have severe adverse consequences for adolescent metabolic health. A recent meta-analysis examining PA and metabolic outcomes found that a 10-min increase in MVPA was associated with a smaller waist circumference and lower fasting insulin levels⁽⁵²⁾. These findings are supported by several studies⁽⁵³⁻⁵⁵⁾, which generally reported that MVPA is related more strongly to decreased adiposity compared with LPA. Some studies have shown that the effect of MVPA was independent of the amount of sedentary time, which may indicate that in-

creasing PA intensity above LPA provides a greater health benefit than does increasing PA quantity alone⁽⁵⁶⁾. Thus, in the present study, the lack of MVPA may be a major contributing factor to the rising prevalence of overweight or obesity in children.

Our data clearly show that fewer girls achieved the WHO recommendations than boys. Fewer boys and girls in the OW/OB group achieved the WHO recommendations than those in the NW group, especially in 2014, depending on day of the week. Ribeiro et al.⁽⁵⁷⁾ found that 53.7% of Portuguese adolescent boys and 24.6% of girls achieved the WHO recommendations, where 62% of Norwegian boys and 50% of girls met the WHO recommendations⁽⁵⁸⁾. Our results show that the Chinese OW/OB group (38.1% for boys and 15.8% for girls) are less active than European children, particularly Norwegian; but the NW group (70.7% for boys and 29.2% for girls) activity level was similar to that of some European children in 2014. In contrast, more Chinese children achieved the WHO recommendations than Australian children (13% for boys and 24% for girls)⁽⁵⁹⁾, except for the OW/OB group of girls. The results highlight the possibility that children's PA patterns may differ depending on cultural and social background differences, using the same method and/or different methods^(17,60). To promote the WHO recommendations among children, further studies are required to compare the PA patterns in children from different countries.

Our results highlight the importance of promoting MVPA and reducing LPA among children as they transition into adolescence. However, when we consider changes as well as absolute levels in weight status, this seems especially relevant for OW/OB children. Girls in general^(61,62), and OW/OB children of both genders⁽⁶³⁾, are often highlighted as priority groups for PA promotion; but less emphasis has been placed on timing, specifically on the importance of weekends as a target for intervention. Further development of family- and community-based interventions that focus more on PA during weekends may be especially important.

Although the results of this study provide important information regarding the use of AC in assessing longitudinal changes in PA in children, several limitations should be noted. First, the results were obtained from a single medium-sized city in the south of China with a relatively small sample size. Hence, the findings may not be generalizable to other cities or to the entire country. Second, we did not address dietary intake. Only BMI was used to estimate the weight status of these children. Moreover, it is important to clarify the characteristics of PA in children that affect weight status with increasing age. Third, PA was measured using hip-mounted ACs, which have inherent limitations related to the accuracy of assessing PA on inclines and during activities such as cycling, swimming, and upper-body movement. Future studies will address these problems.

Conclusions

In conclusion, the present study suggests that longitudinal changes in PA, predominantly in PA quantity and intensity, are related to weight status in children. Most boys had higher PA than girls. Moreover, PA tended to decline with age in OW/OB children, particularly on the weekends, whereas no change was observed in NW controls. Efforts to prevent the decline of PA in children, particularly in OW/OB children and on weekends, may be a suitable health promotion target.

Conflict of Interests

No commercial company or manufacturer has any professional relationship with any author involved in this work; and the authors declare no conflict of interests.

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