Abstract In Japan, there is a higher incidence of childhood obesity in the Tohoku district than in other areas. It is known that reduced physical activity is associated with increased body weight, but little is known about the physical activity patterns of children in this area. Accordingly, this study was designed to measure the physical activity of 145 children (73 boys and 72 girls) in Hashikami Town, Aomori Prefecture. Physical activity was assessed through a questionnaire as well as through two weeks of pedometer use. Boys spent more time engaging in physical activity than girls did, reporting 9.5 (0.6–22.0) versus 7.0 (1.2–21.5) hours per week [median (range)] (p=0.002). On school days, boys took an average of 13,586±4,386 (mean±SD) steps per day, while girls took 12,248±4,112; on holidays, boys took 9,531±4,557, while girls took 9,419±4,524. There was no significant sex-based difference in the number of steps per day (F=1.197, p=0.276), but both boys and girls significantly reduced the number of steps they took on holidays (F=116.537, p<0.001). In addition, 36 (24.8%) children reduced the number of steps they took by more than 50% on holidays compared to school days. In general, the participants engaged in the internationally recommended amounts of physical activity. Yet their reduced level of physical activity on holidays seems to be a matter for concern, as it is a possible cause of the higher incidence of childhood obesity in this area. J Physiol Anthropol 29(2): 59–64, 2010 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.29.59]

Keywords: childhood obesity, Tohoku district, physical activity, pedometer

Introduction

Researchers in many countries have expressed considerable concern about recent rapid increases in the rates of childhood obesity (WHO, 2000; Hedley et al., 2004; Mészáros et al., 2008). Obesity that begins in childhood often continues into adulthood, which is closely associated with lifestyle-related diseases (Guo et al., 2002). Moreover, childhood obesity is already known to complicate lifestyle-related diseases such as hyperlipidemia, diabetes, and hypertension (Nguyen et al., 2008).

In Japan, the rate of childhood obesity has increased significantly in the last three decades (Ministry of Education, Culture, Sports, Science and Technology, 2006). For example, the rates of obesity among 10-year-olds and 11-year-olds increased from 5.86% and 6.46%, respectively, in 1977, to 9.46% and 9.85%, respectively, in 2006. A significantly higher incidence of childhood obesity is found in the Tohoku district, the northern part of Honshu Island (Cabinet Office, Government of Japan, 2008). According to this report, the obesity rates for 12-years-old boys in Aomori, Iwate, and Miyagi prefectures are 20.18%, 15.62%, and 16.03% respectively, which are all considerably higher than the national average for that age, 12.41%.

Various factors are implicated in the development of obesity, but the balance between energy intake and energy expenditure is the principal determinant of weight gain or loss. Recent lifestyle changes, especially in diet and physical activity habits, have surely contributed to the increased prevalence of obesity in children as well as adults across the globe (WHO, 2000). In previous studies on the subject, daily physical activity has often been assessed through the use of pedometers (Tudor-Locke and Bassett Jr., 2004). Although pedometers are unable to measure the intensity of walking, or to detect other forms of exercise such as upper body movement, biking, and swimming, they are easy to use and cost-effective, and the data they provide is objective. The validity of pedometer use in studies on children is well attested (Rowland and Eston, 2005; Beets et
al., 2005), and target values, 13,000 steps/day for boys and 11,000 for girls, have been established (President's Council on Physical Fitness and Sports, 2001). Lower numbers of steps/day are frequently reported to be associated with increased body weight in children (Vincent et al., 2003; Duncan et al., 2006; Al-Hazzaa, 2007). Yet little is known about the number of steps/day taken by children in the Tohoku district, in spite of this region's higher incidence of obesity. Therefore, this study aimed to measure the physical activity of children in this region, mainly through the use of pedometers, and to examine the relationship between activity level and obesity.

Methods

Participants
The study was conducted in Hashikami Town, Aomori Prefecture, in October and November of 2008. This town is located on the border with Iwate Prefecture and faces the Pacific Ocean. Its population is nearly 15,000. We announced this project to all of the elementary schools in the town, and teachers from the schools recruited participants. One hundred forty-seven children (74 boys and 73 girls), from 4 out of 7 schools, enrolled in this study. According to town statistics for 2008, the total number of elementary school children was 872; thus the response rate was 16.9%. All of the participants usually walk to and from school. This study was approved by the ethics committee of Hashikami Town, and written informed consent was obtained from the guardians of all participants.

Assessments of anthropometrics, physical activity, and daily lifestyles
Participants’ heights were measured to 0.1 cm and their body weights (dressed in light underwear) to 0.1 kg. The formula used by the Japanese Society of School Health was adopted, such that a child whose body weight was equal to or greater than 20% of the standard weight for his or her height was classified as obese (Ministry of Education, Culture, Sports, Science and Technology, 2006). Teachers at each school instructed the participants in how to use a pedometer and distributed identical forms on which the participants were to record all data during the study period. Participants were asked to record the number of steps they took each day, as measured by their pedometers (Yamasa EM-180, Yamasa, Tokyo, Japan), for two weeks, from rising in the morning to going to bed in the evening except during water activity and intense exercise. We have previously reported that the accuracy of this pedometer is very close to that of an accelerometer (Mitsui et al., 2008); we have also tested its accuracy prior to this survey in a treadmill study in which 7 university students walked 80 m/min, and found that it is acceptably accurate, with <1% error (unpublished data). The participants in the present study were also asked to answer certain lifestyle-related questions on each day, including whether they ate breakfast that day, and how much time they spent watching TV, playing computer games, and engaging in exercise; their answers were recorded on the same sheet.

Data analysis
For a participant’s data to be included in our statistical analyses, we had to have data on that participant from at least 5 school days and 2 holidays. Data are expressed as means±SD, or as median (range) when the data are not normally distributed. An unpaired t-test and a Mann-Whitney U test were used for the comparison of means and medians, respectively. The numbers of steps/day taken by children of each sex on school days and on holidays were compared using two-way repeated measures of ANOVA because previous studies have shown that boys are more active than girls and that children are more active on school days than on holidays (Duncan et al., 2006; Rowlands et al., 2008). In addition, the change ratio in the number of steps/day between school days and holidays, (holiday-school day)/school day, was calculated. Correlation coefficients were calculated between degree of obesity and age, time spent engaged in sedentary pursuits, number of steps taken, and the difference ratio between school days and holidays. To investigate the effect of advancing years, all participants were classified into groups consisting of 1st- and 2nd-graders only, 3rd- and 4th-graders only, and 5th- and 6th-graders only for each sex, and one-way ANOVA was used to compare these groups. When a significant F-value was obtained, Dunnet’s multiple test was adopted to compare each group of children within 1–2 years of the same age with other groups. A value of p<0.05 was considered statistically significant.

Results
One boy and one girl reported data from an insufficient number of days, as defined above, and were therefore excluded from the data analysis. The descriptive characteristics of the participants are shown in Table 1. The mean age of boys was significantly higher than that of girls (p<0.05). The incidence of obesity was 17.8% in boys and 13.9% in girls. There was no significant gender-based difference in the amount of time spent watching TV, but boys spent more time playing computer games (p<0.001). Boys also spent more time playing sports (p=0.002), logging 9.5 (0.6–22) hours/week vs. 7.0 (1.2–21.5) hours/week for girls.

The numbers of steps/day taken by children of each gender on school days and on holidays are displayed in Fig. 1. The mean numbers of steps/day taken by boys and girls were 13,586±4,386 and 12,248±4,112, respectively, on school days, and 9,531±4,557 and 9,419±4,524, respectively, on holidays. Thirty-eight (52.1%) boys and 41 (56.9%) girls engaged in the internationally recommended minimum amount of physical activity, described above. There was no significant main effect for sex (F=1.197, p=0.276), but there was a more significant main effect for type of day (F=116.537,
The interaction between sex and type of day was not statistically significant ($F = 3.695, p = 0.057$).

Table 2 shows the difference ratio between school days and holidays. Only 24 (16.5%) children increased the number of steps they took on holidays, and nearly one quarter of the participants decreased the number of steps they took on holidays by more than 50% compared to the number they took on school days. Table 3 shows the correlation coefficients between degree of obesity and several other variables. Obesity was positively associated with the amount of time spent on TV and computer games ($r = 0.269, p < 0.05$) and negatively associated with the number of steps taken per day ($r = -0.275, p < 0.05$) in boys, though no such significant relationship was observed in girls. Furthermore, no significant relationship was identified between obesity and the change ratio between school days and holidays in either boys ($r = 0.179$) or girls ($r = 0.216$). Table 4 shows the values for the same variables classified according to age group. There was no significant age-related difference in any of the variables in boys, but the amount of time spent exercising significantly increased ($p = 0.030$) in girls. None of the children skipped breakfast regularly.

**Discussion**

On school days, at least, the mean level of physical activity in which the participants engaged matched or exceeded the recommended level: 1 hour of physical activity per day (National Association for Sports and Physical Education, 2004), and ≥13,000 steps/day for boys and ≥11,000 steps/day for girls. Previous studies have observed that children usually...
One-way ANOVA was used to compare these groups. When a significant F-value was obtained, Dunnet’s multiple test was adopted.

In Caucasian women (\(r > 0.417, n=80\)) (Thompson et al., 2004) and African–American women (\(r=0.479, n=69\)) (Hornbuckle et al., 2005). Walking is fairly reflective of overall energy expenditure in ambulatory people (Tudor-Locke and Myers, 2001), which means pedometers are useful tools in assessing physical activity, especially in people who do not engage in intense exercise. In children, who often engage in systematic exercise in physical education and club activities, pedometers may be less appropriate for assessing physical activity because they do not measure the intensity of walking and must be taken off during periods of intense exercise, in activities such as soccer, baseball, and swimming.

The amount of time spent engaged in sedentary pursuits, such as watching TV and playing computer games, is considered to be directly associated with the rate of childhood obesity (Tremblay and Willms, 2003). Likewise, we too found a significant positive relationship between these two factors, at least in boys. The amounts of time spent on TV and computer games by both boys and girls in Hashikami Town did not exceed Japanese national averages: according to a comprehensive report by a private institution (Benesse Corporation, 2005), the average approximate amounts of time that elementary school children spent watching TV and playing computer games were 2 hours and 1 hour, respectively.

As mentioned above, boys usually walk more than girls do. In the present study, however, although boys reported spending more time engaged in exercise, they did not report taking significantly greater numbers of steps. In addition, both boys and girls in this study reduced their walking activity on holidays, and nearly one quarter of our participants decreased the number of steps they took by more than 50% on holidays. The latter observation was unexpected, and presents a serious concern. In contrast to a previous study that showed a greater reduction in physical activity among girls on holidays (Rowlands et al., 2008), our study indicated that boys reduced their physical activity by 29.9%, while girls reduced theirs by only 23.1%. One cause of the greater reduction in physical activity among boys may be the increased amount of time they spent playing computer games on holidays.

Another cause of the significant reduction in the numbers of steps taken on holidays may be the fact that children do not walk to and from school on holidays. While motor transportation to and from school is common in other countries, reaching rates of 40.0%, 64.0%, and 72.5% among Filipino, English, and Cypriot children, respectively (Tudor-Locke et al., 2003; Cooper et al., 2003; Loucaides and Jago, 2008), all children in the present study usually walk to and from school.
from school, and this active transportation constitutes a considerable portion of their daily physical activity. In fact, motor-transported children have been observed to take significantly fewer steps/day than active-transported children (Faulkner et al., 2009).

As in previous studies (Vincent et al., 2003; Al-Hazzaa, 2007), we did not observe any significant differences in numbers of steps/day among the age groups, for either boys or girls. Yet it should be noted that, as children grow, the length of their strides increases and that this will naturally result in a smaller number of steps being required to travel the same distance. Thus the observation that children do not reduce the numbers of steps they take per day as they grow older may actually indicate that they are exercising more. Along the same lines, the amount of time that girls spent exercising significantly increased with age: specifically, 5th- and 6th-grade girls were more active than 1st- and 2nd-grade girls. A possible explanation for this is that the growing concern for the security of young girls limits their outdoor activity.

This study has several limitations. First, the research was conducted in October, and it should be noted that children will naturally reduce their walking activity, along with all other outdoor activities, in the winter months (Duncan et al., 2008). Further research is needed to quantify the seasonal effect on physical activity in this region. Second, the participants were volunteers rather than randomly selected individuals, and the sample size was relatively small; a more comprehensive randomized survey is needed to generalize our results. Third, the accuracy of pedometers for studies on school children, and especially younger school children, is controversial (Eisenmann and Wickel, 2005). Nakae et al. (2008) recommended accelerometers, which are more suitable for young children because, unlike pedometers, they can record slow walking activity. Although accelerometers are more accurate than pedometers, their high cost may limit their use in population studies; for example, the widely used Kenz Lifecorder accelerometer (Suzuken, Nagoya, Japan) costs approximately $30,000 yen, while the pedometer used in this study costs approximately $1,500 yen. In designing the present study, we decided that the additional accuracy offered by accelerometers was not worth the significant increase in cost.

In conclusion, the physical activity habits of children in Hashikami Town generally met international standards, in spite of this region’s high rate of childhood obesity. Their activity level fell dramatically on holidays, however: nearly one quarter of children reduced the number of steps they took per day by more than 50% on holidays compared to school days. These results indicate that a significant reduction in physical activity on holidays may be associated with a higher incidence of obesity. We recommend that children receive appropriate instruction, both at school and at home, on healthy ways to spend their holidays.

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