A Study on the Daily Physical Activity of Junior High School Students in Japan

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Abstract

The purpose of this study was to estimate daily energy expenditure (EE) and daily activity factor (DAF: $EE/basal\ metabolism - 1$) of junior high school students in Japan using heart rate (HR) monitoring method. Daily activity recording and 24 hour HR monitoring were measured in all the subjects. The relational formulas between HR and oxygen consumption were obtained from bicycle ergometer test. Subjects were 112 junior high school students (68 male and 44 female) from the 1st to the 3rd year. The averages of EE (kcal/kg) of the 1st, 2nd, and 3rd year students were 54.3, 46.7, and 44.5 (kcal/kg) for males and 50.1, 44.4, and 40.5 (kcal/kg) for females respectively. In the same way DAF were 0.80, 0.61, and 0.59 for males and 0.77, 0.65, and 0.51 for females. It was shown that EE (kcal/kg) and DAF have a tendency to decrease as school year increases in both male and female students.

Key words: physical activity, energy expenditure, heart rate, oxygen, children

Introduction

The energy requirements for Japanese students who are 15 years old and older are available to the public¹⁾ and are calculated according to activity level. The energy requirements for students who are 14 years old and younger, however, are calculated at one fixed level of physical activity (moderate), which equates to a daily activity factor (DAF) of 0.43 to 0.62. These figures are the magnifying power against basal metabolism (BM), which is used to obtain the energy requirement for one day of living. Actual levels of physical activities, however, are not yet clearly known. The incidence of obesity in children is rising in Japan²⁾. Obesity caused by excess nutrition intake and lack of physical activity is a typical contributing factor of chronic disease in children as well as in adults. Some investigators^{3,4)} have suggested that there is, as of yet, little evidence to support this theory in children. However, obesity in children is increasing and is becoming an issue for children. In order to make the actual level of physical activity of children clear, daily energy expenditure (EE) of junior high school students was estimated by monitoring heart rate (HR) during a 24-hour period. Furthermore, a daily activity factor (DAF) was calculated from the children's EE values and basal

metabolism.

Subjects and Methods

1. Subjects

One hundred twelve healthy students, 68 males and 44 females, participated in this study. These students were in their first to third year of junior high school in Hirosaki, Japan. They were given a detailed explanation of this study, and informed consent was obtained from all subjects, their parents, the school administrator, and the school nurse. The subjects were from two different schools. One was a relatively large, center-city school, whereas the other was a small, suburban school. Body weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively, with the subjects wearing light clothing and no shoes. Skin fold thickness was measured at the triceps and subscapular with a skin caliper (Eiken type, Meiko Co., Tokyo,

Fig.1 Classification of daily activities.

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Japan). Body surface area was calculated using Fujimoto's equation⁹⁾. Subjects had shown no symptoms of illness at their periodic school health examination. Measurements and investigation were performed from September 1991 to December 1993.

2. Heart rate measurement over a 24-hour period
Heart rate was continuously recorded minute-by-minute

Table 1 Physical characteristics of subjects

Year	1st	1-2	2nd	2-3	3rd	1-3
Male						
n	29		27		12	
Age	13.0 ± 0.3***		14.0 ± 0.3***		15.1 ± 0.3***	
(yr)	12.6 ~ 13.5		13.6 ~ 14.5		14.7 ~ 15.5	
Height	154.6 ± 7.8***		161.8 ± 7.2*		167.1 ± 6.1***	
(cm)	135.7 ~ 167.4		141.9 ~ 173.1		154.4 ~ 177.2	
Weight	50.5 ± 12.8*		55.5 ± 10.8		59.4 ± 9.5**	
(kg)	30.4 ~ 86.2		32.9 ~ 76.5		45.5 ~ 76.6	
Body surface#	1.426 ± 0.192		1.534 ± 0.165		1.618 ± 0.142	
(m ²)	1.049 ~ 1.869		1.119 ~ 1.819		1.367 ~ 1.879	
Skinfold thickness##	24.1 ± 11.9		20.9 ± 8.7		21.1 ± 8.1	
(mm)	12.0 ~ 62.0		9.5 ~ 41.5		11.5 ~ 36.0	
Female						
n	21		16		7	
Age	13.0 ± 0.3***		14.0 ± 0.3***		14.9 ± 0.3***	
(yr)	12.7 ~ 13.5		13.6 ~ 14.5		14.6 ~ 15.5	
Height	154.0 ± 5.3		156.8 ± 4.8		159.0 ± 5.5*	
(cm)	144.2 ~ 164.1		149.8 ~ 164.1		153.0 ~ 177.2	
Weight	50.1 ± 9.5		52.8 ± 9.3		54.9 ± 11.8	
(kg)	38.6 ~ 72.0		43.2 ~ 75.4		44.4 ~ 86.2	
Body surface#	1.419 ± 0.128		1.470 ± 0.124		1.507 ± 0.154	
(m ²)	1.231 ~ 1.677		1.315 ~ 1.728		1.344 ~ 1.879	
Skinfold thickness##	31.2 ± 15.6		33.0 ± 15.8		34.8 ± 18.3	
(mm)	15.0 ~ 67.5		14.0 ~ 72.0		20.0 ~ 72.0	

The data are given in mean ± SD (upper) and range (lower).

#: Calculated from Fujimoto's equation. ##: sum of triceps and subscapular.

1-2, 2-3, 1-3 represent the comparison between 1st and 2nd, 2nd and 3rd, 1st and 3rd year, respectively.

*:p<0.05, **:p<0.01, ***:p<0.001.

Table 2 Time allocated to each activity category

Year	1st	1-2	2nd	2-3	3rd	1-3
Male						
n	29		27		12	
Sleeping	478 ± 69		476 ± 49*		442 ± 46	
	(33.2 ± 4.8)		(33.4 ± 2.9)		(30.7 ± 3.2)	
Staying home	366 ± 85*		432 ± 136		422 ± 99	
(excluding sleep time)	(25.4 ± 5.9)		(30.0 ± 9.6)		(29.3 ± 6.9)	
Studying in school	265 ± 49		233 ± 74***		316 ± 38**	
	(18.4 ± 3.4)		(16.0 ± 5.2)		(21.9 ± 2.7)	
Commuting	51 ± 17		46 ± 17		49 ± 14	
	(3.5 ± 1.2)		(3.2 ± 1.2)		(3.4 ± 1.0)	
Other activities	281 ± 89		249 ± 98		211 ± 54**	
in school	(19.5 ± 6.2)		(17.4 ± 6.8)		(14.7 ± 3.7)	
Female						
n	21		16		7	
Sleeping	482 ± 67		480 ± 57**		385 ± 90**	
	(33.5 ± 4.7)		(33.3 ± 4.0)		(26.7 ± 6.3)	
Staying home	362 ± 100		368 ± 117*		502 ± 79**	
(excluding sleep time)	(25.2 ± 6.9)		(25.6 ± 8.1)		(34.9 ± 5.5)	
Studying in school	251 ± 68		251 ± 38		237 ± 58	
	(17.5 ± 4.7)		(17.4 ± 2.7)		(16.5 ± 4.0)	
Commuting	45 ± 13		43 ± 12*		57 ± 12*	
	(3.1 ± 0.9)		(3. ± 0.8)		(3.9 ± 0.9)	
Other activities	300 ± 56		299 ± 78		259 ± 60	
in school	(20.8 ± 3.9)		(20.8 ± 5.4)		(18.0 ± 4.2)	

The data are given in mean ± SD (min).

Values in parentheses are the percent ratio of each activity category to 1440 min(%).

1-2, 2-3, 1-3 represent the comparison between 1st and 2nd, 2nd and 3rd, 1st and 3rd year, respectively.

*:p<0.05, **:p<0.01, ***:p<0.001.

over a 24-hour period with an HR recorder (Memory MAC, VINE Co. Tokyo, Japan). The subjects were instructed to stay in bed, on their backs, for 10 minutes after waking so their HR could be recorded during the basal metabolic state.

3. Recording of daily activity

After it was determined that the subjects understood all of the procedures involved in this experiment, they were instructed to record their activities minute-by-minute for a 24-hour period.

4. Examination of the relationship between oxygen consumption (VO_2) and HR

The relationship between VO_2 and HR was obtained by a previously-reported procedure⁽⁶⁻⁸⁾. This relationship was expressed as two regression formulas (A and B) corresponding to sedentary and active situations, respectively. Formula A was derived from the VO_2 and HR in the basal metabolic state and while resting. Formula B was derived from three point values obtained while exercising on a bicycle ergometer. Heart rate in the basal metabolic state was defined as the mean of HR during the 10 minutes in bed, as previously mentioned, and VO_2 was taken from the reference value in the Recommended Dietary Allowances⁽⁹⁾ for the Japanese. Oxygen consumption and HR during rest were obtained before exercising. The exercise load was increased in three levels (0, 25, and 50 watt) on the bicycle ergometer, each level lasting 4 minutes. Oxygen consumption and HR were measured every minute, and the values at the 3rd or 4th minute from each of the three levels were used to calculate Formula B. These calculations were performed within 10 days before or after the 24-hour HR measurement.

Statistical analysis was performed using unpaired student's *t*-test and was considered significant at $p < 0.05$.

Results

Characteristics of the subjects are shown in Table 1. Mean height and body weight were slightly greater than the national average⁽⁹⁾ reported in April 1992. Height and body weight of subjects in the 3rd year of junior high school were statistically greater than those of subjects in the 1st year in males, and in females, only the height of subjects in the 3rd year was statistically greater than that of the 1st year. Skinfold thickness in males and females was not statistically different among these three groups of students.

Daily activity categories are shown in Figure 1. The time

allocation for each activity, calculated from recordings of daily activity, is shown in Table 2. Among these categories, lunch time at school was listed under the category of "other activities" at school and physical education class was listed under the category of "studying". Time spent on sleeping and participating in other school activities was shorter for the 3rd year subjects than for the 1st and 2nd year subjects, for both males and females. Time spent at home and commuting to school was longer for 3rd year female students. Time spent in academic classes was significantly longer for the 3rd year male subjects than for those in the 1st and 2nd year. These values are generally similar to those reported in a study on how Japanese nationals⁽¹⁰⁾ spent their time. This study reports the following daily time allocations for males and females, respectively: 483 and 460 minutes sleeping, 406 and 429 minutes at home (excluding sleeping), and 45 and 48 minutes commuting. Slight differences in procedure did not influence the results in our study. Among the 1st and 2nd year students about half of the males and one-third of the females participated in school sports and/or club activities. Most of these students, however, did not have physical education class on the day measurements were taken. On the other hand, the 3rd year students almost all of the males and females participated in sports activities and had physical education class for 50 or 100 min on the day measurements were recorded.

Table 3 shows the mean, median, maximum, and minimum HRs recorded over 24 hours and the mean $\pm$ standard deviation (SD) of HRs for each activity category. The mean maximum HR for the observed day was almost 159 ~ 161 beats/min for males

Table 3 Heart rate over 24 hours and at basal condition

24 hour heart rate \ Year	1st	2nd	3rd
Male 24 hours			
n	29	27	12
Mean	83 $\pm$ 6	81 $\pm$ 6	78 $\pm$ 6
Median	81 $\pm$ 7	79 $\pm$ 6	77 $\pm$ 7
Maximum	159 $\pm$ 13	156 $\pm$ 12	161 $\pm$ 14
Minimum	55 $\pm$ 6	53 $\pm$ 5	50 $\pm$ 5
Basal condition	68 $\pm$ 5	68 $\pm$ 6	65 $\pm$ 8
Female 24 hours			
n	21	16	7
Mean	83 $\pm$ 8	82 $\pm$ 5	82 $\pm$ 4
Median	80 $\pm$ 9	81 $\pm$ 6	82 $\pm$ 4
Maximum	165 $\pm$ 13	163 $\pm$ 13	161 $\pm$ 27
Minimum	54 $\pm$ 6	53 $\pm$ 5	53 $\pm$ 4
Basal condition	69 $\pm$ 6	69 $\pm$ 7	66 $\pm$ 6

The data are given in mean $\pm$ SD (beats/min).

Fig.2 Mean heart rate (HR) for each activity category in proportion to HR at basal metabolism (BM) (100%) among male students. Each bar represents the mean and SD.

Fig.3 Mean heart rate (HR) for each activity category in proportion to HR at basal metabolism (BM) (100%) among female students. Each bar represents the mean and SD.

and 161 ~ 165 beats/min for females, whereas the HR of some students who attended physical education class was recorded as high as 200 beats/min, which was near the HR maximum for 13 ~ 15 year olds¹¹⁾. The mean HR values among both male and female students of all three years were almost the same.

Mean values for each activity category in relation to the HR (100%) in the basal state are shown in Figures 2 and 3. There were no statistical difference in HR values among the three years for both males and females. Energy expenditures (kcal/kg/min) derived from the 24-hour HR monitoring and the relational regression formulas between HR and VO_2 , using the previously-reported procedure, are shown in Figures 4 and 5. Energy expenditures (kcal/kg/min) for staying home, commuting, and participating in other school activities were statistically different between the 1st and 3rd year male subjects, while in female subjects, EEs (kcal/kg/min) for sleeping and participating in other school activities were statistically different between the 1st and 3rd years. In general, energy expenditures (kcal/kg/min) of 3rd year subjects were lower than those of 1st year subjects. Daily EE (kcal/day) and DAF are shown in Table 4. The DAF is defined as the level of physical activity and is calculated as :

$$\text{DAF} = \text{EE (kcal/day)} / \text{BM (kcal/day)} - 1.$$

In this study, BM (kcal/day) was estimated from the reference value in the Recommended Dietary Allowances⁹⁾ for the Japanese. Daily EEs (kcal/day) of males and females were not

statistically different among the three years, but EE (kcal/kg) of the 3rd year subjects was statistically lower than that of the 1st year subjects for both males and females. The DAF for males was statistically lower with each increasing year of junior high school, whereas in females, there was only a tendency for the DAF to become lower with each increasing year of junior high school. Consequently, DAF of junior high school students corresponded to physical activity level III (light heavy) to II (moderate) for adults and had a tendency to become lower with each increasing school year.

Discussion

The RMR (Relative Metabolic Rate) method has generally been used to estimate EE of adults in Japan¹²⁾. The RMR is calculated as follows: $(\text{O}_2 \text{ in activity} - \text{O}_2 \text{ in resting}) / \text{O}_2 \text{ in the basal metabolic state}$. The RMR values of many activities, for example walking (70m/min), running (140m/min), and studying are estimated and are generally the same in spite of differences in sex, age, height, and weight¹¹⁾. Accordingly, the RMR method also has been used to estimate energy requirement. Whether or not this method is applicable to junior high students has not been determined¹³⁾. Other methods that are similar to RMR also reported that RMR may not be applicable for junior high school students¹⁴⁾. The HR method was used in junior high school

Table 4 Energy expenditures(EE) and daily activity factors(DAF)

Year	1st	2nd	3rd
Male			
n	29	27	12
EE(kcal/day)	2699 ± 670	2512 ± 517	2635 ± 501
EE(kcal/kg)	54.3 ± 10.5*	46.7 ± 12.2	44.5 ± 6.1
EE(kcal/kg-WT/min)	0.038 ± 0.007**	0.032 ± 0.008	0.031 ± 0.004
EE(kcal/kg-LBM/min)	0.047 ± 0.008***	0.039 ± 0.009	0.037 ± 0.005
DAF	0.80 ± 0.33*	0.61 ± 0.33	0.59 ± 0.22
Female			
n	21	16	7
EE(kcal/day)	2496 ± 631	2314 ± 455	2173 ± 497
EE(kcal/kg)	50.1 ± 10.0*	44.4 ± 8.1	40.5 ± 9.5
EE(kcal/kg-WT/min)	0.03 ± 0.007*	0.031 ± 0.006	0.028 ± 0.007
EE(kcal/kg-LBM/min)	0.047 ± 0.012	0.042 ± 0.008	0.039 ± 0.008
DAF	0.77 ± 0.37	0.65 ± 0.30	0.51 ± 0.32

The data are given in mean ± SD.

WT: Body weight (kg), LBM: Lean body mass (kg).

Statistical comparison performed between the 1st and 3rd year.

*:p<0.05, **:p<0.01, ***:p<0.001.

Fig.4 Energy expenditure for each activity category among male students.
Each bar represents the mean and SD.
*:p<0.05, **:p<0.01, ***:p<0.001.

Fig.5 Energy expenditure for each activity category among female students.
Each bar represents the mean and SD.
*:p<0.05, **:p<0.01.

students because the efficacy of RMR in this age group is unknown. Actual levels of physical activity for junior high school students are not clearly known at this time. These issues are becoming more important as the incidence of obesity in Japanese children rises. The consumption of calories relative to energy expended through daily physical activities needs to be better understood at this time of increasing incidence of obesity.

HR method is widely used to estimate the EE of younger subjects. Mental and emotional stimulus usually increases HR and may cause us to overestimate EE in daily life⁶⁾. In addition, it is complicated to obtain individual estimation equations for VO_2 and HR. However, it is still considered to be a useful method which can continuously estimate the EE without seriously interfering with the activity itself. Spurr¹⁵⁾ reported that the maximum error of EE within individual of HR method was +20 % ~ -15 % compared with whole body calorimeter, indirect calorimeter. Kalkwarf⁶⁾ reported that HR method of almost the same procedure as in this study showed the smallest error of EE among two HR methods. Moreover, this method is useful to estimate average EE in the community instead of individual EE due to significant error.

The time allocation for each activity of the junior high school students in this study was similar to those of the junior high school students reported by NHK in 1990¹⁰⁾. We believe the subjects in this study are average Japanese junior high school students. The results obtained from the 24-hour HR monitoring showed similar activity levels in all three years for both males and females. The EE estimated from HR, however, was not same. In this study, the SDs of EE (kcal/day), EE (kcal/kg), and DAF were large because physical activity was not restricted and the number of subjects was small. Among the 1st and 2nd year students about half of the males and one-third of the females participated in school sports and/or club activities. Most of the students, however, did not have physical education class on the day measurements were taken. Among the 3rd-year students almost all of the males and females participated in sports activities but had physical education class for 50 or 100 min on the day measurements were recorded. Comparing with averages of EE among 1st, 2nd and 3rd year students may be impossible, because time to spend in sport activity was different in each group. However, it is important to note that the energy expenditures (kcal/kg) of the 3rd year students were statistically lower than those of the 1st year students for both males and females in spite of the fact that all of the 3rd year students had physical education class and most of the 1st and 2nd year students did not have physical education class. The DAF also had a tendency to lower from physical activity level III (light heavy) to II (moderate) as the school years advanced for both males and females. One of the reasons of this decrease in DAF may be that almost all of the males and females in the 3rd year took physical education classes but were not engaged in other sports activities on the day of

measurement. Another possible reason is the increased time spent on studying both in school and at home and decreased time spent on sleeping, as indicated in the students' recording of their daily activities. Because junior high school students spend most time on studying among all different of youngsters in Japan and their free time is limited, it is believed that they have no spare time to increase their individual level of physical activity¹⁷⁾. Competition in academic pursuits and sports steadily increases may make junior high school students and their parents may neglect the importance of daily physical activity in order to remain to be competitive academically. School teachers and school nurses need to appeal to the parents to increase the physical activity of students to avoid conditions that would promote obesity.

Conclusion

Daily energy expenditures and daily activity factors of 112 healthy students (68 males and 44 females) from the 1st to 3rd year in two junior high schools were estimated by monitoring their HR for 24 hours.

The following results were noted:

1. Energy expenditures of 1st, 2nd, and 3rd year students were 2699 ± 670 kcal/day (54.3 ± 10.5 kcal/kg), 2512 ± 517 kcal/day (46.7 ± 12.2 kcal/kg), and 2635 ± 501 kcal/day (44.5 ± 6.1 kcal/kg) for males and 2496 ± 631 kcal/day (50.1 ± 10.0 kcal/kg), 2314 ± 455 kcal/day (44.4 ± 8.1 kcal/kg), and 2173 ± 497 kcal/day (40.5 ± 9.5 kcal/kg) for females, respectively.
2. Energy expenditures when staying home (excluding sleep time), commuting, and participating in other school activities of the 3rd-year students were statistically lower than those of the 1st-year students for males, whereas Ees during sleeping and participating in other school activities of the 3rd year female students were statistically lower than those of the 1st year female students.
3. Daily activity factors calculated from energy expenditure and reference basal metabolism were 0.80 ± 0.33 , 0.61 ± 0.33 , and 0.59 ± 0.22 for males, and 0.77 ± 0.37 , 0.65 ± 0.30 , and 0.51 ± 0.32 for females in 1st-, 2nd-, and 3rd-year, respectively. These results showed a tendency to lower from physical activity level III (light heavy) to II (moderate) for adults according to the Recommended Dietary Allowances for the Japanese.

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