A Study on Physical Activity in Junior High School Students: Energy Expenditure in the Second-Grade Students

Kazuyuki KIDA*, Guang SUN*, Reizo MITA*
and Saburo USUTANI**

I Introduction

The energy requirement for Japanese people 15 years old and over is publicly available (Energy Requirement in Recommended Dietary Allowances for the Japanese (Ministry of Health and Welfare 1989)) and is calculated according to activity level. The requirement for people 14 years old and younger, however, is calculated at one fixed level-level II of physical activity (Moderate), which equates to a daily activity factor of 0.5. This figure becomes the magnifying power against basal metabolism which is used to obtain energy required for living one day. Actual levels of physical activities, however, are not clearly known yet.

Although some investigators have suggested that lower levels of physical activity may cause chronic disease in younger people, there is, as yet, little evidence to support this (Charney 1967, Saris 1985, Despres 1990). In order to obtain fundamental information to fill this gap, the energy expenditure (EE) and daily activity factors (DAF) of second grade students in junior high schools were estimated using the heart rate (HR) method as described in a previous study (Kida 1992).

II Subjects and Methods

1. Subjects

Forty five healthy students (27 male and 18 female), aged from 13 to 14 years old, of the second grade of junior high school in Hirosaki city took part in this study. Detailed explanation was given before the study began, and informed consent was obtained from the parents of all subjects. The subjects came from two different schools. One was located in the center of the city and was relatively large, while the other was in the suburbs and was small. The socioeconomic circumstances of the two schools were different. The physical characteristics of the subjects are shown in Table 1. 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. Skinfold thickness was measured at the biceps and subscapular with a skinfold caliper (Eiken type, Meiko Co.) to calculate body density (Nagamine 1964) and body fat (Brozek 1963). Body surface area was calculated by means of Fujimoto's equation (Fujimoto 1968). Subjects had shown no symptoms in their periodical school check-up. Measurement and investigation were performed from September to December of 1992.

* 弘前大学医学部公衆衛生学教室

** 青森県弘前保健所

* *Department of Public Health, Hirosaki University School of Medicine, Hirosaki, Japan*

** *Hirosaki Health Center in Aomori Prefecture, Japan*

2. HR measurement for 24 hours

HR was continuously recorded minute-by-minute with a HR recorder (Memory Mac, Vine Co.) for 24 hours. All the subjects were instructed to stay in bed on their back for 10 minutes after waking to record HR during basal metabolic condition. Recordings were done on regular schooldays (10 males and 4 females attended class only in the morning owing to school activities).

3. Daily activity recording

After the whole procedure of this experiment was well understood, all the subjects were instructed to record their activities minute-by-minute for a 24 hours period.

4. Examination of the relationship between oxygen consumption and HR

The relationship between oxygen consumption (VO_2) and HR was obtained by the same procedure as that previously reported (Kida 1992). The relation between VO_2 and HR were 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 basal metabolic and resting conditions and formula B was derived from three point values obtained while exercising on a bicycle ergometer. HR in basal metabolic condition was the mean for 10 minutes in bed as mentioned above and VO_2 was taken from the reference value in Recommended Dietary Allowances for the Japanese. VO_2 and HR in resting condition were obtained before exercising. The exercise load was increased in three stages (0, 25, 50 watt) by ergometer, each step lasting 4 minutes. VO_2 and HR were measured every minute and the values at 3rd or 4th minute from the three steps were used to calculate formula

B.

This calculating procedure was performed within 10 days before or after the 24-hour HR measurement.

III Results

Mean height and body weight (Table 1) were slightly greater than the national average (Ministry of Education in Japan 1992) published in April of the same year. Using Rohrer's index, the obesity rate for both male and female was 6.7% over 160. The values obtained for height, skinfold thickness, body fat percentage and basal metabolic rate differed significantly between male and female. The basal metabolic rate was obtained from the reference values in

Table 1 Characteristics of subjects

	mean $\pm$ SD (min~max)	
	Male	Female
Number	27	18
Age (yr)	14.0 $\pm$ 0.3 (13.6~14.5)	14.0 $\pm$ 0.3 (13.6~14.5)
Height (cm)	161.8 $\pm$ 7.2** (141.9~173.1)	156.3 $\pm$ 5.3 (145.0~164.1)
Weight (kg)	55.5 $\pm$ 10.8 (32.9~76.5)	52.1 $\pm$ 9.0 (43.2~75.4)
Rohrer index (kg/cm ³) $\times 10^7$	130.2 $\pm$ 19.5 (102.6~167.5)	136.1 $\pm$ 21.9 (103.9~195.5)
BMI (kg/m ²)	21.1 $\pm$ 3.3 (16.3~27.4)	21.3 $\pm$ 3.4 (16.8~30.7)
Body surface #1 (m ²)	1.534 $\pm$ 0.165 (1.119~1.819)	1.459 $\pm$ 0.123 (1.305~1.728)
Skinfold thickness #2 (mm)	20.8 $\pm$ 8.7* (9.5~41.5)	32.5 $\pm$ 15.1 (14.0~72.0)
Body fat #3 (%)	17.3 $\pm$ 4.8** (11.2~28.8)	25.9 $\pm$ 10.0 (14.0~52.8)
Basal metabolism #4 (kcal/day)	1,560 $\pm$ 167*** (1,149~1,866)	1,395 $\pm$ 117 (1,248~1,663)

#1 : Calculated from Fujimoto's formulas

#2 : Sum of triceps and subscapular

#3 : Estimated from Nagamine's and Brozek's formulas

#4 : From Reference basal metabolism

* : $p < 0.05$, ** : $p < 0.01$, *** : $p < 0.001$, t-test between male and female

Fig. 1 Classification of daily activities

Table 2 Time allocated to each activity category
mean $\pm$ SD(min)

Activities	Male	Female
Sleeping	478 $\pm$ 50 (33.0 $\pm$ 3.4)	483 $\pm$ 61 (33.6 $\pm$ 4.2)
Staying home (excluding sleep time)	429 $\pm$ 135 (30.0 $\pm$ 9.4)	363 $\pm$ 121 (25.2 $\pm$ 8.4)
Studying school	234 $\pm$ 73 (16.2 $\pm$ 5.1)	252 $\pm$ 37 (17.5 $\pm$ 2.6)
Commuting	48 $\pm$ 20 (3.2 $\pm$ 1.2)	41 $\pm$ 13 (2.8 $\pm$ 0.9)
Others activities in school	254 $\pm$ 98 (17.7 $\pm$ 6.8)	302 $\pm$ 80 (20.9 $\pm$ 5.6)

Values in parentheses are the percent ratio of each activity category to 1,440 min(%)

Recommended Dietary Allowances for the Japanese (Ministry of Health and Welfare in Japan).

The daily activity category is shown in Fig. 1. The time allocation for each activity, calculated from daily activity recording, is shown in Table 2. These values are generally similar to those reported in a study on the living time of Japanese nationals (NHK 1990). That study reports the following time allocations for boys and girls respectively: 483 and 460 minutes sleep time, 406 and 429 minutes time at home (excluding sleep time), and 45 and 48 minutes commuting. Slight differences of procedure did not influence the result. Fifty-two

Table 3 Heart rate over 24 hours and for each activity category
mean $\pm$ SD(beats/min)

	Male	Female
24 hours		
Mean	81 $\pm$ 6	82 $\pm$ 5
Median	79 $\pm$ 6	81 $\pm$ 6
Maximum	163 $\pm$ 16	168 $\pm$ 16
Minimum	53 $\pm$ 5	54 $\pm$ 5
Activity categories		
Sleeping	65 $\pm$ 8	65 $\pm$ 7
Staying home (excluding sleep time)	84 $\pm$ 7	87 $\pm$ 9
Studying in school	88 $\pm$ 9	87 $\pm$ 12
Commuting	111 $\pm$ 11	114 $\pm$ 14
Others activities in school	97 $\pm$ 12	95 $\pm$ 7

percentage of male students and thirty-nine percentage of female students belonged to school sports clubs and engaged in club activities on the day measurements were recorded.

Table 3 shows the mean, median maximum, and minimum HR recorded over 24 hours and the mean $\pm$ SD of HR for each activity category. The mean maximum HR for the observed day was 163 beats/minute for male students and 168 beats/minute for female students, while the HR of some students who attended physical training was recorded as high as 200 beats/minute, which

Fig. 2 Mean heart rate (HR) for each activity category in proportion to HR at basal metabolism (BM) (100%). Each value and bar represents the mean and 1SD.

Table 4 Energy expenditure (EE) for each activity category

Activity	mean $\pm$ SD (kcal)		
	male	female	total
Sleeping	491 $\pm$ 109 (20.3 $\pm$ 5.6)	483 $\pm$ 132 (21.0 $\pm$ 3.7)	488 $\pm$ 119 (20.6 $\pm$ 4.9)
Staying home (excluding sleep time)	731 $\pm$ 314 (29.3 $\pm$ 11.5)	581 $\pm$ 231 (25.8 $\pm$ 9.9)	671 $\pm$ 293 (27.9 $\pm$ 11.0)
Studying in school	443 $\pm$ 172 (17.5 $\pm$ 5.1)	443 $\pm$ 118 (19.2 $\pm$ 3.8)	443 $\pm$ 153 (18.2 $\pm$ 4.7)
Communing	163 $\pm$ 77 (6.5 $\pm$ 2.7)	121 $\pm$ 40 (5.3 $\pm$ 1.6)	146 $\pm$ 68 (6.0 $\pm$ 2.4)
Others activities in school	691 $\pm$ 347 (26.7 $\pm$ 10.1)	696 $\pm$ 343 (28.6 $\pm$ 9.6)	693 $\pm$ 345 (27.5 $\pm$ 10.0)
Total	2,512 $\pm$ 517 (100)	2,324 $\pm$ 524 (100)	2,437 $\pm$ 528 (100)

Values in parentheses are the ratio of EE in each activity category to EE in a day (%).

was near to the HRmax for 14 years old (Sheffield 1969). The median HR values for both males and females over 1440 minutes were slightly lower than mean values.

Figure 2 shows the percentage of mean HR for different activities in proportion to the mean HR (100%) obtained for 10 minutes in basal metabolic condition. The high values in communing and other activities in school, suggested corresponding high EE. No significant differences were found between male and female students.

Table 4 shows the EE estimated from the HR values for each activity reported in the daily activity recording. The ratio of the EE of each activity to the EE of the whole day is also shown in parentheses. The tendency of both male and female subjects was almost the same. The EE was highest for males when staying home (excluding sleep time) and during school activities for females. There was no statistically significant difference between males and females in all the ratios of EE for each activity to

Fig. 3 Energy expenditure for each activity category
Each value and bar represents the mean and 1SD.

Table 5 Energy expenditure(EE) and daily activity factors(DAF)

	mean±SD		
	male	female	total
EE(kcal/day)	2,512±517	2,324±524	2,437±528
EE(kcal/kg/day)	46.7±12.2	45.3±10.6	46.2±11.6
EE(kcal/kg-WT/min)	0.032±0.008	0.031±0.007	0.032±0.008
EE(kval/kg-LBM/min)	0.038±0.008	0.042±0.009	0.040±0.009
DAF	0.61±0.33	0.67±0.39	0.63±0.36

EE in a whole day.

The EE per body weight per minute for different activities is shown in Fig. 3. There was no significant difference for all activities between male and female subjects. The mean daily EE of the male students was 2512 ± 517 kcal, and that of female students was 2324 ± 524 kcal. Expressed by body weight, these values become 46.7 and 45.3 kcal/kg/day, respectively.

Daily activity factors (DAF=EE/basal metabolism - 1) were calculated from the EE value estimated from actual recording and the basal metabolic rate obtained from the Recommended Dietary Allowances for the Japanese (Table 5). DAF for males and

females was 0.61 ± 0.33 and 0.67 ± 0.39 respectively, which were between levels II and III of physical activity for adults.

IV Discussion

The Energy Allowance for each level of physical activity is only available for people 15 years and older in the Recommended Dietary Allowances for the Japanese. Reduction of physical activities and excess nutrition intake—especially when both factors exist simultaneously—are considered to lead to obesity and earlier occurrence of chronic diseases in younger people. Therefore appropriate meal intake and additional physical exercise for people 14 years and

younger is advised for their fitness and well-being.

The relative metabolic rate (RMR) method has been used to estimate EE in Japan for a long time. This requires a RMR value for each activity. As these RMR values and energy expenditure rates (Torun 1983) were not available for people under the age of 14, we adopted the HR recording method (Spurr 1986, Spady 1980, Kida 1988), which 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 life. 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 natural style of the activity.

In this study, the DAF of the second grade male and female students were 0.61 and 0.67. Each value did not vary significantly between two schools. The DAF of students who participated in physical exercise at school during the day measurements were taken, compared with the other, non-exercising group, were 0.60 and 0.66 respectively for males and 0.62 and 0.68 for females. DAF did not vary significantly between male and female subjects. The slightly high average DAF among the non-exercise group was possibly caused by doing part-time job (newsboy), playing TV game at home, attending chorus in school, and so on. Yamamoto et al. (1983, 1984) using almost the same HR method reported that daily EE in elementary school boys and girls aged 11 years old was 2263 ± 226 kcal/day and 2210 ± 302 kcal/day respectively.

Their study calculated DAF as 0.82 ± 0.19 and 0.84 ± 0.33 for boys and girls respectively. In a previous study (Kida 1992), conducted in the same season as this study, we found that the DAF of first grade students in junior high school was 0.80 ± 0.33 for males and 0.81 ± 0.39 for females. The current study found that the DAF of second grade students in junior high school was 0.61 ± 0.33 and 0.67 ± 0.39 respectively for males and females. The results of the two papers show a significant decrease in physical activity or reduction of EE in junior high students. Also, EE (kcal/kg/day) was significantly lower in second grade students compared with first grade students. The cause was that second grade students spent more time watching TV and less time studying in school than first grade students.

The results suggest that physical activity among second grade students has decreased in spite of their continuing physical development. Physical activity should be maintained adequately throughout the growing period. Further investigation is necessary to clarify all the causes and to find suitable solutions to improve the current situation which may lead to an inactive lifestyle. The results of this study suggest that a daily activity factor of 0.5 may be unsuitable for junior high school students.

V Conclusion

The energy expenditure and daily activity factor of 45 second grade students (27 male and 18 female) in two junior high schools were estimated using the heart rate method.

The results were:

1. Energy expenditure was 2512 ± 517

kcal/day or 0.032 ± 0.008 kcal/kg/min for male students, and 2324 ± 524 kcal/day or 0.031 ± 0.007 kcal/kg/min for female students.

2. Energy expenditure values while sleeping, staying home (excluding sleep time), commuting, studying and doing other activities in school were nearly constant for male and female subjects.

3. The ratios of EE throughout the day were 20.6% for sleeping, 27.9% for staying home, 18.2% for studying in school and 27.5% for other activities in school.

4. DAF calculated from EE and reference BM was 0.61 ± 0.33 for males and 0.67 ± 0.39 for females, which was between physical activity levels II and III for adults according to the Recommended Dietary Allowances for the Japanese.

Acknowledgments: We are grateful to the students and teachers who participated in this study and also to the school administrators of Ishikawa Junior High School and Dai-ichi Junior High School for their support.

This study was funded by the Foundation For Total Health Promotion 1992.

References

- Brozek, J., Grande, F., Anderson, J.T. & Keys, A. (1963): Densitometric analysis of body composition; Revision of some quantitative assumptions, *Ann. N.Y. Acad. Sci.*, 110, 113—140
- Charney, E., Goodman, H.C., McBride, M., Lyon, B. & Pratt, R. (1976): Childhood antecedents of adult obesity Do chubby infants become obese adults?, *N. Engl. J. Med.*, 295, 6—9
- Despres, J.P., Bouchard, C. & Malina, R.M. (1990): Physical activity and coronary heart disease risk factors during childhood and adolescence, *Exerc. Sport Sci. Rev.*, 18, 243—261
- Fujimoto, S., Watanabe, T., Sakamoto, A., Yukawa, K. & Morimoto, K. (1968): Studies on the physical surface area of Japanese. Part 18 Calculation formulas in three stages over all age, *Jpn. J. Hyg.*, 23, 443—450
- Kida, K. (1988): Study on estimating energy expenditure by heart rate. II. Energy expenditure in sedentary by HR-VO₂ method, *Hirosaki Med. J.*, 40, 601—609
- Kida, K., Sun, G., Igarashi, M., Matsu-ura, O., Tsushima, N. & Usutani, S. (1992): A study on physical activity in junior high school pupils. Part 1. Energy expenditure in a first-grade pupil, *Jpn. J. School Health*, 34, 300—308
- Ministry of education in Japan (1992): Report of School Health Statistics 1991, 1—7, Printing Bureau in Ministry of Finance (Tokyo).
- Ministry of Health and Welfare in Japan (1989): Recommended Dietary Allowance for the Japanese fourth revision, 8—20, Dai-ichi syuppan (Tokyo).
- Nagamine, S. & Suzuki, S. (1964): Anthropometry and body composition of Japanese young men and women. *Hum. Biol.*, 36, 8—15
- NHK (1992): The study on living time of Japanese Nationals in 1990, 347—373, NHK (Tokyo).
- Saris, W.H.M. (1985): The assessment and evaluation of daily physical activity in children. A review, *Acta Paediatr. Scand.*, 318 (suppl), 37—48
- Sheffield, L.T., Roitman, D. & Reeves, J.J. (1969): Submaximal exercise testing, *J.S.C. Med. Ass.* 65 (suppl), 18—25
- Spady, D.W. (1980): Total energy expenditure of healthy, free ranging school children, *Am. J. Clin. Nutr.*, 33, 766—775
- Spurr, G.P., Reina, J.C. & Barac-Nieto, M. (1986): Marginal malnutrition in school-aged Colombian males: metabolic rate and estimated daily energy expenditure, *ibid.*, 44, 113—126
- Torun, B. (1983): Inaccuracy of applying energy expenditure rates of adults to children, *ibid.*, 38, 813—814
- Yamamoto, K., Kitagawa, K., Tsubouchi, S., Kato, Y. & Asahina, K. (1983): Daily energy expenditure in elementary school boys aged 11 years, *Rep. Res. Cent. Phys. Ed.*, 11, 63—98
- Yamamoto, K., Kitagawa, K., Tsubouchi, S., Sugajima, Y. & Asahina, K. (1984): Daily energy