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Serum Lipid Levels and Factors Affecting Atherogenic Index in Japanese Children

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Abstract An evaluation was made of the serum lipid levels and factors relating to atherogenicity in schoolchildren in Akita, Japan, in order to determine actual conditions and promote awareness of health. The subjects were 2878 boys and 2729 girls aged 9, 12 and 15 years, who lived in cities, towns and villages in the Akita prefecture. Physical and lifestyle data including serum lipids were collected from the subjects in their schools under the direction of the prefectural board of education. Total cholesterol levels were found to be nearly equal to those currently representative for Japanese children, ethnically situated between blacks and whites in the United States of America. Atherogenic indices (AIs) were lower than those in all other countries owing to the elevated high-density lipoprotein (HDL) cholesterol levels observed in this study. According to data obtained from the questionnaires that were part of the study, regularly taking breakfast and exercising in sports clubs seems connected to maintaining lower atherogenicity in childhood. *J Physiol Anthropol Appl Human Sci 24(4): 511–515, 2005* http://www.jstage.jst.go.jp/browse/jpa
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Introduction

Degenerative diseases have been increasing among children as socioeconomic environments and lifestyles have changed these past several decades. Many children develop high blood pressure, obesity and/or high serum lipid levels, all representative risk factors for cardiovascular diseases. Along with malignant neoplasm, cardiovascular diseases are leading causes of death in most developed countries. It is, therefore, worth investigating the serum lipid levels of children in order to find a way to prevent cardiovascular diseases and their foundation in the early stages of life. To carry out such an investigation it is necessary to conduct medical examinations including blood sampling on boys and girls in schools, but there are few opportunities for this. Nevertheless, Okada et al. (2002) collected serum lipid data from 19 prefectures nationwide in Japan, and reported total HDL and low-density lipoprotein (LDL) cholesterol levels that create new criteria for Japanese children. They explained that the new criteria should prove valuable in childhood health strategies.

Recently, the prefectural board of education in Akita carried out blood sampling and a questionnaire survey on lifestyle in order to determine actual conditions and increase children's awareness of health. Using these materials, the present study attempts to show serum lipid levels for children in Akita, and to compare them with the data obtained nationwide in Japan. In addition, factors affecting the atherogenic index (AI), proposed as a marker of plasma atherogenicity, are investigated in this study.

Methods

The subjects were 2878 schoolboys and 2729 schoolgirls aged 9, 12 and 15 years from all over the Akita prefecture. Height and weight had been recorded at the yearly medical examinations in the spring. Blood samples were obtained at fasting status in the morning, and sent to a clinical laboratory where were measured serum total cholesterol, HDL cholesterol, glucose, hemoglobin, and white blood cell (WBC) count. AI was calculated using the following equation, that is (total cholesterol–HDL cholesterol)/HDL cholesterol. Questionnaires on lifestyle habits such as bedtimes, rising times, regular exercise, and so on, were distributed to the subjects and subsequently collected. Data from 5607 examinees were analyzed in this study.

Data were processed descriptively with means and standard deviations, and regression analyses were employed to investigate the relationships among the measurement variables. Since most of the measurements correlated with age, adjusted values were calculated and employed in order to exclude the age effect. Adjusted value was calculated as y–k (x–xbar), where x and y are the actual age and measurement value, xbar is a mean of x for each group, and k is the regression coefficient of y on x, respectively. A two-sided *t*-test was performed to investigate the differences between two groups.

Results and Discussion

Table 1 shows means and standard deviations of the physical and lifestyle characteristics of the subjects. Height and weight of each age group are larger than those of Japanese children in general, as reported in the national survey organized by the Ministry of Education (2003). In that material, mean heights for boys aged 9, 12 and 15 years are 133.7 cm, 152.6 cm and 168.6 cm, and those for girls are 133.5 cm, 152.1 cm and 157.2 cm, respectively. Mean weights for boys aged 9, 12 and 15 years are 31.3 kg, 45.1 kg and 60.4 kg, and those for girls are 30.5 kg, 44.8 kg and 52.3 kg, respectively. Geographical cline, according to Bergmann's ecological rule, has been observed in the body builds of Japanese children, and the larger values in the present study are consistent with this phenomenon. Children living in Akita, located in the northern part of Japan, are always ranked as one of the "largest body build" groups.

Total cholesterol levels for children in Akita are close to those reported in the nationwide study by Okada et al. (2002) when expressed as percentiles. For instance, fifty percentiles of total cholesterol for boys aged 9, 12 and 15 years in Akita are 170, 160 and 157 mg/dl, respectively. Corresponding values in the nationwide study are 169, 161 and 156 mg/dl. Similarly, percentiles for girls in Akita are close to those in the nationwide study. Fifty percentiles for girls aged 9, 12 and 15 years are 170, 170 and 172 mg/dl, respectively. Those in the nationwide study are 171, 167 and 174 mg/dl. Accordingly, total cholesterol levels in Akita may be considered nearly equal to those of representative Japanese children.

As for boys, remarkable changes in total cholesterol with age are observed, as in other studies (Takasaki et al., 1994; Kouda et al., 2003). Boys at the age of 9 years show higher total cholesterol than those at the ages of 12 and 15 years. On the other hand, girls exhibit little change in total cholesterol between 9 and 15 years of age. It is supposed that total cholesterol decreases during puberty partly because large increases in body cells and sex hormones occur through their consuming of cholesterol (Berenson et al., 1981; Tanaka et al., 1987). The small change in total cholesterol for girls seems due to the significant increase in body fat, which may cancel any decrease in cholesterol.

Mean total cholesterol levels for children in various ethnic groups in the United States of America are 173 mg/dl for blacks aged 9 to 11 years and 169 mg/dl for blacks aged 12 to 15 years, 170 mg/dl for whites aged 9 to 11 years and 159 mg/dl for whites aged 12 to 15 years, and 168 mg/dl for Mexican Americans aged 9 to 11 years and 160 mg/dl for Mexican Americans aged 12 to 15 years (Hickman et al., 1998). The present study shows a mean total cholesterol level of 168 mg/dl for all subjects aged 9 to 15 years. It is difficult to compare these values among the ethnic groups because of age and sex differences, but Japanese children seem to have somewhat higher total cholesterol levels than whites and Mexican Americans.

Compared with data collected 10 years ago by Fukushige et al. (1996), who obtained blood samples from each group of approximately 300 Japanese schoolchildren categorized by sex and age, the mean total cholesterol levels for boys are almost the same. Meanwhile, the mean total cholesterol levels for girls are higher than those of a decade ago by 3 to 11 mg/dl. In general, it is surmised that the total cholesterol levels of Japanese children have been gradually increasing as westernized eating habits including a high intake of animal fats have been adopted in their daily lives. As a matter of fact, total fat intake by the Japanese has increased more than threefold in the past 50 years, i.e., from 18.3 g/person/day in 1950 to 57.4 g/person/day in 2000 according to the National Nutrition Survey in Japan.

Fifty percentiles of HDL cholesterol levels for children in

Table 1 Physical and lifestyle characteristics of children

	9 years old		12 years old		15 years old		All	
	Boys n=910 Mean (SD)	Girls n=872 Mean (SD)	Boys n=1057 Mean (SD)	Girls n=964 Mean (SD)	Boys n=911 Mean (SD)	Girls n=893 Mean (SD)	Boys n=2878 Mean (SD)	Girls n=2729 Mean (SD)
Height (cm)	134.7 (6.0)	135.2 (6.8)	154.3 (8.1)	153.2 (5.7)	169.7 (5.9)	157.7 (5.1)	153.0 (15.5)	148.9 (11.2)
Weight (kg)	33.4 (8.3)	33.1 (8.1)	47.7 (11.9)	46.8 (9.0)	61.5 (11.1)	53.6 (9.0)	47.6 (15.4)	44.7 (12.1)
BMI (kg/m^2)	18.2 (3.5)	17.9 (3.2)	19.9 (3.8)	19.9 (3.3)	21.3 (3.4)	21.6 (3.4)	19.8 (3.8)	19.8 (3.6)
Total-ch (mg/dl)	171.3 (26.2)	172.8 (25.9)	161.8 (25.2)	170.9 (27.0)	158.9 (25.3)	173.6 (27.9)	163.9 (26.1)	172.4 (27.0)
HDL-ch (mg/dl)	63.9 (13.7)	63.1 (14.2)	61.5 (12.7)	63.0 (12.4)	57.5 (12.1)	62.7 (12.4)	61.0 (13.0)	62.9 (13.0)
AI	1.77 (0.60)	1.85 (0.67)	1.71 (0.56)	1.79 (0.60)	1.87 (0.70)	1.85 (0.62)	1.78 (0.62)	1.83 (0.63)
Glucose (mg/dl)	86.7 (6.1)	84.7 (6.2)	87.5 (6.0)	86.1 (5.8)	85.8 (7.6)	85.2 (7.2)	86.7 (6.6)	85.4 (6.4)
Hb (g/dl)	13.5 (0.7)	13.4 (0.7)	14.1 (0.8)	13.6 (0.9)	15.1 (1.0)	13.3 (1.1)	14.2 (1.1)	13.5 (1.0)
WBC ($\times 10^2$ cells/μl)	64.1 (16.0)	61.7 (15.3)	59.4 (14.2)	60.2 (14.0)	57.0 (14.2)	61.8 (15.3)	60.2 (15.0)	61.2 (14.9)
Bedtime (hour)	21.5 (0.6)	21.5 (0.6)	22.6 (1.0)	22.8 (0.9)	23.6 (1.3)	23.5 (1.2)	22.5 (1.3)	22.6 (1.2)
Rising (hour)	6.5 (0.5)	6.5 (0.4)	6.4 (0.6)	6.5 (0.5)	6.6 (0.6)	6.5 (0.6)	6.5 (0.6)	6.5 (0.5)
Sleep (min)	538 (42.7)	538 (39.3)	471 (63.9)	462 (57.1)	425 (76.0)	417 (71.7)	478 (77.2)	471 (75.6)

AI, atherogenic index; WBC, white blood cells.

Akita are also close to those in the nationwide study, although the reduction of levels with age is earlier by 1 year for boys in Akita. Hickman et al. (1998) indicate that mean HDL cholesterol levels are 58 mg/dl for blacks aged 9 to 11 years and 55 mg/dl for blacks aged 12 to 15 years, 51 mg/dl for whites aged 9 to 11 years and 48 mg/dl for whites aged 12 to 15 years, and 52 mg/dl for Mexican Americans aged 9 to 11 years and 50 mg/dl for Mexican Americans aged 12 to 15 years. In the present study, the corresponding mean for all subjects is 62 mg/dl. Japanese children show a greater tendency towards high HDL cholesterol than any other groups. Dwyer et al. (1997) found similar results and supposed that some genetic basis, a high level of physical activity, and the traditional dietary consumption of soybean products might be responsible for higher HDL cholesterol in Japanese children. Although there was no available data for the differences in "genetic basis" among races, Dwyer et al. (1997) described that Japanese children expend more energy daily and are accustomed to eating tofu and related products made from soybeans, which contain phytoestrogens as does the female sex hormone. Estrogen tends to raise HDL cholesterol.

AIs for girls are significantly higher than those for boys except at 15 years of age. After reaching puberty, it is probable that female sex hormones play a role in preventing atherogenicity from increasing. AIs in Japanese children are obviously lower than those in blacks, whites and Mexican Americans as reported by Hickman et al. (1998). That is, AIs calculated from the means of total and HDL cholesterol in their literature are approximately 2.0 for blacks, 2.3 for whites and 2.2 for Mexican Americans, respectively. Low AIs in Japanese children would be, then, owing to their high HDL cholesterol levels.

Otherwise, glucose, hemoglobin and WBC levels are within the common ranges. In boys, the means of hemoglobin and WBC levels were evidently different among age groups. Based on answers given in the questionnaires, bedtimes, rising times and sleeping hours were determined for each age group. Rising times are almost the same among the age groups, but shorter sleeping hours are observed in the older age groups, since bedtimes moved later with age.

The subjects in this study were growing children and apt to be affected by age. Therefore, the relationships of each measurement variable with age were tested via regression analysis. The results are shown in Table 2 with regression equations and correlation coefficients. Most of the variables have statistically significant relationships with age, especially in boys. Accordingly, when significant relationships were found between the variables and age, raw data were transformed into adjusted values for a mean age of each sex in order to negate the age effect.

Table 3 shows the simple correlation coefficients of AIs with various variables for both sexes. In cases in which each variable significantly correlated with age, adjusted values were employed in the calculations, as mentioned above. Although correlation coefficients at significance levels are very low because of the large number of samples, there are statistically significant relationships between AIs and various variables. The highest correlation is found between AI and body mass index (BMI) for both sexes. This implies that obesity has already caused atherosclerotic changes in childhood. Boys show a closer relationship of BMI with AI than girls. Interestingly, WBC counts have relatively high correlation coefficients with AIs for both sexes. It is known that an increase in WBC count correlates well with coronary artery disease risk factors in middle-aged and elderly people (Bovill et al., 1996; Friedman et al., 1974), although the detailed

Table 2 Regressions of each variable on age

	Equation	r
Boys (n=2878)		
Height (cm)	y=5.82x+83.1	0.896**
Weight (kg)	y=4.69x+8.79	0.725**
BMI (kg/m^2)	y=0.519x+13.6	0.328**
T-ch (mg/dl)	y=−2.07x+189	−0.189**
HDL-ch (mg/dl)	y=−1.07x+73.8	−0.196**
AI	y=0.016x+1.59	0.061**
Glucose (mg/dl)	y=−0.146x+88.5	−0.053**
Hb (g/dl)	y=0.269x+11.0	0.598**
WBC (cells/ul)	y=−1.18x+74.4	−0.188**
Bedtime (hour)	y=0.344x+18.4	0.638**
Rising (hour)	y=0.029x+6.14	0.118**
Sleep (min)	y=−18.9x+704	−0.583**
Girls (n=2729)		
Height (cm)	y=3.74x+104	0.802**
Weight (kg)	y=3.42x+3.59	0.682**
BMI (kg/m^2)	y=0.606x+12.5	0.405**
T-ch (mg/dl)	y=0.125x+171	0.010
HDL-ch (mg/dl)	y=−0.062x+63.7	−0.010
AI	y=0.0004x+1.82	0.001
Glucose (mg/dl)	y=0.074x+84.5	0.028
Hb (g/dl)	y=−0.012x+13.6	−0.030
WBC (cells/ul)	y=0.031x+60.8	0.001
Bedtime (hour)	y=0.325x+18.7	0.636**
Rising (hour)	y=−0.008x+6.58	−0.039*
Sleep (min)	y=−20.0x+712	−0.638**

y, value of each variable; x, age in years; **, $p<0.01$; * $p<0.05$

Table 3 Correlation coefficients between atherogenic index and each variables. Age-adjusted values are partly used for calculation

	Height	Weight	BMI	Glucose	Hb	WBC	Bedtime	Rising	Sleep
Boys (n=2878)	0.008	0.352**	0.429**	0.004	0.140**	0.155**	0.006	0.015	0.003
Girls (n=2729)	−0.023	0.283**	0.358**	0.097**	0.083**	0.156**	−0.049**	−0.001	0.047*

As total and HDL cholesterol are related to the calculation for AI, these variables are excluded. **, $p<0.01$; *, $p<0.05$

Table 4 Comparison of physical and lifestyle characteristics between two groups based on breakfast or sports club. Age-adjusted values are partly used for calculation

	Breakfast			Sports club		
	Almost everyday Mean (SD)	Rarely Mean (SD)	*t*	Participating Mean (SD)	Nonparticipating Mean (SD)	*t*
Boys						
n	2680	198		2197	681	
Height (cm)	153.0 (6.9)	152.8 (7.1)	0.39	153.3 (7.0)	151.8 (6.2)	5.01**
Weight (kg)	47.5 (10.6)	47.9 (11.0)	−0.51	47.7 (10.6)	47.1 (10.8)	1.28
BMI (kg/m^2)	19.8 (3.6)	20.0 (3.6)	−0.75	19.8 (3.5)	19.8 (3.7)	0.00
Total-ch (mg/dl)	163.7 (25.5)	166.5 (27.0)	−1.48	163.3 (25.4)	165.9 (26.1)	−2.32*
HDL-ch (mg/dl)	61.0 (12.9)	60.5 (11.6)	0.53	61.7 (12.9)	58.9 (12.3)	5.00**
AI	1.77 (0.62)	1.83 (0.61)	−1.32	1.73 (0.59)	1.92 (0.68)	−7.07**
Glucose (mg/dl)	86.7 (6.6)	87.0 (6.6)	−0.62	86.7 (6.7)	86.8 (6.3)	−0.34
Hb (g/dl)	14.2 (0.9)	14.2 (0.8)	0.00	14.1 (0.9)	14.4 (0.9)	−7.60**
WBC ($\times 10^2$ cells/μl)	60.1 (14.8)	61.2 (14.1)	−1.01	60.0 (14.9)	60.7 (14.3)	−1.08
Bedtime (hour)	22.5 (1.0)	22.7 (1.2)	−2.67**	22.5 (0.9)	22.6 (1.1)	−2.40*
Rising (hour)	6.5 (0.6)	6.6 (0.7)	−2.23*	6.5 (0.6)	6.5 (0.6)	0.00
Sleep (min)	477.7 (61.4)	478.3 (78.1)	−0.13	477.9 (60.8)	477.1 (68.3)	0.29
Gilrs						
n	2560	169		1656	1073	
Height (cm)	148.8 (6.8)	148.3 (6.2)	0.93	149.7 (6.8)	147.4 (6.4)	8.83**
Weight (kg)	44.5 (8.7)	45.4 (10.4)	−1.29	44.9 (8.6)	44.1 (9.2)	2.31*
BMI (kg/m^2)	19.8 (3.3)	20.3 (4.0)	−1.88	19.7 (3.2)	19.9 (3.4)	−1.56
Total-ch (mg/dl)	172.2 (27.0)	174.8 (26.8)	−1.21	171.4 (26.6)	173.8 (27.5)	−2.27*
HDL-ch (mg/dl)	63.0 (13.0)	62.1 (13.0)	0.87	63.8 (13.2)	61.6 (12.6)	4.33**
AI	1.82 (0.63)	1.90 (0.59)	−1.60	1.77 (0.61)	1.91 (0.64)	−5.74**
Glucose (mg/dl)	85.3 (6.4)	86.0 (6.5)	−1.38	85.4 (6.2)	85.3 (6.8)	0.40
Hb (g/dl)	13.4 (1.0)	13.6 (0.9)	−2.53*	13.4 (0.9)	13.5 (1.0)	−2.71**
WBC ($\times 10^2$ cells/μl)	61.0 (14.8)	63.6 (16.1)	−2.20*	60.3 (14.3)	62.6 (15.6)	−3.96**
Bedtime (hour)	22.6 (0.9)	22.8 (1.2)	−2.73**	22.7 (0.9)	22.5 (1.0)	5.42**
Rising (hour)	6.5 (0.5)	6.6 (0.6)	−2.48*	6.5 (0.5)	6.5 (0.5)	0.00
Sleep (min)	472.2 (57.3)	467.6 (71.0)	0.99	468.4 (56.0)	477.3 (61.1)	−3.91**

AI, atherogenic index; WBC, white blood cells; *t*, results of *t*-test;**, $p<0.01$; *, $p<0.05$.

mechanisms are unclear. In the present study, a similar relationship was found even in childhood.

As for lifestyle characteristics, taking breakfast and participating in sports club activities are found to be associated with some physical characteristics (Table 4). Boys and girls participating in sports club activities show significantly lower AIs than nonparticipating groups. The differences are thought to be derived from lower total cholesterol and higher HDL cholesterol for the groups participating at sports clubs. Groups of both sexes taking breakfast almost every day tend to have lower AIs than those rarely taking breakfast, although no statistically significant differences are found. Breakfast and regular exercise at sports clubs seem desirable for maintaining a lower AI. Incidentally, boys and girls taking breakfast regularly are also in the habit of going to bed early and getting up early. Owing to this, children might be encouraged to take breakfast in the morning. Ironically, BMI for girls rarely taking breakfast tends to be slightly higher despite missing meals.

In summary, total and HDL cholesterol levels for schoolboys and girls in Akita are as high as those collected nationwide in Japan. Compared with past data for Japanese children, serum lipid levels, as shown in this study, are increasing, especially in girls. As is usual with other studies, HDL cholesterol levels for both sexes are higher than those for other countries. This probably contributes to the lower AIs seen in Japanese children. Breakfast and exercise in daily life are particularly pointed out to be negative risk factors for atherogenic changes in childhood.

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