Original Article

Energy expenditure and energy intake in 10-12 years obese and non-obese Chinese children in a Guangzhou boarding school

Cai-Xia Zhang MD[1], Yu-Ming Chen MD PhD[1], Wei-Qing Chen MD PhD[1], Xue-Qing Deng[1] and Zhuo-Qin Jiang MD [2]

[1]*Department of Biostatistics and Epidemiology, School of Public Health, Sun Yat-sen University, Guangzhou, PR China.*
[2]*Department of Medical Nutrition, School of Public Health, Sun Yat-sen University, Guangzhou, PR China.*

Objective: The objective of this study was to observe the variation of energy intake and energy expenditure in the obese Chinese children. **Methods:** Basic metabolic rate was measured by using open-circuit indirect calorimetry in 54 obese children and 60 non-obese children aged 10-12 years in a full- time boarding school in Guangzhou suburb, China. Total energy expenditure was estimated by using a factorial method. Dietary intake was surveyed by the weighed inventory method. Physical activity was determined using a 2-day activity diary. **Results:** Univariate analysis showed that basic metabolic rate was significantly higher ($p<0.05$) in obese children than in non-obese ones, but the significant difference disappeared after controlling for fat free mass and fat mass. Energy intake and total energy expenditure were significantly higher ($p<0.05$) in obese than in non-obese children. Obese children spent more time in sleeping and light physical activity, but less time in moderate physical activity and vigorous physical activity than non-obese children ($p<0.05$). **Conclusions:** Compared to non-obese children, both energy intake and expenditure were higher in obese Chinese children. It appears that an area for preventive strategies may be to encourage increased physical activity expenditure in this age group.

Key Words: obesity, children, energy intake, energy expenditure, Chinese Guangzhou

INTRODUCTION

Obesity is a major threat to children's health today. Accompanied with the rapid socioeconomic progress in China in recent years, the prevalence of childhood obesity is increasing rapidly and indications show that this trend will continue. The obesity prevalence in children and adolescents aged 7-12 years in the coastal large cities of China was only 0.4% in 1985, but reached a much high level of 10.6% in 2000.[1] Control of this rapid increase is urgently required, because of many serious adverse consequences of childhood obesity, such as early onset of coronary heart disease, the metabolic syndrome, diabetes and the persistence of obesity into adulthood.[2-4] A deep understanding of risk factors is the pre-requirement of effective control with regard to children obesity. However, little is known in China. The increase of obesity prevalence may be correlated with nutrition and lifestyle transition over the past two decades, including more animal foods, inactivity, and a more westernized lifestyle.[5,6]

Obesity results from a chronic energy imbalance, i.e., energy intake exceeds energy expenditure from metabolism and physical activity. The relation between obesity and energy metabolism in children has been the subject of many investigations. Some studies reported a similar or less energy intake,[7,8,9] others found a higher energy intake[10] in obese children than in non-obese children. Greater energy expenditures were observed in obese individuals in some,[11,12] but not in other studies.[9, 13] Further studies are needed to address these issues. This study aims to compare energy expenditure and energy intake between obese and non-obese children. We hypothesized that energy intake and energy expenditure were not reduced in the obese Chinese children.

METHODS

Participants

Potential subjects were recruited, aged 10-12 years, in a full-time boarding school in the Guangzhou suburb, China. They were screened for eligibility and were then invited to participate in the study. According to World Health Organization Standard on child weight-for-height criterion,[14] obesity was defined as body weight 120% or more above the expected weight for height. Non-obese was defined as weight ranging from 90% to 110% of that predicted for height. Non-obese children were frequency matched by gender and age to obese ones. Medical history, physical examination, and routine laboratory tests, including fasting plasma glucose, total cholesterol and

Corresponding Author: Prof. Zhuo-Qin Jiang, Department of Medical Nutrition, School of Public Health, Sun Yat-sen University, 74, Zhongshan Road 2, Guangzhou 510080, PR China.
Tel: +86-20-87330617; Fax: +86-20-87330446.
Email: jiangzhq@mail.sysu.edu.cn
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Table 1. Serum lipids and glucose in obese and non-obese children

	Obese (n =54)	Non-obese (n =60)
TC(mmol/L)	4.3±0.7	4.2±0.8
TG(mmol/L)	0.9±0.5*	0.6±0.2
HDL-C(mmol/L)	1.3±0.2*	1.6±0.3
LDL-C(mmol/L)	2.9±0.8*	2.5±0.8
Glucose (mmol/L)	4.2±0.4*	4.0±0.4

* Significantly different from non-obese, $p<0.05$. Data expressed as mean ± SD

triglyceride were performed and reasonably excluded health problems other than obesity (**Table 1**). None of the subjects was taking any drugs. As a result, there were fifty-four obese children (32 males, 22 females, mean age 11.0 years) and sixty non-obese children (30 males, 30 females, mean age 11.1 years) eligible for the study. Written informed consent was obtained from the children and their parents before the start of the study. The Ethical Committee of Sun Yat-sen University approved this study.

Anthropometric measurements

Measurements of height, weight, triceps and sub-scapular skinfolds were carried out under fasting conditions. Body weight was determined to the nearest 0.1 kg on standard physician beam scales with the children wearing only their underwear and no shoes. Height was measured to the nearest 0.1 cm on standardized, wall-mounted height boards according to the following protocol: no shoes, heels together, and child's heels, buttocks, shoulders, and head touching the vertical wall surface with line of- sight aligned horizontally. Each of the standard physician beam scales and wall-mounted height boards used to measure the children were calibrated previously, using three different weights and one reference tape. Skinfold thickness was measured to the nearest millimeter three times with a Holtain skinfold caliper on the left side of the body (UK). The triceps skinfold locus is halfway between the acromion and olecranon on the back of the arm measured with the elbow bent. We measured the triceps skinfold with the arm pendant, whereas the subscapular skinfold was measured just below the tip of the scapula.[15] Readings were taken 3 seconds after the caliper jaws were released. Body composition was assessed based on two skinfold-thickness measurements (triceps and subscapular). The mass of the body includes two parts, i.e., fat-free mass (FFM) and fat mass (FM). FFM represents the active metabolic tissue of the body and includes muscle mass and organ mass, and the remainder is the FM. The formulas of Yao[16] were used to calculate the percentage of body fat. These formulas had been validated with underwater weighing and had a good validation. Body fat mass was obtained by multiplying body weight by the percentage of body fat. FFM was calculated by subtracting FM from body weight. Body surface area (BSA) was calculated according to the formulas of Du Bois.[17]

Energy intake

The food intake of each child was measured by the weighed inventory method.[18] Trained investigators weighed and recorded all food and drinks consumed by the children for three consecutive weekdays. At the same time, the leftovers from each child were also weighed and recorded. Between-meal snack and beverage consumption were also recorded. Because this study was conducted in a boarding school, we can also ask the nutritionist to provide a complete description of the methods of preparation and cooking, as well as recipes for composite dishes. Calculation of energy and macronutrient intake was done for each day, and the average of the three-day's calculation was included in final statistical analyses. Energy intake and the contents of proteins, fats, and carbohydrates were derived from food composition tables.[19,20] Dietary quality was reported for macronutrient intakes (carbohydrate, fat and protein) as mean intakes in grams and percentages of energy.

Energy expenditure

Basic metabolic rate

Basic metabolic rate (BMR) was determined by using open-circuit indirect calorimetry.[21] Measurements were done in the children's dormitory after an overnight fast. The subjects were instructed not to eat or to get out of bed before the technical team arrived between 0600 and 0700. Subjects usually had to be wakened. All had been familiarized with the mask in advance and were in their own beds and completely relaxed with the technical team, both of whom were familiar to them. Then a half-face mask with a non-rebreathing valve was fitted to the subjects' mouths and connected by respiratory tubes to the Douglas bag. Expired air was then collected in Douglas bag with the use of a 2-way valve. For all measurements, expired air was collected in a Douglas bag for exactly 10 min. During the collection, duplicate aliquots of room air were obtained in plastic 50-mL syringes for analysis of inspiratory concentrations of oxygen and carbon dioxide. The volume of air in Douglas bag was measured with an air flow meter under constant flow, and the concentrations of oxygen and carbon dioxide in expired and ambient air were analyzed with Beckman medical gas analyzers (Beckman OM-11 O_2 and LB-2 CO_2, respectively). The analyzers were calibrated against gases of known concentration before each test. All BMR measurements were made at ambient temperatures of 19~21°C. BMR was calculated from oxygen consumption and carbon dioxide production according to equation.[22]

Physical activity

Activity diary records were kept for 2 consecutive schooldays. The activity diary was a modification of the method originally described by Bouchard et al.[23] Students were asked to record the dominant activity they had carried out every 15 minutes on a record sheet which was divided into 96 periods for each day (1,440 minutes). It has been shown that this activity diary method provides a close estimate of physical activity levels in adolescents.[24,25] In the Bouchard et al [23] method, activities were categorized into nine levels: 1 indicated sleeping and 9 indicated intense manual work. The subjects chose the number that best described the type of exercise they did. In the present study, however, it was considered difficult for the children to judge to which category their physical activity belonged. Instead, children were asked to write the type of physical activity on the record sheet in the appropriate square. The investigators then classified these activities as follows: "sleeping" (during the day and night); "light physical activity" (e.g., standing, using the computer, reading, doing homework); "moderate physical activity" (e.g., walking, doing housework); "vigorous physical activity" (e.g., sport activities such as playing basketball, football, competitive running). The average number of hours spent in each category was also calculated. Before starting the formal study, each participant was given a detailed explanation and demonstration of how to use the activity diary form.

Total energy expenditure

Total energy expenditure (TEE) was estimated by using a factorial method: TEE = BMR×physical activity level (PAL).[26] The BMR of the individual subject was measured by using open-circuit indirect calorimetry. PAL was calculated by allocating the amount of time spent in each category level throughout the day. Physical activity ratios (PARs) were assigned to each level and the daily PAL determined by summing the products of the PAR and duration of each category level. The amount of time spent on activities in each category was then multiplied by the energetic cost of the activity and summed to obtain an estimate of TEE.

Statistical analysis

SPSS (version 13.0; SPSS, Inc, Chicago) was used to analyze the data. BMR values were divided by body weight and body surface area so that values could be expressed as kJ · kg body weight^{-1} · h^{-1} and kJ · (m^2 · h)$^{-1}$, respectively. These values were then compared with the use of two-tailed *t* tests for independent samples. General linear model covariate analysis was used to compare BMR in the obese and non-obese children with the use of only FFM as a covariate and then with both FFM and FM as the covariates. Obesity and sex were the grouping variables. Differences between means of age, weight, height, %BF, FFM, FM, TEE, energy intake and duration of the physical activity time in obese and non-obese children were tested for significance using a Student's *t* test. Correlations between variables were made using Pearson's product moment correlation.

RESULTS

The characteristics of the 114 children are shown in Table 2. Body weight, %BF, FFM, and FM were significantly greater in obese children than in non-obese ones. There were no significant differences in age and height between obese and non-obese children of the same gender.

The relations between BMR and FFM, and BMR and FM are shown in Figures1-2. BMR (kJ/d) was significantly correlated (p< 0.001) with FFM and FM in obese, non-obese children and a combination of both. Correlation coefficients ranged between 0.72 and 0.90 (all p<0.001, except r=0.38 for BMR & FM in non-obese, p<0.003).

Obese children had significantly higher BMR in absolute value (6104±813 vs. 5103±493 kJ/d; p<0.05), and similar BMR in kJ per unit of body surface area (4290±329 vs. 4230±315 kJ/m^2.d), but significantly lower

Table 2. Characteristics of obese and non-obese children

	Obese (n =54)	Non-obese (n =60)
Age (y)	11.0±1.1	11.1±0.7
Height (cm)	146±8.6	145±6.5
Weight (kg)	52.3±12.7*	35.8±5.2
BMI	24.1±3.5*	16.9±1.2
%BF	29.0±6.0*	17.0±2.6
FM (kg)	15.7±6.9*	6.2±1.6
FFM (kg)	36.5±6.5*	29.6±4.0
Body surface area (m^2)	1.4±0.2 *	1.2±0.1

* Significantly different from non-obese, p<0.05. Data expressed as mean ± SD

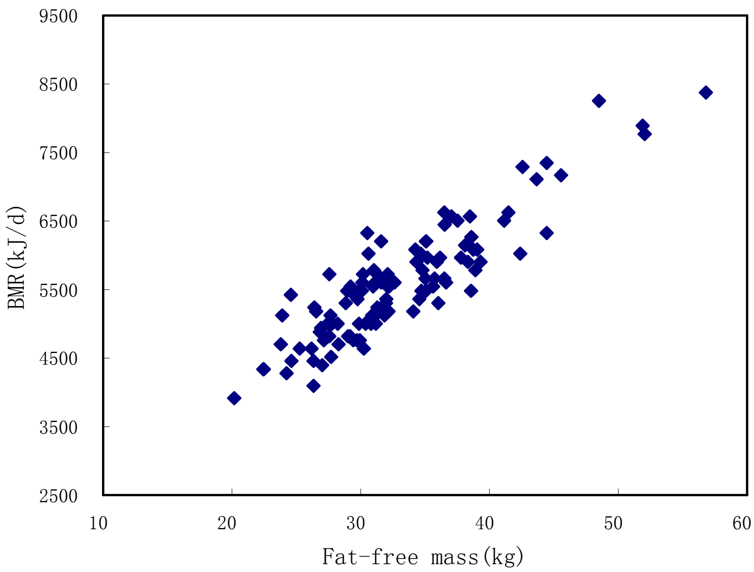

Figure 1. Correlations between BMR and FFM in 114 males and females, obese and non-obese children

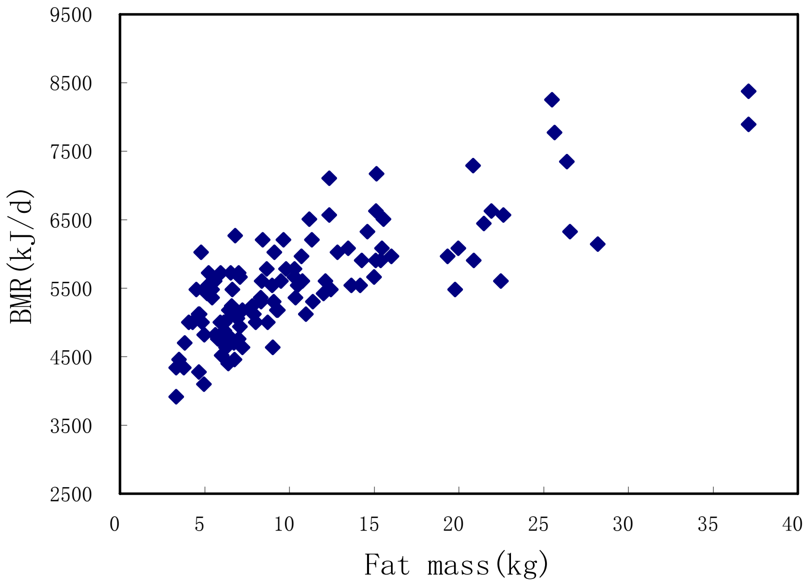

Figure 2. Correlations between BMR and FM in 114 obese and non-obese children

Table 3. The BMR of obese and non-obese children of both genders

	Obese children		Non-obese children	
	Males (n=32)	Females (n=22)	Males (n=30)	Females (n=30)
kJ/d	6384±850*$^{\#}$	5696±554$^{\#}$	5280±498*	4926±426
kJ/kg.d	122±16$^{\#}$	116±16$^{\#}$	150±15*	136±18
kJ/m^2.d	4437±269*	4076±291	4392±280*	4067±263
kJ/d †	5859±67*$^{\#}$	5574±71$^{\#}$	5559±63*	5298±65
kJ/d ‡	5833±66*	5449±82	5647±69*	5329±64

#: p<0.05 , obese versus non-obese; *: p<0.05, males versus females; † Adjusted for FFM as a covariate; ‡ Adjusted for FFM and FM as covariates. Data expressed as mean ± SD

Table 4. Energy intake of obese and non-obese children

	Obese children	Non-obese children	*t*	*p*
Energy intake (kJ/d)	9694±731	8617±621	8.31	<0.001
Protein (g/d)	93.3±7.2	79.3±8.9	9.10	<0.001
% of energy	16.1±0.6	15.4±0.3	2.36	>0.05
Fat (g/d)	75.2±3.9	67.5±4.7	9.18	<0.001
% of energy	29.2±1.3	29.4±0.9	1.92	>0.05
Carbohydrate (g/d)	317±32.5	284±20.3	6.23	<0.001
% of energy	54.7±1.6	55.2±0.9	1.36	>0.05

Data expressed as mean ± SD

BMR in kJ per kilograms of body weight (120±16 vs. 144±18 kJ/kg.d; p<0.05) than in non-obese children. The statistical significance in the absolute BMR remained after adjustment for FFM and sex (F=14.9, p<0.05), but disappeared when further adjusted for FM (F=3.1, p>0.05). (Table 3)

The mean daily intake of energy was 9694 kJ in obese children and 8617 kJ in non-obese ones (p <0.001). The amount of protein, fat, carbohydrate consumed by obese children was significantly higher than those by non-obese ones (p<0.001). There were no significant differences in the percentage energy intake from fat, carbohydrate or protein between the obese and non-obese groups. (Table 4)

Table 5. Total energy expenditure of obese and non-obese children

	Obese	Non-obese	*t*	*p*
Light activity (kJ/d)	4434±666	3653±476	3.02	<0.05
Moderate activity (kJ/d)	944±141	991±135	-0.76	>0.05
Vigorous activity (kJ/d)	841±112	952±240	-1.33	>0.05
Sleeping (kJ/d)	2833±347	2419±223	3.18	<0.05
Total energy expenditure (kJ/d)	9053±1143	8015±916	2.24	<0.05

Data expressed as mean ± SD

Table 6 The distribution of physical activity time in obese and non-obese children

Physical activity	Obese	Non-obese	*t*	*p*
Light activity (minutes/d)	660±8.7	632±17.5	4.38	<0.001
Moderate activity (minutes/d)	92.9±7.5	114±13.3	-4.36	<0.001
Vigorous activity (minutes/d)	32.7±5.8	42.5±8.6	-2.99	<0.05
Sleeping (minutes/d)	655±4.0	651±2.6	2.47	<0.05

Data expressed as mean ± SD

Total energy expenditure and the distribution of physical activity time were summarized in Table 5-6. Total energy expenditure was significantly higher in obese than in non-obese children. The difference between energy intake and total energy expenditure did not significantly differ between the two groups (641±105 kJ/d in obese children versus 602±73 kJ/d in non-obese; p>0.05). Energy expenditure was significantly higher in sleeping and light activity in obese childen（p<0.05）, but no significant difference in moderate and vigorous activity in the two groups (p>0.05). Obese children spent more time in sleeping and participating in light physical activity, but less time in moderate physical activity and vigorous physical activity than non-obese children (p<0.05).

DISCUSSION

This is the first study to report energy expenditure, physical activity and energy intake in Chinese obese children. Our findings show that obese children had both higher energy intake and energy expenditure, but similar FFM and FM-adjusted BMR, spent more time in sleeping and light physical activity, but less time in moderate physical activity and vigorous physical activity than non-obese children.

We found that the obese children had significantly greater energy intakes than did non-obese children. This is consistent with the results of the study of Gazzaniga et al [27] and Zalilah et al.[10] But there were exceptions. Some reports suggested that energy intake is the similar or less in obese compared with non-obese children.[7,8,9] In these studies, self-report methods were used to assess energy intake. Bandini et al [28] and Maffeis et al [29] reported that the self-report method tended to underestimate food intake in children, particularly in obese children. In fact, as a group, the obese children consume more energy than do normal children. Some studies comparing nutrient intake of obese and non-obese children and adolescents have shown that percentage energy intake from fat is greater in obese subjects compared with non-obese.[30,31] Nicklas [32] and Mikami [7] observed a positive relationship between percentage energy from protein and later fatness. However, there was no significant difference in the percentage energy intake from fat, protein and carbohydrate between obese and non obese children in our study. Further research is needed to address the role of the dietary composition or percentage energy from macronutrients in the development of obesity in Chinese children.

Basic metabolic rate (BMR) is the largest component of total daily energy expenditure, accounting for 60–70% of daily energy expenditure.[33] Our study found that the BMR expressed as kJ/d was significantly greater in obese than non-obese children, but was lower when expressed as per kg of body weight. This is consistent with previous studies [9, 12, 34-36] that reported that BMR in obese children was greater than normal when expressed in absolute terms but lower than normal when expressed per kg of body weight. However, Stensel et al [37] found no significant difference in absolute BMR values between obese and non-obese groups. A likely explanation is that FFM was significantly higher in obese than in non-obese children in our study, but slightly lower in obese than in non-obese group in the Stensel's study (40.5 compared with 44.1 kg; NS). Consistent with previous studies,[12,36,37] our study found significant higher BMR even adjusted for FFM in obese children than in non-obese ones. No significant BMR difference remained when FM were further controlled for. This was due to the difference in FM between the obese and non-obese groups. Thus, greater FM would be expected to elevate BMR. This is supported by the fact that both FFM and FM predicted BMR when analysis of covariance was performed in the present study.

The measurement of TEE is especially difficult in children since many methods may change their spontaneous and natural activity patterns. Total energy expenditure was assessed using the factorial method in our study. The factorial method may underestimate TEE because the energy expenditure value for each activity from the published tables might be lower than those indirectly measured by calorimetry.[38,39] To avoid this underestimation, in the present experiments TEE was calculated by using measured BMR. Results from our study found that the absolute value of TEE was greater in obese than in non-obese children. This result is in accordance with earlier investigations.[11,12]

Maffeis et al [11] found that the obese children spent more time in sedentary activities, and more time in rest, less time in physical activity. Delany et al [13] found that obese children spent less time in activity than lean children and the obese children were engaged in less strenuous activity. Consistent with previous studies, our study found that obese children spent significantly more time in light physical activity and sleeping and less time in moderate physical activity and vigorous physical activity. The energy expenditure during sleeping and light activity was significantly higher in the obese group. In other words, obese children were more sedentary than non-obese children. Our finding suggests that decreased physical activity or increasing inactivity may play a role in child obesity. Therefore, it would be helpful for obese children to control their weight by reducing inactivity time and performing some long-duration and high-intensity physical exercises. One school-based intervention study conducted in China showed that the prevalence of overweight and obesity reduced in schoolchildren through a 3-year intervention program focused on nutrition education and physical activity.[40] Some school-based physical activity programs were successful in preventing a decline in children' total activity levels and increasing overall health.[41,42] Our finding of dietary intake suggest that a helpful strategy for weight management might be the continuous encouragement of a more active lifestyle together with a reduction of energy intake.

There were a number of limitations in this study. First, sampling bias could not be avoided because the subjects in this study were enrolled from only one boarding school in China. Subjects were living in the same environment and had similar schedules, which may modify their behaviors of energy intake and expenditures. Also, children who can attend boarding school are from a certain socio-economic status that indicates a relatively higher level of family income. Therefore, it could not be assumed that these subjects were truly representative of obese and non-obese Chinese children in general. Generalization of the findings from this study should be done with great caution. Secondly, pubertal stage was not determined in the present study, so that we could not assess the association of it with metabolic rate. Thirdly, anthropometry was used in the present study to estimate body composition. Although this method is not the most accurate one, it is the most widely used technique and an acceptable method for the assessment of body composition in childhood.[43] We tried to keep method errors as low as possible through high methodological discipline and by using equations developed for Chinese children. In addition, total energy expenditure was measured by the factorial method. The most accurate technique for the measurement of TEE is the doubly labeled water method. But its application in large-scale studies is limited by high cost and technical complexity. Furthermore, the factorial method has been recommended by the World Health Organization (WHO) for estimating individual and population energy requirements.[26, 44]

In conclusion, our findings showed that compared to non-obese children, both energy intake and energy expenditure were significantly higher in obese children. Time spent in moderate physical activity and vigorous physical activity was significantly less in obese than in non-obese children, whereas time spent on light physical activity and sleeping was significantly greater in obese children. This study contributes to the body of evidence at a group basis, there does not appear to be an energy defect that predisposes children to obesity. Longitudinal studies are needed to clearly elucidate the role that energy expenditure and energy intake play in the development of obesity.

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CONFLICT OF INTEREST
Cai-Xia Zhang, Yu-Ming Chen, Wei-Qing Chen, Xue-Qing Deng, and Zhuo-Qin Jiang, no conflicts of interest.

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Original Article

Energy expenditure and energy intake in 10-12 years obese and non-obese Chinese children in a Guangzhou boarding school

Cai-Xia Zhang MD[1], Yu-Ming Chen MD PhD[1], Wei-Qing Chen MD PhD[1], Xue-Qing Deng[1] and Zhuo-Qin Jiang MD[2]

[1]*Department of Biostatistics and Epidemiology, School of Public Health, Sun Yat-sen University, Guangzhou, PR China.*
[2]*Department of Medical Nutrition, School of Public Health, Sun Yat-sen University, Guangzhou, PR China.*

中國廣州市某寄宿學校 10-12 歲肥胖和非肥胖兒童能量消耗和能量攝入

目的：本研究的目的是觀察中國肥胖兒童能量攝入和能量消耗的變化。**方法：**以中國廣州市某寄宿學校 10-12 歲的 54 名肥胖兒童和 60 名非肥胖兒童爲研究對象。以開放式間接測熱法測定基礎代謝，總能量消耗採用因子加總法估算，盤存稱重法用于計量能量攝入，用 2 天的活動記錄來估計體力活動。**結果：**單變項分析顯示，肥胖兒童基礎代謝的能量消耗大於非肥胖兒童，統計上有顯著差異(p<0.05)；但是控制了脂肪組織和瘦體組織後，基礎代謝的能量消耗在肥胖兒童和非肥胖兒童之間的差異沒有顯著性。肥胖兒童的能量攝入和總能量消耗高於非肥胖兒童 (p<0.05)。肥胖兒童花費的睡眠時間和輕體力活動時間多於非肥胖兒童，而中體力活動時間和重體力活動時間少於非肥胖兒童 (p<0.05)。**結論：**與非肥胖兒童相比，中國肥胖兒童的能量攝入和能量消耗較高。顯然對 10-12 歲的兒童，預防肥胖的策略之一可能是鼓勵增加體力活動的能量消耗。

關鍵字：肥胖，兒童，能量攝入，能量消耗，中國廣州