การศึกษากิจกรรมการเคลื่อนไหวร่างกายและการใช้พลังงาน
ระหว่างเด็กไทยที่อ้วนและไม่อ้วนในกรุงเทพมหานคร

นางสาวจิรภา น้าคณาคุปต์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

หลักสูตรสาขาวิชาเวชศาสตร์การกีฬา

คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2542

ISBN 974-334-426-8

STUDY OF PHYSICAL ACTIVITY AND ENERGY EXPENDITURE IN OBESE AND NON-OBESE THAI CHILDREN IN BANGKOK METROPOLIS

Miss Chirapa Nakhanakhup

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science in Sports Medicine

Program of Sports Medicine

Faculty of Medicine

Chulalongkorn University

Academic Year 1999

ISBN 974-334-426-8

Thesis Title	STYDY OF PHYSICAL ACTIVITY AND ENERGY EXPENDITURE IN OBESE AND NONOBESE THAI CHILDREN IN BANGKOK METROPOLIS
By	Miss Chirapa Nakhanakhup
Inter-Department	Sports Medicine
Thesis Advisor	Assistant Professor Sompol Sanguangrungsirikul, M.D., M.Sc.
Thesis Co-advisor	Assistant Professor Juraiporn Somboonwong, M.D., M.Sc.

Accepted by the Faculty of Medicine, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

.... Dean of Faculty of Medicine
(Professor Pirom Kamolratanakul, M.D.)

THESIS COMMITTEE

.... Chairman
(Associate Professor Prasong Siriviriyakul, M.D.)

.... Thesis Advisor
(Assistant Professor Sompol Sanguangrungsirikul, M.D., M.Sc.)

.... Thesis Co-advisor
(Assistant Professor Juraiporn Somboonwong, M.D., M.Sc.)

.... Member
(Assistant Professor Chandhita Pruksananonda, M.D.)

.... Member
(Assistant Professor Dootchai Chaiwanichsiri, M.D.)

จิรภา น้าคณาคุปต์ : การศึกษากิจกรรมการเคลื่อนไหวร่างกายและการใช้พลังงานระหว่างเด็กไทยที่อ้วนและไม่อ้วนในกรุงเทพมหานคร (Study of Physical Activity and Energy Expenditure in Obese and Nonobese Thai Children in Bangkok Metropolis) อ.ที่ปรึกษา: ผศ. นพ. สมพล สงวนรังศิริกุล, อ. ที่ปรึกษาร่วม: ผศ. พญ. จุไรพร สมบุญวงค์, 50 หน้า. ISBN 974-334-426-8

การวิจัยครั้งนี้ มีวัตถุประสงค์เพื่อ ศึกษากิจกรรมการเคลื่อนไหวร่างกายและการใช้พลังงานในเด็กไทยที่อ้วนและไม่อ้วนในกรุงเทพมหานคร จำนวนทั้งสิ้น 47 ราย ที่มีอายุระหว่าง 9 – 12 ปี เป็นเด็กอ้วน 21 รายและเด็กไม่อ้วน 26 ราย ทำการวัดขนาดสัดส่วนของร่างกายประเมินการใช้พลังงานของร่างกายทางอ้อมโดยการวัดอัตราการใช้ออกซิเจนของร่างกาย ประเมินกิจกรรมการเคลื่อนไหวร่างกาย โดยบันทึกอัตราการบีบตัวของหัวใจด้วยอุปกรณ์ติดตามบันทึกอัตราการบีบตัวของหัวใจและคำนวณระดับการมีกิจกรรมของร่างกายจากอัตราส่วนระหว่างการใช้พลังงานของร่างกายทั้งหมดต่อการใช้พลังงานของร่างกายขณะพัก ผลการศึกษาพบว่า เด็กอ้วนมีน้ำหนัก ดัชนีมวลกาย ร้อยละของน้ำหนักต่อส่วนสูง ความหนาของไขมันใต้ผิวหนัง ร้อยละของไขมันในร่างกาย มวลไขมันในร่างกายและอัตราการใช้พลังงานรวมของร่างกายทั้งขณะพักและขณะมีกิจกรรมมากกว่าเด็กไม่อ้วนอย่างมีนัยสำคัญทางสถิติ ($p<0.01$) อัตราส่วนระหว่างปริมาตรของคาร์บอนไดออกไซด์ที่ขับออกต่อปริมาตรของออกซิเจนที่ใช้ไป เท่ากับ 0.91 ± 0.06 ในเด็กอ้วน และ 0.89 ± 0.08 ในเด็กไม่อ้วน แสดงว่าเด็กทั้งสองกลุ่มมีการบริโภคอาหารในสัดส่วนที่เป็นคาร์โบไฮเดรทสูง ระดับการมีกิจกรรมของร่างกายในเด็กอ้วนและเด็กไม่อ้วน เท่ากับ1.48 ± 0.17 และ 1.51 ± 0.22 ตามลำดับ ซึ่งต่ำกว่าค่าที่องค์การอนามัยโลกกำหนดคือ 1.7 จากผลการวิจัยสรุปว่า เด็กอ้วนและเด็กไม่อ้วนในกลุ่มนี้ มีระดับกิจกรรมของร่างกายที่ลดลงและบริโภคอาหารที่มีคาร์โบไฮเดรทสูง ซึ่งอาจเป็นปัจจัยเสี่ยงต่อการเกิดโรคอ้วนเพิ่มขึ้น การจัดโปรแกรมการออกกำลังกายและการจัดกิจกรรมต่าง ๆ ควบคู่ไปกับการให้ความรู้ทางโภชนาการที่เหมาะสมให้แก่เด็กวัยเรียนและผู้ปกครอง จะช่วยในการป้องกันและรักษาโรคอ้วนในเด็ก.

ภาควิชา ______________ ลายมือชื่อนิสิต ______________

สาขาวิชา เวชศาสตร์การกีฬา ลายมือชื่ออาจารย์ที่ปรึกษา ______________

ปีการศึกษา 2542 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ______________

4075210030 : MAJOR SPORTS MEDICINE

KEY WORD: PHYSICAL ACTIVITY / ENERGY EXPENDITURE / OBESITY

CHIRAPA NAKHANAKHUP : STUDY OF PHYSICAL ACTIVITY AND ENERGY EXPENDITURE IN OBESE AND NONOBESE THAI CHILDREN IN BANGKOK METROPOLIS. THESIS ADVISOR : ASSIST. PROF. SOMPOL SANGUANRUNGSIRIKUL, M.D., M.Sc. THESIS CO-ADVISOR : ASSIST. PROF. JURAIPORN SOMBOONWONG, M.D., M.Sc. 50pp. ISBN 974-334-426-8

The objective of this study was to assess the physical activity and energy expenditure in a total of 47 Thai children in Bangkok, aged 9 – 12 years consisting of 21 obese and 26 nonobese children. Anthropometric and body composition measurements were performed. Energy expenditure was determined by indirect calorimetry based on oxygen consumption. Physical activity was assessed using heart rate monitoring method and physical activity index was calculated by the ratio of total energy expenditure to sedentary energy expenditure. The results showed that weight, body mass index, relative weight, per cent body fat, fat mass, as well as activity energy expenditure (AEE), sedentary energy expenditure (SEE), and total energy expenditure (TEE) were significantly higher ($p<0.01$) in the obese children when compared to the nonobese group. The mean values of respiratory quotient (RQ) were 0.91 ± 0.06 in obese and 0.89 in nonobese group, respectively, indicating the contribution of carbohydrate substrate to energy production. Both obese and nonobese children were similar in physical activity level of 1.48 ± 0.17 and 1.51 ± 0.22, respectively, which were lower than that recommended by the World Health Organization (1.7). It is concluded that this group of obese and nonobese children had low level of physical activity and high carbohydrate intake might increase the risk of obesity at the later age. To prevent obesity in children, programming of exercise and activities as well as nutritional education should be emphasized for school children and parents.

ภาควิชา ____ ลายมือชื่อนิสิต ____

สาขาวิชา เวชศาสตร์การกีฬา ลายมือชื่ออาจารย์ที่ปรึกษา ____

ปีการศึกษา 2542 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ____

ACKNOWLEDGEMENTS

I deeply indebted to the volunteers and their families for their participation; to Mrs. Munthana Kuptapun, assistance director, Miss Angsumalin Yimsanit teacher at the Wimuttayarampittayakorn school, Miss Khanittha Naknoi teacher at the Piboonpasan school, for subject recruitment.

Special gratitude is expressed to Assistant Professor Dr. Sompol Sanguanrangsirikul and Assistant Professor Dr. Juraiporn Somboonwong, for their kindness, helpful guidance, valuable advice, and comments. Without their guidance, I would not have the skills and ability to complete my thesis.

I would like to express my special thank to Mr. Tanormsak Saenakum, Mr. Wuttiporn Suwankul, Miss Supa Jomjaeng, Miss Chanitnan Hadda, Pol. Maj. Chaweewan Deechuay, Miss Charinthip Khongsakpornchai, and all my friends, for their assistance, sincerity, friendship, and encouragement.

Last and most important, I must thank my loving family for their understanding, support, and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

AEE	activity energy expenditure
ATP	adenosine triphosphate
BMI	body mass index
°C	degree in celsius
CO_2	carbon dioxide
FFM	fat free mass
FM	fat mass
H	height
HDL	high density lipoprotein
$^{2}H_2\ ^{18}O$	doubly labeled water
H_2O	water
hr	hour
HR	heart rate
I	intercept
IBW	ideal body weigh
kcal	kilocalorie
kg	kilogram
LBM	lean body mass
LPL	lipoprotein lipase
O_2	oxygen
PAL	physical activity level
RMR	resting metabolic rate

RQ	respiratory quotient
SD	standard deviation
SEE	sedentary energy expenditure
SKF	skinfold measurement
T_3	triiodothyronine
TEE	total energy expenditure
VO2	oxygen consumption
VLDL	very low-density lipoprotein
W	weight

CHAPTER I

INTRODUCTION

In consideration of the lifetime pattern of growth, it is rapid in infancy and early childhood, remains relatively steady during middle childhood, increases rapidly during the adolescent period, and finally increases slowly until an eventual cessation with the attainment of adulthood. In growing children, the energy requirement would need to be supplemented by additional calories required for growth. School-age children (6-12 years) have been called the latent time of growth. The rate of growth during this age increases 5 to 6 cm in height and 3 to 3.5 kg in weight per year (Robergs and Roberts, 1997).

Currently, over the course of only a few past generations, the developed nations of the world have become to live in different conditions, i.e., in high technology societies with a workforce and life-style that demand little of any physical activities. Opportunities for significant energy expenditure have declined in recent decades due to urban living with its dependence on the automobile, discouragement of walking and cycling because of heavy traffic, labor-saving devices of many kinds at home and at work, the single store house, and decline of work (Roberts, 1997; Robinson, 1998; Russner, 1998). Children spends a substantial part of their lives watching television, watching videos, playing video games, or using computers. Many children go to summer camp to learn how to use the latest computer programs rather than for physical activities. They now play soccer on a video game rather than on the ball field. More dense living also has decreased the amount of open spaces for play.

Several studies have investigated that television viewing reduces spontaneous activity levels and also promotes food intake (Dietz and Gortmake, 1985; Robinson and Killen, 1995; Gortmaker et al., 1996). Watching television has undesirable effects on food intake, since the food advertised will generally be fattening and television viewing stimulates snacking, thus ensuing risks to develop overweight and obesity (Pipop Jirapinyo et al., 1988; Rising et al., 1994; Ward et al., 1997; Bar-Or et al., 1998).

All these factors make it easier for the modern citizen-adult and child alike-to eat more and exercise less, and hence to achieve a positive energy balance. When energy intake exceeds energy expenditure (due to increased food intake and/or decreased energy expended on physical activity), the excess energy must be stored as fat (Maclean and Graham, 1982; Malina and Bouchard, 1991).

Thailand has experienced rapid socio-economic growth as the result of its change from an agricultural to a new industrial country, causing a lot of changes in culture, attitude, life style and health behaviors, especially consumption pattern which leads to the nutritional problem. Western fast food outlets serving high-energy, low-fiber snacks and fast food centers are popular dining places for children, especially those in areas of high economic growth, such as Bangkok. It is found that the prevalence of obesity in children is increasing. In Bangkok it was estimated to be 5.8 per cent (Uraiwan Chittchang, 1990). Therefore, nutritional status of children in a country with rapid economic growth should be more frequently monitored than in a country with slower economic growth. The risk of childhood obesity is higher in only children than in children of larger family (Mo-Suwan and Geater, 1996). Overprotection and overfeeding are the probable factors.

The data from out-patient clinic of Siriraj Hospital showed that childhood obesity was attributable to the lack of knowledge about food value, exercise, and daily behavior (Pipop Jirapinyo et al., 1988). In 1990, Pipop Jirapinyo and Narit Chanruangvanich performed a comparative study of weight, height, skinfold thickness, total body fat, and lean body mass of healthy Thai children aged 5-15 years from Bangkok and Rajchaburi. All nutritional parameters of children from Bangkok were higher than those of children from Rajchaburi. It was concluded that overnutrition was a problem in this group of children from Bangkok and should be tackled immediately.

Regarding the mechanism of obesity, it results from energy intake in excess of energy expenditure. The energy expended through physical activity is the most variable component of total energy expenditure, both within and among individuals. Data on activity levels are primarily based on interviews and questionnaires. However, both methods have different levels of accuracy and reliability. Other methods, such as the heart rate monitoring method, indirect calorimetry, motion analyzer, and doubly labeled-water method, make it possible to increase the accuracy of the values measured and to obtain better information on physical activity by measuring the energy expenditure of children in free-living conditions.

At the present time, the amount of information available on the level of activity and the energy expenditure for physical activity through the accurate and reliable methods is scanty. Most information, especially in Thai children, obtained from interviews and questionnaires. In this study, we used indirect calorimetry method by computerized instrumentation, heart rate monitoring method and direct observation to assess energy expenditure during physical activity.

Objective

To assess the energy expenditure and physical activity in a group of obese and nonobese children in Bangkok Metropolis.

Research Question

Do obese children have lower physical activity and energy expenditure than nonobese children?

Hypothesis

Obese children have lower physical activity and energy expenditure than nonobese children.

Operational Definitions

1. Flex heart rate (HR) is defined as the heart rate while standing which is proved to be a reasonable indicator for the transition point or flex point from the resting type of activities, such as sitting, to dynamic activities, such as walking. It is calculated as the average value of the highest HR measured during resting activities and the lowest HR during the lightest imposed exercise (Saris, 1996).

2. Physical activity is defined as any body movement produced by skeletal muscles that results in increased energy expenditure .

3. Sedentary activity is defined as any inactive daytime activity including sitting and standing (e.g., writing, reading, studying, playing quietly, watching television, sitting in the car, on the bus, or at the cinema).

4. Resting metabolic rate (RMR) is defined as the metabolic rate of a person at rest, which is measured early in the morning in a laboratory under optimal conditions of quietness and relaxation, following an overnight fast and 8 hr sleep. It is regarded as an approximation of basal metabolic rate.

5. Obese children are defined as the children whose weight for height exceed the standard value according to Thai Standard, Ministry of Public Health, 1987, by more than 20 per cent (relative weight > 120 per cent).

6. Nonobese children are defined as the children weighing ranging from 90 per cent to 119 per cent of the expected weight for height according to Thai Standard, Ministry of Public Health, 1987.

Expected Benefit

The result of this study is to expose the caloric cost of activity level related energy expenditure under free-living conditions in obese and nonobese children. The individual prescription of appropriate levels of daily energy intake and expenditure has the potential to serve as a useful tool for the prevention of obesity, particularly in children who are at risk.

CHAPTER II

LITERATURE REVIEW

OBESITY

Obesity is best defined as an excessive proportion of body weight as fat above an arbitrary standard. It is a disorder in which the psychobiological cues for eating are discordant with energy requirements. In this chapter some important aspects of obesity are reviewed, including the criteria for diagnosis, etiological factors, incidence, prognosis, pathogenesis, and complications as well as assessment of body composition and physical activity level.

A. Criteria for Diagnosis

Criteria for diagnosis of obesity have varied and have included the following indices (MacKenzie and Neinstein, 1996).

1. Percentile weight for age: Body weight 20 per cent over ideal body weight (IBW) is considered to be obese. However, this measure does not take into account height.

2. Weight (W) for height (H): The National Center for Health Service chart stops at 120 pounds and 59 inches. Above this range the curve is inaccurate and depends on age.

3. Weight-for-height percentiles for age: The percentiles are probably accurate but charts are based on data from the 1960s. Criteria often used for body weight in relation to IBW include:

90 - 110 per cent of IBW	normal
111 - 120 per cent of IBW	overweight
> 120 per cent of IBW	obesity
> 200 per cent of IBW	morbid obesity

4. Quetelet's or body mass index (BMI): Body weight in kilograms is divided by height in square meters. The formula is accurate in adults, but accuracy in children and adolescents is variable primarily due to their rapid growth and development and the differential deposition of adipose tissue with linear growth. The Expert Committee on Clinical Guidelines for Overweight in Adolescent Preventive Services (Himes and Dietz, 1994) recommended using a BMI greater than the 95 th percentile for age and sex to be considered obese.

5. The ponderal index: It is the ratio of height to the cube root of weight [(ht/(wt)1/3]. An index less than 13 is associated with increased mortality.

6. Body fat measurements: Total body fat can be measured indirectly by determining total body water, lean body mass, and body density; estimating body volume by water and gas displacement; or establishing total body fat using xenon, krypton, or cyclopropane. However, these are impractical in a clinical setting. Another method used to estimate per cent body fat has been skinfold thickness. Slaughter et al. (1988) have advocated using the following equation to estimate percent body fat in children:

Male: sum skinfold > 35 mm.; 0.783 (SKF) + I

sum skinfold < 35 mm.; 1.21 (SKF) - 0.008 $(SKF)^2$ + I

Female: sum skinfold > 35 mm.; 0.546 (SKF) +9.7

sum skinfold < 35 mm.; 1.33 (SKF) - 0.013 $(SKF)^2$ + 2.5

Sum skinfold = triceps and subscapular skinfold thickness

I = intercept varies with maturation level and racial group for male as follows:

Age	Black	White
Prepubescent	-3.5	-1.7
Pubescent	-5.2	-3.4
Postpubescent	-6.8	-5.5
Adult	-6.8	-5.5

Another index uses the regional distribution of body fat. The ratio of abdominal or waist circumference to hip or gluteal circumference generates an index that correlates well with future obesity-related health risk. Abdominal fat is characteristic of males (android distribution), while hip fat (gynoid distribution) is characteristic of females.

7. In general, methods that use just height and weight are cheap and easy but do not include a consideration of regional body fat distribution. Skinfold measurements are also cheap and easy but can be inaccurate. Simple portable office ultrasound instruments that increase the accuracy of measuring fat thickness by removing interobserver variance are now available.

B. Etiological Factors

Obesity is a major pediatric health problem. Its prevalence is increasing steadily in children and adults and there is evidence that children and adolescents of all ages are fatter than in the past. Most obesity occurs in children for whom no underlying cause of pathology is recognized; this is "simple obesity". It occurs as a result of a complex interaction between genetic and environmental factors. Less evident is the impact of genetics on the way individuals use food and the satisfaction they get from a given amount of food. There is convincing evidence that many obese people or those who gain weight easily eat less food than those who maintain easy weight control and are not obese. The reason appears to be that the obese group uses food more efficiently, has a tendency to store food quickly in the form of fat, and has much more difficulty in mobilizing fat to meet energy needs (Guthric, 1986).

The high incidence of obesity among parents of obese children and the fact that early-onset obesity appears to be almost intractable lead one to believe that hereditary factors are important. The incidence of obesity in their children is about 9 per cent to 14 per cent. If one parent is obese, the incidence rises to 41 per cent to 50 per cent. If both parents are obese, it rises to 66 per cent to 80 per cent (Lankford and Jacobs-Steward, 1986).

Environmental factors that have affected the prevalence of obesity include season, geographic region, population density (Dietz and Gortmaker, 1984), socioeconomic factors including education, income, family size (Ravelli and Belmont, 1979; Mo-Suwan and Geater, 1996), and activity levels (Figueroa-Colon, 1993).

However, there are some disorders that may have a primary medical association with obesity such as Cushing's syndrome, hypothyroidism, and growth hormone difficiency, etc. Most of these disorders are rare. They are usually differentiated from simple childhood obesity by short stature, delayed bone age, and delayed development of secondary sexual characteristics.

C. Incidence and Prognosis

Obesity in childhood is a growing problem. Data from the National Health and Nutrition Examination Survey I (NHANES I) study conducted between 1972 and 1974 and the NHANES III study conducted between 1976 and 1987 indicate that the prevalence of obesity and superobesity (triceps skinfold measures > 95th percentile) are increasing (Schonfeld-Warden and Warden, 1997). Studies in the United States confirm the growing prevalence of obesity in children and adolescents (Gortmaker et al., 1987). Additionally, many obese children become obese adolescents and adults. It has been estimated that 40 per cent of obese children at 7 years of age and 70 per cent of obese adolescents are obese as adults. Retrospective investigations have revealed that approximately 30 per cent of the obese adults had a history of juvenile obesity (Pipes, 1993). Nonobese children who become obese with advancing age are far less common (Figueroa-Colon et al., 1993).

D. Pathogenesis

1. Thermogenesis

Obese individuals have been described as utilizing energy calories more "efficiently" than lean subjects. They have been characterized as requiring fewer calories per unit of lean body mass. If they eat a number of calories equal to those eaten by a lean subject, more of the calories will be available as extra energy to be deposited as fat (Pi-Sunyer, 1988).

The expenditure of energy takes three forms: basal metabolic rate (BMR) or resting metabolic rate (RMR), thermic effect of food, and physical activity. Each of them is discussed as follows.

Basal or Resting Metabolic Rate. BMR or RMR can be considered to be the energy required for the maintenance of homeostasis when the body is at rest. In most healthy children, RMR makes up about 50 to 60 per cent of total energy expenditure (TEE). Fat mass, fat-free mass, sex, and age explain about 80 per cent of the variance in RMR (Bogardus et al., 1986, West, 1990). Because the metabolic rate is defined primarily by the cell mass of the body, it is reasonable to express it in terms of the lean body mass. The contribution of the lean body mass to the RMR is much greater per kilogram than that of body fat (Zurlo et al., 1990; Maffeis, Schutz, Micciolo et al., 1993).

Thermic Effect of Food. The rise of metabolic rate above basal after eating has been called the thermic effect of food. About 10 per cent of the ingested diet that can be metabolized is lost as heat, which is used up in the intermediary metabolism of substrates, in the utilization of ATP, and in the formation of ATP from reduced coenzymes by oxidative phosphorylation (Pi-Sunyer, 1988).

Physical Activity. It is presumably important in normal growth and maturation. Apparently the day-to-day activities of childhood and adolescence are adequate to maintain the integrity of growth and maturation processes, with the possible exception of adipose tissue. Relative physical inactivity, perhaps in combination with a chronically excessive energy intake, is associated with greater levels of fatness. Fatness is more effectively regulated through combined physical activity and dietary monitoring, although this is not easily achieved, and relapses into excess body fat is the rule rather than the exception (Rising, 1994; Moore et al., 1995; Salbe, 1997; Maffeis, Zaffanello, and Schutz, 1997; Bar-Or, Foreyt et al., 1998; Wong, 1999).

2. Endocrinopathy in Obesity

In children, obesity may be seen with certain congenital syndromes, including Prader-Willi syndrome, adiposogenital dystrophy, Laurence-Moon-Biedl syndrome, Bongiovanni-Eisenmenger syndrome, and pseudo-hypoparathyroidism. Whereas the cause of obesity is seldom a hormonal abnormality, obesity may lead to abnormalities of hormone levels. Owing to the delvelopment of insulin resistance, insulin levels in the blood rise. Triiodothyronine (T_3) rises in conditions of high caloric intake with adequate carbohydrate (through not to abnormal levels). Thyroxine levels are normal. The urinary excretion of free cortisol and of hydroxycorticoids, sometimes elevated in obesity, is probably related to an increase in cortisol turnover. These changes are related to the higher lean body mass in the obese. Blood cortisol levels are usually in the low-normal range. Stimulatory tests with arginine, insulin hypoglycemia, or L-dopa demonstrate a poor growth hormone response. This growth hormone response reverts toward normal with weight loss (Pi-Sunyer, 1988).

3. Fat Cells

Fat cells or adipocytes are distributed throughout the body. The number of fat cells in the infant is genetically determined; however, research shows that during three critical phases of growth, the body has the potential to accumulate an excess number of fat cells. The three periods when the potential for hyperplasia occurs are during the last 3 months of fetal development, the first 3 years of life, and adolescence. After 18 month of age, fat cells increase not only in number but also in size (hypertrophy) until approximately adulthood, when the number is fixed; however, they can continue to grow in size indefinitely. Juvenile-onset obesity can result from both hyperplasia and hypertrophy. Adult-onset obesity results from hypertrophy of fat cell alone (Lankford and Jacobs-Steward, 1986).

4. Lipoprotein Lipase

Adipose tissue lipoprotein lipase (LPL) is an enzyme that determines the rate of uptake by fat cells of circulating plasma triglyceride. It originates in adipocytes and muscle cells and then is secreted to the capillary endothelium where it acts on circulating VLDL triglycerides. Activated LPL enhances the breakdown of triglycerides to glycerol phosphate and free fatty acids, which smaller cells can enter adipose cells, be re-esterified, and be stored as triglyceride.

Obese individuals could have elevated LPL as a primary defect that enhances their ability to "pull" triglyceride into cells, or obesity could develop from some other causes and the enhanced LPL activity could be secondary to the enlarged fat cells (Pi-Sunyer, 1988).

E. Complications

Excess weight and body fat in adolescents have been associated with increased plasma insulin levels, elevated blood lipid and lipoprotein levels, and elevated blood pressure , which are factors known to be associated with obesity-related adult morbidity. Obese infants and children are at moderately increased risk of becoming obese adults. This increased risk is associated with greater severity of childhood obesity, decreased time interval to adult age, and greater number of obese family members.

There is an association between childhood obesity and cardiovascular risk factors. In the Muscatine study, obese children had significantly lower HDL cholesterol levels, higher triglyceride levels, and higher systolic blood pressure, although there was no difference from normal ranges for total cholesterol, LDL cholesterol, apolipoprotein a1, apolipoprotein b, or diastolic blood pressure. Other studies have provided conflicting results and do not prove that childhood obesity increases the risk of cardiovascular disease, nor is there evidence that treatment of obesity decreases the risk of adult coronary artery disease. Other complications of obesity described in children, although some of those included have not been firmly established, are cholelithiasis, Blount disease and slipped capital femoral epiphysis, pseudotumor cerebri, Pickwickian syndrome and abnormal pulmonary function tests (Behrman et al, 1996).

ASSESSMENT OF BODY COMPOSITION

Two general procedures are used to evaluate body composition (McArden et al., 1996): direct evaluation by chemical analysis of the animal carcass or human cadaver, and indirect evaluation by underwater weighing, skinfold thickness, and weight and height measurements. The direct method for assessing the fat content of cadavers, while of considerable theoretical importance obviously cannot be used with live subjects. The indirect evaluations are described below.

A. Underwater Weighing

The relative amount of body weight as fat, compared to more dense or heavy muscle and bone, influences body density. Therefore, body density is the standard for determining body fat. Measuring body density involves a comparison of the weight of subjects submerged in a water tank to their weight in air. When the proportion of fat to the rest of body weight is approximately 15 per cent, the specific gravity will be about one. As the fat portion, which has a specific gravity of 0.92, increases, the specific gravity of the body decreases (that is, the weight underwater is lower than the weight in the air), and the body is more likely to float. Besides being expensive, underwater weighing is often frightening to a subject and until recently was used only for research purposes. The underwater weighing that is now popular in health spas seldom corrects for air in the lungs and is therefore not completely accurate.

This measurement has problems of cost, subject cooperation, and potential hazards that limit its usefulness in assessing a person's fat "status". As a result, we rely on the standards based on skinfold, or fatfold thickness (Guthric, 1986).

B. Skinfold Thickness Measurement

The usefulness of skinfold thickness, which provides a measure of subcutaneous fat, depends on a professional skill in the use of a caliper. Measurements most frequently involve the thickness of the skin, or fatfold, over the triceps muscle on the outside back of the arm; the biceps on the inside of the arm; or the subscapular region, which is beneath the shoulder blades. These measurements are then compared to standards for the appropriate age and sex or are incorporated into formulas to predict the percentage of body fat. Some formulas require measurements for as many as 10 sites, but these are not practical for routine assessment. Although the subscapular is the most useful single measurement, the single triceps skinfold has an advantage because subjects will willingly permit this measurement, whereas they are less enthusiastic about others that require undressing (Guthric, 1986).

C. Weight and Height Measurements

Because of the difficulties in measuring skinfolds in infants and young children and the lack of appropriate standards for some other groups, it depends almost totally on the interpretation of height and weight data to assess body fat. For infants and children in Thailand, standards are based on data from the Thai Standard, Ministry of Public Health (MOPH), 1987. Individuals with body weights in excess of 110 per cent of the midpoint of the standard for age, sex, and height (after care is taken to make necessary adjustments for clothing or heel height) are considered overweight. Those with weights in excess of 120 per cent are considered obese.

Other standards using information on height and weight have been developed for specific uses. These include the ponderal index and the body mass index (BMI), which have been already mentioned above.

ASSESSMENT OF PHYSICAL ACTIVITY LEVEL

Several methods have been used to assess activity level as the followings:

A. Recall questionnaires (self-administered or interviewer-administered)

B. Diaries (activity diaries)

C. Time-and-motion analyses (through direct observation or a review of photographs)

D. Heart rate monitoring

E. Analyses of the number and intensity of body movement by motion analyzers, accelerometers, pedometers, and actometers

F. Calorimetry

A. Questionnaires

The use of questionnaires is the least expensive and most common way of surveying populations or groups of children. Because the child's memory or his or her capacity to understand the questions may limit the accuracy of this method, one should try to obtain additional information from parents or teachers. Typically, questionnaires yield reliable information about the nature of a child's activities but are less accurate for determining the duration and intensities. Also, children seem to recall participation in organized sports better than recall recreational, nonorganized activities (Bar-Or and Malina, 1995).

B. Diaries

By keeping activity diaries, children do not need to rely on memory and can document fairly accurately the duration of each activity. The validity of diaries needs to be established, and the time and effort required to record information may interfere with the child's other activities (Bar-Or and Malina, 1995).

C. Time-and-motion Analyses

The time a child spends in each activity is recorded. Whether this technique involves direct observation or the study of photographs, it yields only descriptive, qualitative information. To calculate energy expenditure, one must refer to tables that provide the energy equivalents for each activity. However, tables prepared for adults should not be used to evaluate children's activity levels, because the values differ markedly between children and adults and between different groups of children, even after corrections are made for differences in body mass. Although time-and-motion analysis involving direct observation is costly, because it requires one observer per child, it is still considered the "gold standard" for describing children's activity patterns and for validating other methods (Bar-Or and Malina, 1995).

D. Heart Rate Monitoring

Heart rate monitoring is based on the linear relationship between heart rate and oxygen consumption (VO_2) for a wide range of exercise intensities. Because today's monitors are small and unobtrusive, children rarely object to using them. In addition, heart rate monitoring is inexpensive and does not interfere with the child's spontaneous activities. The limitation of such monitoring is that heart rate is influenced not only by activity level but by a number of other factors, such as eating meals, climatic conditions and emotional state also. As a result, the heart rate method usually overestimates actual energy expenditure, particularly for outdoor activities. Nomograms are being developed to correct oxygen consumption-heart rate regressions for the effects of warm and humid conditions on children. By referring this value to the individual regression line, the energy expenditure at a given heart rate can be calculated and integrated during day-time activities (Bar-Or and Malina, 1995).

E. Analyses of the Number and Intensity of Body Movement by Motion Analyzers, Accelerometers, Pedometers, and Actometers

Technological advances have expended the use of motion analyzers. The earliest and most primitives of such equipment, pedometers, and actometers, simply counted steps and other limb motions. A single-plane accelerometer (Caltrac) that is worn on the hip has been validated against direct observations of preschooler's activities during a 1-hr period. It is likely that the results of accelerometry could be improved if several monitors, each on a different part of +the body, were worn simultaneously and if each device could detect motion in more than one plane. A recently developed three-plane accelerometer (Tritrac 3RD) is now available commercially, but its reliability and validity have yet to be determined (Bar-Or and Malina, 1995).

F. Calorimetry

The energy expended by an individual can be assessed by two different techniques: direct and indirect calorimetry (McArdle et al.,1996).

1. **Direct Calorimetry**

All of the metabolic processes that occur in the body result ultimately in the production of heat. Consequently, heat production and metabolism can be viewed in a similar context. Human heat production can be measured directly in a calorimeter similar to the bomb calorimeter used to determine the energy content of food. Direct calorimetry is highly accurate and of great theoretical importance, yet its use is limited.

2. Indirect Calorimetry

Energy production can also be calculated, by measuring the products of the energy producing biological oxidations, i.e., CO_2, H_2O, and the end products of protein catabolism produced or by measuring the O_2 consumed. One problem with using O_2 consumption as a measure of energy output is that the amount of energy released per mole of O_2 consumed varies slightly with the type of compound being oxidized. More accurate measurements require data on the foods being oxidized. Such data can be obtained from an analysis of the respiratory quotient and the nitrogen excretion (Ganong, 1997).

A common way of determining food energy utilization is thus to measure oxygen consumption. This is the most important form of indirect calorimetry. There is also a constant relationship between kcal released and CO_2 production, although values of kcal per liter CO_2 are not nearly as similar when fats and carbohydrates are compared. Consequently, CO_2 production is a less accurate means of determining metabolic energy utilization by indirect calorimetry.

Indirect calorimetric evaluations are aided by measuring the respiratory quotient, or RQ, which indicates the predominant fuels in current use, so that adjustments can be made for the contributions from carbohydrates and fats. The RQ is the ratio of liters CO_2 produced to O_2 consumed by an individual and calculates to 1.0 for carbohydrates, about 0.70 for fats, and approximately 0.8 for proteins (Linder, 1985).

All energy-releasing reactions in the body ultimately depend on the utilization of oxygen. By measuring a person's oxygen uptake at rest and under conditions of steady-rate exercise, it is possible to obtain an indirect estimate of energy metabolism because the anaerobic energy yields is quite small under such conditions. Spirometry and doubly labeled water are the two applications of indirect calorimetry by measuring oxygen consumption and carbon dioxide production, respectively (McArdle and Katch, 1996).

2.1 Spirometry

Closed-circuit Spirometry. The closed-circuit spirometry is used routinely in laboratory settings to estimate resting energy expenditure. The subject breathes from a profiled container, or spirometer, of 100 per cent oxygen. This equipment constitutes a "closed system" because the person rebreathes only the gas in the spirometer. Carbon dioxide in the exhaled air is adsorbed by a canister of soda lime (potassium hydroxide) placed in the breathing circuit. A drum attached to the spirometer revolves at a known speed and records change in the volume of the system as oxygen is consumed.

Open-circuit spirometry. The open-circuit method provides a relatively simple means for measuring oxygen uptake and indirect determining energy expenditure. With this method, the subject does not rebreath from a container of oxygen, as in the closed-circuit method, but instead inhales ambient air with a constant composition of 20.93 per cent oxygen, 0.03 per cent carbon dioxide, and 79.04 per cent nitrogen. The nitrogen fraction also includes a small quantity of inert gases. Because oxygen is used during energy-yielding reactions and carbon dioxide is produced, the exhaled air contains less oxygen and more carbon dioxide than the inhaled air. The difference in composition of the inspired and expired gas volumes reflects the body's constant release of energy through aerobic metabolic reactions.

2.2 Doubly labeled-water method

Doubly labeled-water is now the method to measure energy expenditure in free-living conditions and therefore to measure physical activity. The doubly labeled-water method is a form of indirect calorimetry and is based on the principle that isotopically labeled oxygen in body water would exit the body as water and as carbon dioxide, whereas isotopically labeled hydrogen in body water would exit the body as water. Thus the turnover rates of isotopic hydrogen- and oxygen-labeled water would differ, and that difference would be proportional to carbon dioxide production and hence the rate of energy expenditure. The major problem with this method is the high cost of the ^{18}O isotope and of the isotope ratio mass spectrometer necessary to determine the isotopic enrichment in deuterium and ^{18}O (Schoeller and Santen, 1982; Schutz and Jequier, 1988; Bar-or and Malina, 1995).

CHAPTER III

MATERIALS AND METHODS

MATERIALS

1. A weighing scale (Yamato DP-6100 GP)
2. A scale for height
3. Lange skinfold calipers
4. Cardiotachometer (Polar Sport Tester; Polar electro Oy FIN-90440, Finland)
5. Oxygen and carbon dioxide gas analyzer [Quinton Metabolic Cart (QMC)]
6. Electrocardiographic monitor (Quinton instrument CO, Q4500)
7. Treadmill (Quinton instrument CO, Q55 series 90)
8. A noninvasive blood pressure monitor (Quinton instrument CO, model 412)

METHODS

Subjects

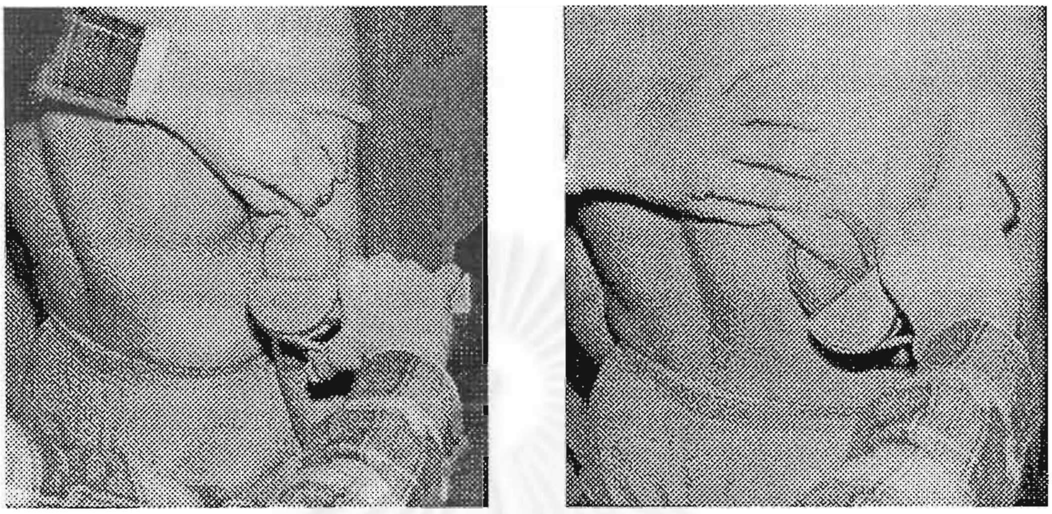
Subjects were recruited from 2 schools in Bangkok Metropolitan, Wimuttayarampittayakorn and Piboonprachasan school, with permission of the school directors, as the representatives of children from Bangkok. To be eligible to participate, children had to meet the following criteria: 1) have a simple obesity ; 2) aged 9 to 12 years old with no physical or mental disability that would interfere with diet or activity; and 3) live in Bangkok.

We initially enrolled 53 children, 6 anticipated some dropouts over time. Therefore, forty-seven children, aged 9 - 12 years (mean 10.67 ± 1.02 years) took part in this study, including nonobese children (n = 26), 14 boys and 12 girls, with body weight ranging from 90 to 119 per cent of the expected weight for height from the Thai Standard, Ministry of Public Health (MOPH), 1987 and obese children (n = 21), 16 boys and 5 girls, weighing 20 per cent or more above that predicted for height. Subjects with diabetes mellitus or other metabolic or endocrine disorders were excluded. No child was taking any drugs. Informed consent was obtained from the parents of each subject.

Anthropometric Measurement

The measurements of weight, height, and skinfold thickness were carried out by the same investigator. Height was measured to the nearest 0.5 cm on a wall scale under the following conditions: without shoes; heels together; child's heels, buttocks, shoulders, and head touching the vertical wall surface; and with line of sight aligned horizontally. Body weight was measured to the nearest 0.02 kg on digital platform scale (Yamato DP 6100 GP). Children were weighed without shoes and empty pocket. Body mass index (BMI) was computed as weight divided by squared height (Wt / Ht squared).

Triceps and subscapular skinfold thickness were measured on the right side mid - upper arm and 1 cm below inferior angle of the subscapular of the body by Lange skinfold calipers (CMS Weighing Equipment Ltd., London, United Kingdom) (figure 3.1). Each side needed at least 3 measurements before being averaged to represent its value. To estimate relative body fat from skinfold thickness, the formulas of Lohman were used (Lohman,1986). Fat-free mass was calculated by subtracting fat mass from body weight; fat mass was obtained by multiplying the percentage of body fat by body weight.



A. Triceps B. Subscapular

Figure 3.1 Measurement of skinfold thickness; A. Triceps and B. Subscapular

Experimental Design

The children arrived by car at the Department of physiology at approximately 8:30 AM, having fasted from 8 PM of the day before test. The child was to lie down on the bed placed in a comfortable temperature-controlled (24°C) and humidity-controlled environment. After 30 minutes of absolute rest, the procedure was explained to the child, indirect calorimetry was performed by continuous respiratory exchange measurements. During respiratory exchange measurements, each child rested quietly while watching television. Special care was taken to prevent spontaneous movements that might contribute to increased energy expenditure. After RMR measurement a light meal was served and 2 hours later an exercise test was performed.

The relationship between heart rate (HR) and oxygen consumption (VO_2) was established in each child as a result of the exercise test. The individual HR-VO_2 regression line was determined by means of a physical exercise test, during which VO_2 and HR were simultaneously measured under standard open-circuit method. HR and VO_2 were used to generate regression equations as follow:

$VO_2 = a(\text{HR}) + b$, where a is the slope and b is the intercept.

The calculation of energy expenditure using the non-protein data of Lusk is the simple process involving the multiplication of oxygen consumption (L/min), time (minutes), and the caloric equivalent for the respective RER of the exercise (kcal / L VO_2).

Kcal = VO_2 (L / min) × RER caloric equivalent (Kcal / L) × Time (minutes)

Indirect Calorimetry for Determining Resting Metabolic Rate

Respiratory exchange measurements were determined by means of open-circuit, oxygen gas analyzer (Quinton Metabolic cart; Instrumentarium Oy, Datex Division, Helsinki, Finland). The exercise test was conducted in an air-conditioned laboratory with atmosphere temperature of 24-26°C, barometric pressure of 722-755 Torr, and relative humidity of 50-70 per cent.

The instrument was calibrated before each test with standardized gas mixture (Low gas; oxygen 10.74 ± 0.2 per cent and carbon dioxide 0.00 per cent with balanced nitrogen, High gas; oxygen 25.7 ± 0.2 per cent and carbon dioxide 5.14 ± 0.1 per cent with balanced nitrogen), and the system was cleared of room air before each measurement was started. During the calibration procedure VO_2 was measured using a mouthpiece connected to a two - way respiratory valve to determine pulmonary ventilation. The expired air was measured and analyzed breath-by-breath by an automated system. The diagram of respiratory exchange measurement system was shown in figure 3.2.

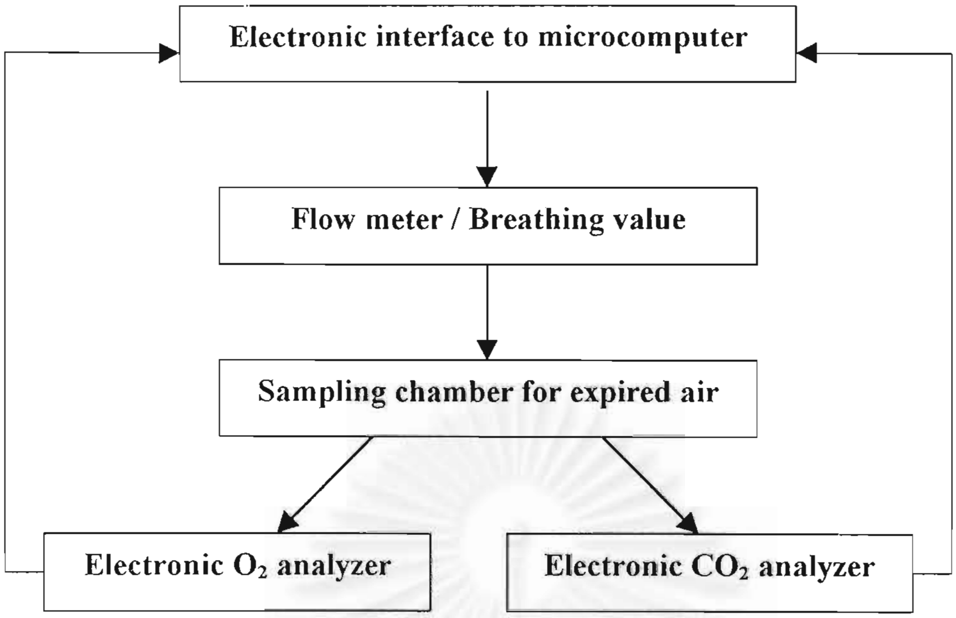


Figure 3.2 Diagram of respiratory exchange measurement system

A computer was interfaced with at least three instruments: a system to continually sample the subject's expired air, a flow meter or turbine device to record the volume of air breath, and oxygen and carbon dioxide analyzers to measure the fractional composition of the expired gas mixture. A printed or graphic display of the data was provided throughout the measurement period. Resting metabolic rate was calculated from oxygen consumption and carbon dioxide production using the formula of Lusk (Lusk,1982).

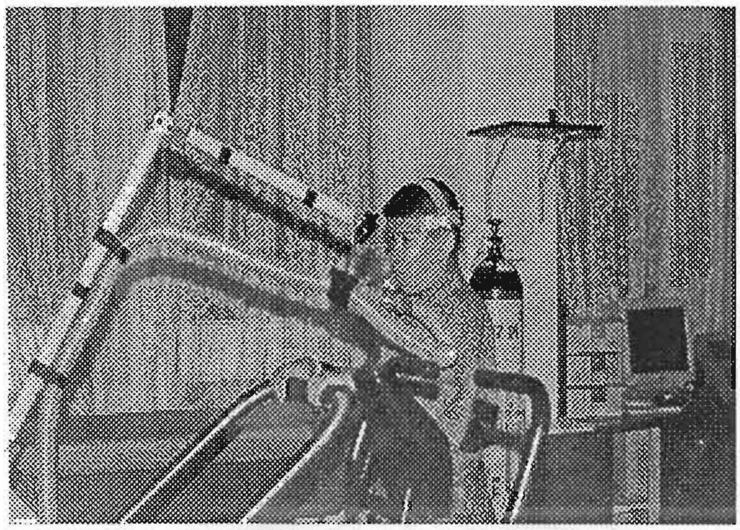


Figure 3.3 Measurement of oxygen uptake using oxygen and carbon dioxide gas analyzer (QMC).

Exercise Test Protocol for Heart Rate – Oxygen Consumption Relationship

The child performed grade exercise test on a mechanically braked, metabolic test device (QMC) and treadmill ergometer that was calibrated routinely according to the directions of the manufacturer (Quinton Instruments, Seattle, Wash., USA). The modified Balke protocols used for research testing of children involved a constant belt speed with stepwise increases in treadmill slope. Children walked on the treadmill at the same speed of 3 miles per hour with a 2-per cent increase in gradient every 2 min beginning at 6 per cent (Rowland, 1996).

Four electrodes were applied to the child's skin, heart rate and rhythm were continuously monitored by electrocardiographic monitoring equipment (Quinton instrument CO, model 4500). Blood pressure was measured by a noninvasive blood pressure monitor (Quinton instrument CO, model 412). Multiple-lead ECGs were taken during rest, exercise, and recovery.

Oxygen consumption and carbon dioxide production were measured by a standard open-circuit method (figure 3.3). Before the measurements, the child was informed about the protocol and carefully familiarized with the experimental apparatus, in particular, about breathing through the mouthpiece and running on the treadmill. The test was stopped when the child met one of the following criteria: 1) heart rate was above 85 per cent of maximal heart rate 2) was volitionally fatigued 3) could no longer continue the test. During recovery period, the speed of treadmill was slowed down and grade reduced.

A critical HR, the flex HR, was determined for each child. Flex heart rate is defined as the heart rate while standing which is proved to be a reasonable indicator for the transition point or flex point from the resting type of activities, such as sitting, to dynamic activities, such as walking (figure 3.4). It is calculated as the average value of the highest HR measured during resting activities and the lowest HR during the lightest imposed exercise. Above the flex value, the calibration curve was used to estimate the energy expenditure corresponded to that of the active period, and below the flex value the resting metabolic rate was used to determine the energy expenditure at rest.

Heart Rate and Activity Monitor During Field Days

Heart rate was recorded using the polar Accurex plus monitor (Polar Sport Tester; Polar Electro Ky, Kempele, Finland), which could store heart rate at 1-min intervals in the memory of the receiver. A transmitter band in which the electrode was worn around the chest, and the wrist watch stored the HR (receiver) (figure 3.6). The heart rate was recorded continuously for 3 days (2 weekdays and 1 weekend day) during normal daily activities under free-living conditions.

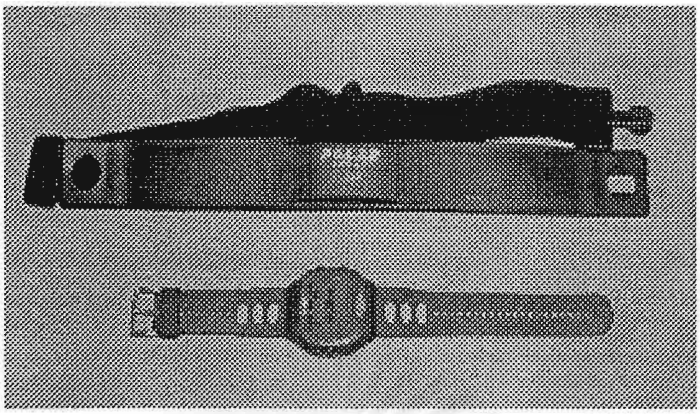


Figure 3.5 Heart rate monitoring (Polar Sport Tester)

The child was instructed to fix the band with the electrodes and the HR transmitter on the chest and to turn the recorder on and off at the wrist. Pulse rate was recorded at 1-min intervals continuously for up to 16 hours. Information was retrieved daily by the same operator by means of interface unit (Polar interface plus) and computer for which are additional program. The HR monitor started when the child arose in the morning and continued until bedtime, when the child removed the instrument. At the end of the study, complete 3-day HR measurements were obtained from each child.

Data Calculation

Total energy expenditure was calculated by summation of sleeping energy expenditure, sedentary energy expenditure, and activity energy expenditure. Sleeping energy expenditure was assessed by multiplying the sleeping time (in minutes) by RMR (in kcal per minute). Sedentary energy expenditure was calculated by multiplying the nonsleeping time under flex HR during the day by RMR. We calculated activity energy expenditure by determining VO_2 for each HR greater than the flex HR from each individual calibration line.

Statistical Analysis

The data in this study were statistically analyzed using the SPSS/Window (Statistical Package for the Social Science) program. The data are expressed as means ± SD. An unpaired-t test was used to compare anthropometric characteristics of obese and nonobese children and to compare the regression coefficients between oxygen consumption and heart rate for workloads above the flex heart rate between the two groups.

CHAPTER IV

RESULTS

Characteristics of the Subjects

Forty-seven children in 2 schools were classified into two groups according to weight for height, 21 obese children (16 boys, 5 girls), and 26 nonobese children (14 boys, 12 girls). Physical characteristics and body compositions of them are presented in table 4.1. Obese children had significantly greater body weight, body mass index, relative weight, per cent body fat, fat mass, and oxygen consumption. There were no significant differences in age, height, fat-free mass, and respiratory quotient between obese and nonobese children.

Total Energy Expenditure. As presented in figure 4.1, the critical HR (flex HR) was not significantly different between obese and nonobese children (104 ± 5 vs 101 ± 3 beats / min). The average slopes between HR (x) and VO_2 (y) for workloads above the flex HR of the two groups have shown in the following equations:

Obese children; $y = 0.009635\,x - 0.349$, with $r = 0.81$

Nonobese children; $y = 0.008923\,x - 0.414$, with $r = 0.80$

Total energy expenditure was calculated by summation of sedentary energy expenditure and activity energy expenditure. We calculated activity energy expenditure by determining VO_2 above the flex HR. Figure 4.2 shows the examples of thirteen hour profile of obese (figure 4.2 a) and nonobese (figure 4.2 b) during a normal school day and weekend.

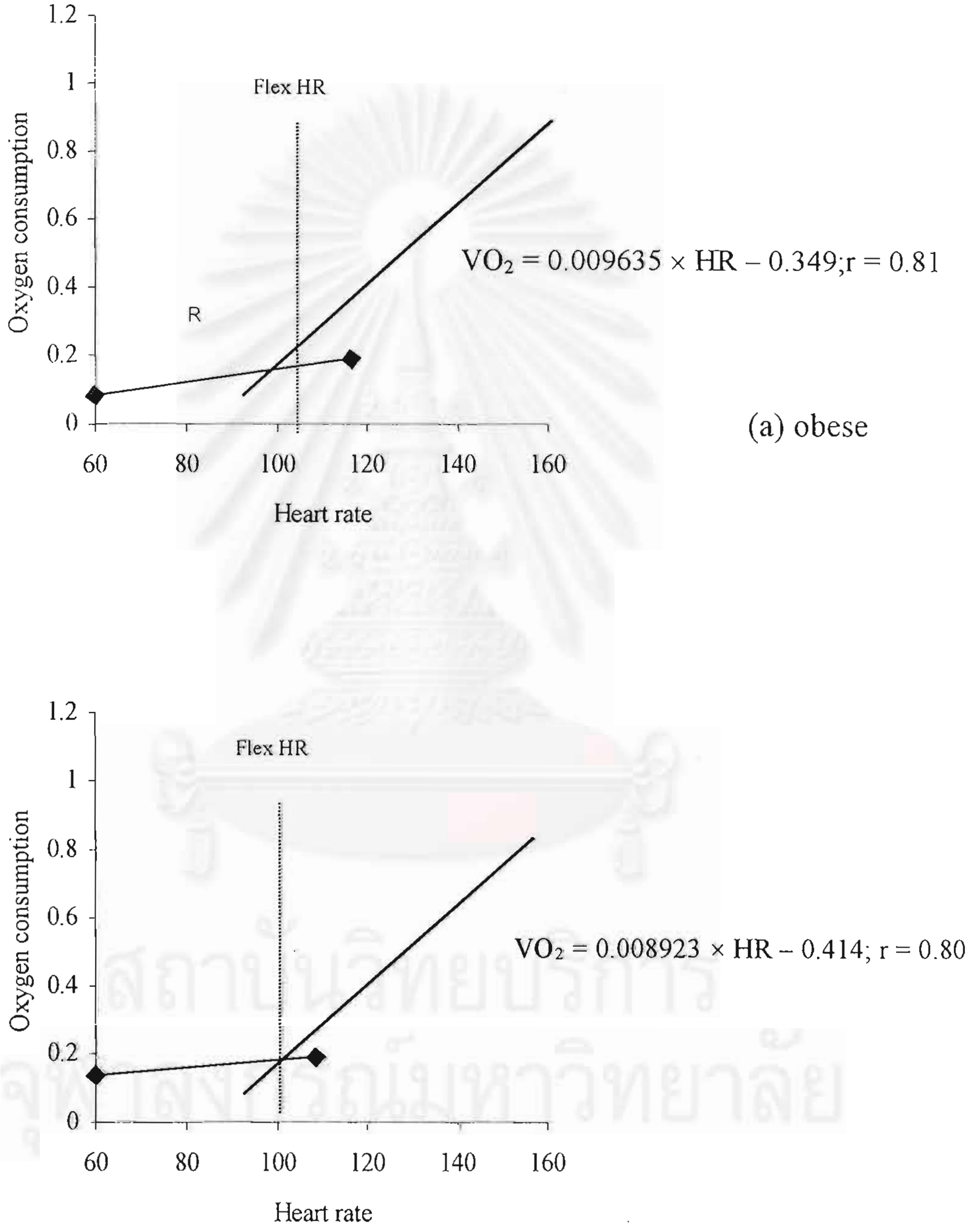
The absolute values for TEE and expressed in relation to FFM were significantly higher ($p < 0.01$) in obese than in nonobese children (Table 4.2). Expressed in relation to body weight, TEE was significantly ($p<0.05$) lower in obese than in nonobese children. However, within each group, the boys had significantly greater absolute energy expenditure values than the girls. There was no significant difference in respiratory quotient (RQ) either between obese and nonobese children as shown in table 4.1.

Resting Metabolic Rate. Expressed in absolute values and in relation to FFM, RMR was significantly higher in obese than in nonobese children ($p < 0.01$). Expressed in relation to body weight, RMR was significantly ($p<0.01$) lower in obese than in nonobese children.

Activity Energy Expenditure. Expressed in absolute values and in relation to FFM, AEE was significantly higher in obese than in nonobese children ($p<0.05$). However, no difference was found in the two groups when the AEE was expressed in relation to body weight.

Physical Activity Index. The physical activity index, defined as the ratio of TEE / 0.1 TEE + RMR, of obese children was nonsignificantly different when compared to nonobese groups, as shown in table 4.2.

Figure 4.1 Example of the mathematical approach to calculate TEE from HR. Mean oxygen consumption (VO_2) as a function of HR (x) at rest (R) and during activities in (a) obese and (b) nonobese children.



(b) nonobese

Figure 4.2 Mean of twenty-four-hour profile of obese children a normal school day and weekend.

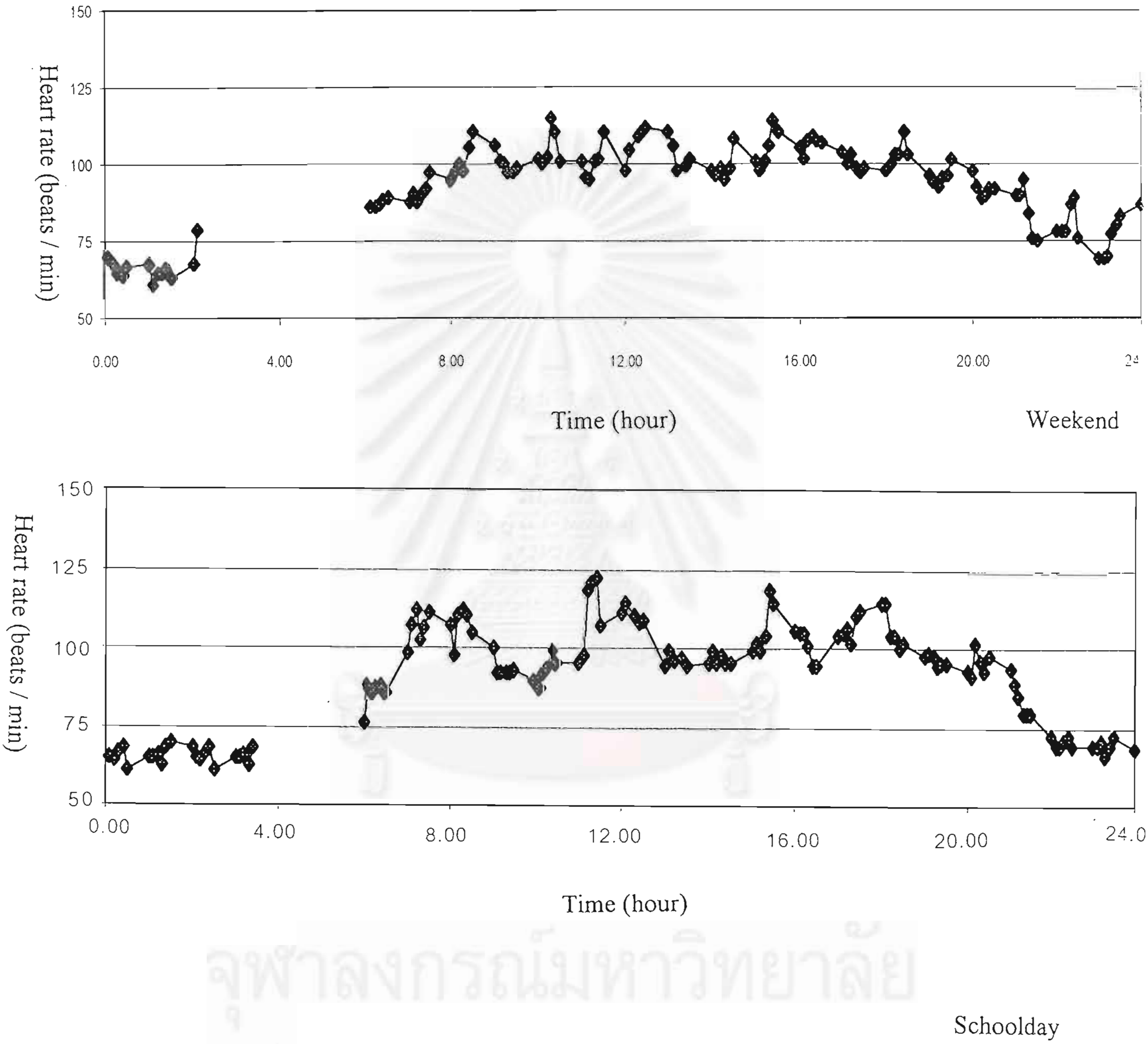
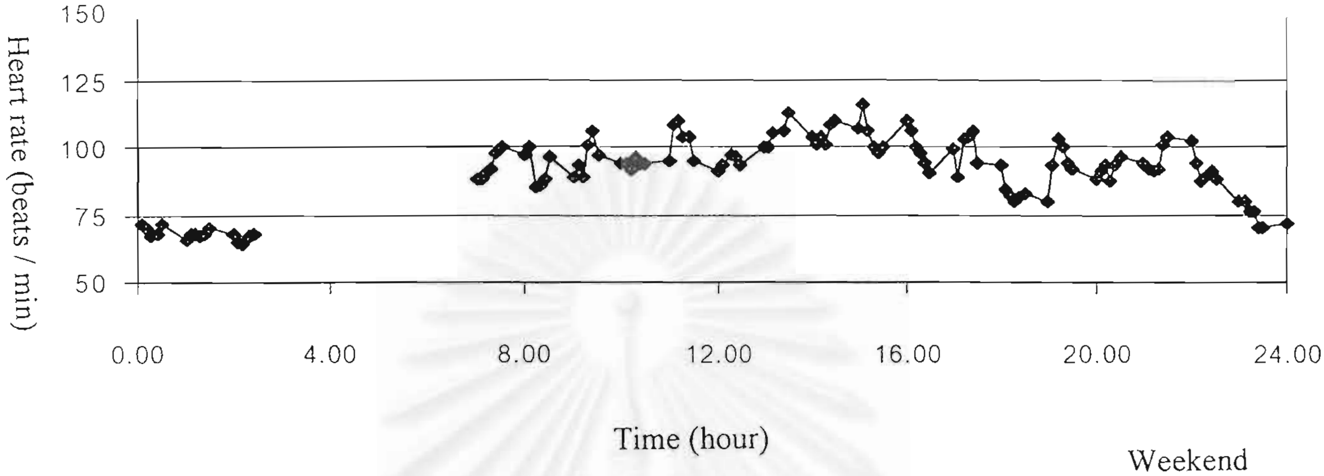
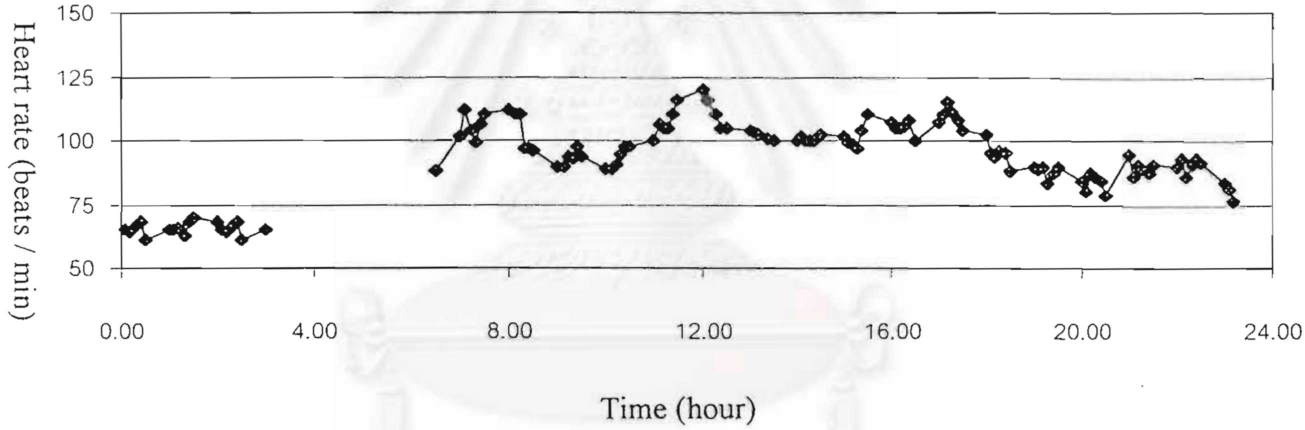


Figure 4.3 Mean of twenty-four-hour profile of nonobese children a normal school day and weekend.



Weekend



Schoolday

Table 4.1. Physical characteristics and body composition of obese and nonobese children

	Obese children (n = 21)	Nonobese children (n = 26)
Male / female ratio	16:5	14:12
Age (yr)	10.67 ± 1.02	11.12 ± 0.52^{ns}
Body weight (kg)	53.85 ± 8.41	36.73 ± 6.36*
Height (cm)	146.05 ± 8.16	148.06 ± 6.77^{ns}
BMI (kg / m^2)	25.13 ± 3.04	16.46 ± 1.86*
Relative weight (%)	145.57 ± 20.13	92.92 ± 10.47*
Sum skinfold (mm)	51.10 ± 6.83	17.35 ± 4.91*
Per cent body fat	40.54 ± 5.40	16.47 ± 4.21*
FM (kg)	22.10 ± 5.04	6.12 ± 2.29*
FFM (kg)	31.74 ± 5.89	30.20 ± 4.58^{ns}
RQ	0.91 ± 0.06	0.89 ± 0.08^{ns}
VO_2at rest	0.23 ± 0.02	0.19 ± 0.04*

Data are expressed as mean ± SD.

BMI, body mass index; FM, fat mass; FFM, fat-free mass; RQ, respiratory quotient; VO_2, oxygen consumption.

* Significant difference compared to obese group, $p<0.01$.

NS = nonsignificant difference.

Table 4.2. Resting metabolic rate, total energy expenditure, activity energy expenditure, and physical activity level in obese and nonobese children.

	Obese children (n = 21)	Nonobese children (n = 26)
TEE		
- Absolute (kcal / day)	2,402.92 ± 281.77	1,888.68 ± 350.57*
- Relative to BW (kcal/kg/day)	45.63 ± 8.70	52.11 ± 9.09**
- Relative to FFM(kcal/kg/day)	78.30 ± 17.84	62.89 ± 9.47*
RMR		
- Absolute (kcal / day)	1,327.31 ± 156.79	1,106.66 ± 292.47*
- Relative to BW (kcal/kg/day)	24.16 ± 6.72	30.39 ± 6.71*
- Relative to FFM(kcal/kg/day)	42.93 ± 8.07	36.72 ± 7.60*
AEE		
- Absolute (kcal / day)	1,075.62 ± 337.59	794.84 ± 253.07*
- Relative to BW (kcal/kg/day)	20.50 ± 7.28	21.99 ± 6.63^{NS}
- Relative to FFM(kcal/kg/day)	35.38 ± 14.04	26.52 ± 7.68**
Physical activity index	1.48 ± 0.17	1.51 ± 0.22^{NS}

Data are expressed as mean ± SD.

RMR, resting metabolic rate; AEE, activity energy expenditure; TEE, total energy expenditure.

* Significant difference compared to obese group, p<0.01.

** Significant difference compared to obese group, p<0.05.

NS = nonsignificant difference.

CHAPTER V

DISCUSSION

The result of this study revealed that fat-free mass was similar in both obese and nonobese groups. This finding is in contrast to the other previous studies that fat-free mass of obese children was more than that of nonobese children (Freymond et al, 1989; Maffeis et al, 1993; Ward et al, 1997). When compared with the children in the United States, those in Bangkok were lower in fat-free mass but higher in total body fat (Pipop Jirapinyo and Narit Chanruangvanich, 1990). Low protein diet may be one of the contributing factors of difference in fat-free mass. High carbohydrate dietary intake, as demonstrated by high RQ of 0.9, might promote fat mass rather than fat-free mass in Thai obese children in this study.

TEE in obese children was found to be greater than nonobese children, principally because of a higher energy expenditure during resting and activity conditions. This is in accordance with that previously reported that the obese children had a higher TEE, activity–related energy expenditure (AEE), sleeping energy expenditure, and resting energy expenditure than did nonobese children (Delany, 1998). Some authors have claimed that the greatest part of this difference in TEE may be due to the larger FFM in obese group (Freymond et al., 1989; Bandini et al., 1990; Maffeis et al., 1993; Rising et al, 1994). Nevertheless, in the present study, it was shown that FFM was similar in obese and nonobese groups. The energy expended in activity was found to be higher in obese children than nonobese one. It is possible that the greater body weight of obese children causes a higher energy cost of weight-bearing activities than in nonobese children (Maffies et al., 1993; Prentice et al., 1996). As demonstrated by heart rate monitoring, the obese children spent less time in physical activity, more time in sedentary activities, and more time in rest. Therefore, the longer resting duration and greater body weight, rather than fat-free mass, in obese group may explain the difference in TEE.

Physical activity index of WHO recommendation value is of 1.7 for children. This level is desirable for cardiovascular fitness (WHO., 1985). In this study, however, such values in obese and nonobese children were 1.48 and 1.51, respectively, which were lower than WHO recommendation value. A reduction of the physical activity that is indicated by physical activity index might be an important factor contributing to their sedentary life-style in spite of the fact that their communities provide parks, playgrounds, pools, gymnasium, and jogging trials that are safe, readily accessible, and attractive for children. Interestingly, both groups have a similar physical activity index, reflecting a similar behavior pattern. However, in 2 obese children whose relative weight for height was above 150 per cent of body weight, physical activity level was reduced to a greater extent, that is 1.2 by average.

The mean values of respiratory quotient were 0.91 ± 0.06 and 0.89 ± 0.08 in obese and nonobese groups, respectively, indicating the contribution of carbohydrate substrate to energy production. This group of obese children, hence, encountered a problem of nutrient imbalance – more carbohydrate intakes were stored as fat than used for energy and metabolism. Overfeeding was also the probable mechanism leading to obesity. Low energy intake in nonobese children may also explain why they are less likely to become obese despite low levels of activity. Our data do not confirm this finding. Control of the energy intake along with the assessment of energy expenditure in children is needed for further study.

Genetic predisposition to obesity has been recognized in our study about 60 per cent of family history of obesity. This data was determined from an interview with parents and children. Members of the same family, however, tend to eat the same food. Although genetics can influence the metabolic rate, i.e., the speed at which calories are burned, so can exercise. Calories not burned are stored as fat. Besides of this, genetic may play a role in creating a set-point weight, which is a predetermined weight that the body works to keep. Genetics also may determine, at least in part, the number of fat cells in the body. The development of too many fat cells during childhood may signal the beginning of a lifelong weight problem. Although genetics may play some role for most overweight children the problem is not genes, it is lifestyle.

The sedentary life style of these children may be influenced by a number of physical and social environmental factors. In our study, we observed that both groups spent daytime to watching television rather than playing outdoors, thus physical activity has declined, reflecting increasingly sedentary life-styles in these groups. There has been an increase in the amount of sedentary activity, such as television watching (Dietz et al, 1985). However, it is easier for parents to watch over children watching television rather than playing outdoors. Excessive television viewing may also deter persons from being physically active (Robinson, 1998). Television does not change a child's metabolic rate, but any increase in television viewing is an increase inactivity (Dietz et al, 1994, Klesges et al. 1993). Thus, it is possible that energy expenditure for physical under free-living conditions is further reduced in children, especially in low-income families. The remote control has further increased the sedentary nature of television watching. Children are more inactive than in the past. In addition, television watching increases snacking frequency and choice of high-fat snacking foods. Higher energy intakes have been reported in children of lower socioeconomic status (Devaney et al., 1994).

To prevent and correct obesity in children, family and teacher should be role models or provide encouragement of physical activity, especially by exercise to induce and increase in fat-free mass and a decrease in fat mass (Van Etten, 1997). In addition, nutritional education should emphasized for both children and parents. Schools are often considered to be ideal vehicles for the delivery of interventions for childhood obesity. Exercise program should be varied to introduce children to many types of fitness and recreational activities.

In this study, it is suggested that to control excessive weight gain in children, the encouragement of positive physical activity behavior and nutritional education are needed. Environmental factors, including dietary intake and activity energy expenditure are modifiable and thus play an important role in the prevention and treatment of obesity. Because the important health concerns of childhood obesity must focus on balancing energy intake and expenditure.

In conclusion, the result of this study indicated that the obese children had a higher total energy expenditure, activity energy expenditure, and sedentary energy expenditure than did nonobese children. However, it does not imply that they are more active, because the energy cost of activity might be high only because of the increased body weight. Low level of physical activity and high carbohydrate intake might increase the risk of obesity at the later age. To prevent obesity in children, programming of exercise and activities as well as nutritional education should be emphasized for school children and parents.

REFERENCES

Bandini LG, Schoeller DA, Cyr HN, Dietz WH. Validity of reported energy intake in obese and nonobese adolescents. *Am J Clin Nutr* 1990; 52: 421-5.

Bar-Or O, Foreyt J, Bouchard C, Brownell KD, Dietz WH, Ravussin E, Salbe AD, Schwenger S, Jeor S, Torun B. Physical activity, genetic, and nutritional considerations in childhood weight management. *Med Sci Sports Exerc* 1998; 30(1): 2-10.

Bar-Or O, Malina RM. Activity, fitness, and health of children and adolescents. In: Cheung LWY, Richmond JB, editors. *Child Health, Nutrition, and Physical Acctivity.* USA: Human kinetics, 1995.

Behrman RE, Kliegmass RM, Arvin AM. Obesity. In: Behrman RE, Kliegmass RM, Arvin AM, editors. *Nelson textbook of pediatrics.seventh edition.* USA: W.B. Saunders company, 1996.

Bogardus C, Lillioja S, Ravussin E, Abbott W, Zawadzki JK, Young A, Knowler WC. Familial dependence of the resting metabolic rate. *N Engl J Med* 1986; 315: 96-100.

Campbell AGM. Nutrition. In: Campbell AGM, editor. *Forfar and arnell's textbook of pediatrics.* London: Longman group UK ltd.,1992.

Claudio M, Zchutz Y, Micciolo R, Zoccante L, Pinelli L. Resting metabolic rate in six-to ten-year-old obese and nonobese children. *J Pediatr* 1993; 122: 556-62.

DeLany JP. Role of energy expenditure in the development of pediatric obesity. *Am J Clin Nutr* 1998; 68(suppl): 950S-5S.

Dietz WH, Bandini LG, Morelli JA. Effect of sedentary activities on resting metabolic rate. *Am J Clin Nutr* 1994; 59: 556-60.

Dietz WH, Gortmaker SL. Factors within the physical environment associated with childhood obesity. *Am J Clin Nutr* 1984; 39 : 619-24.

Dietz WH, Gortmaker SL. Do we fatten our children at the television set? Obesity and television viewing in children and adolescents. *J Pediatr* 1985; 75: 807-12.

Devaney BL, Gordon AR, Burghart JA. Dietary intakes of students. *Am J Clin Nutr* 1996; 61(suppl): 205s-12S.

Figueroa-Colon R, Almen TK, Suskind RM. Treatment of childhood obesity. In: Suskind RM, Lewinter-Suskind L, editors. *Textbook of Pediatric Nutrition. second Edition.* New York: Raven Press, 1993.

Freymond D, Larson K, Bogardus C, Ravussin E. Energy expenditure during normo- and overfeeding in peripubertal children of lean and obese Pima Indians. *Am J Physiol* 1989; 257: E647-53.

Ganong WF. Energy balance, metabolism, & nutrition. In: Ganong WF, editor. *Review of medical physiology.* USA: Appleton & Lange, 1997.

Garn SM, Clark DC. Trends in fatness and the origins of obesity. *Pediatrics* 1976; 57: 443-56.

Goran MI, Carpenter WH, Poehlman ET. Total energy expenditure in 4-to6-yr-old children. *Am J Physiol* 1993; 264: E706-11.

Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH. Television viewing as a cause of increasing obesity among children in the United States, 1986-1990. *Arch Pediatr Adolesc Med* 1996; 150: 356-62.

Guthric HA. Weight control. In: Roberson NR, editor. *Introductory nutrition. Sixth edition.* USA: Mosby college publishing, 1986.

Himes JH, Dietz WD. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. *Am J Clin Nutr* 1994; 59: 307- 14.

Pipop Jirapinyo, Narit Chanruangvanich. A comparative study of anthropometric indices of Thai children aged 5-15 years in Bangkok and Rajchaburi. *Siriraj Horp GAZ* 1990; 42: 616-25.

Pipop Jirapinyo , Raenu Wong-arn, Arunrutsamee Bunnak, Prapun Arnpreung, Nuan-anong Srimaruta, Werapong Chatranon. Knowledge, attitude and practice in food values, exercise and daily behavior in obese children at out-patient clinic of Siriraj hospital. *Siriraj Hosp Gaz* 1988; 40: 463-66.

Klesges RC, Shelton ML, Klesges LM. Effects of television on metabolic rate: Potential implications for childhood obesity. *Pedritrics* 1993; 91: 281-8.

Lohman TG. Applicability of body composition techniques and constants for children and youths. *Exerc Sport Sci Rev* 1986; 14: 325-57.

Lankford TR, Jacobs-Steward PM. Energy, obesity, and underweight. In: Lankford TR, Jacobs-Steward PM, editors. *Foundations of normal and therapeutic nutrition.* USA: John Wiley&sons, 1986.

Linder MC. Energy metabolism, intake, and expenditure. In: Linder MC, editor. *Nutritional biochemistry and metabolism with clinical applications.* USA: Elsevier Science publishing company,Inc., 1985.

MacKenzie R, Neinstein LS. Obesity. In: Neinstein LS editor. *Adolescent health care a practical guide. Third edition.* USA: Williams&Wilkins a waverly company, 1996.

Maclean WC, Graham G. Obesity. In: Maclean WC, Graham G, editors. *Pediatric Nutrition in Clinical Practice.* California: Addison-wesley publishing company, Inc., 1982.

Maffeis C, Schutz Y, Micciolo R, Zoccante L, Pinelli L. Resting metabolic rate in six-to-ten-year-old obese and nonobese children. *J pediatr* 1993; 122: 556-62.

Maffeis C, Schutz Y, Schena F, Zaffanello M, Pinelli L. Energy expenditure during walking and running in obese and nonobese prepuberty children. *J Pediatr* 1993; 123: 193-9.

Maffeis C, Schutz Y, Zaffanello M, Piccoli R, Pinelli L. Elevated energy expenditure and reduced energy intake in obese prepubertal children: Paradox of poor dietary reliability in obesity? *J Pediatr* 1994; 124: 348-54.

Maffeis C, Zaffanello M, Schutz Y. Relationship between physical inactivity and adiposity in prepubertal boys. *J Pediatr* 1997; 131: 288-92.

Malina RM, Bouchard C. Energy and nutritional requirements. In: Malina RM, Bouchard C, editors. *Growth, maturation, and physical activity.* USA: Human kinetics, 1991.

McArden W, Katch FI, Katch VL. Measurement of human energy expenditure. In: McArdle W, Katch FI, Katch VL. editors. *Exercise physiology. Forth edition.* USA: Williams&Wilkins a waverly company, 1996.

Ministry of public health. Thailand health profile. Bangkok Thailand, 1987.

Moore LL, Nguyen DT, Rothman KJ, Cupples LA, Ellison RC. Preschool physical activity level and change in body fatness in young children. *Am J Epidemiol* 1995; 142: 982-8.

Mo-suwan L, Geater AF. Risk factors for childhood obesity in a transitional society in Thailand. *Int J Obesity* 1996; 20: 697-703.

Pipes PL. Prevention of chronic disease with dietary intervention in childhood. In: Pipes PL, Trahms CM, editors. *Nutrition in infancy and childhood. Fifth editor.* USA: Mosby-year book,Inc. 1993.

Pi-Sunyer FX. Obesity. In: Shils ME, Young VR, editors. *Modern nutrition in health and disease. Seventh editor.* USA: Lea&febiger. 1988.

Prentice AM, Black AE, Coward WA, Cole TJ. Energy expenditure in overweight and.obese adults in affluent societies: an amalysis of 319 doubly-labelled water measurements. *Eur J Clin Nutr* 1996; 50: 93-7.

Ravelli GP, Belmont L. Obesity in nineteen-year-old men: family size and birth order associations. *Am J Epidemiol* 1979; 109: 66-70.

Ravussin E, Swinburn BA. Energy expenditure and obesity. *Diabetes Rev* 1996; 4: 42-61.

Rising R, Harper IT, Fontvielle AM, Ferraro RT, Spraul M, Ravussin E. Determinants of total daily energy expenditure: variability in physical activity. *Am J Clin Nutr* 1994; 59: 800-4.

Robergs RA, Roberts SO. Ergometry and calorimetry. In: Robergs RA, Roberts SO. Editor. *Exercise physiology exercise, performance, and clinical applications*. USA: Mosby-year book,Inc. 1997.

Roberts WC. Floating in fat: fat kids and fat adults. *Am J cardiol* 1997; 80: 1117-9.

Robinson TN. Does television cause childhood obesity?. *JAMA* 1998; 279: 959-60.

Robinson TN, Dietz W. Weight gain: Overeating to obesity. In: Rudolph AM, Hoffman JIE, Rudolph CD, editors. *Rudolph's Pediatrics.* USA: Appleton & Lange, 1996.

Robinson TN, Killen JD. Ethnic and gender differences in the relationships between television viewing and obesity, physical activity, and dietary fat intake. *J Health Educ* 1995; 26: S91-8.

Rossner S. Childhood obesity and adulthood consequences. *Acta Paediatr* 1998; 87: 1-5.

Rowland TW. Exercise testing. In: Rowland TW, editor. *Developmental exercise physiology*. USA: Human Kinetics, 1996.

Salbe AD, Fontvielle AM, Harper IT, Ravussin E. Low levels of physical activity in 5-year-old children. *J Pediatr* 1997; 131: 423-9.

Saris WH. Assessment of energy expenditure and daily physical activity. In: Bar-Or, editor. *The child and adolescent athlete*. USA: Barcelona Blackwell Science ltd, 1996.

Schoeller DA, Santen E. Measurements of energy expenditure in humans by doubly labeled water method. *J Appl Physiol* 1982; 53(4): 955-59.

Schonfeld-Warden N, Warden CH. Pediatric obesity an overview of etiology and treatment. *Pediatric clinics of north America* 1997; 44 (2): 339-61.

Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RH, Van Loan MD, Bemben DA. Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* 1988; 60: 709-23.

Sobal J, Stunkard AJ. Socioeconomic status and obesity: a reviews of the literature. *Psycho bull* 1989; 105(2): 260-75.

Spurr GB, Prentice AM, Murgatroyd PR, Goldberg GR, Reina JC, Christman NT. Energy expenditure from minute-by-minute heart-rate recording: comparison calorimetry. *Am J Clin Nutr* 1988; 48: 552-9.

Treuth MS, Adolph AL, Butte NF. Energy expenditure in children predicted from heart rate and activity calibrated against respiration calorimetry. *Am J Physiol* 1998; 275: E12-E18.

Uraiporn chittchaeng.

Van Etten LMLA, Westerterp KR, Verstappen FTJ, Boon BJB, Saris WHM. Effect of an 18-wk weight-training program on energy expenditure and physical activity. *J Appl Physiol* 1997; 82: 298-304.

Ward DS, Trost SG, Felton G, Saunders R, Parsons MA, Dowda M, Pate RR. Physical activity and physical fitness in African-American girls with and without obesity. *Obes Res* 1997; 5: 572-7.

West JB. Energy balance. In: West JB, editor. *Best and Taylor's physiological basis of medical practice. Twelve edition.* USA: Williams & Wilkings, 1990.

Wong WW, Butte NF, Ellis KJ, Hergenroeder AC, Hill RB, Stuff JE, Smith EO. Pubertal African-American girls expend less energy at rest and during physical activity than Caucasian girls. *J Clin Endocrinol Meteb* 1999; 84: 906-11.

WHO (World Health organization). Energy and protein requirements. In: *Report of a joint FAO/WHO/UNU Expert consultation.* Geneva: World Health Organization, 1985.

Zurlo F, Larson K, Bogardus C, Ravussin E. Skeleton muscle metabolism is a major determinant of resting energy expenditure. *J Clin Invest* 1990; 86: 1423-27.

APPENDICES

APPENDIX A.

Descriptive characteristic of nonobese children

SEX	AGE	BW	HT	IBW %	BMI	SKF	%BF	FM	FFM	VO2 r	RQ r	RQ e
M	12	38.8	151	96	17	22	21.1	8.16	30.64	0.16	0.9	0.84
M	12	40	138	90	15	10	9.6	2.5	37.5	0.14	0.95	0.99
M	12	52.25	163	101	19.7	25	23.6	12.3	39.95	0.22	0.9	0.97
M	12	40	138	90	15	13	12.7	3.32	36.68	0.157	0.93	0.95
M	12	33.45	145	94	15.9	19	18.4	6.15	27.3	0.17	0.95	0.91
M	11	41.35	157	90	16.8	20	19.3	7.98	33.37	0.2	0.86	0.92
M	12	35.5	143	105	17.4	16	15.6	5.54	29.96	0.16	0.96	0.92
M	11	32.6	144	93	15.7	10	9.6	3.13	29.47	0.178	0.95	0.92
M	10	35.68	145	101	17	20	19.3	6.88	28.8	0.22	0.9	0.85
M	11	35	149	90	15.4	22	21.1	7.17	27.83	0.18	0.87	0.93
M	12	33.1	139	105	17.1	14	13.7	4.52	28.58	0.24	0.81	0.88
M	12	41.5	156.5	90	16.1	13	12.7	5.02	36.48	0.27	0.71	0.8
M	12	45.34	150	118	20.2	38	31.35	14.21	31.13	0.28	0.82	0.93
M	10	41.5	146	115	19.5	36	29.8	12.36	29.14	0.28	0.9	0.93
F	12	45	161	90	15.5	14	13.6	5.43	39.57	0.144	0.94	0.79
F	12	45.65	154	98	19.3	28	24.5	11.2	34.45	0.2	0.98	0.88
F	12	43.05	156	90	17.7	20	18.9	8.13	34.92	0.15	0.89	0.94
F	11	39	143	91	15.6	11	10.6	3.12	35.88	0.136	0.97	0.93
F	12	32.2	148.5	92	16.6	21	19.69	6.34	25.86	0.169	0.75	0.85
F	12	34.3	146	96	16.1	14	13.6	4.66	29.64	0.21	0.99	0.94
F	12	33.2	143.5	90	16.1	25	22.62	7.51	25.69	0.14	0.97	0.9
F	12	34.3	142.5	97	16.9	20	18.9	6.48	27.82	0.2	0.98	1
F	12	26.15	142.5	94	15.9	13	12.6	3.29	22.86	0.156	0.9	0.97
F	12	34.9	151	99	15.3	13	12.59	4.39	30.51	0.26	0.78	0.82
F	12	40.9	152	91	17.7	26	23.29	9.52	31.38	0.18	0.83	0.93
F	11	33.58	145	96	16	23	21.2	7.12	26.46	0.16	0.8	0.91

APPENDIX B.

Descriptive characteristic of obese children

	AGE	BW	HT	IBW %	BMI	SKF	%BF	FM	FFM	VO2 r	RQ r	RQ e
M	11	48.4	149	124	21.8	45	36.8	17.83	30.57	0.2	0.72	0.79
M	12	64.16	163	127	24.2	38	31.4	20.12	44.04	0.25	0.9	0.71
M	12	50.1	151.5	122	21.8	47	38.4	19.24	30.86	0.21	0.96	0.76
M	11	64.95	145	183	30.9	73	58.8	38.16	26.79	0.23	0.89	0.81
M	12	57.75	154	134	24.4	53	43.09	24.88	32.87	0.23	0.97	0.79
M	12	50	146	139	23.5	39	32.1	16.07	33.93	0.21	0.98	0.85
M	8	43.82	136	149	23.7	54	43.88	19.22	24.6	0.24	0.98	0.8
M	10	48.32	150.5	121	21.3	32	28.82	13.92	34.4	0.24	0.85	0.88
M	10	41	132.5	149	23.4	50	40.75	16.7	24.3	0.22	0.95	0.98
M	9	40.3	133	144	22.8	46	37.6	15.16	25.14	0.24	0.9	0.97
M	10	56.65	136.5	189	30.4	62	50.1	28.4	28.25	0.24	0.98	0.93
M	10	52.1	144.5	149	25	51	41.53	21.63	30.47	0.25	0.94	0.82
M	10	50.88	137	168	27.1	58	47.01	23.92	26.96	0.23	0.93	0.96
M	9	62.8	146	174	29.5	66	53.3	33.46	29.34	0.28	0.92	0.98
M	9	54	145	154	25.7	56	45.44	29.46	24.54	0.23	0.88	0.81
M	11	52.84	145	151	25.1	65	52.49	27.73	25.11	0.28	0.9	0.96
F	10	43.08	140.5	130	22	54	39.2	16.88	26.2	0.24	0.97	0.88
F	10	65.8	151	150	28.9	78	42.58	28.02	37.78	0.26	0.83	0.82
F	11	53	150	120	22.1	52	38.09	19.57	33.43	0.23	0.9	0.97
F	11	64.38	160	129	25.1	52	38.09	24.52	39.86	0.2	0.9	0.93
F	11	66.56	151	151	29.2	70	47.92	31.89	34.67	0.27	0.86	0.93

APPENDIX C.

Descriptive of energy expenditure in nonobese children

SEX	R MIN	RMR	ACT MIN	AEE	TEE	KCAL	PAL
M	1101	867.674	339	1188.97	2056.646	53	1.91
M	1184	826.303	256	591.873	1418.177	54.02	1.46
M	1204	1303.91	236	488.017	1791.924	34.29	1.35
M	1184	956.97	256	869.817	1826.787	69.58	1.6
M	1226	1039.4	214	615.761	1655.157	49.48	1.37
M	1071	1044.23	369	1458.27	2502.492	60.51	1.94
M	1087	869.251	353	1088.26	1957.508	55.13	1.83
M	1173	1040.84	267	971.685	2012.521	61.73	1.62
M	1200	1300.3	240	611.052	1911.348	53.56	1.27
M	1187	1043.86	253	710.162	1754.024	51.46	1.43
M	1135	1310.68	305	846.709	2157.385	65.17	1.41
M	1162	1598.07	278	724.84	2322.91	58.62	1.26
M	1172	2012.18	268	854.679	2533.522	55.87	1.2
M	1091	1503.72	349	970.756	2474.479	59.61	1.41
F	1095	783.903	345	1217.92	2001.818	49.97	2.03
F	1176	1181.17	264	486.175	1667.347	36.52	1.4
F	1198	923.946	242	839.482	1763.428	40.95	1.59
F	1151	781.235	289	760.137	1541.371	51.96	1.64
F	1161	984.554	279	497.148	1481.702	46.01	1.5
F	1129	1193.75	311	1016.5	2210.246	64.43	1.55
F	1155	847.992	285	534.236	1382.228	41.63	1.5
F	1080	1084.75	360	804.663	1889.41	55.08	1.49
F	1186	918.443	244	536.168	1454.611	55.62	1.4
F	1180	1465.69	260	793.491	2259.181	64.54	1.33
F	1184	1031.07	256	625.215	1656.289	4.049	1.39
F	1119	859.315	321	563.955	1423.27	42.38	1.41

APPENDIX D.

Descriptive of energy expenditure in obese children

SEX	RMIN	RMR	ACT MIN	AEE	TEE	KCAL/kg	PAL
M	1162	1092.43	278	810.081	1902.511	39.22	1.48
M	1219	1500.59	221	854.207	2354.796	36.69	1.35
M	1121	1176.58	319	1046.11	2222.691	44.44	1.4
M	1096	1256.5	344	1238.61	2495.107	38.41	1.65
M	1121	1176.88	319	1577.49	2754.368	47.69	1.7
M	1086	1140.33	348	1217.26	2357.59	47.14	1.71
M	1150	1386.67	290	997.014	2383.688	54.39	1.46
M	1204	1405.31	236	917.768	2323.079	48.07	1.41
M	1180	1184.98	260	1501.58	2686.567	65.52	1.6
M	1204	1422.44	236	836.82	2259.265	56.05	1.36
M	1198	1432.89	242	624.721	2057.609	36.32	1.25
M	1117	1388.3	323	853.407	2241.702	43.02	1.39
M	1135	1181.35	305	1667.81	2849.156	55.99	1.6
M	1277	1725.68	163	436.327	2162.004	34.42	1.11
M	1139	1215.41	301	1315.26	2530.665	46.86	1.65
M	1137	1429.73	303	1548.68	2978.41	56.36	1.65
F	1166	1402.4	274	719.385	2121.783	49.24	1.31
F	1144	1439.43	296	1263.97	2703.404	41.08	1.57
F	1176	1218.97	264	1343.72	2562.689	49.85	1.73
F	1238	1218.85	202	846.544	2065.397	32.07	1.45
F	1123	1477.71	317	971.208	2448.917	36.79	1.41

APPENDIX E.

Caloric equivalents for the range of nonprotein respiratory quotient (RQ) values

RQ	Kcal / L O2
1.00	5.047
0.99	5.035
0.98	5.022
0.97	5.010
0.96	4.998
0.95	4.985
0.94	4.973
0.93	4.961
0.92	4.948
0.91	4.936
0.90	4.924

RQ	Kcal / L O2
0.89	4.911
0.88	4.899
0.87	4.887
0.86	4.875
0.85	4.862
0.84	4.850
0.83	4.838
0.82	4.825
0.81	4.813
0.80	4.801

RQ	Kcal / L O2
0.79	4.788
0.78	4.776
0.77	4.764
0.76	4.751
0.75	4.739
0.74	4.727
0.73	4.714
0.72	4.702
0.71	4.690
0.707	4.686

BIOGRAPHY

Miss Chirapa Nakhanakhup was born on October 22, 1968 in Kamphaengphet, Thailand. She graduated diploma in nursing science equivalent to bachelor of science in nursing from Buddhachinnaraj nursing college in 1990.