

**IRON AND NUTRITIONAL STATUS, PHYSICAL AND
COGNITIVE PERFORMANCE OF SCHOOL
ADOLESCENTS IN NAKHON CHAISRI DISTRICT,
NAKHON PATHOM PROVINCE**

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อธิการบดีมหาวิทยาลัย

จาก

.....บัณฑิตวิทยาลัย มหาวิทยาลัยมหิดล.....

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NAKHON PATHOM PROVINCE**

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This is a cross-sectional study involving 586 students (311 males and 275 females) carried out in three secondary schools in Nakhon Chaisri, Nakhon Pathom Province, Central Thailand. The purpose was to determine the iron and nutritional status and their relation to health-related physical fitness and cognitive abilities in adolescents, aged 12-15 years.

The results revealed that the age of onset of voice change in males and menarche in females averaged 13.3 ± 1.1 y, and 12.4 ± 1.1 y, respectively. The anaemia prevalence was only 3.1% for males and 1.5% for females. Iron depletion was prevalent, 12.4% and 15.1% for males and females, respectively.

The prevalence of underweight, stunting, and wasting based on the Thai reference in both sexes was around 5%. Based on the NCHS reference, the prevalence increased to 13.2 % for underweight and 10.9 % for stunting in males, and less than 10 % in females for both indicators. Based on BMI-for-age (WHO criteria), the prevalence of thinness and overweight of males was 21.2 % and 10.0 %, and of females was 5.2% and 8.5 %, respectively. Average daily nutrient intakes were adequate for most nutrients studied, except calcium and vitamin A, in both sexes.

Males were better than females in almost all health-related physical fitness tests i.e., aerobic capacity by one-mile run/walk (MRW) test, and abdominal and upper body strength/endurance tests. Based on the Prudential Fitnessgram criteria, most students (58.7% of males and 87.9% of females) performed poorly in MRW, but about 60-95% of both sexes were at healthy fitness levels according to muscle strength/endurance and flexibility tests. The mean IQ scores were not significantly different between sexes. Males were significantly lower in all scholastic aptitude tests (SAT) than females. About 70% of males and 50% of females were poor in SAT numerical and reasoning scores.

Multiple regression analysis indicated that haemoglobin was significantly related to the MRW test in females and the upper-body strength/endurance test in males. Body fat and fat-free mass representing body composition, and height significantly accounted for almost all physical fitness tests. Age significantly affected upper-body strength/endurance and flexibility in females. Haemoglobin was not significantly related to any tests of cognition in both sexes. Age was significantly related to some cognitive test scores. Height significantly related to all cognitive tests in females, but not in males.

In summary, iron status as a haemoglobin parameter was significantly related to aerobic capacity and upper-body strength/endurance. Body composition and height were key factors affecting physical fitness. However, the relationships between iron status and cognitive abilities in school adolescents were not observed in this study.

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ทัศนวิรรณ ภู่อารีย์: ภาวะธาตุเหล็กและโภชนาการ สมรรถภาพทางกายและทางการเรียนรู้ของเด็กนักเรียนวัยรุ่นในอำเภอนครชัยศรี จังหวัดนครปฐม (IRON AND NUTRITIONAL STATUS, PHYSICAL AND COGNITIVE PERFORMANCE OF SCHOOL ADOLESCENTS IN NAKHON CHAISRI DISTRICT, NAKHON PATHOM PROVINCE). คณะกรรมการควบคุมวิทยานิพนธ์ : พัทธนี วินิจจะกุล, Ph.D., กัลยา กิจบุญชู, Ph.D., สมสรร วงษ์อยู่น้อย, กศ.ค., ปรานี ผ่องแผ้ว, M.Sc. 223 หน้า. ISBN 974-665-499-3

การศึกษานี้ดำเนินการในโรงเรียนมัธยมศึกษา 3 แห่ง ในอำเภอนครชัยศรี จังหวัดนครปฐม เพื่อศึกษาภาวะธาตุเหล็ก โภชนาการ และความสัมพันธ์ระหว่างภาวะธาตุเหล็กกับสมรรถภาพความแข็งแรงทางกายและการเรียนรู้ในเด็กนักเรียนวัยรุ่นชายและหญิง อายุ 12-15 ปี ชาย 311 คน หญิง 275 คน รวม 586 คน

พบว่าเด็กชายมีเสียงเปลี่ยนเมื่ออายุเฉลี่ย 13.3 ± 1.1 ปี เด็กหญิงมีประจำเดือนครั้งแรกเมื่ออายุเฉลี่ย 12.4 ± 1.1 ปี พบภาวะโลหิตจางในเด็กชาย 3.1% เด็กหญิง 1.5% พบภาวะพร่องเหล็กในเด็กชาย 12.4% เด็กหญิง 15.1% ความชุกของภาวะขาดอาหารโดยน้ำหนักและส่วนสูงเทียบกับค่าอ้างอิงของไทยพบประมาณ 5% เมื่อเทียบกับค่าอ้างอิงของ NCHS พบความชุกสูงขึ้นในเด็กชาย คือน้ำหนักต่ำกว่าเกณฑ์เพิ่มเป็น 13.2 % และเตี้ย 10.9 % และพบความชุกสูงขึ้นในเด็กหญิงด้วยคือพบน้อยกว่า 10 % เมื่อใช้ดัชนีมวลกายตามอายุตามเกณฑ์ของ WHO พบความชุกของเด็กผอมในเด็กชายและเด็กหญิง 21.1 % และ 5.2 % และน้ำหนักเกิน 10.0 % และ 8.5% ตามลำดับ ปริมาณสารอาหารโดยเฉลี่ยที่ได้รับต่อวันเพียงพอ ยกเว้นแคลเซียมและวิตามินเอ

เด็กชายมีสมรรถภาพความแข็งแรงทางกายดีกว่าเด็กหญิงในด้านการทดสอบสมรรถภาพการวิ่ง 1 ไมล์ และสมรรถภาพความแข็งแรงและความทนของกล้ามเนื้อท้องและส่วนบนของร่างกาย เมื่อเทียบกับเกณฑ์ของ The Prudential Fitnessgram ส่วนใหญ่ทั้งเด็กชายและเด็กหญิงอยู่ในเกณฑ์ต้องปรับปรุงสมรรถภาพการวิ่ง (58.7% ในเด็กชาย และ 87.9 % ในเด็กหญิง) แต่เด็กทั้งชายและหญิง 60-95% มีสมรรถภาพความแข็งแรงและความทนของกล้ามเนื้อและความยืดหยุ่นของร่างกายอยู่ในเกณฑ์ดี เด็กชายและเด็กหญิงส่วนใหญ่มีไอคิวเฉลี่ยอยู่ในเกณฑ์ปกติและไม่แตกต่างกันทางสถิติ แต่ความถนัดทางการเรียนของเด็กหญิงสูงกว่าเด็กชายทุกด้าน โดยประมาณ 70% ของเด็กชาย และ 50% ของเด็กหญิงอ่อนด้านการคำนวณและการใช้เหตุผล

จากการวิเคราะห์พหุคูณ สัมพันธ์กับสมรรถภาพการวิ่งในเด็กหญิง และสมรรถภาพความแข็งแรงและความทนของกล้ามเนื้อส่วนบนของร่างกายในเด็กชาย ไขมัน มวลร่างกายที่ไม่รวมไขมัน และความสูงสัมพันธ์กับสมรรถภาพทางกายเกือบทุกประเภท อายุสัมพันธ์กับสมรรถภาพกล้ามเนื้อร่างกายส่วนต้นและความยืดหยุ่นในเด็กหญิง ไม่พบความสัมพันธ์ระหว่างไอคิวกับผลการทดสอบการเรียนรู้ อายุสัมพันธ์กับผลการทดสอบบางแบบ และพบว่าความสูงสัมพันธ์กับไอคิวและความถนัดทุกด้านในเด็กหญิง แต่ไม่พบในเด็กชาย

โดยสรุป ภาวะธาตุเหล็กมีความสัมพันธ์กับสมรรถภาพการวิ่ง และความแข็งแรงและความทนของกล้ามเนื้อส่วนบนของร่างกาย องค์ประกอบของร่างกายและความสูงเป็นปัจจัยสำคัญที่มีผลต่อสมรรถภาพความแข็งแรงทางกาย แต่ไม่พบความสัมพันธ์ระหว่างธาตุเหล็กกับการเรียนรู้ในเด็กนักเรียนวัยรุ่นในการศึกษานี้

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LIST OF ABBREVIATIONS

AMA	Arm-muscle area
AMC	Arm-muscle circumference
ANOVA	Analysis of variance
ATP	Adenosine triphosphate
BF	Body fat
BMI	Body mass index
CA	Chronological age
CSK	Calf skinfold thickness
cAMA	Corrected arm-muscle area or bone-free arm-muscle area
cm	Centimeter
DNA	Deoxyribonucleic acid
df	Degree of freedom
dL	Decilitre
ELISA	Enzyme-linked immunoassay method
FFM	Fat-free mass
g	Gram
GH	Growth hormone
GM	Geometric mean
Hb	Heamoglobin
HiCN	Cyanmethaemoglobin
HF	Healthy fitness
HFZ	Healthy fitness zone

LIST OF ABBREVIATIONS (Cont.)

h	Hour
Ht	Height
ID	Iron depletion
IDA	Iron deficiency anaemia
IQ	Intelligence quotient
IQA	Inter-quartile range
INMU	Institute of nutrition, Mahidol University
kg	Kilogram
L	Litre
ln	Natural logarithm
LH	Leuteinizing hormone
M	Mathayom
m	Meter
mg	Milligram
min	Minutes
mL	Millilitre
MA	Mental age
MAC	Mid-arm muscle circumference
MCHC	Mean cell haemoglobin concentration
MCV	Mean cell volume
MOPH	Ministry of Public Health
MRW	One-mile run/walk test

LIST OF ABBREVIATIONS (Cont.)

n	Number of sample size
N	Normal
NCHS	The National Center of Health Statistics
NI	Need improvement
NS	Not significant
PCV	Packed cell volume
r	Pearson correlation coefficient
R	Multiple regression coefficient
RDA	Recommended dietary allowances
RPM	Raven Progressive Matrices Test
SAT	Scholastic aptitude test
SAT-V	Verbal scholastic aptitude test
SAT-N	Number scholastic aptitude test
SAT-R	Reasoning scholastic aptitude test
SD	Standard deviation
SES	Socio-economic status
SF	Serum ferritin
SPSS	The Statistical Package for Social Science
SSSK	Sum of triceps and calf skinfolds
TBF	Total body fat
TMM	Total muscle mass
TSK	Triceps skinfold thickness

LIST OF ABBREVIATIONS (Cont.)

VO _{2max}	Maximal oxygen consumption
WAIS	Wechsler Adult Intelligence Scales
WHO	World Health Organization
WISC	Wechsler Intelligence Scales for Children
WISC-R	Wechsler Intelligence Scales for Children, revised
Wt	Weight
χ^2 test	Chi-square test
μ g	Microgram
#	Number

CHAPTER I

INTRODUCTION

1.1 Background

Adolescence, which is defined by WHO as aged 10-19 years (1), is a significant period of human growth and maturation. Because of the rapid accretions of new tissues and certain changes such as sexual development, physiological and psychological changes, nutritional requirements of adolescents increase relative to childhood period. Increased iron need is an important one for expanding red cell mass and myoglobin for the newly gained muscle tissue. For female adolescents in particular, there is further increased iron need for compensation of menstrual blood losses. For these reasons, both male and female adolescents are considered to have risks of iron deficiency (2). However, the risks may be less violent for males. Since a rapid change in somatic growth causes increased energy and nutrient needs, malnutrition in adolescents could still be prevalent (3). However, data on this age group is very scant.

Anaemia is defined as a decreased concentration of blood haemoglobin below cut-off values varying by age and sex. It is the most obvious clinical sign of iron deficiency. Additionally, iron deficiency can cause other abnormalities in different population groups. Severe anaemia in pregnant women is associated with an increase risk of maternal and fetal mortalities (4). Iron deficiency anaemia is found to be associated with premature and low birth-weight infant (5). Iron deficiency is also related to various functional consequences. It has an adverse effect on psychomotor

development, cognition and behavior of infants and young children (6-8). Iron deficiency impairs cognition and educational performance in school children (8-11). It may impair skeletal muscle function and reduced physical capacity and work performance in adolescents and adults (10-12). It also relates to immune function and increases morbidity from infections (13-14). Additionally thermo-regulation of iron-deficient adults is affected when they expose to cool environment (15). In general, iron supplementation could correct the effects of iron deficiency except cognition that can be permanent damage if the deficiency occurs during infancy (7).

Apart from anaemia and iron deficiency, chronic energy deficiency, which is considered to be one of a serious malnutrition problem for infants and children worldwide, has been also shown to associate with body stature, physical work capacity, and productivity. During the growth of school-age children (aged 6-10 years), even marginal malnutrition results in growth retardation, slowing of sexual maturation, delay of the growth spurt and reducing physical work capacity (measured in terms of VO_{2max}) due to smaller body size. Available data suggested that when smaller boys grow up to be adults they were unable to perform as well in heavy physical work as their nutritionally normal counterparts and earned less (16).

1.2 Need and Rationale

In recent years, more interest is given to prepare women before they enter reproductive burden. Preventing nutritional deficiency, e.g. iron and folate deficiency, during pregnancy might need to be done since girls enter their reproductive years. Moreover, most attention is given to female adolescents with the premise that boys and men are generally not vulnerable groups. However, in Thailand, the evidence that

the prevalence of anaemia was as high as 17% among men aged 15 and above (17) did indicate the need to obtain information for both male and female adolescents.

While adolescence is clearly an important life-period in human growth and development, information on iron and general nutritional status of this group, and programme in nutrition and health related has been quite limited. Available reports among school-aged children and adolescents from other countries suggested that iron deficiency anaemia impaired children's cognitive abilities (18-21) and physical fitness and capacities (22-24). Improving iron status of iron-deficient children and adolescents aged 8-15 years also corrected these negative functional consequences (18-23). Moreover, studies in Colombian schoolchildren aged 6-16 years also demonstrated the adverse effects of nutritional status particularly chronic undernutrition on physical capacities (25-26)

A well-designed study among elementary schoolchildren aged 9-12 years in rural eastern coastal area of Thailand (27) revealed the differences in the mean IQ and educational achievement scores of Thai language between iron-replete and iron-anaemic students. The difference in Thai language test scores was also found, between iron-depleted group and the iron-replete and iron-anaemic groups. However, there was no evidence that iron treatment had an effect either on IQ or on the two educational achievement measures.

A nutritional survey in Thailand among women including adolescents and adult (aged 15-39 years) in rural area of northeastern region (28) indicated a relatively high prevalence of anaemia (21.6%) due to iron deficiency together with haemoglobinopathy and due to a severe deprivation in the nutritional status. A study in female school adolescents aged 12-18 years in rural area compared to municipal area

of northeastern region of Thailand (29) also pointed out the existence of malnutrition and iron deficiency anaemia. The prevalence of iron deficiency and malnutrition in municipal area was lower than the prevalence in the rural area. Although, the prevalence of iron deficiency and malnutrition in adolescents might not be high, it was considered to be more significant due to functional adverse consequences.

It is speculated that malnutrition problem might still exist among Thai adolescent. Study in a school on female adolescents aged 12-18 years in suburban area near Bangkok (31) indicated that anaemia was prevalent although the proportion was low (3.28 %). Physical performance test, which consisted of Harvard step test, leg strength, vital capacity, hand grip and flexibility test, in sub-group study did not correlate with haematological indicators.

The data on functional consequences of iron deficiency and malnutrition among Thai adolescents, especially in urban and suburban areas are limited. Particularly, the data on male adolescents are absolutely limited. This suggests the need to obtain such data and to know how these data especially gross nutritional status and iron status, related to cognitive performance and physical fitness with emphasis on health-related physical fitness among the school adolescents. In addition, none of the study had ever reported about health-related physical fitness in Thai adolescents. It may be useful to assess this component of physical fitness. Therefore, this study had been conduct in both male and female schoolchildren aged 12-15 years in suburban area. Significantly, the information from this study will produce some baselines into effective intervention such as iron supplementation, food-nutrition promotion, and fitness programme that aims to prevent iron deficiency and improve nutrition and health status in adolescents.

1.3 Objectives

1.3.1 General objectives

To determine relationships between nutritional status, with emphasis on iron, anthropometry and body composition, and health-related physical fitness and cognition in adolescent school children aged 12-15 years old.

1.3.2 Specific objectives

1. To assess nutritional status, specifically iron, anthropometry and body composition.
2. To assess health-related physical fitness and cognitive abilities.
3. To determine relationships between
 - iron /anthropometry / body composition and health-related physical fitness.
 - iron / anthropometry / body composition and cognition.

1.4 Conceptual Framework

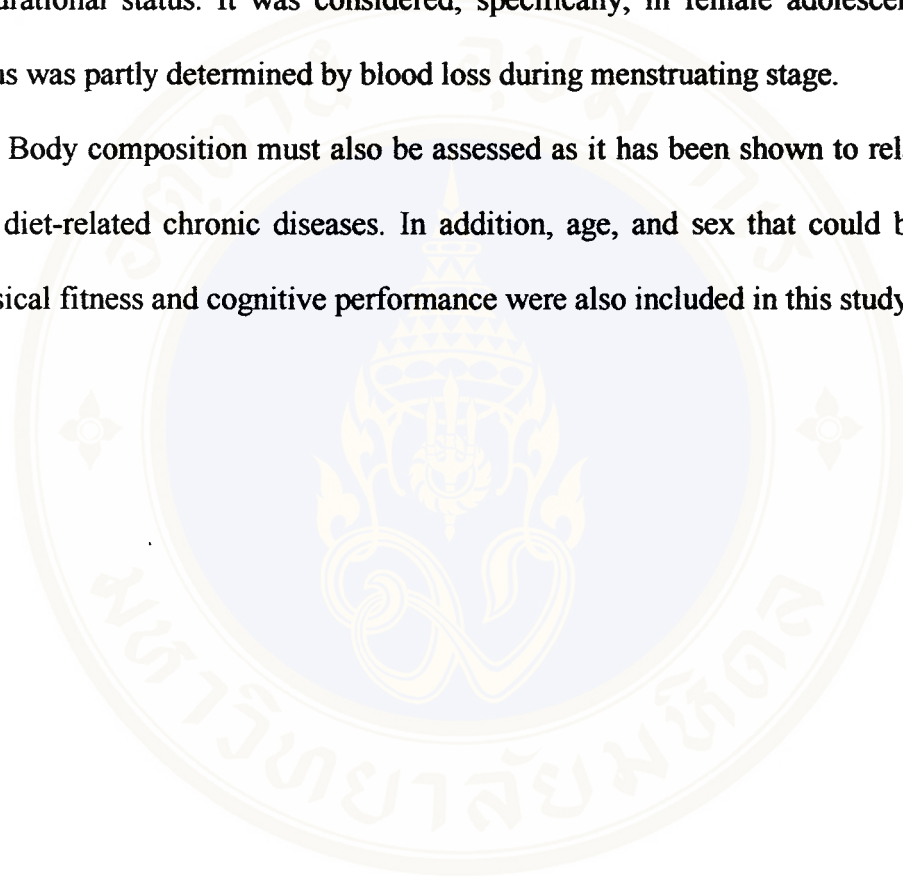
This study was designed as a cross-sectional study. The conceptual model of this study is illustrated in Figure 1.1. The theme of this study was to identify the relationships between functional parameters and nutrition, with special attention to iron status among secondary school adolescents. The functional parameters were focused on two aspects, namely, health-related physical fitness and cognitive performance.

Because it was found from literature that nutritional status, in terms of protein-energy malnutrition, can affect both physical and cognitive performance (16,32-33).

Therefore, nutritional status measured by anthropometry was also included in this study.

Factors related to iron and nutrition status were also studied. These factors included nutrient intake, socioeconomic status, illness or health status, and maturational status. It was considered, specifically, in female adolescents that iron status was partly determined by blood loss during menstruating stage.

Body composition must also be assessed as it has been shown to relate to health and diet-related chronic diseases. In addition, age, and sex that could be related to physical fitness and cognitive performance were also included in this study.



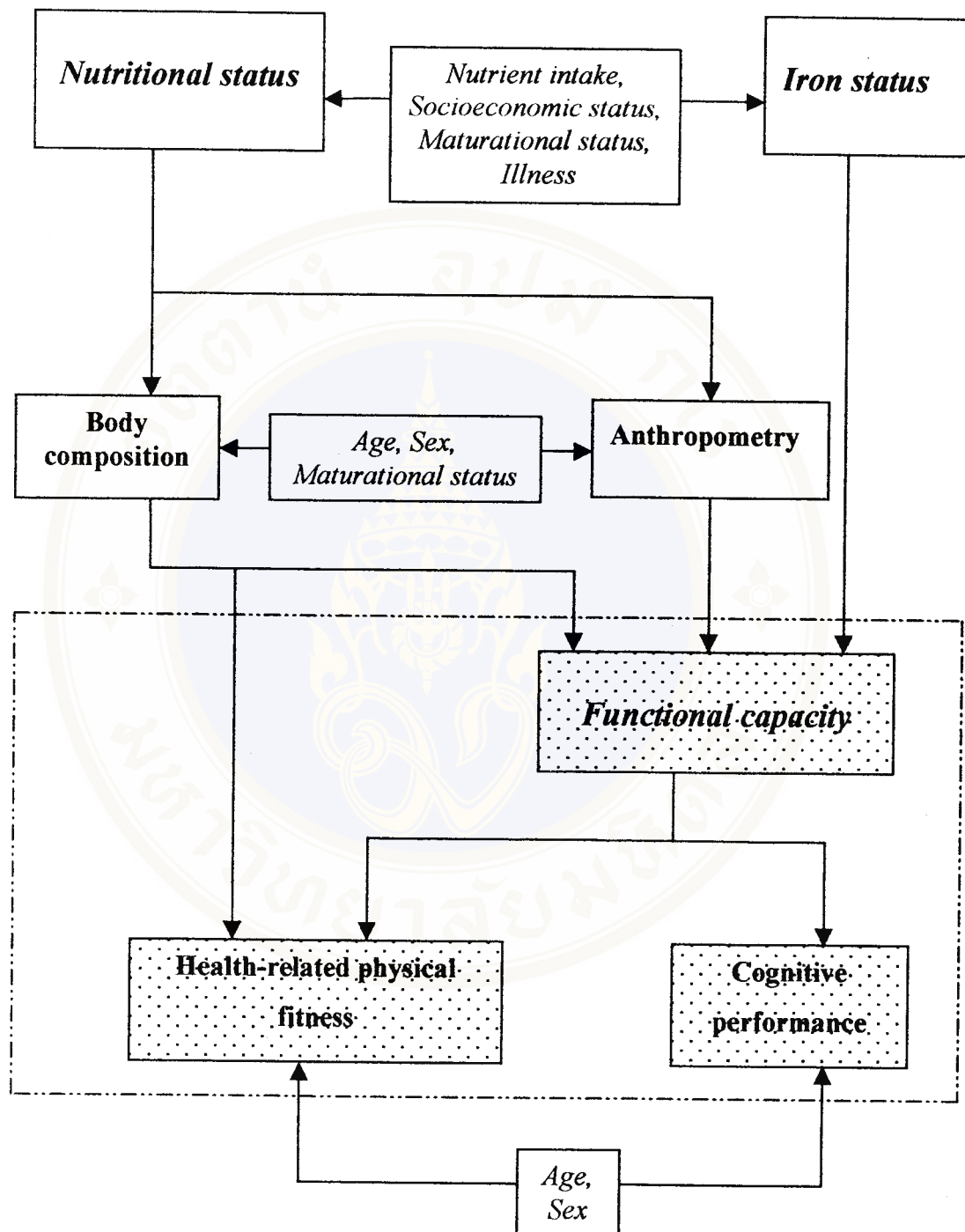


Figure 1.1 Conceptual framework of the study.

1.5 Operational Definition

1.5.1 Iron status

In this study, iron status was used collectively to include anaemia, iron depletion, and iron deficiency anaemia (34).

1.5.1.1 Anaemia

Anaemia was defined as the state of an individual characterized by blood haemoglobin level below the normal values for specified age and sex of an individual as defined by WHO (141).

1.5.1.2 Iron depletion (ID)

Iron depletion was defined as iron status of an individual that was characterized by low level of iron store as measured by serum ferritin concentration, whereas haemoglobin level was within the normal value for specified age and sex of an individual.

1.5.1.3 Iron deficiency anaemia (IDA)

Iron deficiency anaemia was defined as iron status of an individual that was characterized by both serum ferritin and haemoglobin level below the normal values for specified age and sex of an individual.

1.5.2 Nutritional status

Nutritional status was defined as body growth characterized by anthropometric variables, which reflects gross malnutrition of an individual.

1.5.3 Body composition

Body composition was defined as the relative amounts of body fatness and muscle mass, which was estimated by specific equations using anthropometric values (37, 119-123).

1.5.4 Physical fitness

In this study physical fitness was referred to health-related physical fitness that was defined as a dimension of physical fitness associated with health status of an individual (69). It consisted of three components: aerobic capacity, muscular strength/endurance, and flexibility.

1.5.4.1 Aerobic capacity

Aerobic capacity of an individual (also called cardiovascular endurance or maximal aerobic power or maximal oxygen uptake; VO_{2max}) was defined as the highest rate of oxygen taken up and utilized by the body during aerobic exercise (35). In this study, aerobic capacity of an individual was tested by the one-mile run/walk test (36)

1.5.4.2 Muscular strength/endurance

Muscle strength/endurance was defined as the abilities of muscles to exert force or torque (muscular strength), and resist fatigue (muscular endurance) (36). In this study, the Prudential FITNESSGRAM test battery was used to measure these muscle abilities.

1.5.4.3 Flexibility

Flexibility was defined as the abilities of body to move freely through a full range of motion, which was the result of muscles and joints working together (36).

1.5.5 Cognitive performance

Cognitive performance was defined as cognitive abilities of an individual. In this study, the Raven Progressive Matrices (RPM) for intelligence test, and the scholastic aptitude tests (SAT) for verbal, numerical, and reasoning factors were used to determine cognitive abilities of school adolescents.

1.5.6 Maturational status.

The maturational status was identified by the timing of onset of adult-voice in boys and by the timing of menstruation onset in girls.



CHAPTER II

LITERATURE REVIEW

2.1 Adolescence

2.1.1 Puberty and adolescence

Adolescence, the period of transition from childhood to early adulthood, is defined as a period of life beginning with the appearance of secondary sex characteristics and terminating with the cessation of somatic growth, roughly from 11 to 19 years of age (38). According to WHO, an individual aged 10-19 years old is considered as an adolescent (1).

Adolescence period is usually described in two phases: puberty and adolescence. Puberty is a period during which the secondary sex characteristics begin to develop and continue to the capability of sexual reproduction is attained (38). Puberty also includes the beginning of growth spurt and ends with sexual maturation. The growth spurt begins at the first changes in hormonal levels, i.e., the rise of circulating levels of gonadal steroid hormones (testosterone and estrogens) which is induced by luteinizing hormone (LH) from the anterior pituitary. These phenomena take place just before the appearance of external sex characteristics. These hormonal changes lead to the appearance of the first physical signs of puberty, i.e., the development of the breast in girls and testicular enlargement in boys, and the appearance of pubic hair. The pubertal stage begins at approximately 10 – 13 years in girls and 12 – 15 years in boys (39, 41).

Adolescence begins with the appearance of the earliest signs of maturity events, principally the appearance of sexual development and maturation, i.e., menarche in girls and spermarche in boys. Then, this period continues until morphological and physiological changes to full maturation and finishes with the completion of growth in stature (40).

2.1.2 Growth and development during adolescence

2.1.2.1 Growth spurt

Before entering the adolescence period, growth patterns of boys and girls have a little difference, but at the onset of puberty they become more distinct. Differences in growth pattern become apparent in the skeletal system, lean body mass, and fat mass (39). Adolescent growth spurt is described in two phases; the phase of rapid growth during the first year and a half of puberty and the phase with growth slowing down progressively for the next three years (44).

During childhood or prepubertal period, growth, especially height growth depends on growth hormone (GH). It occurs at the rate of 5-6 cm/year in a steady manner, but prior to the adolescent growth spurt, the rate falls to 1-5 cm/year. Prepubertal growth occurs mainly in the limbs, whereas the pubertal growth occurs mainly in the trunk (43).

At puberty, a very considerable change in growth rate occurs. There is an increase in body size accompanied by a change in body shape and body composition and a rapid development of the gonads. The maximal growth velocity varies widely among individuals with the mean peak height velocity (PHV) about 10 ± 1 cm/year in boys and 9 ± 1 cm/year in girls (44). During the acceleration phase of the puberty growth spurt, boys gain 13-15 cm in height and girls gain 11 cm. The remaining height

gain, approximately 13-15 cm in boys and 14 cm in girls, is attained over the subsequent three years of progressive slow down in growth (44). An increase in trunk length attributed to most of the height spurt in adolescents. The earliest parts of the body that reach adult size are the head, hands and feet (43).

The timing of pubertal onset and growth spurt exhibits great individual variability. Girls enter puberty earlier than boys. The growth spurt in terms of the peak height velocity occurs relatively earlier for 2 years in girls than in boys (45). On average, growth spurt in girls starts between the age of 10 and 11, and reaches its peak at age 12. Generally, menstruation onset or menarche occurs a little more than one year after peak height velocity or between the ages of 10 and 15 (43).

In boys, the growth spurt begins when testicular volume is approximately 4 ml, and maximum growth peak is reached when testicular volume reaches about 10-12 ml (44). Generally, boys' growth spurt begins between age 12 and 13 and peaks at age 14. Adult voice of boys is attained about one year after peak height velocity (39).

2.1.2.2 Changes in body composition

Percentages of lean body mass and body fat are similar in prepubertal boys and girls, but this changes at puberty (137). The changes in body composition affect nutritional needs.

During adolescence, growth spurt in fat-free mass (FFM) of males is much more rapid, but females acquire more fat between the ages of 10 and 20 years, the average increment in FFM is 33 kg, but only 16 kg finds in girls (137). The maximal growth of lean body mass in girls by age 18 attains about 2-3 years earlier than that in boys. By maturity, men have approximately 1.5 times the lean body mass of women, whereas women have twice the amount of fat (39). The sex difference in lean body mass during

adolescence is likely due to the fact that the testosterone production rate in males is about 6 times that of females (137)

A marked increase in muscle mass in boys more than in girls is observed. Boys reach their peak muscle development at the time of the PHV, while girls reach their peak shortly after the PVH. Thus, there is a narrow range of time, between 12.5 and 13.5 years on average, when girls have more well-developed muscle than boys. The increase in muscle size is naturally accompanied by an increase in muscle strength.

The gains in weight during adolescence are much more marked than the increases in height. Approximately 20% of adult height and 50% of adult weight are increased during the teen period (45). Weight gain involves an increase in fat-free mass (i.e., blood volume, muscle mass and skeletal mass), and fat tissue. Comparing between boys and girls, a greater increase in fat-free mass (FFM) is found in boys, whereas an increase in body fat in boys is less than that in girls (46). Consequently, boys usually become lean during adolescence.

A loss of limb fat during adolescence is found, especially in boys. The maximum rate of the limb-fat loss is at the time of PHV in boys. In girls, there is a decrease in the velocity of fat accumulation. However, this does not mean an absolute loss of fat (43)

Other changes including an increase in bone mineral density, total body water, intracellular water, the number of red blood cells, and haemoglobin concentration were found in adolescence. All of these are more marked in boys than in girls.

2.1.3 Nutrition and adolescence

Physical growth and the timing of maturity events during adolescence period vary widely among healthy children. This is primarily due to genetic and hormonal factors.

However, environmental and health-related factors, especially nutrition factor, may affect both growth and maturity timing.

For nutrition role, adequate intake of nutrients during puberty development and adolescence is a factor in the phenotypic expression of the genetic potential of bone tissue growth and mineralization (43).

Nutrition plays a double role during puberty development. Nutrition factor interacts with certain hormones such as gonadotropins and growth hormone (GH) in the regulation of gonadal steroid hormone and growth factor levels. It also provides the necessary energy and nutrients such as calcium, phosphorus and vitamin D for skeletal growth and mineralization. Inadequate nutrient intake inhibits hormone secretion, stopping or delaying the onset of puberty development and even determining a lower height gain during adolescence (41).

Adolescence is also a period of increased nutritional requirements. This is due to their growth spurt, sexual maturation and other widespread developmental alterations. For example, more than 20% of total growth in height and up to 50% of adult bone mass are achieved during adolescence. This may lead to a 50% increased in calcium requirement in adolescents (40). Besides the iron increments for expanding blood cells and growth spurt, adolescent girls have a further iron need, up to 15%, to compensate for menstrual blood losses (40). For these reasons, adolescents are considered vulnerable to some nutrient deficiencies, especially iron, calcium, vitamin A and folate deficiencies, and protein-energy malnutrition (44).

2.2 Iron and Functional Consequences

2.2.1 Function of iron in the body

Iron, a micronutrient in human body, plays an essential role in many metabolic processes including oxygen transport, oxidative metabolism, and cellular growth.

Total body iron grouped as a functional iron compound that is known to serve a metabolic or enzymatic function, and an iron compound associated with iron storage and transport averages 50 mg/kg or 3.8 g in men and 2.3 g in women (45).

The functional iron compounds are mostly found in the forms of iron porphyrin complexes or haem, i.e., haemoglobin (30 mg/kg), myoglobin (4 mg/kg), and various haem-containing enzymes and cytochromes (1 mg/kg). The another functional iron compounds also called non-haem compounds either contain iron or require iron as a cofactor (1mg/kg) (46).

For haem compounds, a major compound called haemoglobin representing more than 95% of the protein in red blood cell contains iron more than 65% of the total body iron (45). Haemoglobin, which combines with oxygen efficiently, transports oxygen via the bloodstream from lung to tissues. Myoglobin, the red pigment of muscle, is an oxygen storage protein and represents less than 1% of the protein in the muscle, and about 4% of the total body iron. Myoglobin transports and stores oxygen within muscle and releases oxygen to meet increased metabolic needs during muscle contraction (48). The haem enzymes are located in the mitochondria as well as in other cellular membranes and involved in electron transport. The cytochromes such as cytochrome a, b and c involve in the oxidative production of cellular energy in the forms of adenosine triphosphate (ATP). The highest concentrations of the cytochromes are in tissues having a high rate of oxygen utilization such as heart

muscle (45). Cytochrome P-450 located within the microsomal membranes of liver cells and in the intestinal mucosa is involved in oxidative degradation of drugs and endogenous substrates. Cytochrome b_5 also being a component of liver microsomal membranes probably provides energy for protein synthesis in liver cells. Cytochrome b_5 , also found in the cytoplasm of the red blood cells functions as an intermediate in the methaemoglobin reduction (45). Other haem enzymes are catalases and peroxidases. These include myeloperoxidase of the granulocytes involving in the immune system (47).

The non-haem iron compounds that have iron in their structures are iron enzymes involving in oxidative metabolism. These compounds include the iron-sulfur protein and metalloflavoproteins, such as, reduced nicotinamide adenine dinucleotide (NADH) dehydrogenase, coenzyme Q, succinate dehydrogenase, acronitase, xanthine oxidase, ribonucleotide reductase, and adrenodoxin (47). Other enzymes are iron-dependent enzymes that do not contain iron but they require iron as a cofactor or activator. These enzymes include tryptophan pyrrolase and phosphoenol-pyruvate carboxykinase (45).

Another group of body iron is storage and transport iron. The major iron storage compounds, ferritin and haemosiderin, located primarily in the liver, reticulo-endothelial cells and erythroid precursors in bone marrow represent about 5-30 % of total body iron. In normal adults, ferritin accounts for about half of the storage iron present in the liver, and the other half is haemosiderin, which is believed to represent ferritin in various stages of degradation, because it can react with antibodies against ferritin (45). Transferrin is another form of iron compounds that is shuttled between various tissues to serve iron to the target cells. Iron in transferrin accounts for only

0.1% of total body iron. The major role of transferrin is to transport iron from the reticulo-endothelial system and from the intestine to the bone marrow for synthesis of haemoglobin in developing red blood cells.

2.2.2 Iron status and its assessment

Iron absorption in connection with the amount of iron intake and bioavailability of dietary iron, body's iron store, and iron loss influence the iron balance in human body (48). In healthy and well-nourished individuals, iron balance generally exists in which the quantity of daily iron absorbed from the diet is sufficient to compensate for daily iron losses, to permit metabolic iron utilization, and to maintain adequate body iron stores (4). Iron imbalance can occur due to a variety of factors, such as, low dietary iron intake, poor iron absorption due to low bioavailability of dietary iron, increased iron losses, and/or increased requirements. Consequently body iron stores are mobilized. When iron stores are exhausted or even before total exhaustion, functions of iron in the body may be disturbed.

The progression from adequate iron balance to iron deficiency anaemia that develops in three overlapping stages of iron deficiency are briefly described based on biochemical aspect as follows (45):

- 1). The first stage (or called iron depletion) is storage iron depletion, characterized by a decrease in serum ferritin concentration.
- 2). The second stage is a decrease in transport iron, characterized by an increase in the iron-binding capacity as well as by declining serum iron concentration. This stage is likely to be transient.
- 3). The third stage develops when the supply of transport iron for haemoglobin production (or erythropoiesis) decreases sufficiently to restrict the haemoglobin

concentration and/or other iron compounds. Consequently, a level of haemoglobin fall below the reference values, i.e. being anaemia. This stage is characterized by a low haemoglobin level and by an elevation of erythrocyte protoporphyrin and the appearance of microcytosis. At this stage, it may be composed of two types of iron deficiency called iron deficient erythropoiesis and iron deficiency anaemia.

The first and second stages sometimes referred to latent iron deficiency might not be highly associated with adverse physiological consequences until going to the third stage. The iron nutritional status of the individuals could be determined using a single test, which is the simplest way to assess the prevalence of iron deficiency. The serum ferritin, the transferrin saturation or erythrocyte protoporphyrin and the haemoglobin level define iron depletion, iron-deficient erythropoiesis, and iron deficiency anaemia respectively (49).

According to combined iron-related laboratory parameters, iron status is also determined and expressed in five stages, from iron overload to iron deficiency anaemia (or severe iron deficiency), as shown in Table 2.1 (48).

Iron overload is characterized by elevated serum ferritin and transferrin saturation. Iron deficiency is theoretically categorized into three stages according to severity. The first stage, called iron depletion, involves only decreased iron stores as measured by a reduction in serum ferritin concentration. There is still no evidence of any functional consequences of being iron depletion. The second stage results from an insufficient iron for normal production of haemoglobin and other essential iron compounds, but there is no frank anaemia. A decrease in transferrin saturation and/or an increase in erythrocyte protoporphyrin (and also increased serum transferrin receptor) characterize this stage. This stage is so-called iron deficiency without

anaemia, since haemoglobin level does not fall below the cut-off value. The third stage is iron deficiency anaemia. It is the most severe degree of iron deficiency. By this stage, the restriction in haemoglobin production is severe enough to lead to morphological change of red blood cell, i.e., microcytosis and hypochromia.

Table 2.1 Five stages of iron status assessed by multiple parameters ¹.

Parameters	Iron overload	Normal	Iron depletion	Iron deficiency	Iron deficiency anaemia
Serum ferritin	↑	N	↓	↓	↓↓
Transferrin saturation	↑↑	N	N	↓	↓
Erythrocyte protoporphyrin	N	N	N	↑	↑↑
Haemoglobin	N	N	N	N	↓
MCV ²	N	N	N	N	↓

¹ N = At normal levels or at reference values, ↑ = Above normal levels, ↓ = Below normal levels.

² MCV = Mean cell volume.

2.2.3 Consequences of iron deficiency and iron deficiency anaemia

The ultimate consequence of iron deficiency is anaemia that is related to functional impairments. Increasing evidences have pointed out that iron deficiency alone may cause changes in different enzymes and also adversely affects other metabolic processes including electron transport, catecholamine metabolism, DNA synthesis, and several enzyme systems (50).

If iron deficiency is not severe enough to cause anaemia, the manifestation of iron deficiency is difficult to detect due to compensatory mechanism. When the haemoglobin level is reduced as in mild anaemia, there are several adaptations that

minimize the effects of a decreased oxygen-carrying capacity (45). First, the tissues simply extract oxygen from haemoglobin more completely. Second, there is a redistribution of blood flow that maintains the oxygen supply to the vital organs, primarily the brain and myocardium, at the expense of other tissues. Finally, cardiac output is increased. When anaemia becomes severe, these adaptive mechanisms cannot compensate for the decreased oxygen-carrying capacity of the blood and then acidosis develops. The clinical manifestations of severe anaemia occur. These include fatigue, weakness, shortness of breath, dizziness, and headache.

The other effects of anaemia and iron deficiency are alterations in immune function (13-14, 51), in exercise and work performance (52-54), in behaviour, intelligence and cognitive performance (6-9, 55-56), and in abilities to maintain body temperature in a cold environment (15). Premature delivery (5, 57), and increasing lead absorption were considered to be adverse effects of iron deficiency (52, 58).

2.2.4 The prevalence of iron status in adolescents

Iron deficiency anaemia is the most prevalent nutritional disorder worldwide. Over 2 billion people are iron deficient with a total prevalence estimated at about 40% of the world population. It is prevalent in both developing and developed countries. Pregnant women, infants and young children aged 1-2 years, old non-pregnant women, and preschool children are vulnerable groups, whose global prevalence was estimated to be 51, 48, 35, and 25 %, respectively (2). Prevalence data of iron deficiency for other age groups such as adolescents are often not available. Gillespie (1998) reviewed that anaemia was the most widespread nutritional problem and highly prevalent in adolescents of developing countries, ranging from 32-55 % (2). From four studies that were reviewed, no gender difference was found in three of four studies, whereas in the

fourth more boys than girls were anaemic (2). DeMaeyer and Adiels-Tegman (1985) had earlier estimated based on data available from a few countries that the mean prevalence of anaemia during adolescence in developing countries was 27 % with no gender difference (59).

Hallberg et al measured serum ferritin and defined its value below 16 $\mu\text{g/L}$ iron deficiency. The prevalence of iron deficiency in Swedish adolescents was estimated to be up to 40 % (60). By applying the same criteria to other studies, they estimated similar prevalence of iron deficiency in adolescent girls in Canada, Australia, and the United States (61). Based on free erythrocyte protoporphyrin, the prevalence of iron deficiency among female adolescents in a low socioeconomic group of the Philippines was 24.4 % (62-63). Information from health surveillance in 1996, the prevalence of iron deficiency anaemia among Thai school-age children (6-14 y) using haematocrit was 13.76 % (64). The prevalence was found to be higher in rural areas than in municipal areas. The survey was carried out in schoolchildren aged 6-14 years between 1993-1994 by Nutrition Division, Ministry of Public Health using multiple parameters as indicators of iron status. The results indicated the rates of iron depletion, iron deficient erythropoiesis, iron deficiency anaemia, and anaemia from other causes were 6 %, 2 %, 2.4 %, and 14.8 % respectively (65). Hookworm infection being 11 % was found to significantly relate to iron status of the students. Iron deficiency anaemia among female adolescents in villages in northeastern region using haemoglobin as an indicator varied by seasons, being 32.2 %, 14.5 %, and 13.2 % in hot, cold and rainy season, respectively (66).

It can be speculated from the available data that iron deficiency anaemia in Thai adolescents, may be prevalent but the prevalence is not clear for adolescents, aged 10-

19 years because the prevalence from the existing data only covered the school-aged children (6-14 years).

2.3 Physical Fitness

According to Caspersen et al (1985), physical fitness is a set of attributes that people have or achieve that relates to the ability to perform physical activity, which is any bodily movement produced by skeletal muscles that results in energy expenditure (67). Physical fitness level can be assessed by two measurable components: one relates to health and the other relates to skills that pertain to athletic ability as illustrated in Figure 2.1.

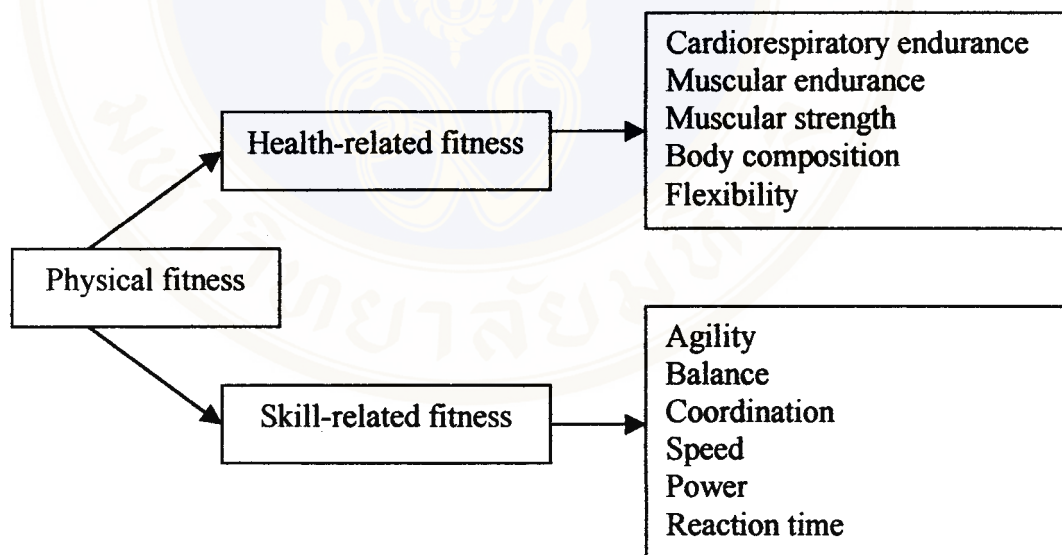


Figure 2.1 Components of physical fitness (67)

Physical fitness can be evaluated by measuring either an aspect of physiological function or selected aspects of motor performance. Initially, physical fitness test has been termed a motor fitness test which represent skill-related fitness test (68). It

consisted of seven components, namely, muscular strength, muscular endurance, circulatory-respiratory endurance, muscular power, agility, speed, and flexibility. Since the concern for good health is important, the concept of physical fitness shifts from a motor fitness to health-related fitness emphasis.

2.3.1 Health-related physical fitness

Health-related physical fitness is defined as a dimension of physical fitness that is associated with health status of an individual (69). Specific components include cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition (68-71), as shown in Figure 2.1. Health-related physical fitness can be improved and/or maintained through regular physical activity. Participation in sport activities that requires motor skills can improve these physical fitness components.

Cardiorespiratory endurance reflects cardiorespiratory capacity to carry out prolonged strenuous exercise of the muscles. A high level of cardiorespiratory endurance can help delay of several chronic diseases such as cardiovascular disease, high blood pressure, less susceptible to develop cancer, prevent obesity, diabetes, and other health problem (72). Many terms have been referred to this component of physical fitness (35). Aerobic capacity is used for assessing the cardiorespiratory fitness and is measured by maximal oxygen uptake (VO_{2max}).

Muscular strength is defined as the ability of the muscle to work against resistance (55). Muscular strength is measured by a single maximal muscle contraction by imposing maximal amount of external force that a muscle or set of muscles can exert for one repetition (73).

Muscular endurance is characterized by the ability of a muscle to perform work until exhaustion. Muscular endurance is defined as the ability of a muscle to contract repeatedly within a given time without becoming exhausted (74).

Lifting a load or moving an object depends on muscular strength, whereas doing that repeatedly over and over requires muscular endurance. Without sufficient muscular strength or endurance ones may not be able to do anything ones wish to do.

Flexibility relates to the range of motion available at a particular joint or set of joints (75). Flexible individuals can bend and twist at their joints easily. Individuals need for flexibility vary. Certain athletes such as gymnasts and divers require more flexibility. General individuals require less flexibility than the athletes. However, everyone needs some flexibility to perform activities of daily living.

Tests of muscular strength, muscular endurance and flexibility have been combined into one broad fitness category because the primary consideration is determining the health status of the musculoskeletal system (36).

Body composition relates to the relative amounts of muscle, fat, bone, and other vital parts of the body (75). It may refer to the proportion of body fat to lean body mass (70-71, 76). The rationale for including body composition as a component of health-related physical fitness is that having a high percentage of body fat, which is known as obesity, is associated with cardiovascular disease and increase risk of other health problems (36).

Generally, there are many physical fitness test batteries. In this study, the prudential FITNESSGRAM was selected to measure the health-related physical fitness of the subjects. The rationale for this was that the prudential FITNESSGRAM was a field test, which did not require complicated equipment. It can be used to educate the

subjects about the status of their physical fitness. Not only it provided information on individual fitness level, but provided information for evaluation of health-related fitness programme (36).

2.3.2 The Prudential FITNESSGRAM

In the early stages of development of the fitness tests in the U.S.A., fitness program for youth was just a test battery. In 1993, there were four national youth fitness tests to be used in the public schools (68). The national physical fitness programmes have mostly emphasized attainment of high levels of performance on components of fitness. However, the Prudential FITNESSGRAM was developed based on the strong believe that extremely high levels of physical fitness are not necessary for accomplishment of objectives associated with good health and improved function. It is believed that regular physical activity contributes to good health, function, and well being, and is important throughout a person's lifetime (36). Thus, the goals of the Prudential FITNESSGRAM are to promote enjoyable regular physical activity and to provide a comprehensive physical fitness assessment and reporting programme for children and youth (36). Table 2.2 lists the fitness components and the test item of the Prudential FITNESSGRAM.

One-mile run /walk test (MRW) MRW was used as a field test of VO_{2max} . In general, for children aged 9 years (or 3rd grade) and older, the reliability of one-mile run /walk test (MRW) is high, with reliability coefficients above 0.80 (35).

The concurrent validity coefficients of the MRW test evaluated by correlating the test performance with VO_{2max} measured on the treadmill have ranged from approximately 0.60 to 0.80 (35). This indicates that the MRW has a moderate concurrent validity as a measure of VO_{2max} .

Table 2.2 Fitness components and test items of the youth fitness test battery (36).

Fitness component	Test items of the Prudential FITNESSGRAM
Aerobic capacity ¹	One-mile run/walk (MRW) , The PACER
Body composition	The percent body fat or Body mass index
Strength and endurance	
- Abdominal	Curl-up
- Upper-body	Push-up, Pull-up, Modified Pull-up, Flexed-arm hang
- Trunk & Lower body	Trunk lift
Flexibility	Back-saver sit-and-reach, Shoulder stretch

¹ Closely related to cardiorespiratory endurance. Synonyms are maximal oxygen uptake and oxygen aerobic power.

The curl-up test For the curl up test, only the validity data are available (74). Studies had compared performances of traditional full sit-ups and curl-ups. The assumption was that these two tests could be used interchangeably. The degree of association between full sit-ups and curl-ups was found to account for only 7 to 42 % of the variance. This means that these tests cannot be used interchangeably. The curl-ups are intended to utilize different muscles over a more restricted range of motion than the full sit-ups. Thus, the curl-up test is measuring in terms of abdominal function, and it is different from what the traditional sit-up measures. Additionally, on the basis of anatomical analyses supported by electromyography, the curl-up test possesses logical validity as a test of abdominal strength/endurance (74).

The modified pull-up test The studies on reliability of the modified pull-up test have been investigated in schoolchildren in all grades. It has been found the high degree of the reliability coefficients of this test, ranging from 70-95 % (74). The

validity of the modified pull-up test indicates that the modified pull-up, free hanging pull-up and flexed arm hang are optional items for measuring upper arm and shoulder girdle strength and muscular endurance (74). The attempt to validate these field-tests against criterion tests that should be close to anatomical matches. Each test has a specific anatomical logical validity, but they are not necessarily anatomically interchangeable. For example, both the modified pull-up and 90° push-up involve the pectoralis major, but the pull-up uses the latissimus dorsi and biceps as contributing muscles while the push-up involves the triceps and anterior deltoid. Correlation among these field tests varies from low ($r = 0.31$) to moderately high ($r = 0.81$) (74). Thus, three tests, namely the modified pull-up, free hanging pull-up and flexed arm hang, are optional items for measuring different types of muscle strength/endurance.

The trunk-lift test Little information is available on the reliability of any version of trunk extension. The test version of prone back extension (height unlimited) by Wear 1963 was found to be a highly reliable test of trunk flexibility ($r = 0.96$) (74). The trunk lift test has logical (i.e. content) validity in measuring of both trunk extensor strength and flexibility. However, no study has been validated against any criterion measure of trunk flexibility.

The back-saver sit-and-reach test For reliability and validity of the back-saver sit-and-reach test, no specific information on this test was available. This is probably due to the newness of the test in non-clinical, school setting (74).

In this study the Prudential FITNESSGRAM test battery is used as a measure of physical fitness of the subjects due to being health-related, and a field-test with rather high reliability and validity. Moreover, no available data have been reported using this

test battery in Thai schoolchildren of secondary educational level except one paper reported in schoolchildren of primary educational level (77).

In this study, the Prudential FITNESSGRAM was selected to measure the health-related physical fitness due to limited data in adolescent groups. The reliability and validity of the Prudential FITNESSGRAM test in youth are described in the technical reference manual of the Prudential FITNESSGRAM (35, 74).

2.4 Iron and Physical Performance

Because physical performance is a result of skeletal muscle's work that requires oxygen and various enzymes in metabolic processes, the study of physical performance related to iron status involve mostly in exercise test, either maximal or submaximal exercise tests.

In exercise tests, there are three factors determining individual's physical performance: energy-liberation processes (aerobic and anaerobic processes), neuromuscular systems (muscular strength and technique), and physical and psychosocial factors (motivation, skills, and tactics) (78). The importance of these factors may vary depending on the type of exercise or activity, the duration and the intensity of work. For example, during prolonged severe exercise or during ordinary daily activities or works, aerobic process that requires oxygen plays the most important role. Consequently, the capability to perform heavy muscle exercise depends on the individual's ability to transport oxygen from lung to active tissues. Thus, iron deficiency will most likely first affect the oxygen content of the blood, which in turn affects cardiac output. And it also reduces the efficiency of oxygen exchange in muscle.

The study of physical performance related to iron deficiency with or without anaemia has been mostly reported in terms of physical work capacity, work performance, work productivity, daily physical activity, and physical fitness.

Physical work capacity is ability to perform maximal physical work. Since it is a function of the intensity and the duration of work, there are many different capacities such as anaerobic, aerobic and endurance capacities. Aerobic capacity measured in terms of VO_{2max} is most often considered. Work performance is measured either in standardized or non-standardized condition of work. It is a response of body to standardized work as indicated either by physiological indices, such as change in heart rate, oxygen consumption (VO_2) and blood lactate, or the work accomplished for a given physiologic response. In standardized condition, an individual's maximum aerobic capacity (VO_{2max}) is estimated by using carefully controlled physiological studies in which a treadmill or stationary bicycle is required. A decrease in work capacity due to iron deficiency anaemia was indicated by an elevation in heart rate and blood lactate levels at a given work load, and a reduction in maximal oxygen uptake (VO_{2max}).

In non-standardized tasks, physical performance is the work accomplished, which depends on factors such as rate of work, motivation, skill, and etc. Occupational work productivity is an example of this type of work performance. Occupational work productivity is rather more relevant to individual's daily life than work performance measured on a treadmill or other applications.

Because the ultimate result of iron deficiency is anaemia, which can most easily identified. A number of studies have been conducted to determine anaemia itself impairs work capacity and work performance (10,12,54). These studies have not only

included carefully controlled physiological studies, but also the studies performed under field conditions. However, not many studies had been carried out to indicate whether iron deficiency itself impaired physical performance.

2.4.1 Iron deficiency and work capacity

Information from animal studies (79) indicated that there was a strong relationship between haemoglobin concentration and times to exhaustion of running on a treadmill of rats. Apart from anaemia, iron deficiency per se can lead to impaired endurance exercise performance. This was due to metabolic and enzymatic changes in the skeletal muscle of iron-deficient rats including decreased concentration of iron-containing enzymes and proteins such as cytochromes, myoglobin, mitochondrial and oxidative enzymes that serve important physiological functions.

In humans, a linear relationship between haemoglobin concentration and the level of maximal work capacity is observed. Gardner and associates studied female tea pickers in Sri Lanka and provided information on heart rate and lactate levels in response to standard exercise loads (graded treadmill test). The results indicated that subjects with lower haemoglobin levels had a lower work capacity (80). Ekblom et al reported that by removing of 1,200 ml of blood from normal individuals over 8-day period reduced the duration of tolerance on a given treadmill speed. A reinfusion of red cells equivalent to 800 ml of blood dramatically and promptly reversed this acute effect (10). Davies and co-workers compared the physiological responses to exercise of normal industrial workers with those of moderate and severe iron deficiency anaemic workers. They found that 24% of anaemic workers with haemoglobin 8 to 10 g/dl, and 35% of anaemic workers with haemoglobin <8 g/dl had the VO_{2max} values

lower than normal (10). Iron therapy in anaemic subjects could improve the $VO_{2\max}$ values.

2.4.2 Iron deficiency and work performance and productivity

While the studies of maximal physical performance have defined the circumstances of iron deficiency anaemia, it is difficult to interpret these findings into day-to-day living conditions in developing countries where iron deficiency is highly prevalent. For example, labourers who work manually perform tasks that require maximal physical effort difficulty. Manual workers do not continue their work until exhaustion, but rather carry them out intermittently, with a period of hard work followed by a recovery period. There is physiological evidence that working in this manner can increase total work output significantly. Thus, an alternative approach to the problem of this study in worker population is to measure actual work output or work productivity.

Several studies have demonstrated a positive relationship between haemoglobin concentration and work productivity, particularly in more-physically-strenuous-tasks. This correlation was found in tea pickers in Sri Lanka (81), in Indonesian rubber tappers (82) and tea-plantation (83), and road-construction workers in Kenya (84). Similar studies in less-physically-strenuous-tasks was also found in female cotton workers in China (85), in loom operators from a jute mill in Indonesia (86), and in Indonesian cigarette rollers (87).

2.4.3 Iron deficiency and physical activity

Studies in animals have indicated a decreased spontaneous activity in iron-deficient rats (88). There is an attempt to find such a relationship in humans. Edgerton and co-workers monitored the physical activity of subjects for periods of four to 24



hours using a sensing recorder attached to the ankle (81). Within two to three weeks of receiving iron treatment, the test subjects were significantly more active than a control group given a placebo. More recently, a study in female jute-factory workers in Indonesia found that anaemic workers and those with VO_{2max} values less than 1.5 l/min were significantly less active at home than non-anaemic workers (86).

2.4.4 Iron status and physical fitness

Some studies in human population during the 1970s found that physical fitness as judged by the Harvard Step Test varied inversely with haemoglobin concentration. A study on a mixed coffee and sugar plantation on the Pacific Coast of Guatemala found a marked decrease in the Harvard Step Test performance of anaemic workers (89). When they were treated with iron, their Harvard Step Test performance not only return to normal, but also they were observed to become more willing, intelligent, and effective workers. Other studies on the same plantation population in Guatemala by Viteri, 1976 and on a rubber plantation in West Java, Indonesia by Basta, 1968 (89) also revealed the similar results. Tumbi and Dodd (1990) in Sri Lanka found that non-anaemic women had better work performance on Harvard Step Test compared to anaemic women with iron (ferrous fumarate) supplementation (90).

2.5 Cognitive Performance

2.5.1 Cognition, cognitive abilities and intelligence

According to Anderson (91), cognition comprises all mental activity or states involved in knowing and the mind's functioning, and includes perception, attention, memory, imagery, language functions, developmental processes, problem solving, and

the area of artificial intelligence. In other words, human cognition is an active process of the mind including thinking, memory, language, problem solving and creativity.

A cognitive ability, in general, is human characteristic or trait that enables persons to do things with their minds. It has been increasingly accepted that intelligence may be composed of some possibly interrelated abilities, which involve cognitive process (92).

Intelligence has a three-dimensional definition: as the capacity to acquire knowledge (sometimes called aptitude), the ability to think and reason abstractly, and the capability for solving problem (93).

Psychologists who measure intelligence use the term intelligence to indicate the amount of knowledge available and the rapidity with which the new knowledge is acquired; the ability to adapt to new situations and to handle concepts, relationships and abstract symbols; and even simply that phenomenon which intelligence tests measures (95). Most psychologists have agreed that the operational definition of intelligence is what intelligence tests measure (95).

In general, the intelligence is measured in terms of an IQ (intelligence quotient) score. An IQ score is a score earned by a person tested on a particular set of a test for measured intelligence and then compared with a test norm (a score of persons whose the test is normal or standardized). Test norms are generally reported as mental ages, and standard scores or percentile scores. A child's mental age (MA) is the age of all other children whose test performance is equal to the child's performance. An IQ is obtained by dividing the mental age by the chronological age (CA) and multiplying by 100:
$$IQ = (MA/CA) \times 100$$
 For example, an eight-year-old child who scores as well as an average ten-year-old on the individually administered Stanford Binet test has a

mental age of 10 and a chronological age of 8. Thus, his/her IQ score in this example is 125.

The distribution of IQ scores of many individuals is statistically described as a normal or bell-shaped distribution. The mean IQ score is arbitrarily set at 100. The IQ scores of 85 and 115 fall in one standard deviation below and one standard deviation above the mean IQ score respectively. Approximately 68% of population have IQ scores within one standard deviation (SD) above and below the mean (i.e. between 85 and 115) for a given group of which they are members. Psychologically, about 50 % of population earning IQ scores between 90 and 110 are classified as having normal intellectual ability. The 25 % of the population scoring below 90 and the remaining 25% scoring above 110 have been classified progressively as described in Table 2.3. Among these populations, approximately 2 % are found in each of the extreme categories of very superior or retarded (94).

Table 2.3 The intelligence classification by IQ score as measured by the Wechsler Adult Intelligence Scales (WAIS) (94).

IQ score	Category of intelligence
130 and over	Very superior
120 – 129	Superior
110 – 119	Bright normal
90 – 109	Normal
80 – 89	Dull normal
70 – 79	Borderline
Below 70	Retardation

IQ scores can predict academic achievement of individuals at the top with IQs above 80 (or about 90 % of the general population) who can proceed through school in regular classes. Meanwhile IQ scores can identify individuals in the bottom (about 10%) with IQs below 80 (or classified as borderline to retardation) who may require specialized educational, psychological, or medical assistance.

2.5.2 Intelligence tests

There are many tests that can be used to measure intelligence of individuals. Most of cognitive tasks employed in these intelligence tests are arithmetic skills, information processing, reasoning, objects' manipulation, vocabulary, and memory functions. However, the objective of intelligence tests is to appraise overall performance so as to obtain an estimate of general intellectual potential.

One of the intelligence tests widely used today by educational, industrial, and clinical psychologists to investigate person's intellectual status are the Stanford-Binet Scale and the Wechsler Scale that includes the Wechsler Adult Intelligence Scales (WAIS) and the Wechsler Intelligence Scale for Children (WISC). Both of them are classified as individual intelligence tests that require a specially trained tester who administers them to one subject at a time. However, there are many other intelligence tests that are administered to a group of subjects, which are classified as group intelligence tests.

Many of group intelligence tests are in use today, primarily in educational setting. Group intelligence tests have some advantages over individual intelligence tests, such as cheaper, quicker, and easier to administer. However, group tests also have potential limitations, such as depending on highly motivation to perform the tests. In this study,

two kinds of intelligence tests called Raven Progressive matrices (RPM) and Scholastic aptitude tests (SAT) are administered as group tests.

Raven Progressive Matrices An intelligence test called Raven Progressive Matrices (RPM) test was developed by John C. Raven (96). The RPM test is composed of a set of figural matrices that can be used as a measure of general intelligence. This test is classified as culture-reduced test (97-98) and non-verbal intelligence test (99).

By Spearman's theory, intelligence has a unitary, comprehensive ability, which is common to all tests of an intellectual nature and called "g-factor". Each test of intelligence may have additionally its own specific factors, which are labeled "s". Spearman finally called the latter factors as "group factors", from which he identified three of these factors as verbal, visual and numerical abilities (100). Recently, Horn and Cattell (1966) have proposed two very broad abilities of human intelligence that they called "fluid" intelligence and "crystallized" intelligence (100). Fluid intelligence, which looked like a combination of Spearman's visual and numerical factors, was largely determined by heredity, whereas, crystallized intelligence, which seemed to be equivalent to Spearman's verbal factor was largely determined by education and other experience.

The RPM test is widely accepted as one of the purest and best measure of "g" or as a measure of fluid intelligence. Moreover, the RPM measures more than problem-solving ability, requiring perceptual ability to deal with gestalts and relationships, as well as a conceptualization of the nature of the problems presented. However, successful performance of the test is heavily influenced by motivational factors. The reliability of the RPM test was not presented in the RPM manual. However, the

factorial relationship between the “g” and intelligence assessed by the RPM is that the RPM typically correlates in the range of 0.6-0.8 (101).

The validity of the RPM test primarily derived from correlational study with other tests. The RPM correlates around 0.5-0.6 with the Mill Hill Vocabulary Scales, and correlates around 0.8-0.95 with tests of intelligence (96). A correlational study with the California Achievement Test yielded a correlation coefficient of 0.76 with the Standard Progressive Matrices. The Standard Version of the RPM test correlates with the WISC-R Full Scale of intelligence at 0.69 (101). Thus, the RPM test is suitable for measuring intelligence with respect to “g-factor” rather than for indicating academic performance or verbal ability.

Scholastic Aptitude Tests (SAT) Traditionally, intelligence tests have been used to measure learning ability of students. The term intelligence test is still used for some individually administered tests and for some of group tests, but its use is declining due to the concept of intelligence associated with inherited capacity, and having some factors included in the concept. Aptitude tests have been increasingly used for predicting achievement and describing learning abilities. Thus, the term “scholastic aptitude tests” is widely used in educational or learning aspect.

Scholastic aptitude tests do not measure a fixed capacity of an individual, but they provide an indication of the individual’s level of learned abilities at present and can be useful in predicting his/her future performance. Performance in aptitude tests differs from that in achievement tests. It is influenced by previous learning experiences, but it is less directly dependent on specific courses of instruction than is performance in achievement tests (102).

The Educational and Psychological Tests Bureau of Srinakharinwirot University, Thailand has developed the Scholastic Aptitude Tests (SAT). The SAT tests were developed on the basis of the Primary Mental Abilities Theory, which was proposed by Louis L. Thurstone in 1924. According to this theory, intelligence does not consist of a single general factor, but is composed of seven primary abilities or factors. These factors are reasoning, word fluency, verbal comprehension, spatial visualization, associative memory, number, and perceptual speed (103). The reliability values of the tests are 0.95, 0.91, and 0.63 for verbal SAT, numerical SAT, and reasoning SAT respectively.

2.6 Iron Status and Cognitive Performance

A large number of studies have been conducted to examine the effects of iron deficiency and iron deficiency anaemia on mental outcomes. Most of these studies concentrate in infants, young children, and schoolchildren.

2.6.1 Iron deficiency and cognitive outcomes in infants and preschool children

Iron deficiency anaemia is found to be associated with poorer performance on developmental rating of infants. Lower developmental scores are mostly seen in infants and young children with anaemia rather than iron deficiency alone. Infants and young children with iron deficiency anaemia often show difficulty with language, poor motor coordination and balance. Evidence from observational studies suggested poorer attention, responsiveness, and mood assessment in infants and young children with iron deficiency anaemia. Most intervention studies in which iron treatment was administered indicated no benefit of iron treatment was found, except that by Oski and

Honig (104). However, Idjradinata and Pollitt (105) supported a reversal of poor mental, motor developmental scores after 4 months of iron therapy. Although, there may be many reasons why most studies have not found significant improvement, generally, it has been accepted that the effects of anaemia on brain development in infants and young children may not be reversible. Studies of long-term effects of anaemia during infancy have shown significant adverse effect on development or cognitive and educational achievement in later life. The test scores of motor and mental development and behaviour of the same children formerly being anaemic and having low scores during the period of infancy show poorer IQs at age 5 years and older (106)

The cognitive benefits of iron treatment in preschool children are more apparent than in infants. It is possible that the critical period at which iron deficiency anaemia can have long-lasting effects has passed. The major influence of iron deficiency anaemia in preschool children is on attention, arousal, and motivation rather than on basic cognitive abilities. The results of the study showed that attention and cognition among preschool children with IDA can be improved after iron treatment (55).

2.6.2 Iron deficiency and cognitive outcomes in schoolchildren and adolescents

There is strong evidence that initially lower scores on tests of cognition or school achievement due to iron deficiency anaemia (IDA) in school-age children can be improved and reversed after iron treatment. This is in contrast to the effects of IDA on cognition of infants, whose poorer performance in developmental tests may not be reversible after iron treatment.

Nine studies had reported the effects of iron status on cognitive function or educational achievement of school-age children. Of these, two were cross-sectional studies and seven studies were placebo-controlled experimental trials. A cross-sectional study of Webb and Oski (107) in schoolchildren, aged 12-14 years compared the Iowa Basic Skill Scores between anaemic and non-anaemic groups. The results showed that although all subjects performed poorly relative to national norms, the scores of the anaemic children were significantly lower than those of the non-anaemic group. Similarly, Webb and Oski also reported the results of teachers' behavioural assessment of the students. The results indicated that iron deficiency anaemia disturbed the attentional, behavioural, and perceptual attributes that in turn affected the students' cognitive scores (108).

Intervention trials, with double blind, placebo and non-anaemic controls were allowed to investigate the causal effect of iron on cognitive performance. These studies were initiated by the report of Pollitt et al, 1985 (109), followed by the studies of Soemantri et al 1985 (19), Kayshap and Gopaldas 1987 (20), Seshadri and Gopaldas 1989 (21), Somantri 1989 (110) Pollitt et al 1989 (27), and Bruner et al 1996 (111), as shown in Table 2.4. All of these studies except one (27) indicated significant improvements in the cognitive function or educational achievement of children who received iron supplementation compared with those who received placebo. However, these studies were conducted with children of different age ranges and different cognitive tests were used (Table 2.4).

Table 2.4 Some cognitive studies in adolescents.

Reference	Age of subjects (y)	Cognitive tests
Pollitt et al, 1985	9.5 (average age)	Matching familiar figures test
Soemantri et al 1985	10-11	Educational achievement, concentration, and Ravens Progressive Colored Matrices IQ assessment
Kayshap and Gopaldas 1987	8-15	Visual recall, digit span, mazes and clerical task
Somantri 1989	8.1-11.6	Educational achievement
Pollitt et al 1989	9-11	Ravens IQ test and educational achievement.
Bruner et al 1996	13-18	Brief test of attention (BTA), Symbol Digit Modalities Test (SDMT), Visual Search and Attention Test (VSAT), Hopkins Verbal Learning Test.

From the available data, the studies dealing with the iron status and cognitive performance of adolescents in Thailand seemed to be rare. There was only one study conducting in schoolchildren of primary educational level aged 9-11 years (27). This study was double-blinded intervention trial. At baseline, children with iron deficiency anaemia (IDA) had lower IQ score than iron-sufficient (IS) control, and IDA and iron deficient (ID) groups scored lower on Thai language than IS group. After iron supplement, all children improved their scores regardless of iron status. There were no differences in improvement between iron and placebo treated children.

From reviews of literatures, the effects of iron deficiency anaemia on physical activity and work productivity are mostly documented in adults. The data involved in adolescents seem to be scarce. Physical performance studies that involved physical fitness usually perform using the motor fitness tests. Moreover, no study in adolescents has ever been reported with respect to health-related physical fitness. In this study, the relationships between iron status and health-related physical fitness in adolescents are, thus, determined by using a health related fitness test battery called the Prudential FITNESSGRAM.

Apart from physical performance, cognitive function of adolescents is also interesting. It is well documented that iron is essential for normal mental and motor development in infants and children. However, it is not clear about the effects of iron deficiency in adolescent group. The studies in this age group are rather limited, particularly in Thais. This study is, thus, performed to identify relationship between iron status and cognition in adolescents.

CHAPTER III

METHODOLOGY

3.1 Study Design

The principal objectives of this study were to assess nutritional status and iron status of school adolescents, their health-related physical fitness and cognitive performance and its relationships. This study was designed as a cross-sectional study, which was carried out from 27 October to 12 November 1998.

3.2 Study Area

This study was conducted in secondary schools located in Nakhon Chaisri District, Nakhon Pathom Province, which was about 30 km southwest of Bangkok (Appendix A). Nakhon Chaisri District, one out of the seven districts of Nakhon Pathom, was purposively selected. The district was about 10 km from the Institute of Nutrition, Mahidol University (INMU). There was easy access to transport from the study sites to the laboratory at the INMU.

3.3 Target Population and Sample

The study focused on children aged 12-15 years who were studying in Mathayom 1-3 of secondary schools in Nakhon Chaisri District. The total number of students studying in Mathayom 1-3 of all secondary schools in Nakhon Chaisri District were 2,208 (statistics in 1998), out of which about 2,000 students were in the age 12-15 years old.

3.3.1 Eligible criteria

The eligible criteria were:

- apparently healthy male and female students
- aged 12 to <16years
- currently studying in Mathayom 1-3 (M1-M3) (equivalent to Grade 7-9) of schools located in Nakhon Chaisri District, Nakhon Pathom Province

3.3.2 Sample size calculation

Since it is suspected that anemia could be the problem in the area. Therefore, sample size was calculated based on previously reported anemia prevalence in the area. This figure was calculated by the statistical formula (112) that was based on the prevalence (P) of anaemia, as described follows:

$$n = \frac{Z_{\alpha/2}^2 P(1-P)}{d^2}$$

Where

n = estimated sample size

$Z_{\alpha/2}$ = normal deviate corresponding to the 95% confidence coefficient,

given $Z_{\alpha/2}$ (two-sided) = 1.96

P = expected prevalence of anaemia in school children estimated to be 0.15 or 15 %, based on the prevalence of anaemia in Thai schoolchildren reported by the Nutrition Division, Ministry of Public Health, 1996 (64)

d = allowable absolute error of the sample prevalence different from the actual population prevalence of anaemia, being 0.03 or 3%

$$\begin{aligned}\text{Then, } n &= \frac{(1.96)^2 \times 0.15 (1-0.15)}{(0.03)^2} \\ &= 544\end{aligned}$$

Allowing for possible drop-out rate of about 10%. Then, the estimated sample size was at least 598.

3.4 Sampling Procedure

3.4.1 Steps of sample selection

There are altogether seven secondary schools in Nakhon Chaisri District, Nakhon Pathom Province. All of them are government schools, but one is for handicapped children. Thus, there were six schools for the sampling. Since the school size (grade 7-12) varied with the total number of students from about 500 –1,500. Therefore, schools were divided by size to be medium and small.

The steps of the sampling method were described as follows. Schools were classified into two groups according to the number of enrolled students. The schools were classified as a medium (1,000-1,500 students) and a small (<1,000 students) size. According to this criterion, only one school (Pattarayan Viddhaya) was classified as a medium size, and five schools were small ones. Two of the five small schools were randomly selected and they were Laembua Viddhaya, and Perm Viddhaya.

In each school, the class list by student's identification numbers of children aged between 12.0 to 15.9 years was used. The sample was drawn in proportion to the total number of the 12-15 year-old students for each sex and class. The steps of sample selection were illustrated in Figure 3.1.

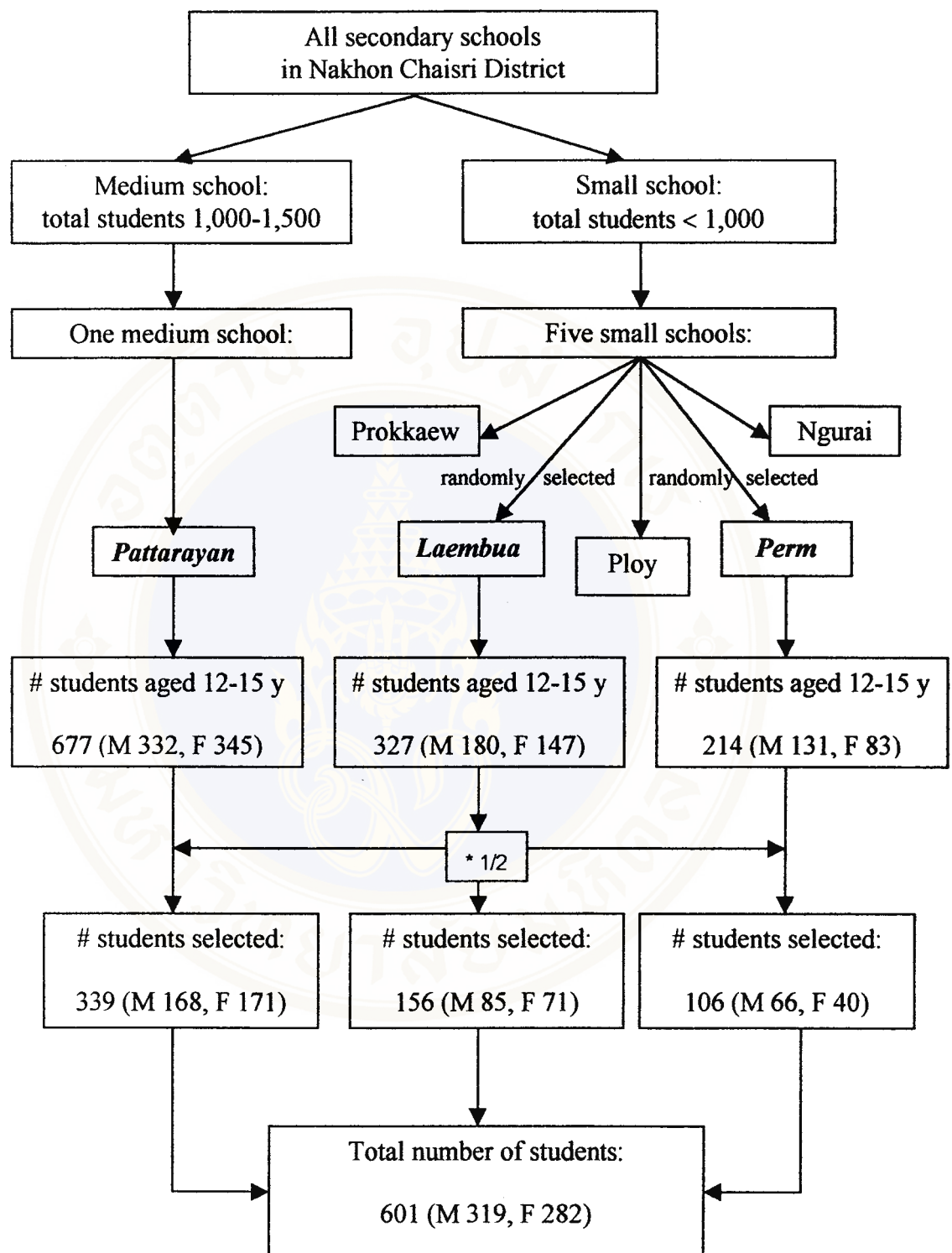


Figure 3.1 Steps of sample selection (M = male, F = female).

* Subsample of one half taken by age-stratified, systematic random sampling.

3.4.2 Method of sample selection

In 1998-1999, there were a total of 1216 children (643 males and 573 females), aged 12.0-15.9 years, enrolled in Mathayom 1-3 (M.1-M.3) of the three selected schools. There were 19 classrooms in Pattarayan, 9 classrooms in Laembua and 6 classrooms in Perm school. The numbers of eligible students in the schools were 677 students (332 males and 345 females) in Pattarayan, 327 in Laembua and 214 in Perm school.

Among the 1216 eligible students, the sample was drawn from every other child on the list from each class. The total number of selected sample was 601 (319 males and 282 females). Thus, the numbers of students included in the sample from each school were 339 (168 males and 171 females) from Pattarayan School, 156 (85 males and 71 females) from Laembua School, and 106 (66 males and 40 females) from Perm school.

The selection ratio between the number of students selected and the total number of students was approximately 1: 2, as shown in Table 3.1.

Table 3.1 The ratio of sample selection by age (class) and sex

Age (y)	# Male students			# Female students		
	Total	Selection	Selection ratio	Total	Selection	Selection ratio
12.0-12.9	43	22	1: 1.95	42	21	1: 2.00
13.0-13.9	209	101	1: 2.07	182	90	1: 2.02
14.0-14.9	220	113	1: 1.95	167	82	1: 2.04
15.0-15.9	171	83	1: 2.06	182	90	1: 2.02
Total	643	319	1: 2.02	573	282	1: 2.03

3.5 Subjects

3.5.1 Ethical consideration

This study was approved by the review committee at the Institute of Nutrition and the Committee on Human Rights Related to Human Experimentation of Mahidol University. Written informed consent was obtained. See also Appendix A.

3.5.2 Subject enrollment and informed consent

The researchers invited the students to participate in this research project through the school meeting. The researchers described the study protocol to school authorities, teachers and the students. Through the students, the study objectives and protocol were informed to the parents and if agree, written informed consents were signed by both parents and students. The students were allowed to withdraw from the study at any time and reasons for withdrawal were documented.

3.5.3 Number of subject included in the study

The number of subjects sampled were 601 (319 males and 282 females). Out of this, only 586 (97.5%) students willingly participated in this project. Seventy-two students (12.3%) were absent from schools due to illness or missing school on some days of the data collection. In total, 514 out of the 568 students or about 87.7% completed the study (Figure 3.2).

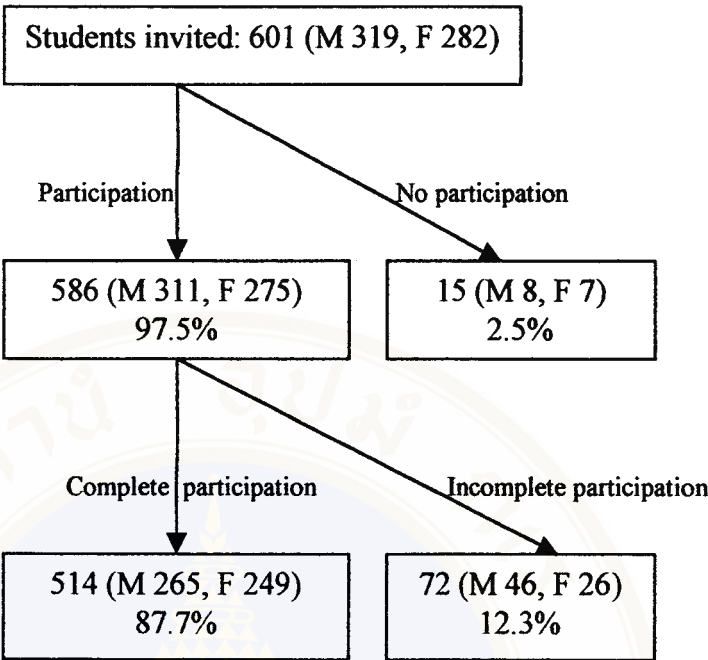


Figure 3.2 Number of students participating in this study (M = Males, F = Females).

3.6 Data Collection

3.6.1 Measurements and variables

The measured variables were derived from the conceptual framework presented in Chapter I (Figure 1.1). The assessments included haematological indicators on iron status, anthropometric measurement of nutritional status and body composition, dietary intakes, health-related physical fitness tests, and cognitive performance tests. Additional variables included maturational status, health status, and selected demographic data. Due to time constraint, dietary assessment was done in a sub-sample of about one-third of the total sample. Serum ferritin determination was done on one-half of the sample due to cost of the analysis. Table 3.2 shows detailed list of measurements and variables collected.

Table 3.2 Measurements and variables collected in this study.

Measurement	Variable	Sample
<i>Iron status:</i>		
- Haematological measurement	Haemoglobin level	All
	Haematocrit	All
	Serum ferritin	Sub-sample (1/2)
<i>Nutritional status:</i>		
- Anthropometric measurement	Body weight	All
	Height	All
	Triceps skinfold thickness	All
	Calf skinfold thickness	All
	Mid-upper arm circumference	All
- Dietary assessment	Level of energy, macro-nutrient, iron, and other nutrient intakes	Sub-sample (1/3)
<i>Health-related physical fitness:</i>		
- Aerobic capacity	One-mile run/walk time	All
- Muscular strength/endurance	Abdominal strength/endurance	All
	Trunk extension strength/endurance	All
	Upper-arm and shoulder girdle strength/endurance	All
- Flexibility	Hamstring flexibility	All

Table 3.2 (continued)

Measurement	Variable	Sample
<i>Cognitive performance:</i>		
- Intelligence	Intelligence scores	All
- Cognitive ability	Scholastic aptitude scores	All
<i>Maturation status:</i>		
- For boys	Voice change	All
- For girls	Menstruation onset	All
<i>Health condition:</i>		
- Diseases	Past illnesses	All
<i>Demography:</i>		
- Socioeconomic status of family	Education level of parents	All
	Income of the family	All
	Other related variables	All

3.6.2 Methods of measurements and data collection

3.6.2.1 Haematological measurements

Haematological measurements consisted of the determination of haemoglobin (Hb), packed cell volume (PCV) or haematocrit, and serum ferritin (SF).

To assess iron status, 2 ml of non-fasting venous blood was drawn from each subject by venipuncture at the superficial veins in the antecubital fossa of the forearm, using a disposable syringe and needle. The 0.5-ml blood was placed into a tube with ethylene diamine tetraacetate (EDTA) as anticoagulant for analysis of haemoglobin.

About 50 μ l of blood was drawn into a 75-mm heparinized capillary tube for the determination of PCV. The rest of blood sample was filled into a 12 $\times$ 75-mm, acid-washed tube and allowed to clot. Serum was obtained by centrifugation at 1,500 g for 20 minutes and kept at -20°C for further analysis of ferritin. A well-trained nurse from Human Nutrition Division, INMU performed blood collection and recorded illness, menstruation status (for girls) and the regular use of medication on the blood collection form (See Appendix B). The Hb was analyzed by the cyanmethaemoglobin method, and the PCV was analyzed by the microhaematocrit method (49). Both analyses were done within 3-5 hours after blood drawing. The serum ferritin was analyzed by the enzyme-linked immunoassay (ELISA) method (142). All blood analyses were done at the INMU laboratory by a well-trained technician. Details of all laboratory analytical methods are in Appendix C.

The principle of haemoglobin determination The principle of the cyanmethaemoglobin method is that haemoglobin is measured photometrically after a conversion to cyanmethaemoglobin or haemoglobinocyanide (HiCN). Its absorbance is measured at the wavelength of 540 nm by a spectrophotometer. According to Lambert-Beer's law, the absorbance of HiCN at this wavelength is proportional to its concentration. A HiCN standard of known haemoglobin content is used to calibrate the measuring instrument. Then, the haemoglobin concentration in the samples was calculated against a standard curve.

The principle of the PCV determination The packed cell volume (PCV) or haematocrit (Hct) is the ratio of the volume occupied by red cells to the volume of whole blood after centrifugation. The measurement of PCV requires only about 50 μ l of blood for each measurement. The blood sample is drawn into a

heparinized capillary tube, which is sealed at one end. The blood capillary tube is then centrifuged at a high speed for 5 minutes. The column length of red cells and plasma is read by using a specific reading device.

The principle of serum ferritin determination The principle of ELISA (142) for serum ferritin measurement is that a solution containing ferritin standard or unknown is incubated with antiferritin antibodies, which has been conjugated with an enzyme (an antibody indicator) in a tube coated with antiserum to human ferritin (a solid phase antibody) at room temperature. During this stage the ferritin being assessed becomes a sandwiched compound between the solid phase and indicator antibody. After removing unreacted antibodies by washing with an excess amount of immunoadsorbant, the amount of enzyme retained in each tube was measured by adding a substrate. After the reaction has been stopped, the absorbance, which is proportional to the amount of ferritin, is measured spectrophotometrically

3.6.2.2 Anthropometric measurement

Anthropometry in this study served two objectives, one for assessing gross nutritional status and another for assessing body composition, which is a component of health-related physical fitness. Anthropometry consisted of five measurements, i.e., body weight, height, mid-upper arm circumference, triceps skinfold thickness, and calf skinfold thickness.

For body weight measurement, *the Salter Digital Bathroom Scale* was used to measure body weight of the students. This scale was an advanced electronic bathroom scale incorporating a microchip technology. The scale was calibrated with standard weights from zero to 80 kg before each weighing session. For standard weighing (113), each student was asked to stand straight on the center of the balance platform in

bare feet and light clothing. The body weight of the student was recorded to the nearest 0.1 kg.

The Lameris Microtoise Tape, which measured up to 200 cm, was used to measure body height. The tape was stuck on the 2-meter high wall. When measuring height (113), the student was asked to stand straight in bare feet with the head in the Frankfurt Horizontal Plane, feet together, knees straight, and heels, buttocks, and shoulder blades in contact with the vertical surface of the wall. The height was recorded to the nearest 0.1 cm.

For the measurement of arm circumference, *the Harpenden Anthropometric Tape*, which was 2 m long, was used to measure mid-upper arm circumference at the right arm site of the subjects. The students were asked to stand erect with the arms hanging freely at the sides of the trunk and with the palms facing the thighs. The arm circumference was measured when the arm relaxed and the elbow extended at the midpoint between the acromion process of the subscapular and the tip of the olecranon of the elbow (70). The circumference was recorded to the nearest 0.1 cm.

The skinfold thickness, which consisted of a double layer of subcutaneous fat and skin, was measured at two sites, a triceps site and a calf site. *The Holtain Skinfold Caliper* was used to measure skinfold thickness at both sites. All skinfold measurements were measured up to 0.1-mm accuracy. The triceps skinfold thickness was measured on the back of the right arm over the triceps muscle, at mid-point between the acromion process of the scapula and the elbow (71). The calf skinfold thickness was measured on the inside of the right leg at the level of the maximal calf girth (36). The students were asked to stand with the right foot on a box so that the right knee and hip were flexed to about 90°. The skinfold thickness was measured on

the maximum calf at the medial side of the right leg (71). Well-trained technicians from the Physiological Nutrition division, INMU performed the measurements throughout the study.

3.6.2.3 Physical fitness test

Health-related physical fitness composed of three components, i.e., aerobic capacity, body composition, and muscle strength, endurance and flexibility was measured using the Prudential FITNESSGRAM test battery. This was developed by The Cooper Institute for Aerobics Research, Dallas (TX). This test was a comprehensive fitness programme for school-aged children and youth. In each component of the Prudential FITNESSGRAM, there were several test options (Appendix C). The test items and appropriate battery tests were selected to cover the fitness components as mentioned. The tests included the one-mile run/walk test, the percentage of body fat, the curl-up test, the modified pull-up test, the trunk-lift test, and the back-saver sit-and-reach test. The Physiological Nutrition Research Team from the INMU with seven well-trained persons performed the Prudential FITNESSGRAM tests and anthropometric measurement. The physical fitness and anthropometric data were recorded in a physical fitness form (Appendix B). Details of the measurements are included in Appendix C.

3.6.2.4 Cognitive performance test

Two available cognitive tests were used to evaluate the cognitive performance of the students. The Raven Progressive Matrices (RPM) was an intelligence test, and the Scholastic Aptitude Test (SAT) was an aptitude test which was developed and standardized by the Educational and Psychological Test Bureau, Srinakharinwirot University, Thailand.

The Raven Progressive Matrices (RPM) The RPM test was an international test due to its content-free, culture-fair, and language-free. This test was composed of a set of figural matrices and was used to test a group of people aged 8-65 years. Raven created the RPM test in 1936 according to the two-factor theory of Spearman who proposed the concept of g-factor as a general factor of mental ability in 1927 (83). The g-factor can be subdivided into educative and reproductive abilities. The objective of the RPM test was mainly to assess educative ability. Although, the RPM with the standard version of tests was first published in 1938, up to now, this test had been revised and reprinted several times. It had been documented that the three versions of RPM, i.e. Coloured, Standard, and Advanced, were among the most widely used measures of nonverbal ability. The Standard Version of RPM reprinted in 1966 (114) was used in this study.

The Standard RPM consisted of five sets, i.e. Set A, B, C, D, and E, with 12 items in each set. Thus, the total items were 60. Each item was expressed in a matrix pattern, which no language was involved. Each matrix consisted of a pattern in which one part was missing. The task for each subject was to determine which pattern fitted the blank space of each matrix item. Then, the subject located the missing pattern in a series of six or eight alternatives. A group of the subjects (not more than 40 in each group) performed the RPM test that was controlled by two testers, and the test time was 40 minutes in total. The researcher manually double-checked answer sheets of all subjects. If the subjects performed each test item correctly, one score per item was given. The score was interpreted in consultation with a psychology expert from the Child Mental Health Center, Department of Mental Health, Ministry of Public Health, Thailand.

The Scholastic Aptitude Tests (SAT) The SAT used in this study was classified as a group of mental ability test. The Educational and Psychological Test Bureau of Srinakharinwirot University, Thailand had firstly constructed and developed an aptitude test for testing mental abilities of Thai students since 1962 (115). The aptitude test was created on the basis of Thurstone's multiple factor theory. Thurstone had postulated the multiple factor theory of mental abilities that was called the Primary Mental Abilities in 1938 (116). Among seven primary factors of mental abilities that were often reported, only verbal (V), numerical (N), and reasoning (R) factors were selected for this study.

The SAT test used in this study had been recently constructed and it was specific for Thai students of secondary education level. This test was consisted of 150 multiple-choice questions divided into three sets that were designated as SAT-V, SAT-N, and SAT-R for verbal, numerical, and reasoning sets, respectively. Each set contained 50 items. The SAT-V set emphasized the abilities to understand the concept of relational among various things, the reading comprehension, vocabulary analogies, antonyms, figural understanding, and sentence completion. The SAT-N set assessed the student's ability to solve mathematical problem through reasoning, rather than recalling school knowledge in mathematics, and the abilities to understand the mathematics concepts and numerical series. The SAT-R set measured the reasoning abilities of verbal and figural categorization, the verbal and figural analogies, and the logic ability. In this study, the experts from the Educational and Psychological Test Bureau of Srinakharinwirot University administered the SAT tests to all subjects with assistance of the researcher and the schoolteachers. The specified time for the SAT-V, SAT-N, and SAT-R tests were 60, 50, and 40 minutes, respectively. The process of an

answer check and analysis of the test scores of all subjects was carefully performed at Srinakharinwirot University. The test scores were interpreted in consultation with an expert of the Education and Psychological Test Bureau, Srinakharinwirot University.

3.6.2.5 Dietary assessment

A one-day 24-h dietary recall was used to assess dietary intake of the students in this study. The subjects were asked to recall total food and drink consumed in the preceding day through well-trained interviewers. Only dietary intakes during weekdays were assessed. If the meals in the preceding day were in a special occasion or in a weekend holiday, the dietary recall had to be postponed. Food models including fresh foods and cooked foods, food weighing scale, and standard measuring cups and spoons were used to aid in recalling and estimating amount of food consumed. Cooked rice was weighed to measure amount eaten at each meal. Well-trained interviewers recorded the list of foods eaten and the quantities consumed in the 24-h dietary recall form (Appendix B).

3.6.2.6 Other variables

Socioeconomic, health, and maturational data were collected by a questionnaire (Appendix B). The questionnaire was improved after its pre-testing at a secondary school in the same district, which was not the study site. All subjects were asked to fill the information in the questionnaires under the close supervision of the researcher.

3.6.2.6.1 Socioeconomic data

Data on family size, number of employed and dependent member in family, parental education, occupation, and income were collected by a questionnaire (Appendix B).

3.6.2.6.2 Health condition

Health indicators that might be related to iron deficiency and nutritional status were collected by a questionnaire (Appendix B). In this study, past illness during the past 6 months and history of illness related to iron and nutrition status were asked.

3.6.2.6.3 Maturation status

Information on maturational status of the subjects included the menstruation onset data of female subjects and the voice change data of male subjects. The menstruation data of females were collected from all female samples aged 12-15 years. The voice change data of males were mostly obtained from students aged 12-14 years, because older children could not recall the exact age when voice changed.

3.7 Data Analysis and Interpretation

All data were entered and analysed by a personal computer (PC). The Statistical Packages for the Social Science (SPSS) for Windows version 7.0 (SPSS Inc.1995) was used to process and analyse data statistically. Data analysis and interpretation was done according to the objectives of the study as follows:

3.7.1 Iron status

3.7.1.1 Criteria for assessing iron status

The assessment of anaemia used single indicator, i.e. the haemoglobin (Hb), or packed cell volume (PCV) as indicator (61). However, multiple indicators that were composed of the Hb and serum ferritin were used to diagnose the state of iron deficiency (34, 117). See also Appendix D for the criteria for assessing anaemia and iron deficiency used in this study.

3.7.1.2 Assessment of iron status

For assessing iron status of male and female students, the level of haemoglobin, haematocrit, and serum ferritin were interpreted by single and multiple indicators, as previously mentioned. The percentages of the students being iron depletion (ID), iron deficiency anaemia (IDA), and anaemia were calculated and presented in each sex, as follows:

$$\% \text{ Prevalence} = \frac{\text{Number of students diagnosed as ID or IDA or anaemia}}{\text{Number of total students}} \times 100$$

3.7.2 Nutritional status

For antropometric measurement of nutritional status, many indicators were calculated from the measured anthropometric data, i.e. body weight (Wt), height (Ht), triceps skinfold thickness (TSF), calf skinfold thickness (CSF), and mid-upper arm circumference (MAC). The calculations of nutritional status indicators were done by equations, as shown in Table 3.3.

Table 3.3 The equations used for calculating nutritional status indicators.

Indicator	Equation	Reference
Body mass index (BMI; kg/m ²)	$\text{BMI} = \frac{\text{Wt}}{(\text{Ht})^2}$	(119)
Body Fat (%)	$\% \text{BF} = 0.735 \text{ SSSF}^* + 1.0 \text{ (for males)}$	(37)
(%BF)	$\% \text{BF} = 0.610 \text{ SSSF}^* + 5.0 \text{ (for females)}$	(37)
Total body fat (TBF; kg)	$\text{TBF} = \frac{\text{Wt} \times \% \text{BF}}{100}$	(120)

* SSSF: Sum of triceps and calf skinfold thickness.

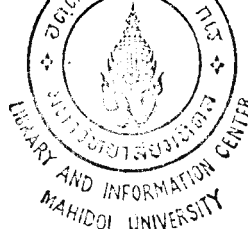
Table 3.3 (continued)

Indicator	Equation	Reference
Fat free mass (FFM; kg)	$FFM = Wt - TBF$	(120)
Arm muscle circumference(AMC;cm)	$AMC = MAC - (\pi \times TSF)$	(121)
Arm muscle area (AMA; cm ²)	$AMA = \frac{[MAC - (\pi \times TSF)]^2}{4\pi}$	(122)
Bone-free arm muscle area (cAMA; cm ²)	$cAMA = AMA - 10.0$ (for males) $cAMA = AMA - 6.5$ (for females)	(123) (123)
Total muscle mass (TMM; kg)	$TMM = Ht \times [0.0264 + (0.0029 \times cAMA)]$	(123)

* SSSF: Sum of triceps and calf skinfold thickness.

3.7.2.1 Reference data for nutritional status assessment

In this study, two reference data were used for assessing the prevalence of overweight and/or obesity, wasted, thinness, and stunting. The first reference was a local reference data, i.e. the standard weight, height, and anthropometric indicators for Thai population aged 1 days-19 years, 1987 (124). The second reference was an internationally available reference data, i.e. NCHS/WHO reference data (125).



3.7.2.2 Criteria for nutritional status assessment

To assess the nutritional status, the anthropometric data of the subjects in each age and sex were compared to the reference data as mentioned earlier. Classifications of overweight and/or obesity, thinness, wasted, or stunting were based on the criteria recommended by WHO, (Appendix D) (126). The prevalence of overweight, obesity, thinness, wasted, and stunting was expressed in percent calculated as follows:

$$\% \text{ Prevalence} = \frac{\text{Number of students identified} \times 100}{\text{Number of total students}}$$

3.7.3 Health-related physical fitness

The laboratory measure of maximum oxygen consumption ($\text{VO}_{2\text{max}}$) was generally the best measure of aerobic capacity. Because of the limitation of $\text{VO}_{2\text{max}}$ measurement, which requires more facilities in laboratory, the $\text{VO}_{2\text{max}}$ of the students in this study was therefore estimated from the regression equation of Cureton (35), which predicted the $\text{VO}_{2\text{max}}$ from the one-mile run/walk time and selected demographic data. The Cureton's equation was shown as follows:

$$\text{VO}_{2\text{max}} = 0.21(\text{Age} \times \text{Sex}) - 0.84(\text{BMI}) - 8.41(\text{MRW}) + 0.34(\text{MRW})^2 + 108.94$$

When,

$\text{VO}_{2\text{max}}$ was expressed in ml/kg/min.

Age was in years.

Sex was coded, 0=Female and 1=Male.

BMI was in kg/m^2 .

MRW (one-mile run/walk time) was in minutes.

The multiple correlation coefficient and standard error of estimation were 0.71 and 4.8 ml/kg/min.

This equation was based on a sample of 490 male and 263 female youth and young adults, 8-25 years of age tested at the University of Illinois and University of Georgia. Because of the curvilinear relation between MRW time and VO_{2max} , predicted VO_{2max} values for MRW times greater than 13 minutes were higher than those predicted for lower MRW times, which was unable to be explained physiologically. Therefore, MRW times greater than 13 minutes were not included for calculation in this study.

3.7.3.1 Criteria assessing health-related physical fitness

The Prudential FITNESSGRAM used criterion-referenced standard to assess the level of physical fitness. The standards had been established to represent a level of physical fitness that offered some degree of protection against diseases that resulted from sedentary living. In this study, the fitness performance was classified into two general areas: need improvement (NI), and healthy fitness zone (HFZ) (Appendix D).

3.7.3.2 Interpretation of physical fitness

The interpretation of physical fitness was done on both individual test item and combined test items. For each test item, the level of fitness in each component of physical fitness was presented in two levels, i.e. NI, and HFZ as described previously.

3.7.4 Cognitive performance

3.7.4.1 Criteria for interpreting the RPM scores

For the RPM test, the total scores of the RPM test were 60. The RPM score of each subject was converted to an equivalent IQ score of the Wechsler Adult Intelligence Scale (WAIS) (See Appendix J). Then, the IQ score was identified into

the intelligence categories, i.e. very superior, superior, bright normal, normal, dull normal, borderline of mental retardation, and mental retardation (See appendix D).

3.7.4.2 Criteria for interpreting the SAT scores

The raw scores of the SAT-V, SAT-N, and SAT-R tests of each student were converted to the normalized T-score using the statistical table for normalized T-score of the Psychological and Educational Test Bureau, Srinakharinwirot University. Finally, the cognitive abilities of each subject by T score was categorized according to the percentile rank as levels of abilities, i.e. excellent, good, fair, poor, and very poor, using the criteria developed by the Psychological and Educational Test Bureau, Srinakharinwirot University (Appendix D).

3.7.5 Dietary data

All food items from 24-h dietary recall were coded (127). Then, the amount of food consume in various units was converted to metric unit of weight, i.e. gram (g) (128). The levels of energy, carbohydrate, fat, protein, iron, vitamin C, calcium and phytate intake were calculated by using the INMUCAL PROGRAM version 3.0 (129). The amount of intake of each nutrient was compared to the Thai RDA, 1985 (130). All nutrient intakes including energy intake of each individual were considered adequate if the amount of intakes were $\geq 70\%$ of the Thai RDA (1985) for population at the same age and sex (130).

3.7.6 Maturational status

Maturational status of boys was classified into pre-adult-voice status and post-adult-voice status. Pre-adult-voice status was characterized if the boys did not have the adult voice. Conversely, the boys were in post-adult-voice status if they had adult voice already.

Maturational status of girls was classified in pre-menarcheal status and post-menarcheal status. Girls who did not attain the first menstruation were classified into pre-menarcheal status. If they had the first menstruation already, they were in post-menarcheal status.

3.7.7 Other essential data

In the analysis of socioeconomic data, health condition, and maturational status, all these indicators were analysed descriptively.

3.8 Statistical Analysis

The Statistical Packages for the Social Science or SPSS for Windows version 7.0 (The SPSS Inc. 1995) was used for the statistical testing and correlation analyses, which were performed separately for each sex. P-values were based on two-sided tests and a p-value of 0.05 and below was considered to be statistically significant.

The appropriate descriptive statistics of each variable in each sex were obtained and reported in mean $\pm$ standard deviation (SD). However, they were also reported in median and inter-quartile ranges (IQR) if they had high variation. All key variables were tested for normal distribution before further statistical analysis.

3.8.1 Tests for mean differences

For quantitative data, if data distributions were normal, the student's t-test and analysis of variance (ANOVA) methods were used for testing the differences between the mean values among the variables. If the distributions were not normal, the Mann-Whitney U test and Kruskal-wallis H test of non-parametric statistics were used.

For categorical data, the Chi-square test was used and the Fisher's exact test was done if the expected value was less than 5 in 2×2 tables.

3.8.2 Correlation analysis

A correlation analysis among variables was performed using correlation and multiple regression analyses. The relationship between two random variables was described by Pearson correlation analysis.

3.8.3 Multiple linear regression analysis

The method of multiple linear regression analysis was applied to determine the magnitude, direction, and strength of the relationships between several independent variables and a dependent variable in the students. The independent variables in this study were divided into three categories: iron status parameters, nutritional anthropometric variables, and demographic data. The dependent variables were categorized into the tests of health-related physical fitness and cognitive performance.

Before analysing the multiple regression, all variables were checked for skewness and kurtosis. Variables that were highly skewed were transformed to log (ln) in order to normalize them. Outliers of the key dependent variables were also detected. Extreme values (the five highest and the five lowest values) were omitted. For analysing factors explaining the dependent variables “enter method” was performed separately for each sex.

CHAPTER IV

RESULTS

4.1 Subject Characteristics

The subjects in this study were students attending M.1 to M.3 of three secondary schools in Nakhon Chaisri District. All of them lived in Nakhon Pathom Province, but in various districts. Most of them were Bhuddist (99.8%).

4.1.1 Age distribution of the subjects

The study subjects consisted of 586 students (311 males and 275 females). The age distribution of the subjects is shown in Table 4.1. The age distribution of male and female subjects was similar. The majority of the subjects (more than 90%) were above 13 years old, which is similar in both sexes (93.3% for males and 92.8% for females). Conversely, the subjects aged 12 years old were less than 10%, which were 6.8% and 7.3% for males and females, respectively. The mean age of the studied students was 14 years old (14.3 ± 0.9), 14.27 ± 0.88 for boys and 14.31 ± 0.94 for girls.

Table 4.1 Age distribution of male and female subjects.

Age (y)	n	Male		n	Female
			(%)		(%)
12.0-12.9	21		6.8	20	7.3
13.0-13.9	100		32.2	89	32.4
14.0-14.9	111		35.7	78	28.4
15.0-15.9	79		25.4	88	32.0
Total	311		100	275	100

4.1.2 Socioeconomic background of the subjects

Information on socioeconomic status of the subjects' families collected by a questionnaire included parents' educational level and occupation, family size, number of earning members in the families, total family income, and daily allowance of the students.

The majority of the parents had primary level education (68.2% and 75.0% for fathers and mothers, respectively), followed by secondary education (M.1-3) level (17.2% for fathers and 11.3% for mothers), and secondary education (M.4-6) level (5.9% and 2.1% for fathers and mothers, respectively). However, there were 6.6% of fathers and 10.7% of mothers that did not finish any levels of education from schools or institutes, as seen in Table 4.2. Overall, mothers of the students had less or lower education than fathers.

Table 4.2 The highest educational levels of subjects' parents.

Educational level	Father (%) (n = 575)	Mother (%) (n = 577)
No schooling	6.6	10.7
Primary school	68.2	75.0
Secondary school (M.1-3)	17.2	11.3
Secondary school (M.4-6)	5.9	2.1
Vocational education	1.9	0.9
University level	0.2	0

Table 4.3 shows the frequency of occupation of the subjects' parents. The common occupations of fathers were farmer (28.2%), followed by daily wage earner

(23.4%), salary earner (22.2%), and a trader (13.8%). As well as father's occupation, farmer (24.1%), salary earner (23.5%), daily wage earner (21.7%), and trader (19.1%) were found to be common occupations of mothers.

Table 4.3 The occupation of the subjects' parents.

Types of occupation	Father (%) (n = 499)	Mother (%) (n = 540)
Farmer	28.3	24.1
Trader	13.8	19.1
Government employee	6.8	1.9
Salary earner	22.2	23.5
Daily wage earner	23.4	21.7
Unemployed	1.4	1.5
No occupation ¹	2.8	7.2
Personal business	1.2	1.1

¹ Including housewife (for mother)

Table 4.4 shows the family income of the subjects. There is no difference in the income of the family of male and female students. The majority of the subjects' families of both sexes (60.9%) had income below 10,000 baht/month, which was less than 350 baht/day.

Most students (88.1%) received their daily allowance from their fathers and/or mothers. The average of daily allowance was 32.1 ± 12.5 baht/day (varied from 10 to 120 baht). The average total expenses at school was 28.8 ± 11.5 baht/day (varied from

4 to 100 baht). The money was spent for lunch (14.1 ± 7.1 baht), drinks and desserts (8.7 ± 6.0 baht), and transportation (5.5 ± 5.8 baht).

Table 4.4 Distribution of the subjects' family income.

Family income (Baht / month)	Male (%) (n = 294)	Female (%) (n = 263)	Both sexes (%) (n = 557)
< 10,000	63.3	58.2	60.9
10,000-19,999	21.8	29.7	25.5
20,000-29,999	4.4	4.9	4.7
30,000-49,999	3.7	2.7	3.2
>50,000	6.1	3.4	4.8
Uncertainty	0.7	1.1	0.9

The average number of family size was 5.6 ± 2.4 persons (range from 2 to 24). The average number of earning member in the families was 2.4 ± 1.3 persons (range from 1 to 10). Dependency ratio of the family, which was the ratio of the number of the children aged below 15 years plus the number of the elderly aged above 60 years to the number of members aged 15-59 years, was calculated. The ratio obtained ranged from 0 to 4.0. Thirty six families (6 %) having zero ratio due to having no children aged < 15 y and the elderly > 60 y, whereas three families (0.5%) had only children and the older persons. About 15% of the students' family had dependency ratio >1.0.

4.1.3 Health condition

Approximately 50 % of the students (51.6 % for males and 54.6 % for females) reported being ill during the past 6 months. Most of the students (81.0 % for males and

83.8 % for females) had common cold. About 20 – 30 % of students had diarrhoea, as seen in Table 4.5.

Table 4.5 Percentages of the subjects reported being ill during the past six months.

Health status	n	Yes (%)
School absent due to illness		
Male	308	51.6
Female	269	54.6
Total	577	53.0
Common cold		
Male	306	81.0
Female	271	83.8
Total	577	82.3
Diarrhoea		
Male	307	30.3
Female	270	22.6
Total	577	26.7

4.2 Maturational Status

4.2.1 Age of menarche

Table 4.6 shows the maturational status of the female subjects. 90% of students were able to recall the first menstruation. Most of the female students (88.9%) were already in the post-menarcheal period since they had started menstruating. The

percentage of post-menarcheal subjects increased with increasing age. The average age of menarche was 12.4 ± 1.1 years (median = 12.3, IQR = 1.3 years). The response rate was very high (98.2%, which only 5 male students missed to complete maturational data).

Table 4.6 Maturational status of female students.

Age (y)	n	Response (%)	Pre-menarcheal (%) (n = 30)	Post-menarcheal (%) (n = 240)
12.0-12.9	20	100	30.0	70.0
13.0-13.9	89	96.6	19.8	80.2
14.0-14.9	78	100	7.7	92.3
15.0-15.9	88	97.3	1.2	98.8
Total	275	98.2	11.1	88.9

4.2.2 Voice change (male students)

The attainment of adult voice of male students is shown in Table 4.7. Almost two-thirds of male students (60.4%) were in the post-adult-voice stage. The percentage of post-adult-voice also increased with age.

The average age at voice change onset of male subjects was 13.3 ± 1.1 years (median = 13.2, IQR = 1.7 years), which was significantly different from the average age at menstruation onset of female subjects ($p = 0.0001$).

Table 4.7 Maturational status of male students.

Age (y)	n	Response (%)	Pre-adult-voice (%) (n = 84)	Post-adult-voice (%) (n = 128)
12.0-12.9	21	84.7	72.2	27.8
13.0-13.9	100	80.0	52.5	47.5
14.0-14.9	111	72.1	26.3	73.8
15.0-15.9	79	42.5	23.5	76.5
Total	311	68.2	39.6	60.4

4.3 Iron Status

It was found that male students were in better iron status than females. The average values of all three parameters of iron status i.e. haemoglobin (Hb), packed cell volume (PCV), and serum ferritin (SF) of male students were observed to be significantly higher than that of females (Table 4.8). Moreover, the mean cell haemoglobin concentration (MCHC), which is an index of hypochromic anaemia if the value is low (< 300 g/L), was also determined. None of the students had the MCHC values below normal (range from 302.7 g/L to 398.5 g/L).

Table 4.8 Haematological findings¹ of the students.

Parameter	Male ² (n = 294)	Female ² (n = 264)
Haemoglobin (g/dL)	14.2 ± 0.9 ^a	13.7 ± 0.9 ^a
Packed cell volume (%)	43.1 ± 2.7 ^a	41.1 ± 2.9 ^a
MCHC (g/L)	330.8 ± 5.4 ^a	332.3 ± 6.6 ^a
Serum ferritin ² (µg/L)	57.14 ^b (34.28 – 96.18)	48.72 ^b (25.89 – 91.68)

^a Mean comparisons are made between males and females: $p = .0001$

^b Mean comparisons are made between males and females: $p = .024$

¹ Mostly expressed as mean ± SD

² Expressed as geometric mean = GM (GM-SD – GM+SD)

4.3.1 Prevalence of low iron status by single haematological parameter

The anaemia prevalence of males by Hb was two times higher than that of females (3.1 % and 1.5 % for males and females, respectively). The prevalence of anaemia of males by PCV was slightly higher than the prevalence of females as well. (2.0 % for males compared to 1.5 % for females, Table 4.9).

Table 4.10 shows the prevalence of low serum ferritin in the sub-sample by using two cut-off values. The prevalence of low serum ferritin, which indicated iron deficient stores (<10 or 12 µg/L depending on age), in the students was very low (< 1%). In a population which infection is likely to be predominant, the cut-off value of SF <30 µg/L was recommended for assessing iron status (117-118). By this cut-off, overall prevalence was 14.8 %. The overall prevalence of low ferritin in males was lower than that of females (12.4 vs. 17.4 %).

Table 4.9 Prevalence of anaemia of male and female students.

Age (y)	n	Prevalence of anaemia (%) Hb ¹	PCV ²
Male			
12.0-12.9	21	0	0
13.0-13.9	96	2.1	2.1
14.0-14.9	105	4.8	2.9
15.0-15.9	72	2.8	1.4
<i>Total</i>	<i>294</i>	<i>3.1</i>	<i>2.0</i>
Female			
12.0-12.9	21	0	0
13.0-13.9	83	0	0
14.0-14.9	77	2.6	2.6
15.0-15.9	83	2.4	2.3
<i>Total</i>	<i>264</i>	<i>1.5</i>	<i>1.5</i>

¹ Criteria for anaemia: Hb < 12.0 g/dL for males and females, aged 12-13 years and for females, aged > 13 years; and Hb < 13.0 g/dL for males, aged >13 years (2).

² Criteria for anaemia: PCV < 36% for males and females, aged 12-13 years and for females, aged > 13 year: PCV < 39 % for males, aged >13 years (2).

Table 4.10 Prevalence of low serum ferritin of the students

Student	n	Category A ¹ (%)	Category B ² (%)
Male	145	0 ³	12.4 ⁴
Female	132	1.5 ³	17.4 ⁴
Total	277	0.7	14.8

¹ Category A: Criteria for low serum ferritin = < 10 µg/L and < 12 µg/L in the students at 12-14-y of age and at 15 y of age, respectively, (61).

² Category B: Criteria for low serum ferritin = < 30 µg/L in all age groups suggesting for subjects in an infection-predominant area (117-118).

³ $\chi^2 = 2.213$, df = 1, p-value = 0.226

⁴ $\chi^2 = 1.376$, df = 1, p-value = 0.241

4.3.2 Prevalence of low iron status by multiple haematological parameters

The prevalence of iron depletion (ID), iron deficiency anaemia (IDA), and anaemia of unidentified causes are shown in Table 4.11.

Table 4.11 Prevalence of iron depletion (ID)¹, iron deficiency anaemia (IDA)², and anaemia³ of the students.

Iron status	Prevalence (%)	
	Male (n = 145)	Female (n = 132)
Iron depletion ⁴	12.4	15.1
Iron deficiency anaemia	0	2.3
Anaemia (unidentified causes)	6.2	0.8
Normal	81.4	81.8

¹ Iron depletion (ID): Hb is normal whereas SF is below the cut-off value (< 30 µg/L).

² Iron deficiency anaemia (IDA): Both Hb and SF levels are below the cut-off values.

³ Anaemia: Only Hb level is below the cut-off value (see Table 4.9 for the cut-off values of Hb).

⁴ $\chi^2 = 0.438$, df = 1, p-value = 0.508

When both hemoglobin and ferritin were examined together, only 2.3% were confirmed to be IDA, while 15.1% of females had only iron depletion. 6.2% of males also had anemia, which was not verifiable to be due to iron deficiency.

4.4 Nutritional Status

4.4.1 Anthropometry and body composition

Anthropometric data of the students are presented in Table 4.12. The mean weight of males (median = 44.5, IQR = 13.0 kg) was less than that of females (median = 46.0, IQR = 9.5 kg) but not significantly different. Height was significantly higher in males than in females ($p = 0.0001$). Male students had lower mean BMI than females and the difference was statistically significant ($p = 0.0001$).

There were significant differences in the mean TSK and CSK between males and females ($p = 0.0001$). Similarly, male students had significantly less body fat (BF) than females ($p = 0.0001$). The amount of BF of male was about one-half of that of females (median = 10.85, IQR = 4.49 % for males compared to median = 20.74, IQR = 7.74 % for females).

In contrast, fat-free mass (FFM) and total muscle mass (TMM) was significantly higher in males than females. The average MAC values of male students were significantly lower than that of females ($p = 0.002$). The calculated arm-muscle circumference (AMC) of males was significantly higher than that of females ($p = 0.0001$).

Table 4.12 Anthropometric data of the students.

Parameter*	Male (n = 311)	Female (n = 271)
Body weight (kg)	46.4 ± 11.6	47.0 ± 8.8
Height (cm)	157.7 ± 9.4 ^a	154.6 ± 5.7 ^a
BMI (kg/m ²)	18.5 ± 3.4 ^c	19.6 ± 3.2 ^c
Triceps skinfold thickness (mm)	8.3 ± 5.0 ^c	14.3 ± 5.1 ^c
Calf skinfold thickness (mm)	8.3 ± 5.1 ^c	13.5 ± 5.4 ^c
Body fat (%)	13.2 ± 7.3 ^c	22.0 ± 6.2 ^c
Total body fat (kg)	6.7 ± 6.2 ^c	10.8 ± 5.4 ^c
Mid-arm circumference (cm)	22.9 ± 3.6 ^d	23.4 ± 2.8 ^d
Arm-muscle circumference (cm)	20.3 ± 2.7 ^a	18.9 ± 1.7 ^a
Total muscle mass (kg)	14.9 ± 4.6 ^b	14.0 ± 2.5 ^b
Fat-free mass (kg)	39.7 ± 7.6 ^a	36.2 ± 4.4 ^a

* By one-sample Kolmogorov-Smirnov test, students' t test was used if normal distribution was obtained, and non-parametric Mann-Whitney U test was used if the distribution was non-normal.

^a Mean comparisons were made between males and females of the same variable by students' t test : p = 0.0001.

^b Mean comparisons were made between males and females of the same variable by students' t test : p = 0.002.

^c Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = 0.0001.

^d Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = 0.002.

4.4.2 Nutritional status by three anthropometric indicators

The calculation of nutritional status was based on both Thai (1987) and NCHS references. The Z-scores (or SD-scores) of weight for age and height for age, which were calculated based on NCHS reference, were presented in Figure 4.1 and Figure 4.2, respectively.

The mean Z-scores of weight for age for males (-0.84 ± 1.17) was significantly lower than that of females (-0.59 ± 0.92) ($p = 0.0001$). In contrast, the mean Z-scores of height for age between males and females were not significantly different (Table 4.13).

Table 4.13 The mean Z-scores of weight-for-age and height-for-age of male and female students¹.

Students	Male (n = 311)	Female (n = 271)	Total (n = 582)
Weight-for-age	-0.84 ± 1.17^a	-0.59 ± 0.92^a	-0.72 ± 1.06
Height-for-age	-0.83 ± 0.96	-0.85 ± 0.83	-0.84 ± 0.90

¹ Calculated based on the NCHS reference.

^a Difference between males and females of the same variables was made by non-parametric Mann-Whitney U test due to non-normal distribution of the variable : $p = .0001$.

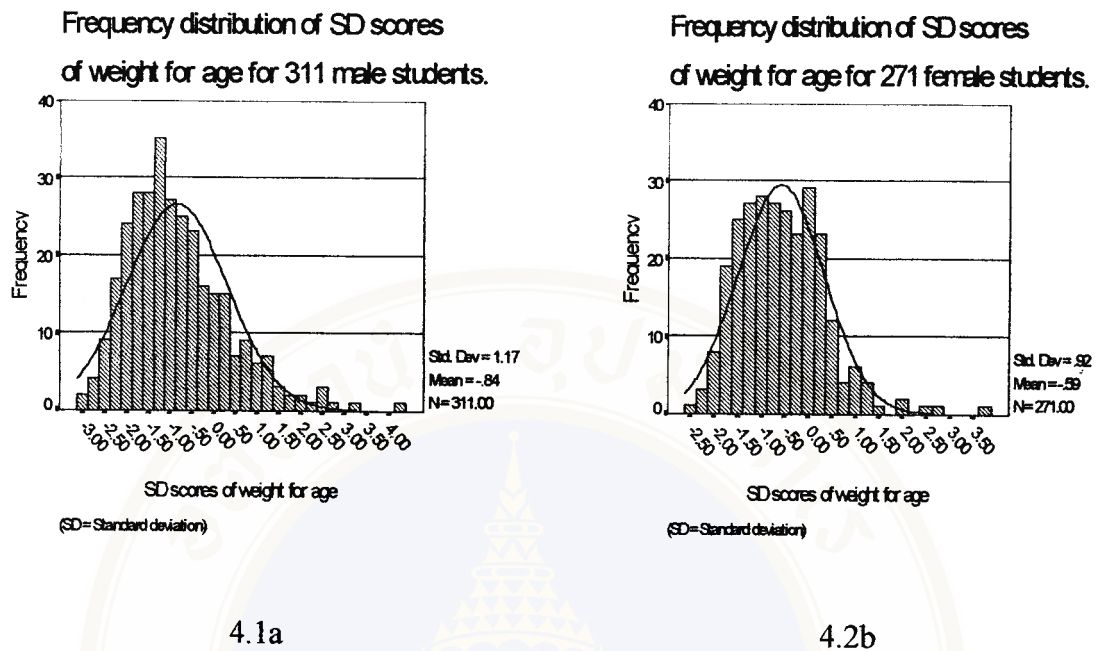


Figure 4.1 Frequency distribution of Z-scores (or SD scores) of weight for age of male students (4.1a) and female students (4.2b).

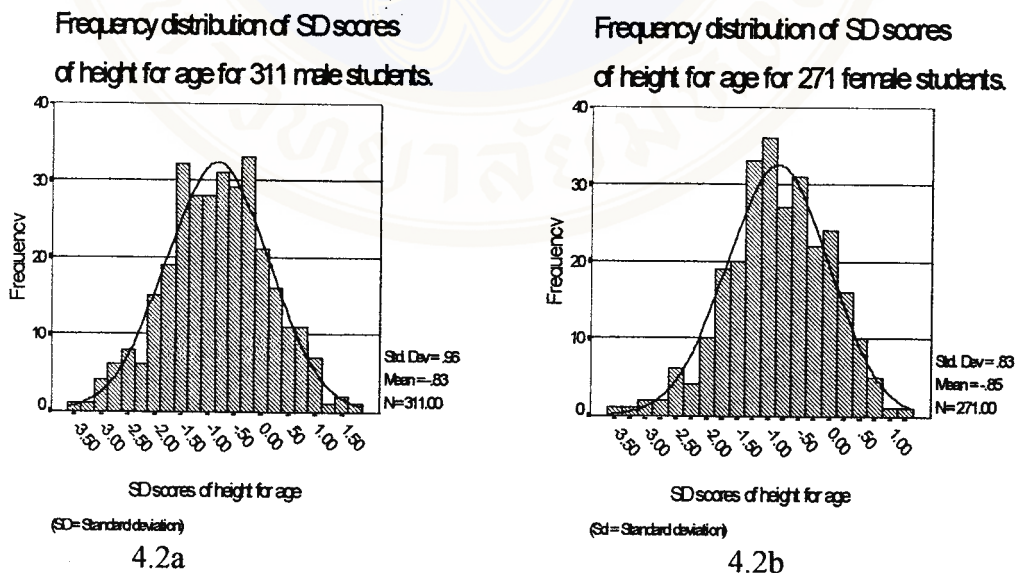


Figure 4.2 Frequency distribution of Z-scores (or SD-scores) of height for age for male students (4.2a) and female students (4.2b).

4.4.3 Prevalence of malnutrition by Thai reference

The prevalence of undernutrition of the students using weight-for-age, height-for-age and weight-for-height by Thai reference was rather low (not more than 10%) in this studied group. Males appeared to be slightly more underweight, stunted and wasted than females (Table 4.14).

The prevalence of overweight (weight-for-height > 97th percentile) was not high for both sexes (9.6% for males and 7.7% for females)

Table 4.14 Nutritional status of the students using three anthropometric indicators, based on Thai reference.

Nutritional status	Male (%)	Female (%)	Combined sexes ⁵ (%)
Weight-for-age			
Underweight ¹	6.1	4.8	5.5
Normal	93.9	95.2	94.5
	χ^2 test = 0.500,	p = 0.779	
Height-for-age			
Stunning ²	7.1	5.9	6.5
Normal	92.9	94.1	93.5
	χ^2 test = 0.326,	p = 0.569	
Weight-for-height			
Wasted ³	5.5	5.2	5.3
Normal	84.9	87.1	85.9
Overweight ⁴	9.6	7.7	8.8
	χ^2 test = 0.707,	p = 0.569	

¹ Underweight = Weight-for-age < 10th percentile of Thai reference (1987).

² Stunting = Height-for-age < the 10th percentile of Thai reference (1987).

³ Wasted = Weight-for-height < 3rd percentile of Thai reference (1987).

⁴ Overweight = Weight-for-height > 97th percentile of Thai reference (1987).

4.4.4 Prevalence of malnutrition by NCHS reference

When using weight-for-age and height-for-age as indicators using the NCHS reference, the prevalence of underweight and stunting of males (Table 4.15) was higher than that of females (13.2% vs. 2.2% for underweight and 10.9% vs. 7.7% for stunting).

Table 4.15 Nutritional status of the students using weight-for-age and height-for-age as indicators, based on NCHS reference.

Nutritional status	Male (%)	Female (%)	Combined sexes (%)
Weight-for-age			
Underweight ¹	13.2	2.2	8.1
Normal	86.8	97.8	91.9
	χ^2 test = 23.472, p = 0.0001		
Height-for-age			
Stunting ²	10.9	7.7	9.5
Normal	89.1	92.3	90.5
	χ^2 test = 1.715, p = 0.190		

¹ Underweight = Weight-for-age < - 2SD of the NCHS reference.

² Stunting = Height-for-age < -2 SD of the NCHS reference.

Comparing between two references, the prevalence of underweight of male students using NCHS reference was markedly higher than that using Thai reference (6.1 % vs .13.2 %,). The prevalence of stunting in both males and females was also increased when using NCHS (7.1 % for males and 5.9 % for females) comparing to Thai reference (10.9 % for males and 7.7 % for females), as shown in Figure 4.3-4.4.

Using BMI-for-age, the prevalence of thinness in boys was about four times that of girls (21.2 % vs. 5.2 %) (Table 4.16).

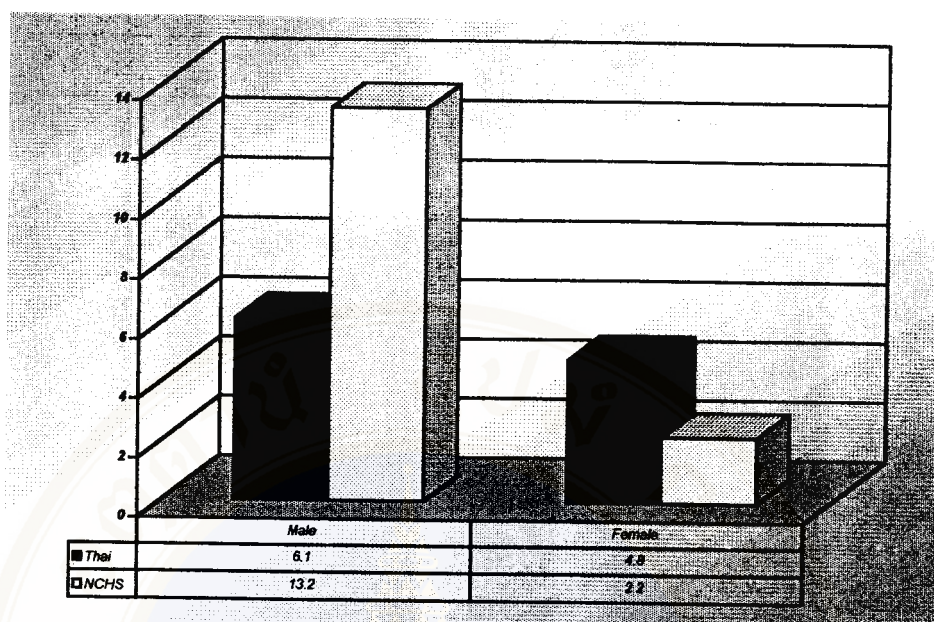


Figure 4.3 Prevalence of underweight of male and female students comparing between Thai and NCHS references.

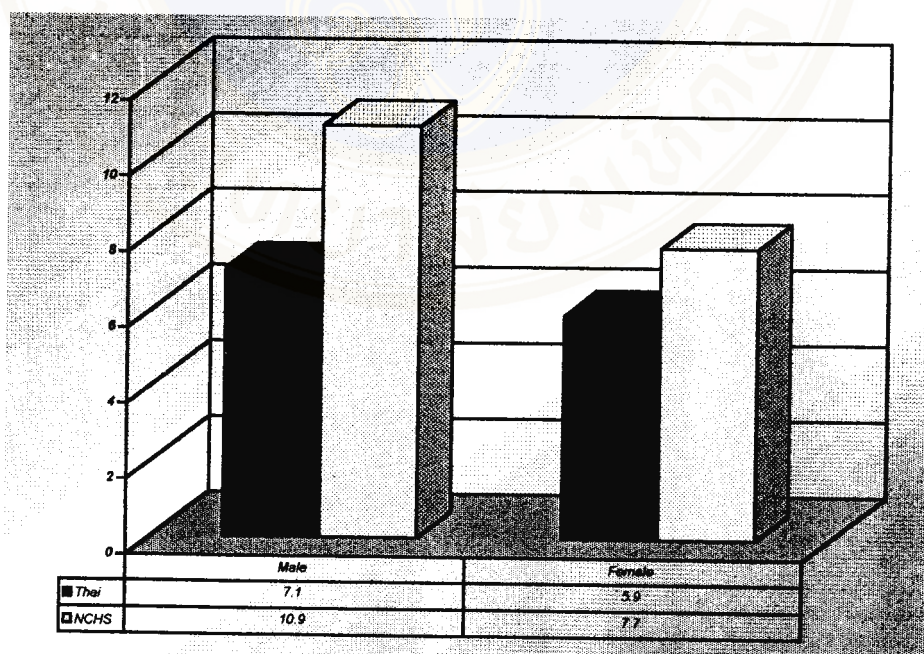


Figure 4.4 Prevalence of stunting of male and female students comparing between Thai and NCHS references.

Table 4.16 Nutritional status of the students using BMI-for-age as an indicator, based on WHO criteria.

Nutritional status	Male (%)	Female (%)	Combined sexes (%)
BMI-for-age			
Thinness ¹	21.2	5.2	13.7
Normal	68.8	86.3	77.0
At risk of overweight ²	10.0	8.5	9.3
χ^2 test = 33.286, p = 0.0001			

¹ Thinness = BMI-for-age < 5th percentile of the NCHS reference.

² Overweight = BMI-for-age $\geq$ 85th percentile of NCHS reference.

4.5 Dietary Intake

Data on dietary intake of the subjects were collected in a sub-sample based on a one-day 24-h-recall method. The average intake levels of several nutrients including energy, fat, protein, iron, calcium, vitamin A, vitamin C, and non-nutrient, i.e. phytate were calculated.

4.5.1 Macronutrient intakes

4.5.1.1 Energy and protein intakes

Table 4.17 showed that the mean of energy and various nutrient intakes of the students. The mean energy intake was significantly higher in males than in females ($p = 0.0001$). The median values were 1880 kcal/d (IQR = 760 kcal/d) for males and were 1479 kcal/d (IQR = 603 kcal/d) for females.

The mean level of protein intake was also significantly higher in males than in females (median = 64.1, IQR = 36.8 g/d for males and 51.5, IQR = 26.8 g/d for females). Males consumed more energy and protein than females ($p = 0.0001$).

Table 4.17 The energy and nutrient intakes of the students.

Nutrient intake*	Male (n = 206)		Female (n = 202)	
	Amount/day	% RDA	Amount/day	% RDA
Energy intake(kcal)	1934 ± 634 ^a	85.6 ± 28.8 ^d	1527 ± 512 ^a	77.4 ± 25.9 ^d
Protein intake(g/d)	70.8 ± 28.1 ^b	146.7 ± 63.1 ^b	55.3 ± 13.6 ^b	115.6 ± 49.3 ^b
Iron (mg/d)	14.0 ± 7.5 ^b	116.5 ± 62.6 ^b	11.0 ± 6.4 ^b	73.5 ± 42.4 ^b
Calcium (mg/d)	442.3 ± 396.8 ^c	36.9 ± 33.1 ^c	342.0 ± 272.6 ^c	28.5 ± 22.7 ^c
Vitamin A (µg-RE/d)	442.0 ± 772.4 ^c	64.7 ± 120.0	352.0 ± 560.6 ^c	58.7 ± 93.4
Vitamin C ¹ (mg/d)	136.7 ± 176.5	230.2 ± 296.1	112.9 ± 166.2	190.3 ± 279.6
Phytate ² (mg/d)	130.8 ± 197.7		99.3 ± 157.2	

* By one-sample Kolmogorov-Smirnov test, students' t test was used if normal distribution was obtained, and non-parametric Mann-Whitney U test was used if the distribution was non-normal.

^a Mean comparisons were made between males and females of the same variable by parametric students' t test : $p = 0.0001$.

^b Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : $p = 0.0001$.

^c Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : $p = 0.005$.

^d Mean comparisons were made between males and females of the same variable by parametric students' t test : $p = 0.002$.

¹ n = 202 for males and = 200 for females.

² n = 159 for males and = 140 for females.

The sources of dietary protein intake are shown in Table 4.18. Both males and females received more protein from animal sources than vegetable sources. The

average amount of animal protein intake was about two-thirds of total intake and about one-third of protein intake came from vegetable sources.

The average amount of protein intake from animal source (Table 4.18) of males was significantly higher than that of females (median = 40.7, IQR = 30.1 g/d and 34.6, IQR = 25.1 g/d for males and females, respectively). But, the median proportion of animal protein intake was similar between males and females (median = 66.1, IQR = 17.1 % and median = 66.5, IQR = 18.8 % for males and female, respectively).

Table 4.18 The quantity of protein intake from different sources.

Protein source	Male (n = 206)		Female (n = 202)	
	(g/d)	(% of total protein)	(g/d)	(% of total protein)
Animal	46.3 ± 23.0 ^a	63.8 ± 11.8	37.3 ± 20.1 ^a	64.9 ± 13.5
Vegetable	24.4 ± 10.4 ^a	36.1 ± 11.8	18.0 ± 7.8 ^a	35.1 ± 13.4

^a Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = 0.0001.

4.5.1.2 Caloric distribution

The caloric distribution of energy is shown in Table 4.19. The caloric distribution of CHO: fat: protein was approximately 60:25:15.

Table 4.19 The proportion of macronutrient intakes of the students.

Macronutrient	Male n = 206	Female n = 202
Carbohydrate (%)	61.7 ± 8.2	60.9 ± 9.6
Fat (%)	23.5 ± 7.3	24.5 ± 8.5
Protein (%)	14.8 ± 3.3	14.6 ± 3.8

4.5.2 Micronutrient intakes

Among various micronutrients, the intake levels of iron, calcium, vitamin A, vitamin C and including an iron-inhibitor factor i.e. phytate were reported as shown in Table 4.17. The intake levels were significant higher in males than in females except vitamin C and phytate.

Table 4.20 presents the sources of dietary iron intake. Approximately 40% of iron intake came from animal source, and about 60% came from vegetable source.

Table 4.20 The quantity of iron intake from different sources.

Iron source	Male (n = 206)		Female (n = 202)	
	(mg/d)	(% of total iron)	(mg/d)	(% of total iron)
Animal	6.1 ± 5.0 ^a	41.3 ± 19.1	5.0 ± 4.1 ^a	43.4 ± 20.3
Vegetable	7.9 ± 4.8 ^b	58.7 ± 19.1	6.1 ± 4.5 ^b	56.6 ± 20.3

^a Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = 0.009.

^b Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = 0.0001.

4.5.3 Levels of energy and nutrient intakes

Compared with the Thai Recommended Dietary Allowance (RDA) (1987), the levels of energy and nutrient intakes below 70 % of Thai RDA was calculated and defined as having low intakes. Table 4.21 shows the percentage of the subjects classified according to level of nutrient intake. Over 50% of the students were in adequate level of energy, protein, iron and vitamin C intakes, and the proportions of students with adequate levels of energy and all nutrients except vitamin A and C were significantly higher in males than in females.

Table 4.21 Percentages of male and female students classified according to nutrient-intake levels.

Nutrient	n	Low intake (%)	Adequate intake (%)	χ^2 test
Energy intake ¹ (kcal/d)				$\chi^2 = 6.931, p = 0.01$
Male	206	29.1	70.9	
Female	202	41.6	58.4	
Total	408	35.3	64.7	
Protein intake (g/d)				$\chi^2 = 11.394, p = 0.001$
Male	206	3.4	96.6	
Female	202	12.4	87.6	
Total	408	7.8	92.2	
Iron intake (mg/d)				$\chi^2 = 50.75, p = 0.0001$
Male	206	23.3	76.7	
Female	202	57.9	42.1	
Total	408	40.4	59.6	
Vitamin C intake (mg/d)				$\chi^2 = 0.634, p = \text{NS}$
Male	202	47.0	53.0	
Female	200	51.0	49.0	
Total	402	49.0	51.0	
Calcium intake (mg/d)				$\chi^2 = 7.102, p = 0.01$
Male	206	88.3	11.7	
Female	202	95.5	4.5	
Total	408	91.9	8.1	
Vitamin A intake($\mu\text{g-RE/d}$)				$\chi^2 = 0.810, p = \text{NS}$
Male	206	78.6	21.4	
Female	202	82.2	17.8	
Total	408	80.4	19.6	

Conversely, over 20 % of the total subjects had low calcium intakes, and vitamin A, especially more than 90 % having low calcium intake. About 95% of female students had low calcium intake, which is significantly higher than males (Table 4.21).

4.6 Health-Related Physical Fitness

Table 4.22 showed the comparisons of health-related physical fitness between male and female students.

Table 4.22 Health-related physical fitness data of the students.

Parameter*	Male	Female
MRW (min)	10.2 ± 1.7 ^a	13.0 ± 1.7 ^a
Calculated VO _{2max} (ml/kg/min)	46.9 ± 4.1 ^b	40.9 ± 3.9 ^b
Curl-up test (# completed)	32.3 ± 12.9 ^a	22.1 ± 10.2 ^a
Pull-up test (# completed)	17.9 ± 6.4 ^a	8.2 ± 4.0 ^a
Trunk-lift test (inch)	9.9 ± 1.9	9.6 ± 1.8
Sit-reach test (inch)	11.5 ± 2.1	11.8 ± 2.3

* By one-sample Kolmogorov-Smirnov test, students' t test was used if normal distribution was obtained, and non-parametric Mann-Whitney U test was used if the distribution was non-normal.

^a Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = .0001.

^b Mean comparisons were made between males and females of the same variable by parametric students' t test : p = .0001.

When considering as a group, male students were found to be fitter than females in one-mile run/walk test, calculated VO_{2max}, the curl-up test, and the modified pull-up tests. This was due to the significant higher mean values of the parameters in each test

of males than females. But, there was no significant difference in the trunk-lift test and flexibility test.

4.6.1 The aerobic capacity by MRW

Table 4.23 presents the percentages of the students in various levels of health-related physical fitness.

When using MRW as an indicator of physical fitness, nearly 60 % of the male students and almost 90 % of female students were in the Need Improvement (NI) level, as shown in Table 4.23. The percentage of male students in healthy fitness zone (HFZ) was significant more than that of females (41.3 % and 12.1 % for males and females, respectively) ($p = 0.0001$).

The percentages of females in NI level increased with increasing age (from 66.7, 83.1, 87.0 and 98.8 % at the ages of 12, 13, 14 and 15 years, respectively). In contrast to male students, very high percentage in the 12-year-old group fills in NI level (85.0 %). However, an increased percentage of NI with ages in males was still observed after this age, being from 47.5, 55.0 and 72.0 % at the ages of 13, 14 and 15 years, respectively (Table 4.23).

4.6.2 Muscle strength, endurance and flexibility

The results of the tests of the muscle strength, endurance and flexibility are shown in Table 4.23.

For the curl-up test, the percentages of the students in NI and HFZ levels were significantly higher in males than in females. Comparing among age groups in each sex, no significant differences in these proportions were found.

Table 4.23 Percentages of the students classified according to physical fitness levels¹ by the Prudential FITNESSGRAM test.

Age (y)	Aerobic capacity MRW test ²			Abdominal strength/endurance Curl-up test ³			Upper-body strength/endurance Pull-up test ⁴			Trunk-extensor strength/flexibility Trunk-lift test ⁵			Hamstring flexibility Sit-reach test ⁶		
	n	NI(%)	HF(%)	n	NI(%)	HF(%)	n	NI(%)	HF(%)	n	NI(%)	HF(%)	n	Fail(%)	Pass(%)
Male															
12.0 – 12.9	20	85.0	15.0	21	23.8	76.2	21	19.0	81.0	21	28.6	71.4	21	4.8	95.2
13.0 – 13.9	99	47.5	52.5	99	27.3	72.7	99	6.1	93.9	99	30.3	69.7	99	6.1	93.9
14.0 – 14.9	109	55.0	45.0	109	20.2	79.8	109	3.7	96.3	110	26.4	73.6	110	4.5	95.5
15.0 – 15.9	75	72.0	28.0	78	32.1	67.9	76	1.3	98.7	78	24.4	75.6	78	2.6	97.4
Total	303	58.7	41.3	307	25.7	74.3	305	4.9	95.1	308	27.3	72.7	308	4.5	95.5
	$\chi^2 = 16.93, df = 3$ p = 0.001			$\chi^2 = 3.549, df = 3$ p = NS			$\chi^2 = 11.714, df = 3$ p = 0.008			$\chi^2 = 0.856, df = 3$ p = NS			$\chi^2 = 1.232, df = 3$ p = NS		
Female															
12.0 – 12.9	21	66.7	33.3	21	42.9	57.1	21	14.3	85.7	21	47.6	52.4	21	9.5	90.5
13.0 – 13.9	83	83.1	16.9	86	27.9	72.1	86	17.4	82.6	86	40.7	59.3	86	31.4	68.6
14.0 – 14.9	77	87.0	13.0	78	41.0	59.0	78	10.3	89.7	78	41.0	59.0	78	12.8	87.2
15.0 – 15.9	84	98.8	1.2	86	32.6	67.4	86	5.8	94.2	86	33.7	66.3	86	36.0	64.0
Total	265	87.9	12.1	271	34.3	65.7	271	11.4	88.6	271	39.1	60.9	271	25.8	74.2
	$\chi^2 = 20.167, df = 3$ p = 0.0001			$\chi^2 = 3.923, df = 3$ p = NS			$\chi^2 = 6.021, df = 3$ p = NS			$\chi^2 = 1.898, df = 3$ p = NS			$\chi^2 = 15.881, df = 3$ p = 0.001		

¹ NI = Need improvement, HF = Healthy fitness. See also Appendix J for criteria.

² $\chi^2 = 61.988, df = 1, p = 0.0001$ ³ $\chi^2 = 5.075, df = 1, p = 0.024$ ⁴ $\chi^2 = 8.304, df = 1, p = 0.004$ ⁵ $\chi^2 = 9.169, df = 1, p = 0.002$ ⁶ $\chi^2 = 52.657, df = 1, p = 0.0001$

Similar to the curl-up test, the percentages of the male students in NI level and HFZ level of the modified pull-up test was significantly higher than that of females. These results indicate that males might have stronger muscles compared to the females. Age had significant influence on the MRW test only in males, but not in females.

In addition, the results of trunk-lift and flexibility tests showed no significant differences among age groups in both males and females except for flexibility test of female students (Table 4.23).

4.6.2.1 Abdominal strength and endurance

The levels of physical fitness by abdominal strength and endurance are shown in Table 4.23.

Approximately a quarter of male (25.7 %) and one third of female (34.3 %) students had to improve abdominal muscle strength. Male students approximately had stronger abdominal muscle than female, since about three quarters of males (74.3 %) and two thirds of females (65.7 %) were in the HFZ and >HFZ, as shown in Table 4.23.

4.6.2.2 Upper-body strength and endurance

The physical fitness level by the modified pull-up test is shown in Table 4.23. Only a small proportion of the students (4.9 % males and 11.4 % females) were in the NI category as measured by upper body muscle strength and endurance. The majority of the students were in the HFZ (95.1 % for males and 88.6 % for females).

4.6.2.3 Trunk extensor strength and flexibility

The levels of physical fitness by trunk-lift test are shown in Table 4.23. About 27 % of boys and 39 % of girls were classified as NI by their trunk extensor strength and

flexibility, whereas over 60 % (72.7 % of males and 60.9 % of females) were in the HFZ.

4.6.2.4 Flexibility

Table 4.23 shows the flexibility levels by the sit-and-reach test of the students. The results of the flexibility of males and females were quite contrasted. The majority of the subjects (95.5 % for males and 74.2 % for females) passed the flexibility tests. However, the percentage of females that failed the flexibility test was seven times higher than males (4.5 % for males and 25.8 % for females). Male students were generally fitter in flexibility than females.

4.7 Cognitive Performance

The intelligence, which referred to mental abilities of the student individuals, was measured by various tests, namely, the Raven's Progressive Matrices (RPM) and the scholastic aptitude test (SAT) which includes three aspects (verbal, numerical and reasoning). A correlation analysis among these tests yielded a moderate correlation, as shown in Table 4.24.

Table 4.24 The Pearson correlation coefficients (r) between intelligence tests.

Cognitive test	RPM	SAT-V	SAT-N	SAT-R
RPM test	1.00			
Verbal aptitude test (SAT-V)	0.37 ^a	1.00		
Numerical aptitude test (SAT-N)	0.51 ^a	0.47 ^a	1.00	
Reasoning aptitude test (SAT-R)	0.46 ^a	0.50 ^a	0.52 ^a	1.00
n	549	554	554	554

^a p = 0.0001

4.7.1 Intelligence level by the RPM test

The Raven's Progressive Matrices (RPM), which had a minimal language involvement, was used to measure the general intelligence of the students. Table 4.25 shows the RPM scores of male and female students. No significant difference between males and females was observed in both mean RPM and IQ scores derived from RPM.

Table 4.25 The cognitive test scores of male and female students by RPM test.

Cognitive test	Male (n = 308)	Female (n = 272)
RPM score	40.4 ± 8.0	41.0 ± 7.3
IQ score ¹	102.4 ± 8.5	103.0 ± 7.7

¹ Derived from RPM score

Only the intelligence quotient (IQ) derived from RPM scores were presented due to being a well-known index of intelligence and easily understood. The intelligence levels of the students by IQ scores were shown in Table 4.26.

The distributions of the students classified according to the intelligence levels of both males and females were quite similar. As expected, most students had normal intelligence level (73.7 % and 75.7 % for males and females, respectively). None of the students had superior intelligence. About 17 % of the students had bright intelligence (17.5 % for males and 17.3 % for females). However, about 6.5 % were classified to be dull, and 2.3 % of males and 0.7 % of females were in borderline of mental retardation.

Table 4.26 Percentages of male and female students classified according to intelligence levels¹ or IQ scores.

Age (y)	n	Bright (%)	Normal (%)	Dull (%)	Borderline of mental retardation (%)
Males					
12.0 – 12.9	21	0	71.4	23.8	4.8
13.0 – 13.9	99	9.1	79.8	8.1	3.0
14.0 – 14.9	111	25.2	68.5	3.6	2.7
15.0 – 15.9	77	22.1	74.0	3.9	0
<i>Total</i>	308	17.5	73.7	6.5	2.3
$\chi^2 = 28.259$, df = 9, p = 0.001					
Females					
12.0 – 12.9	21	14.3	76.2	9.5	0
13.0 – 13.9	86	9.3	81.4	7.0	2.3
14.0 – 14.9	78	24.4	73.1	2.6	0
15.0 – 15.9	87	19.5	72.4	8.0	0
<i>Total</i>	272	17.3	75.7	6.3	0.7
$\chi^2 = 13.263$, df = 9, p = NS					

¹ See also appendix J for criteria of intelligence level.

² $\chi^2 = 2.299$, df = 3, p = NS

4.7.2 Cognitive performance by SAT scores

The scholastic aptitude test (SAT) included the tests of verbal ability (SAT-V), numerical ability (SAT-N) and reasoning ability (SAT-R). The mean scores of the

SAT tests are presented in Table 4.27. For all three aspects of the SAT tests female students had higher scores than males.

Table 4.27 The scholastic aptitude scores of the students.

Cognitive test *	Male (n = 288)	Female (n = 266)
SAT-V score	20.6 ± 4.7 ^a	23.4 ± 5.1 ^a
SAT-N score	20.2 ± 8.4 ^b	23.8 ± 8.5 ^b
SAT-R score	15.3 ± 4.5 ^a	17.3 ± 4.8 ^a

* By one-sample Kolmogorov-Smirnov test, students' t test was used if normal distribution was obtained, and non-parametric Mann-Whitney U test was used if the distribution was non-normal.

^a Mean comparison between males and females of the same variable by parametric students' t test : p = 0.0001.

^b Differences between males and females of the same variable were made by non-parametric Mann-Whitney U test : p = 0.0001.

The cognitive performance levels of the students by the scholastic aptitude test (SAT) are presented in Table 4.28.

According to the verbal SAT test, most of male students had a test score in fair level (37.7 %) and in poor level (44.3 %). Only about 18% of males were good at verbal SAT test. The verbal cognitive ability of females was better than that of males, since the percent verbal test scores in good level were 41.8 % of females compared to 18.0 % of males. Among those in good level, the students not more than 10 % were in excellent level (3.1 % and 9.7 % for males and females respectively).

Table 4.28 Percentages of the students classified according to cognitive performance¹ by scholastic aptitude test scores.

Age (y)	n	Verbal aptitude test (SAT-V) ² (%)			Numerical aptitude test (SAT-N) ³ (%)			Reasoning aptitude test (SAT-R) ⁴ (%)		
		Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
Male										
12.0 – 12.9	19	21.1	42.1	36.8	10.5	15.8	73.7	21.1	26.3	52.6
13.0 – 13.9	92	19.6	33.7	46.7	5.4	21.7	72.8	5.4	29.3	65.2
14.0 – 14.9	104	18.3	43.3	38.5	12.4	30.8	56.7	5.8	28.8	65.4
15.0 – 15.9	72	14.9	33.8	51.4	2.7	13.5	83.8	1.4	14.9	83.8
Total	289	18.0	37.7	44.3	7.6	22.5	69.9	5.5	25.3	69.2
		$\chi^2 = 4.270, df = 6, p = NS$			$\chi^2 = 17.388, df = 6, p = 0.008$			$\chi^2 = 18.385, df = 6, p = 0.005$		
Female										
12.0 – 12.9	21	28.6	33.3	38.1	4.8	33.3	61.9	9.5	33.3	57.1
13.0 – 13.9	85	40.0	38.8	21.2	9.4	34.1	56.5	18.8	40.0	41.2
14.0 – 14.9	76	46.1	31.6	22.4	15.8	39.5	44.7	7.9	34.2	57.9
15.0 – 15.9	85	40.0	29.4	30.6	4.7	34.1	61.2	7.1	35.3	57.6
Total	267	41.8	33.3	25.8	9.4	35.6	55.1	11.2	36.3	52.4
		$\chi^2 = 5.652, df = 6, p = NS$			$\chi^2 = 8.510, df = 6, p = NS$			$\chi^2 = 9.987, df = 6, p = NS$		

¹ See also Appendix J for criteria.

² $\chi^2 = 39.061, df = 2, p = 0.0001$

³ $\chi^2 = 13.635, df = 2, p = 0.001$

⁴ $\chi^2 = 17.394, df = 2, p = 0.0001$

In contrast to the verbal SAT scores, the minority of the students was very good at numerical SAT testing, i.e. only 0.3 % of males and none of females were excellent in this testing. Most of male and female students were in fair, poor and very poor levels. As seen in Table 4.28, nearly 70% of male students that were poor and very poor were 49.1% and 20.8%, respectively. Meanwhile, 55 % of females were poor in this testing. Among this poor level, 9.7 % were classified as very poor.

Only 5.5 % of males and 11.2 % of females had good reasoning SAT testing. Only about one fourth of males (25.3 %) and one third of females (36.3 %) were fair, and the majority of the students (69.2 % males and 52.4 % females) were poor in this testing, as shown in Table 4.28.

4.8 Comparisons Among Students With Different Iron Status

All students were classified into anaemic and non-anaemic groups, according to the haemoglobin levels. The comparisons of various variables were done between these two groups, and the results are shown in Table 4.29.

As expected, the mean Hb and PCV of the non-anaemic group were significantly higher than the anaemic group. In contrast, the other two parameters (the MCHC and SF) were not significantly different.

As seen in Table 4.29, body weight, BMI, all fat-mass and some muscle mass parameters among anaemic students were significantly lower than that of non-anaemic students. Height, arm-muscle circumference (AMC) and fat-free mass (FFM) were not different.

Table 4.29 Parameters of the anaemic and non anaemic students.*

Parameter	Anaemic group ¹		Non-anaemic group ²		P-value
	Mean	(SD)	Mean	(SD)	
Age (y)	14.67	(0.81)	14.27	(0.91)	NS
<i>Haematological</i>					
Hb (g/dL)	11.74	(1.35)	14.02	(0.84)	0.0001 ^a
PCV(%)	35.08	(4.55)	42.00	(3.00)	0.0001 ^a
MCHC (g/L)	335.61	(19.21)	332.32	(3.79)	NS
SF ³ (µg/L)	46.07	(2.57)	53.28	(1.74)	NS
<i>Anthropometry</i>					
Weight (kg)	40.4	(6.4)	46.7	(10.5)	0.023 ^a
Height (cm)	153.8	(9.1)	156.2	(8.0)	NS
BMI (kg/m ²)	17.04	(1.94)	19.03	(3.36)	0.013 ^a
TSK (mm)	7.9	(4.0)	11.2	(5.8)	0.016 ^a
CSK (mm)	7.9	(4.6)	10.8	(5.8)	0.022 ^a
BF (%)	12.9	(6.3)	17.4	(8.1)	0.016 ^a
TBF (kg)	5.4	(3.4)	8.7	(6.2)	0.007 ^a
MAC (cm)	21.0	(2.3)	23.2	(3.3)	0.017 ^a
AMC ⁴ (cm)	18.5	(1.7)	19.6	(2.4)	NS
TMM ⁴ (kg)	12.4	(3.0)	14.5	(3.8)	NS
FFM ⁴ (kg)	35.0	(4.6)	38.0	(6.5)	NS

* See footnote on the next page.

Table 4.29 (continued)

Parameter	Anaemic group ¹		Non-anaemic group ²		P-value
	Mean	(SD)	Mean	(SD)	
<i>Physical fitness</i>					
MRW (min)	11.18	(2.96)	11.5	(2.17)	NS
VO _{2max} ⁴ (ml/kg/min)	46.75	(4.12)	44.03	(4.96)	0.030 ^a
Curl-up (# completed)	30.8	(12.4)	27.2	(13.3)	NS
Pull-up (# completed)	15.2	(6.4)	13.2	(7.3)	NS
Trunk-lift (inch)	9.4	(3.1)	9.8	(1.8)	NS
Sit-reach (inch)	12.7	(2.2)	11.6	(2.2)	NS
<i>Cognitive performance</i>					
IQ	101.9	(4.7)	102.7	(7.8)	NS
RPM	40.0	(4.6)	40.8	(8.3)	NS
SAT-V	23.9	(4.7)	21.9	(5.1)	NS
SAT-N	20.2	(6.7)	22.2	(8.7)	NS
SAT-R	15.6	(3.7)	16.4	(4.8)	NS

¹ n = 13² n = 545³ Geometric mean⁴ Calculated^a Mean comparisons were made between anaemic and non-anaemic groups of the same variable by nonparametric Mann-Whitney U test.

Almost all physical-fitness test values of anaemic and non-anaemic groups were not different. However, a significant difference in calculated VO_{2max} between these two groups was found ($p = 0.030$) (Table 4.29). This can be explained that the

calculated VO_{2max} was calculated from the factors age, sex, BMI, and MRW. Particularly, the mean weight and BMI values were significantly lower in anaemic group than the non-anaemic group. So, this might cause the significantly lower in the estimated VO_{2max} of anaemic than that of the non-anaemic group. For cognitive performance, there were no significant differences in any parameters between anaemic and non-anaemic groups.

Moreover, a sub-sample of students whose blood was also analysed for serum ferritin level was classified into iron-depleted and non-iron-depleted groups according to the ferritin level ($< 30\text{-}\mu\text{g/L}$ indicating iron depletion). No significant differences were found in any comparisons.

4.9 Relationships Between Iron/Nutritional status/Body Composition and Functions

For multiple regression analysis, the independent variables were three categories: iron status parameters, nutritional anthropometric variables, and demographic data. The dependent variables were functional tests, namely, health-related physical fitness and cognitive ability tests.

To avoid collinearity of the independent variables, variables were selected to be explanatory variables for the multiple regression analysis by considering bivariate correlation coefficient as shown in Table 4.30 and 4.31. If the two variables had high correlation coefficient ($r \geq 0.750$), only one of them would be selected to enter in multiple regression analysis.

Table 4.30 Pearson correlation coefficients among age, and variables of iron and nutritional status for males.

	Age	Hb	PCV	Wt	Ht	BMI	TSK	CSK	BF	TBF	MAC	AMC	TMM	FFM
Age	1.000													
Hb	0.339 ^a	1.000												
PCV	0.332 ^a	0.965 ^a	1.000											
Wt	0.312 ^a	0.364 ^a	0.344 ^a	1.000										
Ht	0.538 ^a	0.440 ^a	0.420 ^a	0.687 ^a	1.000									
BMI	0.100	0.215 ^a	0.200 ^a	0.898 ^a	0.312 ^a	1.000								
TSK	-0.122 ^b	-0.004	-0.023	0.649 ^a	0.070	0.818 ^a	1.000							
CSK	-0.084	0.056	0.042	0.693 ^a	0.140 ^b	0.839 ^a	0.934 ^a	1.000						
BF	-0.104	0.025	0.008	0.681 ^a	0.103	0.842 ^a	0.982 ^a	0.983 ^a	1.000					
TBF	0.015	0.108	0.091	0.807 ^a	0.255 ^a	0.901 ^a	0.934 ^a	0.944 ^a	0.954 ^a	1.000				
MAC	0.215 ^a	0.309 ^a	0.297 ^a	0.933 ^a	0.501 ^a	0.936 ^a	0.725 ^a	0.763 ^a	0.756 ^a	0.828 ^a	1.000			
AMC	0.360 ^a	0.423 ^a	0.419 ^a	0.869 ^a	0.631 ^a	0.774 ^a	0.382 ^a	0.472 ^a	0.434 ^a	0.559 ^a	0.914 ^a	1.000		
TMM	0.393 ^a	0.445 ^a	0.437 ^a	0.899 ^a	0.718 ^a	0.752 ^a	0.368 ^a	0.454 ^a	0.417 ^a	0.563 ^a	0.897 ^a	0.986 ^a	1.000	
FFM	0.467 ^a	0.479 ^a	0.461 ^a	0.875 ^a	0.847 ^a	0.641 ^a	0.232 ^a	0.291 ^a	0.264 ^a	0.421 ^a	0.756 ^a	0.877 ^a	0.921 ^a	1.000

^a p-value <0.01, ^b 0.01 < p-value <0.05

Table 4.31 Pearson correlation coefficients among age, and variables of iron and nutritional status variables for females.

	Age	Hb	PCV	Wt	Ht	BMI	TSK	CSK	BF	TBF	MAC	AMC	TMM	FFM
Age	1.000													
Hb	-0.076	1.000												
PCV	-0.096	0.965 ^a	1.000											
Wt	0.213 ^a	-0.037	-0.037	1.000										
Ht	0.234 ^a	-0.015	-0.014	0.485 ^a	1.000									
BMI	0.148 ^b	-0.038	-0.038	0.920 ^a	0.110	1.000								
TSK	0.220 ^a	-0.023	-0.020	0.778 ^a	0.166 ^a	0.816 ^a	1.000							
CSK	0.163 ^a	-0.029	-0.030	0.781 ^a	0.164 ^a	0.819 ^a	0.864 ^a	1.000						
BF	0.194 ^a	-0.025	-0.022	0.823 ^a	0.164 ^a	0.869 ^a	0.928 ^a	0.944 ^a	1.000					
TBF	0.175 ^a	-0.033	-0.033	0.912 ^a	0.272 ^a	0.912 ^a	0.905 ^a	0.931 ^a	0.928 ^a	1.000				
MAC	0.221 ^a	-0.057	-0.042	0.892 ^a	0.243 ^a	0.914 ^a	0.854 ^a	0.811 ^a	0.843 ^a	0.889 ^a	1.000			
AMC	0.161 ^a	-0.075	-0.050	0.758 ^a	0.249 ^a	0.758 ^a	0.481 ^a	0.539 ^a	0.531 ^a	0.631 ^a	0.867 ^a	1.000		
TMM	0.182 ^a	-0.078	-0.056	0.811 ^a	0.427 ^a	0.737 ^a	0.488 ^a	0.545 ^a	0.537 ^a	0.660 ^a	0.857 ^a	0.977 ^a	1.000	
FFM	0.222 ^a	-0.017	-0.015	0.873 ^a	0.634 ^a	0.714 ^a	0.483 ^a	0.466 ^a	0.492 ^a	0.646 ^a	0.735 ^a	0.776 ^a	0.851 ^a	1.000

^a p-value <0.01, ^b 0.01 < p-value <0.05

In addition, the variables would be also selected to enter the equation as explanatory variables by considering their possible biological significance in explaining the key dependent variables. By these considerations, the variables selected were age, haemoglobin level (Hb), height (Ht), the percent of body fat (% BF), and the amount fat-free mass (FFM). The analysis was performed separately for males and females since the equations yielded were quite different between sexes.

The questions to be clarified by the multiple regression analysis were; did the entire set of the explanatory variables jointly account for each test of health-related physical fitness/cognitive performance in the adolescent students? And how much did they account for? And among these explanatory variables, which variable played an important role and which did not?

4.9.1 Health-related physical fitness

Tables 4.32-4.41 show the results of multiple regression analysis that present the unstandardized and standardized regression coefficients and their accompanying p-values of five variables explaining each tests of health-related physical fitness in male and female students.

4.9.1.1 Factors affecting health-related physical fitness

4.9.1.1.1 Aerobic capacity

The results for aerobic capacity by MRW test showed the multiple correlation coefficient (R) = 0.433 and the adjusted R^2 = 0.172, and these values for females were R = 0.335 and the adjusted R^2 = 0.094. This indicated that the entire set of the variables: age, haemoglobin level, height, fat-free mass, and percent body fat, accounted for the MRW test for male and female students in a small amount (17.2 % for males and 9.4% for females).

Table 4.32 Factors influencing **aerobic capacity (MRW, min)** of male students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	4.078	2.760		0.141
Age (y)	-0.142	0.121	-0.079	0.242
Hb (g/dl)	0.0098	0.112	0.055	0.384
Ht (cm)	0.0027	0.018	0.161	0.144
FFM (kg)	-0.0047	0.025	-0.225	0.056
ln (%BF) ²	1.738	0.239	0.453	0.0001

¹ R = 0.433, Adjusted R² = 0.172, n = 278, F_{5, 272} = 12.527, p = 0.0001.

² ln (%BF) = Percent body fat in log.

Table 4.33 Factors influencing **aerobic capacity (MRW, min)** of female students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	18.025	3.252		0.0001
Age (y)	-0.146	0.098	-0.097	0.136
Hb (g/dl)	-0.372	0.101	-0.225	0.0001
Ht (cm)	-0.0019	0.021	-0.075	0.362
FFM (kg)	0.0027	0.030	0.082	0.371
ln (%BF) ²	1.292	0.412	0.226	0.002

¹ R = 0.335, Adjusted R² = 0.094, n = 245, F_{5, 239} = 6.048, p = 0.0001.

² ln (%BF) = Percent body fat in log.

The percent body fat was the only variable significantly explaining the variability of the MRW in males. However, fat-free mass also had a significant trend in describing the MRW ($p = 0.056$). The percent body fat and haemoglobin level were the underlying explanatory factors in females. Haemoglobin representing iron status significantly influenced MRW of female students only.

In terms of MRW test, both male and female students with lower percent body fat were fitter in aerobic capacity, i.e., taking less time for MRW when compared with the students having higher percent of body fat. Additionally, female students with higher haemoglobin level could perform MRW test (or aerobic capacity) better than those lower haemoglobin levels.

4.9.1.1.2 Abdominal muscle strength/endurance

Table 4.34 and 4.35 revealed that the explanatory variables could jointly describe the curl-up test representing abdominal muscle strength/ endurance of male students with the multiple correlation coefficient (R) = 0.222 and the adjusted $R^2 = 0.032$, but the significant result in female students was not found (Table 4.35). This indicated that the combined independent variables accounted for the curl-up test only in male students in a very small amount (3.2%).

The factors significantly influencing on the curl-up test of the male students were height (Ht) and the percent body fat (ln %BF) as shown in Table 4.34. None of the factors were significantly affecting the curl-up test in females (Table 4.35). Based on the multiple regression analysis (Table 4.34), male students who are shorter or had higher the percent body fat was worse off in the curl-up test than those with higher in stature or lower in the percent body fat.

Table 4.34 Factors influencing **abdominal muscle strength/endurance (curl-up test, # completed)** of male students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	24.867	21.631		0.251
Age (y)	-0.930	0.948	-0.071	0.327
Hb (g/dl)	-0.696	0.877	-0.054	0.428
Ht (cm)	0.333	0.145	0.273	0.023
FFM (kg)	-0.300	0.190	-0.197	0.116
ln (%BF) ²	-4.123	1.900	-0.144	0.031

¹ $R = 0.222$, Adjusted $R^2 = 0.032$, $n = 281$, $F_{5, 272} = 2.848$, $p = 0.016$.

² ln (%BF) = Percent body fat in log.

Table 4.35 Factors influencing **abdominal muscle strength/endurance (curl-up test, # completed)** of female students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	6.786	23.215		0.770
Age (y)	-0.0035	0.699	-0.003	0.960
Hb (g/dl)	0.322	0.724	0.028	0.657
Ht (cm)	0.126	0.143	0.074	0.377
FFM (kg)	-0.195	0.211	-0.087	0.356
ln (%BF) ²	-0.587	2.921	-0.015	0.841

¹ $R = 0.084$, Adjusted $R^2 = -0.013$, $n = 251$, $F_{5, 245} = 0.351$, $p = 0.882$.

² ln (%BF) = Percent body fat in log.

4.9.1.1.3 Upper-body strength/endurance

The results for upper-body muscle strength/endurance by the modified pull-up test showed the multiple correlation coefficient (R) and the adjusted R^2 were 0.467 and 0.204, respectively for males and were 0.363 and 0.114, respectively for females. The explanatory variables accounted for the modified pull-up test in a small amount being 20.4% for males and 11.4% for females (Table 4.36 and 4.37).

Almost all independent variables except age were significantly describing the modified pull-up test in males (Table 4.36), whereas the independent variables except haemoglobin level and fat-free mass had a significant effect on this test in females (Table 4.37).

Table 4.36 Factors influencing upper-body strength/endurance (modified pull-up test, # completed) of male students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	27.962	9.977		0.005
Age (y)	0.736	0.432	0.112	0.089
Hb (g/dl)	0.989	0.404	0.152	0.015
Ht (cm)	-0.198	0.067	-0.321	0.004
FFM (kg)	0.305	0.087	0.401	0.001
ln (%BF) ²	-6.362	0.903	-0.427	0.0001

¹ R = 0.467, Adjusted R^2 = 0.204, n = 278, $F_{5,272}$ = 15.156, p = 0.0001.

² ln (%BF) = Percent body fat in log.

Table 4.37 Factors influencing **upper-body strength/endurance (modified pull-up test, # completed)** of female students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	25.723	8.105		0.002
Age (y)	1.027	0.240	0.268	0.0001
Hb (g/dl)	-0.0022	0.248	-0.005	0.930
Ht (cm)	-0.152	0.051	-0.242	0.003
FFM (kg)	0.0002	0.075	0.003	0.976
ln BF ²	-2.805	1.013	-0.193	0.006

¹ $R = 0.363$, Adjusted $R^2 = 0.114$, $n = 251$, $F_{5, 245} = 7.439$, $p = 0.0001$.

² ln (%BF) = Percent body fat in log.

The results of the regression analysis showed the significant relationship between iron status and the modified pull-up test in males only. The male students having higher haemoglobin level were better in the modified pull-up test than those having lower haemoglobin level.

All parameters of the selected anthropometric variables for males and almost all parameters except fat-free mass for females significantly affected this test. Both male and female students who had less body fat or shorter in body height performed the modified pull-up test better than those who had more body fat or longer stature.

The students especially males having higher fat-free mass were better in this test than those having lower fat-free mass. For females in particular, the older students were better in this test than the younger.

4.9.1.1.4 Trunk-extensor strength/flexibility

For trunk-extensor strength and flexibility of males, the variability in trunk-lift test of males was explained by the independent variables with the multiple correlation coefficient (R) = 0.239 and the adjusted R^2 = 0.040. However, the significant result was not observed in females (Table 4.38 and 4.39). The results stated that the independent variables accounted for the trunk-lift test of male students in 4.0 %.

Table 4.38 Factors influencing **trunk-extensor strength and flexibility (trunk-lift test, inch)** of male students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	15.353	3.117		0.0001
Age (y)	0.0044	0.133	0.024	0.739
Hb (g/dl)	-0.237	0.128	-0.126	0.065
Ht (cm)	-0.0036	0.021	-0.203	0.091
FFM (kg)	0.0095	0.028	0.432	0.001
ln (%BF) ²	-0.348	0.267	-0.087	0.193

¹ $R = 0.239$, Adjusted $R^2 = 0.040$, $n = 282$, $F_{4,277} = 3.346$, $p = 0.006$.

² ln (%BF) = Percent body fat in log.

The only one explanatory variable, i.e., fat-free mass significantly affected this test ($p = 0.001$). The result showed the more in fat-free mass, the better in trunk-lift test,

Table 4.39 Factors influencing **trunk-extensor strength and flexibility (trunk-lift test, inch)** in female students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	7.287	3.775		0.055
Age (y)	0.0028	0.113	0.016	0.808
Hb (g/dl)	0.0006	0.117	0.003	0.960
Ht (cm)	0.001	0.023	0.037	0.665
FFM (kg)	0.0018	0.034	0.051	0.594
ln (%BF) ²	-0.124	0.466	-0.020	0.790

¹ $R = 0.079$, Adjusted $R^2 = -0.014$, $n = 251$, $F_{5,245} = 0.306$, $p = 0.909$.

² ln (%BF) = Percent body fat in log.

4.9.1.1.5 Flexibility

For flexibility as measured by the back-saver sit-and-reach test, the entire set of explanatory variable had influences on the flexibility with the multiple regression coefficient (R) = 0.363, adjusted $R^2 = 0.116$ for males, and with $R = 0.282$, adjusted $R^2 = 0.061$ for females (Table 4.40 and 4.41).

Fat-free mass, percent body fat, and height significantly affected flexibility of males, whereas age and haemoglobin did not. For females, the percent body fat, fat-free mass and age were significant variables, while height, and haemoglobin level were not significant.

Table 4.40 Factors influencing flexibility (back-saver sit-and-reach test, inch) of male students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	13.920	3.503		0.0001
Age (y)	0.192	0.150	0.088	0.200
Hb (g/dl)	0.0086	0.142	0.039	0.545
Ht (cm)	-0.0049	0.024	-0.235	0.040
FFM (kg)	0.118	0.031	0.455	0.0001
ln (%BF) ²	-1.354	0.311	-0.278	0.0001

¹ R = 0.363, Adjusted R² = 0.116, n = 281, F_{5, 275} = 8.338, p = 0.0001.

² ln (%BF) = Percent body fat in log.

Table 4.41 Factors influencing flexibility (back-saver sit-and-reach test, inch) of female students.¹

Independent variables	Unstandardized regression coefficient (b)	SE	Standardized regression coefficient (beta)	P
Constant	13.321	4.656		0.005
Age (y)	0.425	0.140	0.197	0.003
Hb (g/dl)	0.0084	0.144	0.036	0.561
Ht (cm)	-0.0039	0.029	-0.112	0.173
FFM (kg)	0.108	0.043	0.231	0.012
ln (%BF) ²	-2.162	0.582	-0.272	0.0001

¹ R = 0.282, Adjusted R² = 0.061, n = 251, F_{5, 245} = 4.221, p = 0.001.

² ln (%BF) = Percent body fat in log.

It was implied that the male students who had less percent body fat, higher and were shorter performed better in the flexibility test than those having more percent body fat (or less fat-free mass) and taller. As well as male students, females with less percent body fat (or more amount of fat-free mass) were better in flexibility. For females only, the older children did better in flexibility than the younger.

The multiple regression analysis for combined sexes was also performed to define the significant explanatory factors (See Appendix E for details). The factors significantly affected each test of the physical fitness in combined sexes and sexes separately are summarized in Table 4.42.

Table 4.42 The underlying factors significantly affecting the physical fitness test of the students.*

Physical fitness tests	Combined sexes	Males	Females
One-mile run/walk (MRW)	Sex ^{a,1}	ln (%BF) ^{a,1}	ln (%BF) ^{b,1}
	ln (%BF) ^{a,1}	FFM	Hb ^{a,2}
	Hb ^{c,2}	Ht	Age
	Age	Age	FFM
	FFM	Hb	Ht
	Ht		
Curl-up	Sex ^{a,2}	Ht ^{c,1}	FFM
	Ht ^{c,1}	ln (%BF) ^{c,2}	Ht
	ln (%BF) ^{c,2}	FFM	Hb
	FFM	Age	ln (%BF)
	Hb	Hb	Age
	Age		
Modified pull-up	ln (%BF) ^{a,2}	ln (%BF) ^{a,2}	Age ^{a,1}
	Sex ^{a,2}	FFM ^{b,1}	Ht ^{b,2}
	FFM ^{a,1}	Ht ^{b,2}	ln (%BF) ^{b,2}
	Ht ^{a,2}	Hb ^{c,1}	Hb
	Age ^{a,1}	Age	FFM
	Hb ^{c,1}		

See footnote on the next page

Table 4.42 (continued)

Physical fitness tests	Combined sexes	Males	Females
Trunk-lift	FFM ^{a,1} Age Ht ln (%BF) Hb Sex	FFM ^{b,1} Hb Ht ln (%BF) Age	FFM Ht ln (%BF) Age Hb
Back-saver sit-and-reach	FFM ^{a,1} Sex ^{a,1} ln (%BF) ^{a,2} Ht ^{c,2} Age ^{b,1} Hb	FFM ^{a,1} ln (%BF) ^{a,2} Ht ^{c,2} Age Hb	ln (%BF) ^{a,2} FFM ^{a,1} Age ^{c,1} Ht Hb

* Analysed by the multiple regression method, and underlying factors were ranked by the standardized correlation coefficient (Beta) values.

¹ Positive relationships

² Negative relationships

^a $P < 0.001$, ^b $P < 0.01$, ^c $p < 0.05$,

4.9.1.2 Relationship between iron status and health-related physical fitness

Haemoglobin level (Hb) representing iron status of the students was found to significantly affect only the MRW and the modified pull-up tests, when considering in combined sexes (Table 4.42).

Considering in sex separately, haemoglobin level was a significant factor affecting the MRW test in female students only. Conversely in the modified pull-up test, haemoglobin level was not found to be a significant factor in females, but it significantly contributed to this test only in male students. In addition, the results also

showed that haemoglobin level might probably significantly affect the trunk-lift test in male students ($P < 0.10$).

It can be concluded that iron status can affect the aerobic capacity of the students, specifically in female students. For muscular strength, endurance and flexibility, the results showed that iron status had a significant relationship with a test of upper-body muscle strength / endurance (the modified pull-up test) only in males. There were no significant relationships between iron status and other tests such as abdominal strength/endurance, flexibility, and trunk extensor strength/flexibility tests.

4.9.1.3 Relationship between nutritional status/body composition and health-related physical fitness

The physical fitness also depends on the anthropometric variables. Body height (Ht), the percent of body fat (In %BF) and fat-free mass (FFM) represented the body size and body composition of the students.

Considering the result of male students (Table 4.42), the percent of body fat (% BF) significantly affected nearly all tests except the trunk extensor strength/flexibility (the trunk-lift test). The amount of fat-free mass (FFM) also significantly affected most tests except the aerobic capacity (the MRW test) and the abdominal muscle strength/endurance (the curl-up test). Height (Ht) plays a significant role in the upper-body strength/endurance (the modified pull-up test) and flexibility (the back-saver sit-and reach test).

Considering the results of female students (Table 4.42), two of five health-related physical fitness tests, i.e., the curl-up and the trunk-lift tests were not significantly affected by the anthropometric variables. Among the remaining tests, the percent body fat significantly described these tests, i.e., aerobic capacity, the upper-body

strength/endurance, and flexibility. Fat-free mass significantly affected flexibility only. Height significantly affected only the upper-body strength/endurance only.

The results showed that body sizes and body composition were the most important underlying factors affecting the health-related physical fitness tests.

4.9.1.4 Relationship between demographic data and health-related physical fitness

Age was a significant factor affecting the physical fitness test specifically in females, but not in male students. Age significantly affected upper-body strength/endurance and flexibility. For all tests except the trunk extensor strength/flexibility test, there was sex difference.

4.9.2 Cognitive performance

4.9.2.1 Factors affecting the cognitive scores

The results of multiple regression analysis that present the unstandardized and standardized regression coefficients and their accompanying p-values of five variables explaining each tests of cognitive performance in male and female students are shown in Tables 4.43-4.48.

4.9.2.2.1 The IQ scores

Table 4.43 and 4.44 present the multiple regression results of the IQ scores of male and female students measured by the Raven Progressive Matrices test. Age was the only one factor significantly explaining the IQ score of male students (Table 4.43). However, the results of males and females were dissimilar. Height was the significant variables explaining IQ scores of female students (Table 4.44).

Table 4.43 Factors influencing IQ scores of male students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	75.981	14.292		0.0001
Age (y)	1.705	0.606	0.200	0.005
Hb (g/dl)	0.300	0.578	0.035	0.604
Ht (cm)	-0.001	0.095	-0.013	0.913
FFM (kg)	0.0073	0.125	0.073	0.561
ln (%BF) ²	-1.246	1.245	-0.067	0.318

¹ R = 0.260, Adjusted R² = 0.051, n = 283, F_{5,277} = 4.001, p = 0.002.

² ln (%BF) = Percent body fat in log.

Table 4.44 Factors influencing IQ scores of female students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	63.559	15.637		0.0001
Age (y)	0.668	0.468	0.094	0.154
Hb (g/dl)	-0.127	0.480	-0.017	0.792
Ht (cm)	0.255	0.096	0.221	0.008
FFM (kg)	-0.141	0.141	-0.094	0.317
ln (%BF) ²	-0.755	1.960	-0.094	0.701

¹ R = 0.215, Adjusted R² = 0.027, n = 250, F_{5,244} = 2.358, p = 0.041.

² ln (%BF) = Percent body fat in log.

This implied that the present body height that reflected nutritional status of the students might affect the intellectual ability of female students. Surprisingly, this effect was not found in males.

For both male and female students, iron status by haemoglobin level, the percent body fat and the amount of fat-free mass did not significantly affect on the intellectual scores.

4.9.2.2.2 The scholastic aptitude tests

The results of multiple regression analysis for the scholastic aptitude tests were shown in Tables 4.45– 4.50.

(a) Verbal scholastic aptitude test

Table 4.45 Factors influencing verbal SAT scores of male students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	7.248	8.257		0.381
Age (y)	0.635	0.361	0.127	0.079
Hb (g/dl)	-0.545	0.333	-0.112	0.103
Ht (cm)	0.0065	0.055	0.141	0.241
FFM (kg)	0.0053	0.072	0.093	0.460
ln (%BF) ²	-0.103	0.731	-0.010	0.888

¹ R = 0.275, Adjusted R² = 0.058, n = 266, F_{5, 260} = 4.248, p = 0.001.

² ln (%BF) = Percent body fat in log.

No independent variable was found to significantly account for the verbal SAT scores of males (Table 4.45). Two variables, i.e. age and height, significantly affected the verbal SAT scores (Table 4.46). This means that the verbal SAT scores of female student increased with an increasing age and female students with higher in height had higher in the verbal scores than the students with shorter in stature.

Table 4.46 Factors influencing **verbal SAT scores** of female students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	-11.476	10.492		0.275
Age (y)	1.059	0.312	0.221	0.001
Hb (g/dl)	-0.0086	0.320	-0.017	0.787
Ht (cm)	0.138	0.065	0.175	0.036
FFM (kg)	-0.0084	0.097	-0.081	0.387
ln (%BF) ²	0.885	1.323	0.050	0.504

¹ $R = 0.294$, Adjusted $R^2 = 0.067$, $n = 247$, $F_{5,241} = 4.554$, $p = 0.001$.

² ln (%BF) = Percent body fat in log.

Iron status parameter (Hb) and other anthropometric data (i.e., ln BF and FFM) did not significantly describe the verbal SAT score as seen in Table 4.45 and Table 4.46.

(b) Numerical scholastic aptitude test

For male students, the entire set of iron status, nutritional anthropometric variables and some demographic data could not significantly explained the numerical aptitude test scores (Table 4.47).

Table 4.47 Factors influencing **numerical SAT scores** of male students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	9.461	15.501		0.542
Age (y)	0.329	0.659	0.037	0.618
Hb (g/dl)	-0.261	0.611	-0.030	0.670
Ht (cm)	0.0053	0.102	0.063	0.606
FFM (kg)	0.125	0.135	0.120	0.355
ln (%BF) ²	-1.395	1.291	-0.074	0.281

¹ R = 0.185, Adjusted R² = 0.016, n = 266, F_{5, 260} = 1.853, p = 0.103.

² ln (%BF) = Percent body fat in log.

Table 4.48 Factors influencing **numerical SAT scores** of female students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	-31.677	17.737		0.075
Age (y)	1.563	0.531	0.191	0.004
Hb (g/dl)	-0.204	0.548	-0.023	0.710
Ht (cm)	0.298	0.110	0.220	0.007
FFM (kg)	-0.0096	0.164	-0.054	0.560
ln (%BF) ²	-2.144	2.273	-0.070	0.346

¹ R = 0.291, Adjusted R² = 0.066, n = 248, F_{5, 242} = 4.488, p = 0.001.

² ln (%BF) = Percent body fat in log.

For females, height and age were observed as the most powerful explanatory variables, and significantly accounted for the numerical aptitude scores (Table 4.48). This means that female students being older or higher in body height were predicted to have better in numerical SAT scores than those being younger or shorter stature.

(c) Reasoning scholastic aptitude test

Age was significantly affected the reasoning scores in males (Table 4.49). The variables significantly accounted for the reasoning SAT scores in females were height and age (Table 50). Additionally, fat-free mass was found to have a trend to significantly relate to the reasoning scores of females with $p = 0.056$ (Table 4.50).

The results indicated that the reasoning SAT scores of both male and female students were higher with an increasing age. Particularly in females, the students with higher in height were better in the reasoning scores than the students with shorter in height.

Table 4.49 Factors influencing reasoning SAT scores of male students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	1.611	7.917		0.839
Age (y)	0.731	0.347	0.155	0.036
Hb (g/dl)	-0.0054	0.321	-0.012	0.867
Ht (cm)	0.0003	0.053	0.006	0.963
FFM (kg)	0.0047	0.070	0.085	0.500
ln (%BF) ²	0.733	0.676	0.074	0.279

¹ $R = 0.223$, Adjusted $R^2 = 0.031$, $n = 266$, $F_{5, 260} = 2.717$, $p = 0.021$.

² ln (%BF) = Percent body fat in log.

Iron status did not significantly affect the reasoning scores of the studied students. As well as iron parameter, other anthropometric variables, i.e., fat-free mass and the percent body fat also did not correlate with the scores. However, fat-free mass might have a chance to correlate with the reasoning scores of females only (Table 4.50).

Table 4.50 Factors influencing reasoning SAT scores of female students.¹

Independent variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	-11.151	10.402		0.285
Age (y)	0.638	0.310	0.136	0.041
Hb (g/dl)	0.0044	0.319	0.009	0.890
Ht (cm)	0.150	0.065	0.196	0.021
FFM (kg)	-0.183	0.095	-0.183	0.056
ln (%BF) ²	0.712	1.287	0.042	0.580

¹ $R = 0.214$, Adjusted $R^2 = 0.026$, $n = 246$, $F_{5,240} = 2.294$, $p = 0.046$.

² ln (%BF) = Percent body fat in log.

The factors significantly affecting each test of the cognitive performance in combined sex (see Appendix E for details) and in sex separately is shown in Table 4.51.

4.9.2.3 Relationship between iron status and cognitive test scores

In this study, the data failed to demonstrate the relationship between the iron status (by measured haemoglobin level) and any cognitive test scores in both male and female students (Table 4.51).

Table 4.51 The underlying factors contributed to the cognitive test scores.*

The tests	Combined sexes	Males	Females
IQ	Ht ^c Age ^b Sex, FFM ln (%BF) Hb	Age ^{b,1} FFM ln (%BF) Hb Ht	Ht ^{b,1} Age, ln (%BF), FFM Hb
SAT-V	Sex ^a Age ^a Ht ^d Hb ln (%BF) FFM	Ht Age Hb FFM ln (%BF)	Age ^{b,1} Ht ^{b,1} FFM ln (%BF) Hb
SAT-N	Sex ^a Ht ^d Age ^b ln (%BF) Hb FFM	FFM ln (%BF) Ht Age Hb	Ht ^{b,1} Age ^{b,1} ln (%BF) FFM Hb
SAT-R	Sex ^c Ht ^c Age ^b ln (%BF) FFM Hb	Age ^{c,1} FFM ln (%BF) Hb Ht	Ht ^{c,1} Age ^{c,1} FFM ln (%BF) Hb

* Analysed by the multiple regression method and underlying variables were ranked by the standardized correlation coefficient (Beta) values.

¹ Positive relationships

^a $P < 0.001$, ^b $P < 0.01$, ^c $p < 0.05$, ^d $p < 0.10$.

4.9.2.4 Relationship between nutritional status/body composition and cognitive test scores

Only one variable of nutritional anthropometric variables, i.e., height could significantly describe the variability of some cognitive test scores. Height reflecting

the nutritional status of the students in the past was a significant factor affecting all SAT scores in female students only. But it could not significantly describe all SAT scores of males (Table 4.51). Other nutritional anthropometric parameters such as the percent of body fat and fat-free mass did not significantly correlate with any test scores of the mental abilities of the studied students.

4.9.2.5 Relationship between demographic data and cognitive test scores

When considering in combined sexes, gender factor was found to be the significant explainable variable for almost cognitive test scores except the IQ test. Age also affected all cognitive test including the SAT and the IQ tests.

For males, age was the significant factor of the IQ scores and the reasoning SAT scores. Therefore, the IQ and the reasoning aptitude tests of male students were predicted to increase with an increasing age (Table 4.51). But for female students, age was found to significantly correlate with all the SAT tests, but not the IQ test. Again, the SAT scores of female students would increase if they increased age.

CHAPTER V

DISCUSSION

Information on nutritional status, specifically iron status and anthropometry, and functional aspects (physical fitness and cognitive performance) in Thai adolescents has been limited. This may be due to the premise that adolescent group is not vulnerable to nutritional problems compared to infants, preschool children, and pregnant women. In this study, a cross-sectional study in male and female adolescents aged 12-15 years was performed. This study was carried out in 3 secondary schools in Nakhon Chaisri District (See Appendix A), which was about 15 km far from Institute of Nutrition, Mahidol University. The study area was purposively selected because of technical, financial, and logistical feasibility.

Prevalence of anaemia, assessed by haemoglobin, was very low (3.1 % for males and 1.5 % for females), which was similar to that reported in two recent studies. A study in Nakhon Pathom Province in similar areas showed the prevalence of 3.3 % in females aged 12-17 years (31). Another study showed the prevalence of 5.4 % in urban area and 7.3 % in rural area of Khon Khen Province (northeastern region) (29). The present anaemia prevalence was comparable to that among adolescents of industrialized countries, such as 3.2 % in the USA in 1992 (131). The two studied schools (Pattarayan School and Perm School) were located in urban area of Nakhon Chaisri District and the students from these two schools contributed more than 2/3 of the total students studied and may be in relatively better off SES group.

In a sub-sample, an additional iron parameter, serum ferritin, was also measured to define iron depletion and iron deficiency anaemia (IDA). In this study, the cut-off 30 µg/L was used as recently suggested for infection-predominant population (117-118). In the studied sample, high frequency of infection during the past 6 months were reported (82.3 % and 26.7 % for common cold and diarrhoea, respectively) (Table 4.5). The prevalence of low serum ferritin was around 15 % (Table 4.10). However, iron deficiency anaemia in females was found to be very low prevalence (2.3 %), whereas the prevalence of iron deficiency anaemia in males was zero. On the other hand, iron intake (single 24 hr recall of a sub-sample) indicated that more than half of females (57.9 %) but less than one fourth (23.3 %) of males consumed iron below 70% of the RDA (Table 21). Better measurements of infection and dietary intakes are clearly needed to verify the situation and elucidate possible roles of diets to etiology of ID in this population. Multiple day measurements of dietary recalls, or food frequency may be needed to assess usual intakes of unevenly distributed consumption of micronutrient-densed food items.

General nutritional status of the students was assessed by anthropometry, using Thai reference (1987). The prevalence of underweight (5.5 %), stunted (6.5 %), wasted (5.3%), and overweight (8.8 %) in both male and female students was low (Table 4.14) and comparable to recently reported rate of malnutrition in secondary schoolchildren in urban area of Thailand. The prevalence in urban area was reported to be less than 10% in all malnutrition types, whereas in rural area, underweight and stunting prevalence was above 10 %, and overweight less than 5 % (136).

Using the NCHS reference, the underweight, and stunting prevalence was higher than that using Thai reference (1987) (Figure 4.3-4.4). This indicated the

differences among these two-reference populations, which had been observed by examining the reference curves of Thai vs. NCHS. Differential rates in weight and height increments and timing of adolescent growth spurt, between boys and girls and between the two references could contribute to the observed differences in prevalence.

5.1 Iron/Nutritional Status And Physical fitness

Recently, more attention is given to the link between nutrition and functions. Functional performance, both physical and cognitive performances are of concern for school-aged adolescents. Generally, physical fitness is measured in terms of skill-related physical fitness or motor fitness that involves some physical abilities and is related primarily to athletic performance. A new area, health-related physical fitness is interesting for children and youth because it focuses on the aspect of physical fitness that is related to day-to-day function and health maintenance (68, 77). Regular physical activity produces physical fitness. Thus, physical fitness throughout their developing years could have an important contribution to lowering the risk of chronic degenerative diseases in the future (77,138). Moreover the children and youth who have high physical potential could be more alert and have better potential to learn and develop their abilities in cognition.

The Prudential Fitnessgram test battery was recently developed for children and youth in the USA. These tests were used for measuring health-related physical fitness in this study. Three key components of the tests, namely, aerobic capacity, muscle strength/endurance, and flexibility, were assessed.

Males were found to be better than females in all three components of health-related physical fitness (Table 4.23). The major factors that were reported to influence

physical fitness tests were body size and body composition (36), biological, and possibly behavioral factors. For body size and body composition, male students in this study were found to be taller and have lower BMI than females. For the same age group (12-15 years), female students accumulated more body fat than males (Table 4.12). Males also had more muscle, as reflected by arm muscle circumference (AMC), total muscle mass (TMM) and fat-free mass (FFM), than females (Table 4.12). These findings correspond with previous reports that after entering pubertal stage, boys had higher increased fat-free mass (FFM), but less increased in body fat than girls' (132). Boys, thus, were leaner.

Aerobic capacity test reflected the capacity of transfer oxygen from the lung to cells and uptake of oxygen by cells, whereas, the tests of muscle strength, endurance and flexibility were used to determine the function of the musculoskeletal system (36). Based on the Prudential Fitnessgram reference, about 60 % of male and 90 % of females were classified to have poor level of aerobic capacity test. On the contrary, the majority of the students (>65 %) were in healthy fitness zone for abdominal, upper-body, and trunk muscle strength and endurance tests, including flexibility test, (Table 4.23). Encouraging more physical activity may improve the aerobic capacity of this studied group.

Behavioural factors might account for the results of physical fitness test of the students. Aerobic capacity test was a one-mile run/walk test (MRW) that the students were instructed that they could run and walk to complete the specified 1.6-km. It was possible that male students were used to do high physical activity level, such as, playing football, running during lunch break and after school, whereas females preferred to sit and talk or read. Girls were also found to be shy to perform some tasks.

Unfortunately, in this study, data on physical activity level of the students were not available. Students who were less physically active and inadequately motivated to do the physical fitness test could perform less than their actual physical ability. The differences in body size and body composition between sexes may also contribute to better fitness in males than in females. The poor performance by MRW test seemed to be increased with age in both sexes (Table 4.23). It is possible that older children were less motivated to keep performing physical activity.

An attempt to compare the physical fitness between anaemic and non-anaemic subjects revealed that there were no significant differences in any tests of health-related physical fitness between the two groups, except the calculated $\text{VO}_2 \text{ max}$. Iron status had been shown to markedly affect physical performance in adolescent (23, 24, 134). Two studies in India showed the consistent findings. A study in young boys aged 5-6 years (134) indicated that the performance in step test in anaemic boys was significant poorer than non-anaemic boys in both sub-maximal and maximal work tests. Another study described poorer performance in a 1.6-km run test by anaemic schoolboys (24). Moreover, the study in the UK showed that girls aged 12-14 years with haemoglobin levels $<12.0 \text{ g/dL}$ had significantly elevated heart rates immediately after step test, and after 1-min. and 2-min. step test compared to non-anaemic girls (23). However, the results of physical performance by Harvard Step test in female students aged 12-17 years in Nakhon Pathom showed no significant difference between anaemic and non-anaemic groups (31). The results of the present study failed to show the effect of anaemia on physical fitness test. This may due to small sample size ($n=13$) and relatively low severity among the anaemic children.

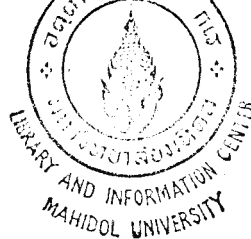
The results from multiple regression analysis for aerobic capacity test of health-related physical fitness (Table 4.32-4.33) indicated that iron status in terms of haemoglobin (Hb) level significantly explained aerobic capacity, especially in female students. The explanation for this finding probably involves the aerobic energy-production system. The amount of oxygen available is an essential factor for the aerobic energy production (39, 136). How much oxygen is available to the cells depends upon how quickly the heart can deliver blood to the cells and how much oxygen the iron-containing haemoglobin (Hb) in the blood cells can carry. Low haemoglobin (Hb) may diminish aerobic capacity of individuals. In this study, Hb levels negatively related to one-mile run/walk (MRW) test in females (Table 4.32), but this finding was not found in males (Table 4.33). It is possible that the wider range of Hb variability and a few extreme values of low Hb in females contribute to different findings between males and females (8.85-15.80 mg/dL for females vs. 11.32-16.30 mg/dL for males, See also Appendix F for details).

Another physical fitness test that was found to related to iron status was the upper-body strength/endurance assessed by modified pull-up test. This test involved muscle function that required sufficient energy and the strength/endurance of the upper-body muscle. Apart from a significant role of haemoglobin in aerobic energy production, iron in muscle, i.e. myoglobin, might partly contribute to this test. Myoglobin involves in transport, storage, and supply of oxygen for metabolic needs during muscle contraction (48). Again, male students were better in haemoglobin level (Table 4.8) and muscle mass than females (Table 4.12). In this study, haemoglobin significantly and positively related to upper-body strength/endurance test in males (Table 4.34), but not in females (Table 4.35).

Body fat was the only anthropometric variable that had a positive correlation to the MRW test (Table 4.33-4.34). Students with higher body fat took a longer time in MRW test, indicating fatter students were less fit in aerobic capacity than the thinner ones. Weight, height, or lean body mass was reported to highly correlate with aerobic capacity in terms of maximal oxygen consumption ($VO_{2\max}$) of boys, aged 6-16 years (16). However in this study, height or fat-free mass (FFM) did not show significant effect on MRW of adolescent students (Table 4.33-4.34).

It was noticeable that body composition, i.e. body fat, significantly accounts for almost all tests of physical fitness except one test (trunk-extensor strength and flexibility) in males, and except two tests (abdominal muscle strength/endurance, and trunk-extensor strength and flexibility) in females (Table 4.42). Fat-free mass (FFM) influenced almost all tests involving muscle function in males (modified pull-up, trunk-lift, and flexibility tests), whereas in females, only flexibility test was influenced by FFM (Table 4.42). These findings may be partly explained by the fact that males had more muscle mass than females (Table 4.12). Most female subjects (nearly 90%) and males (about 60%) had already passed a period of puberty. After pubertal period, males showed more increases in muscle mass, strength, power, and endurance, than females. Adolescent females tended to have more variables accumulated body fat (36). Moreover, behavioural factors may also interfere with the test performance in females.

Height was another factors positively and significantly related to curl-up, modified pull-up and back-saver sit-and reach (flexibility) tests in males, whereas only modified pull-up test in females was influenced by height (Table 4.42). In this study, on average males were significantly taller than females (157.7 ± 9.4 cm. for males vs.



154.6 $\pm$ 5.7 cm. for females Table 4.12). Height might be involved in posture of these tests. Together with more muscle mass, males perform superior to girls.

5.2 Iron/Nutritional Status And Cognitive Performance

The cognitive ability of the students was assessed by two groups of intelligence tests, i.e. the Raven Progressive Matrices (RPM) and the scholastic aptitude tests (SAT). Due to feasibility, only group tests were used which can be a limitation.

The mean IQ scores from the RPM test showed the identical general cognitive ability of male and female students, being 102.4 $\pm$ 8.5 for males and 103.0 $\pm$ 7.7 for females (Table 4.25). In both genders, the proportions of male and female students in each level of intelligence were similar (Table 4.26). For specific cognitive abilities, female students were better in verbal, numerical and reasoning abilities than males (Table 4.27-4.28). The results of SAT tests showed that approximately 70 % of male students and 55 % of females were poor in numerical and reasoning abilities (Table 4.28).

The difference in cognitive abilities between males and females has been reported, depending upon age and components of the tests, but the total scores of gross IQ are generally similar (100). Using Wechsler Adult Intelligence Scale (WAIS), the average scores favoured males in five subtests, and favoured females in four subtests, but the composite IQ scores of males did not differ from females' IQ scores (100). In studies using specific tests, the sex differences were found in both directions. For example, for testing involving mental operation, males tended to excel in tests of cognition (comprehension and understanding). Females showed greater fluency in expressing ideas than males. In terms of the tests involving information, females

tended to excel, especially the abilities to deal with words. These evidences support that the scores of males and females in some specific tests may differ, but the gross IQs can be identical. However, a recent evidence showed no gender difference in most specific cognition, with one exception. Males tended to excel in numerical abilities, especially in high school mathematics (143). In contrast to this study, male students were worse off in numerical SAT scores than females.

The SAT scores could be used to predict academic achievement of the students, and these scores were independent of classroom learning. They, however, depended on learning experience accumulated over time. Thus, SAT scores could reflect intellectual abilities. In this study, it was found that the SAT correlated to the RPM test (intelligence tests) ($r=0.37-0.51$, Table 4.24).

In this study, multiple regression analysis showed that height was significantly related to all tests of cognitive scores in females (Table 4.51). Malnutrition indicated by stunting, being about 6-11 % (Table 4.14-4.15), possibly accounted for the cognitive abilities of the students. Cognitive ability scores among the students with and without malnutrition was compared (See Appendix G for details). The results showed that stunted (both Thai and NCHS references) and thin (BMI-WHO) students significantly had lower scores in all cognitive tests than the normal ones. Underweight students (by NCHS) were significantly lower in all SAT tests than the normal, except IQ test. These findings indicated that malnutrition had adverse effects on cognitive abilities.

Theoretically, there are two significant factors affecting IQ of an individual, i.e. genetics and environmental factor (133). Under a general condition, Vernon concluded that 60% of IQ was attributable to heredity, 30% to the environment, and

10% to the combined effects of these two factors (133). Where there were special interventions from enriched environment, the balance shifted more toward environmental determination (100). The abilities to think and the ability to visualize movement were affected by heredity (100). Among environmental factors, nutritional deficiencies can adversely affect IQ and even produce mental retardation. Protein energy malnutrition, was found to be extremely damaging to intellectual development if it occurred in early childhood (133). Inadequate protein intake was shown to prevent full development of the brain, especially the area involved in memory storage (32). Additionally, other micronutrient deficiencies, especially iron deficiency, have been found to have adverse effects on educational achievement and mental ability (55).

In this study, age was another factor influencing cognition, especially SAT scores. Older children had higher scores. This may be explained by the fact that the scholastic aptitude tests (SAT) assessed the crystallized aspects of cognitive abilities of an individual (102). Although height and age were found to significantly influence cognition, it accounted for cognition in a very small amount (adjusted $R^2 = 0.016-0.067$, Table 4.43-4.48). This may be due to the fact that general intelligence and cognitive abilities of individuals were influenced by several determinants, mainly genetics (up to 60 %). Among environmental factors, besides iron and nutritional status, some important factors were such as environmental deprivation, home factors, learning at school and home, parent status, mothers' conditions during pregnancy affecting growth and development of her baby accounted for intelligence of individuals (133). These other factors were not included in this study and thus may limit the interpretation of the present study.

A number of studies showed effect of anaemia and iron deficiency on cognitive function. However, the results of these studies were inconsistency. In North America, Webb and Oski (1973,1974) studied adolescents aged 12-14 years, and showed that non-anaemic group was better on Iowa tests (107-108). A study in Thailand in younger children (9-11 y), non-anaemic children were seen to perform better on language tests and Raven's matrices (27). The study in India described beneficial effects of 8 weeks of iron supplementation in a group of anaemic 8-15 years old. A study in the UK failed to show significant associations between baseline iron intakes and cognitive function based on the Heims AH4 test, or two components, digitspan and coding, of the Weschler Intelligence Scale for Children (WISC) (139). Southon et al (1994) reported no relationships, neither between initial iron status (based on dietary or biochemical assessments) and the result from the WISC-R UK tests, nor any effect of a multivitamin and mineral supplement given daily for 16 weeks. Recent study by Brunner et al (1996) reported an improvement of verbal learning and memory in non-anaemic, iron deficient adolescent girls after supplement with iron for 2 weeks. In this study, haemoglobin was not significantly related to any tests of cognitive performance.

It has been documented that iron deficiency can alter the functioning of the central nervous system (144). Iron is a cofactor for the enzymes: tyrosine hydroxylase and tryptophan hydroxylase, which are essential for metabolism of neurotransmitters, such as dopamine, norepinephrine, and serotonin (144). From epidemiological studies, it seems clear that iron deficiency is associated with deficits in brain functioning and cognitive behaviour (144). In this study, most students were non-anaemic. The low rate of iron deficiency may account for the failure to find the association between iron

status and cognitive test scores, study in more iron deficient population may be more revealing.

Overall, due to the limitation of the study, population included in this study is relatively healthy and homogenous in their iron and nutritional status. Thus, the results did not reveal clear picture of relationships among variables. Nevertheless, it is an attempt to document situation regarding health-related physical fitness and cognitive performance which data are still limited. This study provided a model and offer source data and experience on battery of tests on nutrition and functions for further considerations. Repeating the similar set of assessments in more heterogeneous and relatively malnourished population will be useful to establish the interested relationships between iron/nutritional status and important functional consequences among adolescents in this age group.

5.3 Internal And External Validity

This study was performed with a well-planned randomly selected sample. However, there was 12.3 % of subjects drop-out, males dropped out more than females (46 or 17.4 % for males and 26 or 10.4 % for females). By examining the data, the age/sex ratio and the socioeconomic status of the remaining subjects did not alter. Thus, the interpretation of the results should not be biased, hence, internal validity should not be a problem.

Because the study was purposively done in one district of Nakhon Pathom Province, the findings can not be generalized to a larger population of Thai 12-15 years old. It would only be generalizable to school adolescents, aged 12-15 y, in

suburb areas that populations were similar in socioeconomic status and life-style as Nakhon Chaisri District.



CHAPTER VI

CONCLUSION

6.1 Pertinent Findings

The cross-sectional study on iron and nutritional status and its functional consequences on health-related physical fitness and cognitive performance in adolescents, aged 12-15 years was conducted in male and female schoolchildren at three secondary schools, which were located in Nakhon Pathom Province, Thailand. This study involved 586 students, 311 males and 275 females. All steps of school and sample selection were systematically randomized. The mean age of the studied students was 14.3 ± 0.9 years. Most participated students (88.9% of females and 60.4% of males) had already passed the pubertal stage. Age at menstrual onset of female students was 12.4 ± 1.1 years. Age at the onset of voice change of males was 13.3 ± 1.1 years. Data on haematological, anthropometry, dietary intake, health-related physical fitness, cognitive abilities, maturational status, and other related data were measured and collected. All data were analysed and reported by gender.

6.1.1 Iron and nutritional status

The pertinent findings of this study are summarized as follows:

1. Anaemia prevalence of school adolescents in Nakhon Chaisri is very low (3.1 % for males and 1.5 % for females)
2. The prevalence of low iron storage indicated by serum ferritin (using cut-off value at 30 $\mu\text{g/L}$) is about 15 % (12.4 % for males and 17.4 % for females)

3. Iron depletion (considering hamoglobin level together with serum ferritin) was approximately 12-15 %.
4. Assessment of nutritional status using weight and height parameters comparing with Thai references, the proportion of malnutrition in males and females were around 5 %, i.e., 6.1 and 4.8 % for underweight (weight-for-age), 7.1 and 5.9 % for stunting (height-for-age), and 5.5 and 5.2 % for wasting (weight-for-height).
5. Using NCHS reference, the prevalence of underweight and stunting in males was 13.2 % for underweight and 10.9 % for stunting. In females, the prevalence was 2.2 % and 7.7 % for underweight and stunting, respectively.
6. Using BMI-for-age as an indicator, the percentage of male students classified to be thinness was 21.2 % for males and 5.2 % and females. Overall, status of male adolescents was worse than that of females.
7. The prevalence of overweight (Thai reference) is 9.6 % in males and 7.7 % in females which was similar to the overweight prevalence based on BMI-for-age (WHO, 1995), which was 10.0 % and 8.5 % in males and females, respectively.
8. Male students had more lean mass, assessed in terms of fat-free mass, total muscle mass, and arm-muscle circumference, and lower fat mass (indicated by fat skinfold thickness, percent body fat, and total body fat) than females.
9. Male students were significantly taller than females at the same age, but their body weight was not significantly different. However, BMI was higher in females than in males.

6.1.2 Dietary intake

Based on a one-day 24-h-dietary recall in sub-sample study (1/3),

1. The average energy and almost all nutrient intakes of the students in both sexes were adequate, except vitamin A and calcium. Most students (> 50%) are adequate in energy and nutrient intake, but 80.4 and 91.9% of the students are inadequate in vitamin A and calcium intake levels, respectively.
2. The average intake of dietary iron is also adequate in males (14.0 ± 7.5 mg/d), but it was rather in borderline level in females (11.0 ± 6.4 mg/d).
3. The percent calorie distribution for CHO: fat: protein was 60: 25: 15.

6.1.3 Health-related physical fitness

Health-related physical fitness measured by the Prudential FITNESSGRAM test battery indicates that :

1. Most students (58.7% of males and 87.9% of females) needed improvement in the aerobic capacity assessed by one-mile run/walk test. The aerobic capacity increased with an increasing age. Males were fitter in aerobic capacity than females.
2. About 60-95% of both male and female students were reasonably fit, as assessed by healthy fitness in abdominal, upper-body and trunk extensor muscle strength, endurance and flexibility. Over 95% of male students and about 75% females passed the flexibility test.

6.1.4 Cognitive performance

Cognitive performance of the students was examined in terms of intelligence and scholastic aptitude scores in three components: verbal, numerical, and reasoning.

1. The mean IQ scores of male and female students were not significantly different, being 102.4 ± 8.5 for males and 103 ± 7.7 for females. About 75% of males and females were in normal intelligence level.
2. The numerical and reasoning scores of the cognitive abilities by the scholastic aptitude scores of most students (about 70% of males and 50% of females) were at poor level. About 40% of females were good at verbal test. In contrast, about 45% of male students are poor in this test.

6.1.5 Iron/nutritional status/body composition relating to health-related physical fitness

The relationships between iron/nutritional status/body composition and health-related physical fitness indicated that:

1. Multiple regression analysis indicated that iron status by haemoglobin level was an underlying variable influencing the aerobic capacity only in females and the upper-body strength/endurance only in males.
2. Anthropometry including body composition was significantly related to physical fitness tests. Body fat was found to negatively correlated with health-related physical fitness of the students. For male students, body fat was significantly and inversely related to almost all tests except, trunk extensor strength/flexibility. For females, body fat was significantly but negatively related to aerobic capacity, upper-body strength/endurance, and flexibility. Height was significantly and positively related to the tests of abdominal strength/endurance, and flexibility in positive direction, but negatively related to upper-body strength/endurance.

3. Upper-body strength/endurance, trunk extensor strength, and flexibility were significantly and positively related to fat-free mass in males, but only related to flexibility in females.

6.1.6 Iron /nutritional status/body composition relating to cognitive performance

The relationships between iron/nutritional status/body composition and cognition show that:

1. Iron status did not significantly relate to any tests of cognitive abilities. .
2. Height was only anthropometric variable significantly relates to all cognitive tests particularly in females, while this result was not found in males.

6.1.7 Age relation to health-related physical fitness and cognitive performance

Some tests of physical fitness and cognitive performance were also related to age.

1. For physical fitness, upper-body strength/endurance test and flexibility test was better in older than younger females.
2. For cognitive tests, IQ scores and reasoning aptitude test scores was higher in older than younger males. In females, scholastic aptitude tests (verbal, numerical, and reasoning), but not IQ test, were increased as age increased.

In summary, the prevalence of anaemia in school adolescents aged 12-15 years in this area of Nakhon Pathom Province is very low. However, iron depletion is found approximately 15 %. Malnutrition in this studied adolescents still exist, including underweight, stunting, and overweight. Grossly, male students in this age group are found to be worse in nutritional status than females.

Based on the findings in the present study, relationship between iron status by haemoglobin and cognitive performance among school adolescents was not found. Due to relatively homogeneity in nutrition/socioeconomic status of the study population, the relationships between nutritional/iron status and functional outcomes can not be established for the studied age range.

6.2 Recommendations

This study conducts in adolescent group whose information is limited. The findings of this study can explain some characteristics of the school adolescents that should be concerned, as follows:

1. Although the present findings did not clearly indicate high prevalence of nutritional deficiencies, the relatively low dietary intake of iron, especially in girls, warrants some concern. Verification of usual intake pattern will help to clarify the needs to promote proper eating, particularly that of micronutrients, to prevent possible nutritional deficiencies. Thus, nutritional/dietary programme, such as nutrition education, nutrient supplementation or dietary promotion through school lunch programme, could be provided in the schools to promote iron and nutritional status of adolescents.
2. 90 % of females are poor in aerobic capacity, which is a significant attribute of health-related physical fitness. The poor aerobic capacity could not be explained by nutritional deficiencies. Other factors, particularly behavioural factors such as lack of motivation for physical activities and exercises may be significant. Proper physical exercise programme should be incorporated into

school activity, such as outdoor physical exercise, to increase physical activities and exercises in order to promote physical fitness of the students.

3. Most of the studied students were in normal level of IQ and some of them are in bright level (about 15 %). Specific concern is on low numerical and reasoning SAT in both sexes, but particularly in males. The SAT scores may reflect the process of learning experience of the students in the schools. Thus, the schools should review academic process and learning aids to provide learning environment that promotes the cognitive abilities of the students, with special attention to male students.
4. The test of health-related physical fitness available for Thai children and adolescents at present is the Prudential FITNESSGRAM test battery. There are no references of health-related physical fitness used for Thai children and adolescents. Thus, the validity of the health-related physical fitness test should be ascertained and further study to establish the reference for healthy Thai children and adolescents should be performed.
5. Health-related physical fitness programme is a new approach to children and youth. Integrating this programme in the school activities could create awareness and participation in the activities to create good nutrition, physical fitness, and health both students, and schoolteachers.

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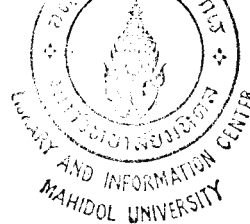
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APPENDIX

APPENDIX A STUDY SETTING

A.1 Location of Study Area

The study area is located in Nakhon Chaisri District, Nakhon Pathom Province, as shown in Figure A.1.

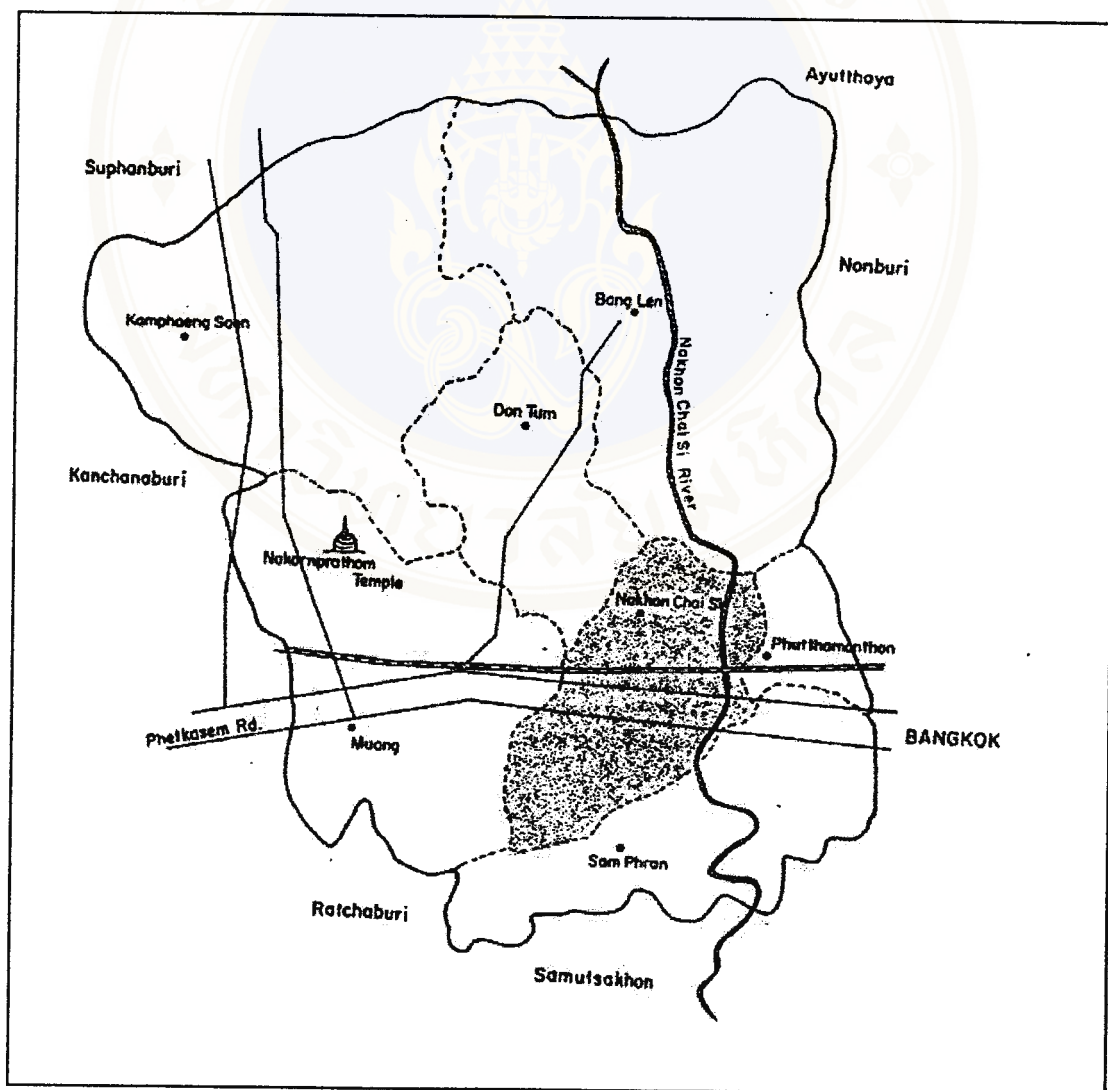


Figure A1 A map of districts in Nakhon Pathom Province.

A.2 Ethical Consideration

This study had approved by the Committee on Human Rights Related to Human Experimentation of Mahidol University, as shown in Figure A.2 and informed consent form was shown in Form A.1.



No. 24/1998

Documentary Proof of Ethical Clearance
The Committee on Human Rights Related to
Human Experimentation
Mahidol University, Bangkok

.....

Title of Project : Iron status, physical and cognitive performance and impacts of weekly iron supplementation among school adolescents in Nakhon Chaisri District, Nakhon Pathom Province

Principal Investigator : Assoc. Prof. Patthanee Winichagoon

Name of Institution : Institute of Nutrition

Approved by the Committee on Human Rights Related to Human Experimentation

Signature of Chairman : Surapol Issaragrissit
(Professor Dr. Surapol Issaragrissit)

Signature of Head of Institute : Athasit Vejajiva
(Professor Dr. Athasit Vejajiva)

Date of Approval : 13 Nov. 1998

Figure A2 A document of ethical approval for this project.

Form A.1

INFORMED CONSENT FORM

Project Title: Iron status, physical and cognitive performance of school adolescents in Nakhon Chaisri District, Nakhon Pathom Province.

Name of the student.....ID.....
Age.....years. Class.....School.....

For the students and parents:

My child,....., and I,....., have known the details of this study including the usefulness and the risks that might be happened in this projects from the explanation of the researchers and his/her associates already. I am willing to permit my child to participate in this study. Whenever my child and I have any questions about this study. My child and I can ask the researchers and his/her associates and they will do their best to answer the questions. I understand that my child and I have a right to withdraw from this study at any time.

Parent's signature.....

Student's signature.....

Witness's signature.....

Date.....

For researchers:

My associates and I have described the details of this project including the usefulness and the risks that might be happened in this study to the students and their parents already.

Researchers' signature.....

Date.....

A. 3 Time Schedule for Measurement Activities

All measurement activities were conducted between October 24 and November 11 in 1998 by the research teams as shown in Table A.1.

Table A.1 Time schedule for data collection and measurement activities.

Activities	Date	Place	Personnel
Anthropometry	27-28 October 1998	Laembua School	Physiological
& Physical	29-30 October 1998	Perm School	Nutrition Research
fitness tests	2-6 November 1998	Pattarayan School	Team, INMU
Blood	2-6 November 1998	Pattarayan School	Human Nutrition
collection	9-10 November 1998	Perm School	Research Team,
	11-12 November 1998	Laembua School	INMU
Diet interview	2-6 November 1998	Pattarayan school	Community
	9-10 November 1998	Perm School	Nutrition Research
	11-12 November 1998	Laembua School	Team, INMU
Intelligence test	27-28 October 1998	Laembua School	The researcher and
& Questionnaire	29-30 October 1998	Perm School	the schoolteachers
	2-6 November 1998	Pattarayan School	
Scholastic	9 November 1998	Pattarayan School	The testers from
aptitude tests	10 November 1998	Laembua School	Srinakharinwirot
	11 November 1998	Perm School	University

APPENDIX B DATA COLLECTION FORMS

Form B.1

Blood Collection Form

Date..... School.....

Name..... Class..... Code ☐ ☐ ☐ ☐ ☐ ☐

1. Did you take some medicines during last month?

☐ No ☐ Yes, specify.....

2. Do you regularly take a medicine?

☐ No ☐ Yes, specify.....

3. Date of menstruation onset.....

4. Is your menstruation cycle regularly?

☐ No ☐ Yes

5. How often is your menstruation cycle? times per month.

6. How many days do you loss blood per time of menstruation cycle?

.....day per time.

7. When did you have the last menstruation before your blood drawing?

8. Body temperature.....° C.

Results of blood analysis

1. Packed cell volume or Haematocrit.....%

2. Haemoglobin level.....g/dL

3. Serum ferritin.....ng/ml

Form B.2

Anthropometry and Health-Related Physical Fitness Form

No.....

Code

First Name.....Last name.....

School.....Class.....Date.....

Anthropometric measurement

Triceps skinfold thickness . mm.Calf skinfold thickness . mm.Mid-upper arm circumference . cm.Body weight . kg.Height . cm.

Health-related physical fitness

Curl-up test # of completedTrunk-lift test . inchesModified pull-up test # of completedFlexibility . inchesOne mile run/walk : min:sec

Form B.3

24-hour Dietary Recall Form

[illegible]

Name of subject.....Class.....Sex.....

School.....Date.....

Types of meal ☐ Regular ☐ Special

Meal & Time	Menu	Amount of food/ drink eaten	Component of food or drink eaten	Amount in each food component	Food code	Weight (g)

Form B.4

The Standard Raven Progressive Matrices Tests

Set A, B, C, D, and E

Code

Name..... Age.....years..... months

Class.....School.....Nakhon Chaisi District, Nakhon Pathom Province

A			B			C			D			E		
1			1			1			1			1		
2			2			2			2			2		
3			3			3			3			3		
4			4			4			4			4		
5			5			5			5			5		
6			6			6			6			6		
7			7			7			7			7		
8			8			8			8			8		
9			9			9			9			9		
10			10			10			10			10		
11			11			11			11			11		
12			12			12			12			12		
Total			Total			Total			Total			Total		
											Grand total		IQ	

Form B.5

Questionnaire form

Iron status, physical and cognitive performance of school adolescents in Nakhon
Chaisi District, Nakhon Pathom Province.

Code

Name.....Class.....

School Nakhon Chaisi District, Nakhon Pathom Province.

Address.....

Date.....

1. Personal information

1.1 Gender

() 1. Male

() 2. Female

SEX

1.2 Date of birth.....

1.3 Age.....

Age.....years.....months

8 9 10 11 AGE

1.4 Religion

() 1. Buddhist

() 2. Christian

() 3. Muslim

() 4. Others, specify...

RELIGION

1.5 Your birth order.....

13 14 V₁

1.6 How many brothers and sisters do you have ?

15 16 V₂

1.7 Birth place of your father.....

17 V₃

1.8 Birth place of your mother.....

18 V₄

2. Socio-economic background

For researcher only

2.1-2.5 How many members do you have at your house

for these age groups?

2.1 Number of members aged < 15 years.....

19	20

 V₅2.2 Number of members aged 15-60 years.....

21	22

 V₆2.3 Number of members aged > 60 years.....

23	24

 V₇2.4 Number of total members at your house.....

25	26

 V₈2.5 How many people are earning money at your house?
.....

27	28

 V₉

Dependency ratio.....

29	30	31	32

 V₁₀

2.6 What is the highest education of your father?

() 1. No education

() 2. Primary education, 1-4 /1-6 years

() 3. Secondary education, 7-9 years

() 4. Secondary education, 10-12 years

() 5. Occupational education

() 6. A first university degree

() 7. Higher a first university degree

() 8. Others, specify.....

33

 V₁₁

2.7 What is the highest education of your mother?

() 1. No education

() 2. Primary education, 1-4/1-6 years

() 3. Secondary education, 7-9 years

() 4. Secondary education, 10-12 years

34

 V₁₂

() 5. Occupational education

() 6. A first university degree

() 7. Higher a first university degree

() 8. Others, specify.....

For researcher only

2.8 What is the marital status of your father/mother ?

() 1. Married () 2. Divorced

() 3. Widowed () 4. Others, specify..

☐
35

V₁₃

2.9 With whom do you live at present?

() 1. Father and/or mother

() 2. Other person who is not your father / mother

() 3. Others, specify.....

☐
36

V₁₄

2.10 What is your father occupation?

() 0. Not living with your father

() 1. Farmer

() 2. Merchant

() 3. Government employee

() 4. Monthly money earner

() 5. Daily money earner

() 6. Unemployed

() 7. No occupation

() 8. Others, Specify.....

☐
37

V₁₅

2.11 What is your mother occupation?

() 0. Not living with your mother

- () 1. Farmer
- () 2. Merchant
- () 3. Government employee
- () 4. Monthly money earner
- () 5. Daily money earner
- () 6. Unemployed
- () 7. No occupation
- () 8. Others, specify.....

For researcher only

☐

38

V₁₆

2.12 What is your parent occupation? (parent = not your father/mother)

- () 0. Living with your father/mother
- () 1. Farmer
- () 2. Merchant
- () 3. Government employee
- () 4. Monthly money earner
- () 5. Daily money earner
- () 6. Unemployed
- () 7. No occupation
- () 8. Others, specify.....

☐

39

V₁₇

2.13 Who supports money to you ?

- () 1. Father and /or mother
- () 2. Parent (not father/ mother)
- () 3. Others, specify.....

☐

40

V₁₈

2.14 What is the average income of your family ?

- () 1. < 5,000 Baht/month.
- () 2. 5,000-9,999 Baht/month
- () 3. 10,000-14,999 Baht/month
- () 4. 15,000-19,999 Baht/month
- () 5. 20,000-29,999 Baht/month
- () 6. 30,000-49,999 Baht/month
- () 7. $\geq 50,000$ Baht/month
- () 8. Others, specify.....

For researcher only

☐

41

V₁₉

2.15 How much money do you get at school?

..... Baht/day.

42	43

V₂₀

2.16 How much money do you spend at school?

Transport costs..... Baht/day

44	45

V₂₁

Meal costs..... Baht/day

46	47

V₂₂

Drink and dessert costs..... Baht/day

48	49

V₂₃

Others, specify..... Baht/day

50	51

V₂₄

Total expenses..... Baht/day

52	53

V₂₅

3. Health condition

3.1 Were you ill during the last 6 month (from May to

October 1998) and that made you absent from school?

- () 0. No () 1. Yes

☐

54

V₂₆

3.2 If you were ill, how many times were you ill?

..... times/6 months

55	56

55 56

V₂₇

3.3 If you were ill, what kinds of diseases did you get?
.....
.....

3.4 If you were ill, how many days were you absent
from school? days/times of illness

3.5 Have you suffered from any specific chronic diseases?
() 0. No () 1. Yes

3.6 Did you take any anti-helminthes drug for the last 6
month (from May to October 1998)?
() 0. No () 1. Yes

3.7-3.17 Have you ever suffered from or had any signs
and symptoms of the following specific diseases?

Sign/symptom or disease	No	Yes
3.7 Bleeding gum		
3.8 Haemorrhagic skin		
3.9 Night blindness		
3.10 Toad skin		
3.11 Fissure tongue		
3.12 Angular stomatitis		
3.13 Fatigue and weakness (even not work hard)		
3.14 Haemorrhoids		
3.15 Constipation		
3.16 Anal skin itching		
3.17 Peptic ulcer		

For researcher only

☐ 57 V₂₈

☐ 58 ☐ 59 V₂₉

☐ 60 V₃₀

☐ 61 V₃₁

☐ 62 V₃₂

☐ 63 V₃₃

☐ 64 V₃₄

☐ 65 V₃₅

☐ 66 V₃₆

☐ 67 V₃₇

☐ 68 V₃₈

☐ 69 V₃₉

☐ 70 V₄₀

☐ 71 V₄₁

☐ 72 V₄₂

- 3.18 How do you take care yourselves when you are ill? For researcher only
- () 1. Not doing anything ☐ 73 V₄₃
- () 2. Buying a medicine from a drugstore
- () 3. Taking a herbal medicine
- () 4. Seeing a doctor at a clinic or a hospital
- () 5. Others, specify.....
- 3.19 Did you have any diarrhoea during the last 6 months
(from May to October 1998) ?
- () 0. No () 1. Yes ☐ 74 V₄₄
- 3.20 If you had diarrhoea, how many times
did you get?..... times/6 months 75 76 V₄₅
- 3.21 Did you have the common cold during the last 6
months (from May 1998 to present) ?
- () 0. No () 1. Yes ☐ 77 V₄₆
- 3.22 If you had the common cold, how many times
did you get?.....times/6 months 78 79 V₄₇
- 3.23 When you have fever and/or headaches, what kinds
of medicines do you take regularly?
- () 1. No medicine intake ☐ 80 V₄₈
- () 2. Aspirin
- () 3. Paracetamol
- () 4. Others, specify.....

4. Maturational status

For researcher only

For male students only

4.1 Have you already got a voice change?

() 0. No () 1. Yes

☐

81

V₄₉

4.2 What date did the voice change begin?

() 0. No voice change

☐

82

V₅₀

() 1. Getting voice-change, and the date of the beginning, specify.....

() 2. Not remember

Age of the voice-change onset

.....years.....months

83 84 85 86

V₅₁**For female students only**

4.3 Have you already got the menstruation?

() 0. No () 1. Yes

☐

87

V₅₂

4.4 What date did the menstruation begin?

() 0. Not getting the menstruation

☐

88

V₅₃

() 1. Getting the menstruation, and the date of the beginning, specify.....

() 2. Not remember

Age of the menstruation onset

.....years.....months

89 90 91 92

V₅₄

Form B.6 Coding book for a questionnaire form.

Variable name	Variable type	Description	Code and code label
ID	<V>	Identification number	001XYZ- 999XYZ 000-999 = Student number X = School, 1 = Pattarayan 2 = Laembua 3 = Perm Y = Class, 1 = Mathayom 1 2 = Mathayom 2 3 = Mathayom 3 Z = Classroom, 1-7
Sex	<V>	Sex	1 = Male, 2 = Female
Age	####	Age	XX/YY 00/00-99/99, Actual age XX = Age in years YY = Age in months
Religion	<V>	Religion	1 = Buddhist 2 = Christian 3 = Muslim 4 = Others

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₁	# #	Birth order	01-99, Actual figures
V ₂	# #	Number of brothers/sisters	01-99, Actual figures
V ₃	<V>	Birth place of father	1 = Bangkok 2 = Nakhon Pathom 3 = Other place
V ₄	<V>	Birth place of mother	Same as V ₃
V ₅	# #	Number of persons < 15 yr	00-99, Actual figures
V ₆	# #	Number of persons 15-60 y	00-99, Actual figures
V ₇	# #	Number of persons >60 y	00-99, Actual figures
V ₈	# #	Number of total persons in Family	00-99, Actual figures
V ₉	# #	Number of persons earning money	00-99, Actual figures
V ₁₀	# # # #	Dependency ratio	00/00-99/99, Actual figures

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₁₁	<V>	The highest education of father	1 = No education 2 = Primary education, 1-4/1-6 3 = Secondary education, 1-3 4 = Secondary education, 4-6 5 = Occupational education 6 = A first university degree 7 = Higher a first university degree 8 = Others
V ₁₂	<V>	The highest education of mother	Same as V ₁₁
V ₁₃	<V>	Marital status of father/mother	1 = Married 2 = Divorced 3 = Widowed 4 = Others
V ₁₄	<V>	Who is the subjects living with?	1 = Father/mother 2 = Parents, not father/mother 3 = Others

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₁₅	<V>	Father occupation	0 = No living with father/mother 1 = Farmer 2 = Merchant 3 = Government employee 4 = Monthly money earner 5 = Daily money earner 6 = Unemployed 7 = No occupation 8 = Others
V ₁₆	<V>	Mother occupation	Same as V ₁₅
V ₁₇	<V>	Parent occupation	Same as V ₁₅
V ₁₈	<V>	Who supports money to the subjects at school?	1 = Father/mother 2 = Not father/mother 3 = Others

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₁₉	<V>	Monthly income of the family	1 = < 5,000 B. 2 = 5,000-9,999 B. 3 = 10,000-14,999 B. 4 = 15,000-19,999 B. 5 = 20,000-29,999 B. 6 = 30,000-39,999 B. 7 = > 50,000 B. 8 = Others
V ₂₀	###	Daily money that the students received for spending at school	000-999, Actual figures
V ₂₁	##	Transport costs	00-99, Actual figures
V ₂₂	##	Meal costs	00-99, Actual figures
V ₂₃	##	Drink and dessert costs	00-99, Actual figures
V ₂₄	##	Others	00-99, Actual figures
V ₂₅	###	Total expenses	000-999, Actual figures

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₂₆	<V>	Illness of the subjects during the 6 months	0 = No, 1 = Yes
V ₂₇	# #	Times of illness	00-99, Actual figures
V ₂₈	<V>	The kinds of diseases	0 = No, 1 = Yes
V ₂₉	# #	Number of absence from school	00-99, Actual figures
V ₃₀	<V>	Chronic diseases of the subjects	0 = No, 1 = Yes
V ₃₁	<V>	Taking an anti-helminthes drug	0 = No, 1 = Yes
V ₃₂	<V>	Bleeding gums	0 = No, 1 = Yes
V ₃₃	<V>	Haemorrhagic skin	0 = No, 1 = Yes
V ₃₄	<V>	Night blindness	0 = No, 1 = Yes
V ₃₅	<V>	Toad skin	0 = No, 1 = Yes
V ₃₆	<V>	Fissure tongue	0 = No, 1 = Yes

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₃₇	<V>	Angular stomatitis	0 = No, 1 = Yes
V ₃₈	<V>	Fatigue and/or weakness	0 = No, 1 = Yes
V ₃₉	<V>	Haemorrhoids	0 = No, 1 = Yes
V ₄₀	<V>	Constipation	0 = No, 1 = Yes
V ₄₁	<V>	Anal skin itching	0 = No, 1 = Yes
V ₄₂	<V>	Peptic ulcer	0 = No, 1 = Yes
V ₄₃	<V>	How to take care themselves when the subjects were sick.	1 = Not doing anything 2 = Buying a medicine from a drugstore 3 = Taking a herbal medicine 4 = Seeing a doctor at a clinic or hospital 5 = Others
V ₄₄	<V>	Having diarrhoea during the last 6 months	0 = No, 1 = Yes
V ₄₅	# #	How many times do diarrhoea occur	00-99, Actual figures

Form B.6 (continued)

Variable name	Variable type	Description	Code and code label
V ₄₆	<V>	Having the common cold during the last 6 months	0 = No, 1 = Yes
V ₄₇	# #	How many times do common cold occur	00-99, Actual figures
V ₄₈	<V>	What kinds of a medicine are taken regularly when having fever or headaches	1 = Not taken 2 = Aspirin 3 = Paracetamol 4 = Others

Variable type: <V> = Qualitative variable.

= Quantitative variable.

Code label: 9, 99, 999 = Blank or not answer.

APPENDIX C METHODS OF MEASUREMENT AND DATA COLLECTION

C.1 Method of Blood Analysis

C.1.1 Determination of haemoglobin by the cyanmethaemoglobin method

The first step of the method was the forming of cyanmethaemoglobin or haemoglobinocyanide (HiCN) by reaction between blood sample and Drabkin's solution. This solution was prepared by dissolving 0.050-g potassium cyanide, 0.200-g potassium ferricyanide, and 0.140-g dihydrogen potassium phosphate in a 1-liter volumetric flask containing 200-300 ml of water, and then diluting with water to 1 liter after adding 1 ml of nonionic detergent.

The second step was the determination of blood haemoglobin by drawing 0.02 ml of blood sample into a tube containing 5.0 ml of Drabkin's solution. After well mixed and standing for at least 5 minutes at room temperature to achieve full colour development, the absorbance of the unknown sample (A_{unk}) and of a standard (A_{std}) was measured at 540 nm. Then, the haemoglobin concentration of unknown sample were calculated as follows:

$$\text{Haemoglobin unknown (g/l)} = \frac{A_{unk}}{A_{std}} \times \text{Haemoglobin standard (g/l)}$$

C.1.2 Packed cell volume

The microhaematocrit procedure required special disposable capillary tubes with 75-mm length, 1.16-mm internal diameter, and 0.20-mm wall thickness. A specially designed centrifuge was used.

Two capillary tubes was filled with whole blood to between 55-60 mm of the total 75 mm length, sealed with a clay-type sealant of 4-6 mm long, and centrifuged with a centrifugal force above 10,000 g for 5 minutes. The PCV was calculated from the measurements of the red cell and plasma columns as follows:

$$PVC = \frac{\text{length of red cell column (mm)}}{\text{length of cells + plasma column (mm)}}$$

The PCV or haematocrit was expressed as percent (%).

C.1.3 Serum ferritin

In this study, serum ferritin was measured by the enzyme-immunoassay for the quantitative determination of ferritin *in vitro* (Cat. No.1 488 708, Boehringer Mannheim). The test principle of ELISA consisted of four steps: immunoreaction, separation step, indicator reaction, and measurement step.

The ELISA method began with the 1-step sandwich assay using streptavidin technology. First, the sample should be serum or plasma that was treated with heparin, EDTA or citrate. Pipette 30 µl of standard/control serum/sample into a plastic tube coated with streptavidin, approximately 14 ng/tube. Add 1.0 ml of incubating solution, which was the mixture of buffer for incubation and anti-ferritin-POD-conjugate. The buffer solution contained phosphate buffer and monoclonal (mouse) anti-ferritin antibodies (biotinylated). The anti-ferritin-POD-conjugate consisted of anti-ferritin antibodies that was labelled with POD (≥ 1 U/ml). The mixture was then incubated for 30 minutes and the immunoreaction occurred. The ferritin was sandwiched between anti-ferritin antibodies and the POD-labelled antibodies and the ferritin sandwich bound to streptavidin on the inner wall of the tube. Secondly, this stage was separation stage by adding washing solution to remove unreacted antibodies. Thirdly, substrate-

chromogen solution (contained phosphate/citrate, H₂O₂ and chromogen) was added to react with the ferritin sandwich to develop colour. Finally, the absorbance was measured spectrometrically at wavelength 405 nm. The ferritin concentration of unknown samples was determined graphically by using a standard curve that was obtained by plotting the mean absorbance of the ferritin standard against the ferritin concentration.

C.2 Method of Physical Fitness Measurement

Table C.1 lists the fitness components and the test item of the Prudential FITNESSGRAM.

Table C.1 The Prudential FITNESSGRAM test items.

AEROBIC CAPACITY

Should select one of the following options:

- ◆ One Mile Run/Walk

The Pacer—recommended for grades K-3 (multistage 20 metre shuttle run)

BODY COMPOSITION

Should select one of the following options:

- ◆ Percent Fat – calculated from triceps & calf skinfolds
- Body Mass Index – calculated from weight & height

MUSCULAR STRENGTH, ENDURANCE & FLEXIBILITY

Should select as indicated:

Abdominal Strength

Must select

- ◆ Curl-up Test

Trunk Extensor Strength & Flexibility

Must select

- ◆ Trunk-lift

Upper Body Strength

Must select one

- Push-up
- ◆ Modified Pull-up
- Pull-up
- Flexed Arm Hang

Flexibility

May select one

- ◆ Back-saver Sit-and-reach
- Shoulder Stretch

-
- ◆ selected for this study

Table C.2 The Prudential FITNESSGRAM used in this study.

Components of physical fitness	Methods of measurement (units)
1. Body composition	Percentage of body fat (%) Body mass index (kg/m ²)
2. Aerobic capacity	One-mile run / walk (min:sec)
3. Abdominal strength / endurance	Curl-up test (# completed)
4. Trunk extension strength / endurance	Trunk-lift test (inches)
5. Upper-arm and shoulder girdle strength / endurance	Modified pull-up test (# completed)
6. Flexibility	Back-saver-sit and reach (inches)

C.2.2 The principal and rationale of the test items

C.2.2.1 Aerobic capacity

According to the Prudential FITNESSGRAM, aerobic capacity is the highest rate oxygen can be taken up and utilized by the body during exercise. One-mile run/walk (MRW) and progressive aerobic cardiovascular endurance run (PACER) are two field tests of aerobic capacity of the students in the Prudential FITNESSGRAM test battery (36). The one-mile run/walk test can be used for all students, but not purposively established for the grade K-3 students in kindergartens. The goal for the students is to complete the one-mile distance at a comfortable pace. The time taken for complete the test is measured. The PACER is an optional test for very young students in grade K-3.

The rationale for using MRW to estimate VO_{2max} is based on the fact that exhaustive exercise lasting longer than two minutes, energy is provided primarily through aerobic metabolism. Therefore, MRW performance is determined, in large part, by the highest rate of aerobic metabolism (VO_2) that can be maintained for the duration of the event. The highest rate of VO_2 that can be maintained during a distance run, in turn, is determined in large part by the VO_{2max} . Thus, distance run performance and VO_{2max} tested in adults and youths have a moderately strong correlation and a distance run performance can be used to estimate VO_{2max} (35).

C.2.2.2 Muscular strength/endurance

C.2.2.2.1 Abdominal strength/endurance

Muscular strength/endurance of the abdominal muscle is measured by curl-up test (36). This test replaces a full sit-up test common to most motor- and health-related test battery. There are some differences between the curl-up and the sit-up tests in arm placement, leg position, feet support, and range of motion of the movement.

In the curl-up test, arms are placed across the chest or at the sides both. This offers approximately the same resistance to the abdominal flexion motion and avoids any excessive hyperflexion of the neck. In addition, arms placed at the sides and sliding forward 3 or 4.5 inches during doing the test offer the advantages of a convenient method of measurement and of being readily standardized between subjects.

Flexed knees in the curl-up test decrease movement of the fifth lumbar vertebra over the sacral vertebrae. However, based on some evidences and common belief, the hip flexors are active whether the knees are flexed or not. Although there is evidence that flexed-knee sit-ups actually cause more intervertebral disc pressure than straight

leg sit-ups, but disc compression is not a major concern with the curl-up. Moreover, the abdominal muscles are responsible for only the first 30-45° of movement in the sit-up, with the hip flexors being responsible for the rest. If the motion is continued beyond 45° the already shortened hip flexors are exercised through only a short arc which can lead to adaptive shortening. Thus, the curl-up should be a more specific and safer than a full sit-up.

The objective of the curl-up test is to complete as many curl-ups as possible at a defined rate. Special equipment is used to measure the distance the students curl up. A completed curl is the initial phase of the sit-up and involves raising the head and shoulders off the exercise mat. The rate of exercise is at 20 curl-ups per minute. The test is to maintain the exercise rate as long as possible or complete a maximum of 75 curl-ups.

C.2.2.2.2 Upper-body strength/endurance

This physical ability is tested by measuring upper arm and shoulder girdle endurance require the subject to move or support the body weight against the pull of gravity and may involve either isometric or isotonic contractions of the muscle executed to exhaustion (68). It has been claimed that tests of this ability measure both strength and endurance. The Prudential FITNESSGRAM provides four standard tests to choose from. These include push-up, pull-up, modified pull-up, and flexed-arm hang (36).

C.2.2.2.3 Trunk extensor strength and flexibility

There are five anatomical and physiological areas that has been identified as critical for the development and maintenance of low back function i.e., low back lumbar, hamstring, and hip flexor flexibility plus abdominal and trunk extensor

strength/endurance. Of these five areas only trunk extensor strength/endurance have shown to predict both first time and recurrent low back pain (LBP). The trunk extensor strength/endurance is measured by the trunk-lift test suggested by the Prudential FITNESSGRAM (36).

This test requires the student to lie in a face-down position and lift the upper body to a maximum of 12 inches off the floor using the back muscles. The position must be held until the measurement can be made. The score is the height the student can hold his/her chin off the floor.

C.2.2.2.4 Flexibility

Two flexibility tests are provided by the Prudential FITNESSGRAM. The first one is the back-saver sit-and-reach test that measures the hamstring flexibility is similar to the traditional sit-and-reach test except that it is performed on one side at a time. One leg is fully extended while other knee is bent. In this position, the student reaches forward as far as possible. Measurement should be made on both the right and left legs.

In the traditional sit-and-reach test, the forward flexion movement of the trunk with the legs extended causes the anterior portion of the vertebrae to come closer together such that the discs bulge posteriorly and the muscles, fascia, and ligaments of the back are stretched. It also involves a forward rotation of the pelvis and sacrum. This causes the elongation of the hamstrings. Stretching both hamstrings simultaneously results in over-stretching the low back, especially in terms of excessive posterior disc compression. Stretching one hamstring at a time as in the back-saver sit-and-reach test can protect the low back by avoiding excessive flexion of the

lumbosacral spine. In addition, testing with one leg at a time eliminates the possibility of hyperextension of both knees.

The second one, the shoulder stretch test is an option to illustrate that flexibility is important throughout the body, not just only at the hamstrings, and that flexibility is every specific to the joints. The shoulder stretch test measures the upper body flexibility. The goal is to touch the fingertips together behind the back by reaching over the shoulder and under the elbow.

C.2.2.3 Body composition

Body composition can be measured by percent body fat estimated from the sum triceps and calf skinfolds using the equation developed by Lohman (37). Body mass index is an alternative measure of the body composition.

C.2.3 Measurement method of the Prudential FITNESSGRAM

C.2.3.1 One mile run/walk

For this test, the subject was asked to run and/or walk a one-mile (or 1.6 km) distance on a flat measured area. The principle of this test was that the subject had to run and/or walk at the fastest pace as possible. The subject was instructed to run in a constant pace during the test. If running the total distance was impossible, walking at a fast pace was definitely permitted. The time taken when each subject completed one-mile run/walk was recorded in minutes and seconds.

C.2.3.2 The curl-up test

The objective of the curl-up test was to measure the strength and endurance of the abdominal muscles. The subject had to complete as many curl-ups as possible up to a maximum of 75 curl-ups. The subject was asked to lie in a supine position on a mat with knees bent at an angle of approximately 140°, feet flat on the floor, legs slightly

apart, and arms straight and parallel to the trunk with palms and hands resting on the mat. Keeping heels in contact with the mat, the subject curled up slowly, and then curled down. The movement of curl up and down was counted to be one curl-up. During the test, each subject continued to curl up and down without pausing until he/she was unable to continue any longer or had completed a maximum number of 75 curl-ups. See also Figure C.1.

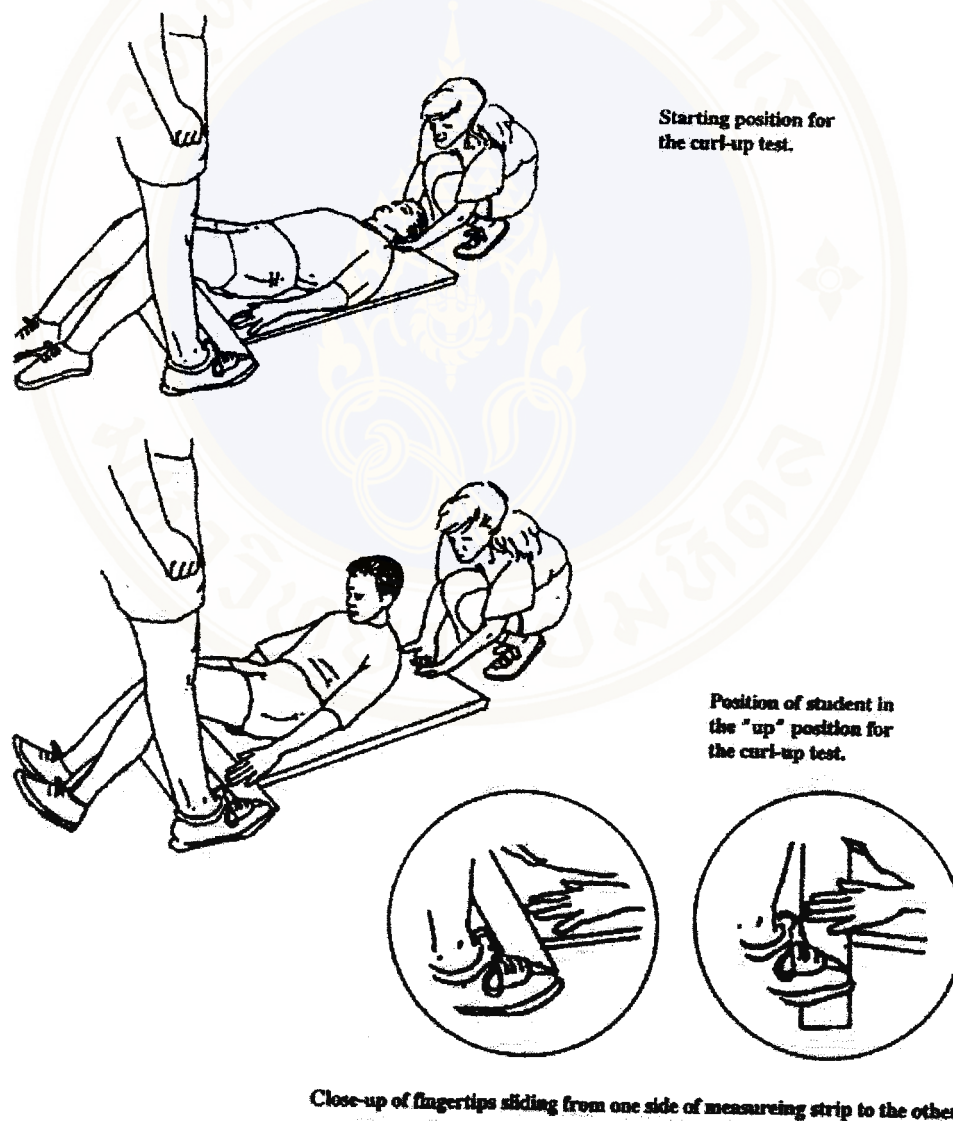


Figure C.1 The curl-up test

C.2.3.3 The trunk-lift test

The objective of the trunk-lift test was to lift the upper body to 12 inches off the floor using the back muscles and hold this position to allow for the measurement. The subject being tested lied on the mat in a prone position. Toes were pointed and hands were placed under the thighs. The subject lifted the upper body off the floor, in a very slow and controlled manner, to a maximum height of 12 inches. The tester placed the ruler on the floor in front of the subject and measured the distance of the subject's chin from the floor. The subject was allowed to test twice in order to record the highest distance. See also Figure C.2.

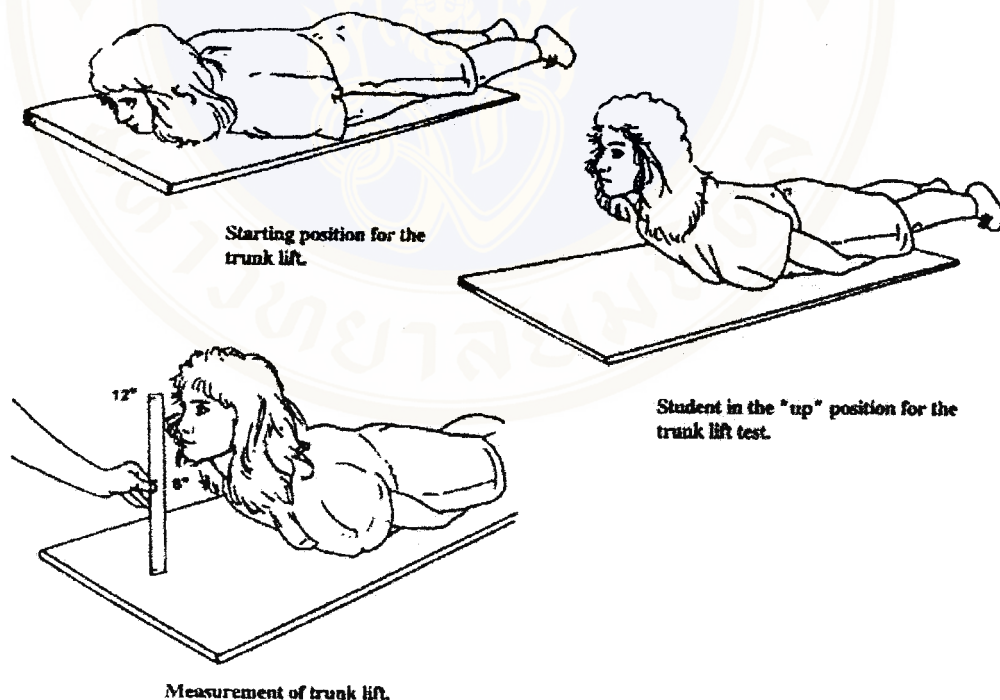


Figure C.2 The trunk-lift test.

C.2.3.4 The modified pull-up test

The principle of this test was the same as the push-up test, which was recommended as a test for the upper body strength and endurance. However, the modified pull-up test, which was an alternative item, was a very good test item to use to examine in schoolchildren. The objective of the modified pull-up test was that the subject should successfully complete as many modified pull-ups as possible. This test used equipment called the pull-up stand with an adjustable bar. See also Figure C.3

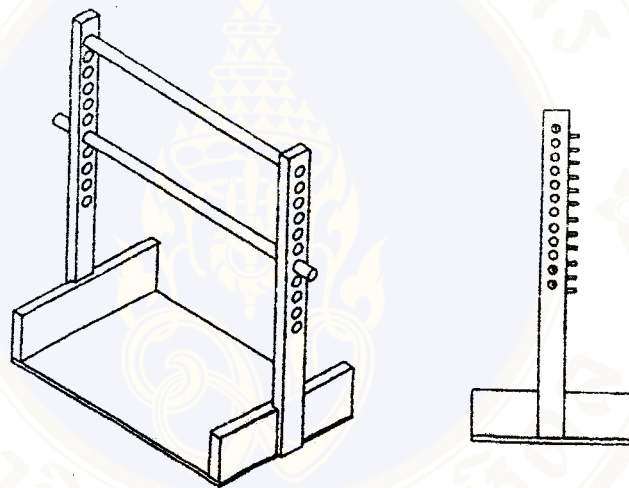


Figure C.3 An Equipment for modified pull-up.

The subject being tested lied down on his/her back with the shoulders directly under the bar that had been set 1 to 2 inches above the subject's reach. Place an elastic band 7 to 8 inches below and parallel to the bar. The subject grasped the bar with an overhand grip (palms away from body). Pull-up began in down position with arms and legs straight, buttocks off the floor, and only the heels touching the floor. The subject then pulled up until chin was above the elastic band. The number of correct pull-ups performed was counted. See also Figure C.4.

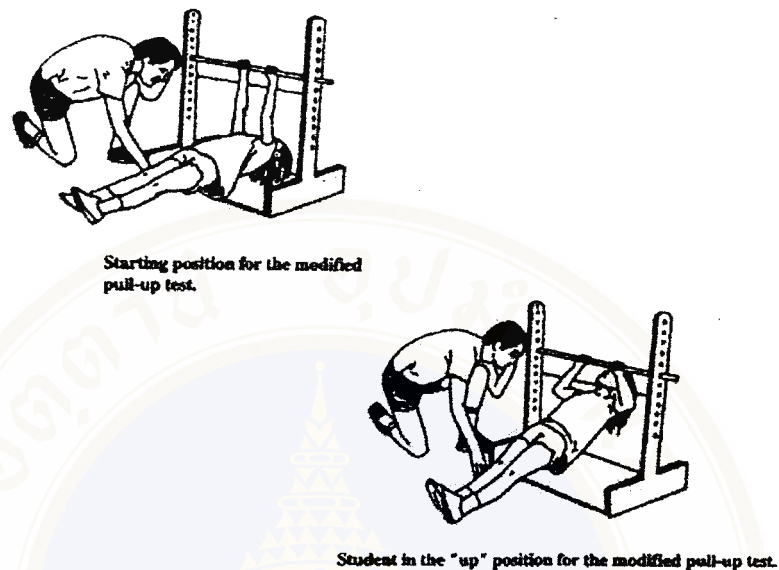


Figure C.4 The modified pull-up test

C.2.3.5 The back-saver sit-and-reach test

This test was used to test joint flexibility. The objective of this test was that the subject was able to reach the specific distance on the right and left sides of the body. This test required apparatus that was a sturdy box approximately 12 inches high. See also Figure C.5.

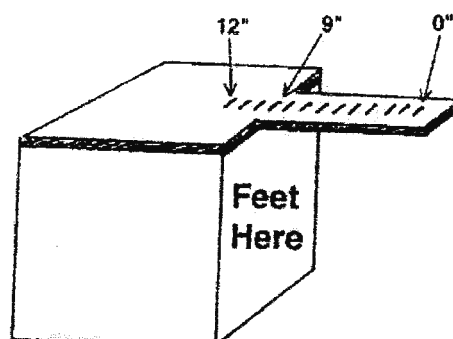
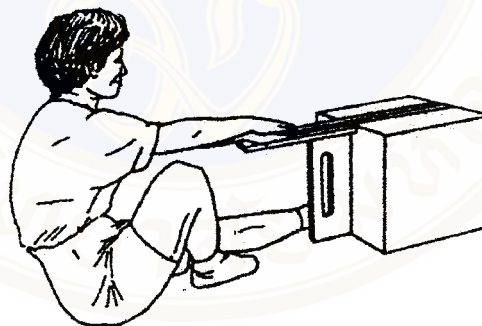
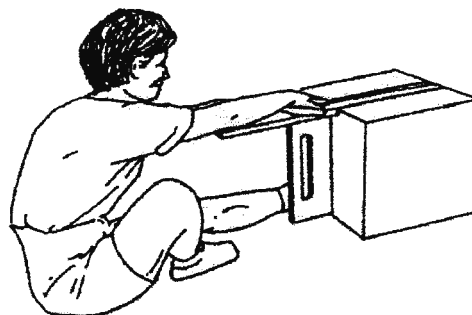


Figure C.5 An Equipment for back saver sit and reach

There was a measuring scale or a ruler placed on top of the box with the 9-inch mark even with the near edge of the box, and the zero end of the ruler extended outward and nearest the subject while being tested. The subject was tested on the right sides of the body only. The subject had to remove his/her shoes and sat down at the test box. The left leg was fully extended with the foot flat against the end of the box. The right knee was bent with the sole of the foot flat on the floor and 2-3 inches to the side of the straight left knee. The both arms were extended forward over the measuring scale with the hands placed one on top of the other. With palms down, the subject reached directly forward with both hands along the scale four times and held this position of the fourth reach for at least one second. The tester recorded the number of inches as a flexibility score. The maximum score was 12 inches. See also Figure C.6.



Starting position for measuring the left side.



Back-saver sit-and-reach stretch for the left side.

Figure C.6 The back-saver sit-and-reach test.

APPENDIX D CRITERIA FOR DATA INTERPRETATION

D.1 Criteria for Assessing Iron Status

The criteria for assessing anaemia and iron deficiency used in this study were shown in Table D.1 and Table D.2, respectively.

Table D.1 Criteria used for assessing anaemia in children aged 12-15 years.

Age	The Hb cut-off value (g/L)	The Hct cut-off value (%)	Reference
12-13 years	120	36.0	(135)
>13-15 years, male	130	39.0	(135)
>13-15 years, female	120	36.0	(135)

Table D.2 Multiple criteria used for assessing iron status in this study (34).

Haemoglobin level	Ferritin concentration ^a	Interpretation
≥ the cut-off value	≥ the cut-off value	Normal (N)
≥ the cut-off value	< the cut-off value	Iron depletion (ID)
< the cut-off value	< the cut-off value	Iron deficiency anaemia (IDA)

^a The cut-off value for ferritin, all age and both sexes = 30 µg/L (117-118).

D.2 Criteria for Assessing Nutritional Status

The criteria for assessing nutritional status used in this study were shown in Table D.3.

Table D.3 Criteria used for assessing nutritional status in this study.

Indicator	Variable	Cut-off value ^a	Reference
Stunting	Height-for-age	< 3 rd percentile of reference or < -2 Z-scores	(40)
Thinness	BMI-for-age	< 5 th percentile of reference	(40)
At risk of overweight	BMI-for-age	≥ 85 th percentile of reference	(40)
Obese	BMI-for-age &	≥ 85 th percentile of reference	(40)
	TSF-for-age	≥ 90 th percentile of reference	(40)
Overweight	Wt-for-Ht ^b	≥ 97 th percentile of reference	(121)
Wasted	Wt-for-Ht ^b	< 3 rd percentile of reference	(121)

^a Relative to the NCHS/WHO reference data except Wt-for-Ht

^b Relative to the Thai reference data, 1987.

D.3 References for the Prudential FITNESSGRAM

The criterion referenced standards for the Prudential FITNESSGRAM tests are provided separately for boys and girls, as shown in Table D.4-D.6.

Table D.4 The Prudential FITNESSGRAM standard values^a of aerobic capacity for male and female students(36).

Age (y)	Male		Male		Female		Female	
	HFZ ^b of MRW		HFZ ^b of VO _{2max}		HFZ ^b of MRW		HFZ ^b of VO _{2max}	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
12	10:30	8:00	42	52	12:00	9:00	37	45
13	10:00	7:30	42	52	11:30	9:00	36	44
14	9:30	7:00	42	52	11:00	8:30	35	43
15	9:00	7:00	42	52	10:30	8:00	35	43

^a See Table 4a for units.

^b HFZ = Healthy Fitness Zone

Table D.5 The Prudential FITNESSGRAM standard values^a of abdominal and upper-body muscle strength, endurance, and flexibility for male and female students(36).

Age (y)	Male		Male		Female		Female	
	HFZ ^b of Curl.up		HFZ ^b of Pull.up		HFZ ^b of Curl.up		HFZ ^b of Pull.up	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
12	18	36	7	20	18	32	4	13
13	21	40	8	22	18	32	4	13
14	24	45	9	25	18	32	4	13
15	24	47	10	27	18	32	4	13

^a See Table 4a for units.

^b HFZ = Healthy Fitness Zone

Table D.6 The Prudential FITNESSGRAM standard values^a of trunk-extensor muscle strength, endurance, and flexibility for male and female students (36).

	Male		Male	Female		Female
Age (y)	HFZ ^b of Trunk		HFZ ^b of	HFZ ^b of Trunk		HFZ ^b of
	Lower	Upper	Flexibility ^c	Lower	Upper	Flexibility ^c
12	9	12	8	9	12	10
13	9	12	8	9	12	10
14	9	12	8	9	12	10
15	9	12	8	9	12	10

^a See Table 4a for units.

^b HFZ = Healthy Fitness Zone.

^c Test scored Pass/Fail = must reach this distance to pass.

D.4 Interpretation of Cognitive Performance

The interpretation of the SAT and the RPM scores were shown in Table D.6-D.7.

Table D.7 Level of mental abilities defined by the T-score and percentile rank of the scholastic aptitude test (SAT).

T-score of SAT	Percentile range	Level of mental ability
65 - 75	93 th – 99 th	Excellent
55 - 64	69 th – 92 th	Good
45 - 54	31 th – 68 th	Fair
35 - 44	7 th - 30 th	Poor
25 - 34	1 st - 6 th	Very poor

Table D.8 Conversion of RPM scores to WAIS^a IQ.

RPM	WAIS^a IQ	RPM	WAIS^a IQ	RPM	WAIS^a IQ
8	68	26	87	44	106
9	69	27	88	45	107
10	70	28	89	46	108
11	71	29	90	47	109
12	72	30	91	48	110
13	73	31	92	49	112
14	74	32	94	50	113
15	76	33	95	51	114
16	77	34	96	52	115
17	78	35	97	53	116
18	79	36	98	54	117
19	80	37	99	55	118
20	81	38	100	56	119
21	82	39	101	57	120
22	83	40	102	58	121
23	84	41	103	59	122
24	85	42	104	60	123
25	86	43	105		

^a Wechsler Adult Intelligence Scale

Table D.9 The intelligence classification by IQ score as measured by the Wechsler Adult Intelligence Scales (WAIS)(033).

IQ score	Category of intelligence
120 and over	Superior
110 – 119	Bright
90 – 109	Normal
80 – 89	Dull
79 and below	Borderline of mental retard

APPENDIX E MULTIPLE REGRESSION ANALYSIS

E.1 Physical Fitness as Outcome Variables

The results of multiple regression analysis in combined sex using each test of physical fitness as an outcome variable are shown in Table E.1-F.5.

Table E.1 Factors explaining aerobic capacity (MRW, min) in combined sex.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	10.116	2.165		0.0001
Age (y)	-0.138	0.079	-0.061	0.082
Sex ^a	1.630	0.193	0.398	0.0001
Hb (g/dl)	-0.179	0.079	-0.081	0.023
Ht (cm)	0.0003	0.014	0.013	0.816
FFM (kg)	0.0056	0.019	0.018	0.773
ln BF ^b	1.563	0.211	0.337	0.0001

^a Male = 0, female = 1.

^b ln BF = Percent body fat in log.

R = 0.687, Adjusted R² = 0.466, n = 533, F_{6, 226} = 78.310, p = 0.0001.

Table E.2 Factors explaining abdominal muscle strength/endurance (curl-up test, # completed) in combined sex.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	23.915	15.800		0.131
Age (y)	-0.273	0.574	-0.020	0.635
Sex ^a	-7.848	1.420	-0.323	0.0001
Hb (g/dl)	-0.590	0.574	-0.045	0.304
Ht (cm)	0.243	0.105	0.160	0.021
FFM (kg)	-0.223	0.141	-0.119	0.114
ln BF ^b	-3.790	1.547	-0.138	0.015

^a Male = 0, female = 1.

^b ln BF = Percent body fat in log.

R = 0.425, Adjusted R² = 0.171, n = 542, F_{6, 535} = 19.608, p = 0.0001.

Table E.3 Factors explaining upper-body strength/endurance (pull-up test, # completed) in combined sex.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	29.232	6.622		0.0001
Age (y)	1.141	0.239	0.151	0.0001
Sex ^a	-5.209	0.589	-0.378	0.0001
Hb (g/dl)	0.642	0.239	0.086	0.007
Ht (cm)	-0.201	0.044	-0.233	0.0001
FFM (kg)	0.252	0.059	0.235	0.0001
ln BF ^b	-6.164	0.649	-0.392	0.0001

^a Male = 0, female = 1.

^b ln BF = Percent body fat in log.

R = 0.749, Adjusted R² = 0.557, n = 539, F_{6, 532} = 113.567, p = 0.0001.

Table E.4 Factors explaining trunk-extensor strength and flexibility (trunk-lift test, inch) in combined sex.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	12.839	2.370		0.0001
Age (y)	0.003	0.086	0.016	0.725
Sex ^a	-0.0022	0.210	-0.007	0.916
Hb (g/dl)	-0.132	0.086	-0.072	0.126
Ht (cm)	-0.0022	0.016	-0.104	0.163
FFM (kg)	0.0074	0.021	0.286	0.0001
ln BF ^b	-0.386	0.229	-0.103	0.093

^a Male = 0, female = 1.

^b ln BF = Percent body fat in log.

R = 0.209, Adjusted R² = 0.033, n = 542, F_{6, 535} = 4.075, p = 0.001.

Table E.5 Factors explaining flexibility (back-saver sit-and-reach test, inch) in combined sex.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	12.066	2.811		0.0001
Age (y)	0.304	0.102	0.134	0.003
Sex ^a	1.404	0.255	0.340	0.0001
Hb (g/dl)	0.0095	0.102	0.042	0.354
Ht (cm)	-0.0046	0.019	-0.176	0.015
FFM (kg)	0.117	0.025	0.0367	0.0001
ln BF ^b	-1.477	0.279	-0.316	0.0001

^a Male = 0, female = 1.

^b ln BF = Percent body fat in log.

R = 0.328, Adjusted R² = 0.097, n = 542, F_{6, 535} = 10.713, p = 0.0001.

E.2 Cognitive Performance as Outcome Variables

The results of multiple regression analysis in combined sex using each test of cognitive performance as an outcome variable are shown in Table E.6-E.9.

Table E.6 Factors explaining IQ scores in combined sexes ^a.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	64.235	10.582		0.0001
Age (y)	1.176	0.383	0.142	0.002
Sex ^b	0.869	0.952	0.158	0.362
Hb (g/dl)	0.294	0.385	0.036	0.445
Ht (cm)	0.141	0.070	0.149	0.046
FFM (kg)	-0.0068	0.094	-0.058	0.472
ln BF ^c	-0.727	1.032	-0.043	0.482

^a R = 0.219, Adjusted R² = 0.037, n = 543, F_{6, 536} = 4.505, p = 0.0001.

^b Males = 0, females = 1.

^c ln BF = Percent body fat in log.

Table E.7 Factors explaining verbal SAT scores in combined sexes ^a.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	-1.770	6.516		0.786
Age (y)	0.948	0.235	0.179	0.0001
Sex ^a	2.796	0.587	0.292	0.0001
Hb (g/dl)	-0.285	0.234	-0.055	0.224
Ht (cm)	0.0083	0.043	0.139	0.055
FFM (kg)	0.0002	0.058	0.003	0.970
ln BF ^b	-0.0073	0.642	-0.007	0.910

^a $R = 0.382$, Adjusted $R^2 = 0.136$, $n = 522$, $F_{6, 515} = 14.683$, $p = 0.0001$.

^b Males = 0, females = 1.

^c ln BF = Percent body fat in log.

Table E.8 Factors explaining numerical SAT scores in combined sexes ^a.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	-14.019	11.513		0.224
Age (y)	1.125	0.414	0.124	0.007
Sex ^a	4.345	1.018	0.265	0.0001
Hb (g/dl)	-0.138	0.415	-0.015	0.740
Ht (cm)	0.144	0.076	0.140	0.058
FFM (kg)	-0.0003	0.102	-0.002	0.977
ln BF ^b	-0.924	1.114	-0.050	0.408

^a R = 0.301, Adjusted R² = 0.080, n = 523, F_{6, 516} = 8.551, p = 0.0001.

^b Males = 0, females = 1.

^c ln BF = Percent body fat in log.

Table E.9 Factors explaining reasoning SAT scores in combined sexes ^a.

Explanatory variables	Regression coefficient (b)	Standard error (SE)	Standardized regression coefficient (beta)	p-value
Constant	-8.622	6.332		0.174
Age (y)	0.653	0.231	0.131	0.005
Sex ^a	1.414	0.564	0.156	0.012
Hb (g/dl)	0.0053	0.230	0.011	0.816
Ht (cm)	0.0087	0.042	0.154	0.040
FFM (kg)	-0.0051	0.057	-0.073	0.368
ln BF ^b	0.926	0.612	0.091	0.131

^a $R = 0.291$, Adjusted $R^2 = 0.074$, $n = 522$, $F_{6,515} = 7.937$, $p = 0.0001$.

^b Males = 0, females = 1.

^c ln BF = Percent body fat in log.

APPENDIX F HAEMOGLOBIN DATA

Descriptive data of haemoglobin of the students are shown in Figure F1 and Table F1

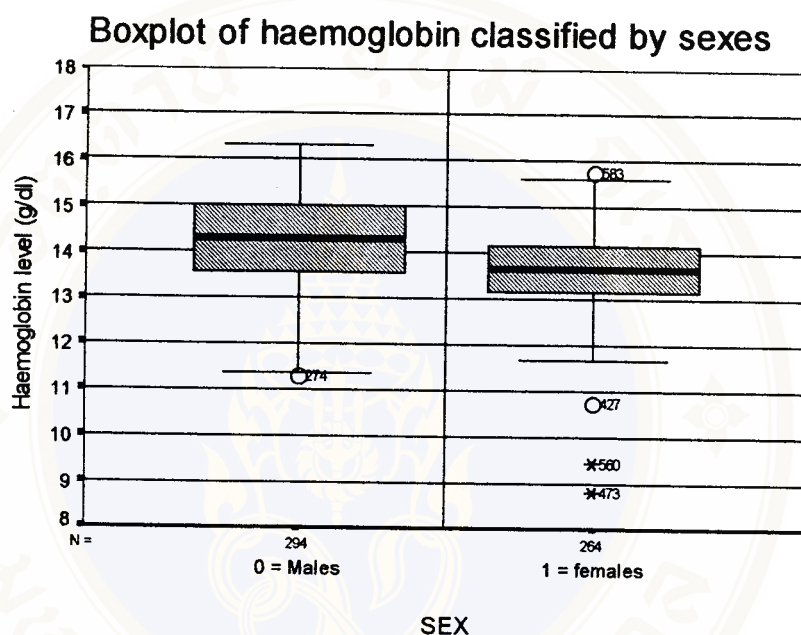


Figure F1 Boxplot of haemoglobin data classified by sexes.

Table F1 Descriptive statistics of haemoglobin data

Descriptive Statistics

SEX		N	Range	Minimum	Maximum	Mean	Std. Deviation
0	HB	294	4.98	11.32	16.30	14.2435	.8818
	Valid N (listwise)	294					
1	HB	264	6.95	8.85	15.80	13.6508	.8607
	Valid N (listwise)	264					

Sex 0 = Males

1 = Females

APPENDIX G COGNITIVE SCORES BY NUTRITIONAL STATUS

Table G1 Comparisons of cognitive test scores of the students classified by chronic malnutrition (Stunting-Thai)

Cognitive scores	Malnutrition	n	Mean $\pm$ SD	p-value
IQ	Stunting	38	99.79 $\pm$ 8.31	0.029 ^a
	Normal	540	102.93 $\pm$ 8.03	
SAT-V	Stunting	38	19.84 $\pm$ 4.68	0.010 ^b
	Normal	513	22.06 $\pm$ 5.09	
SAT-N	Stunting	38	18.32 $\pm$ 6.09	0.008 ^a
	Normal	513	22.22 $\pm$ 8.69	
SAT-R	Stunting	38	14.18 $\pm$ 4.72	0.007 ^a
	Normal	513	16.43 $\pm$ 4.70	

^a Mean comparisons were made by nonparametric Mann-Whitney U test.

^b Mean comparisons were made by parametric independent-samples t-test.

Table G2 Comparisons of cognitive test scores of the students classified by chronic malnutrition (Stunting-NCHS)

Cognitive scores	Malnutrition	n	Mean $\pm$ SD	p-value
IQ	Stunting	55	100.60 $\pm$ 7.77	0.036 ^a
	Normal	523	102.94 $\pm$ 8.08	
SAT-V	Stunting	54	20.50 $\pm$ 4.96	0.033 ^b
	Normal	497	22.06 $\pm$ 5.09	
SAT-N	Stunting	54	18.65 $\pm$ 7.10	0.003 ^a
	Normal	497	22.31 $\pm$ 8.67	
SAT-R	Stunting	54	14.33 $\pm$ 4.57	0.002 ^a
	Normal	497	16.49 $\pm$ 4.70	

^a Mean comparisons were made by nonparametric Mann-Whitney U test.

^b Mean comparisons were made by parametric independent-samples t-test.

Table G3 Comparisons of cognitive test scores of the students classified by
malnutrition (Underweight-Thai)

Cognitive scores	Malnutrition	n	Mean $\pm$ SD	p-value
IQ	Underweight	32	101.53 $\pm$ 6.34	0.173 ^a
	Normal	546	102.79 $\pm$ 8.16	
SAT-V	Underweight	31	20.50 $\pm$ 4.96	0.033 ^b
	Normal	520	22.06 $\pm$ 5.09	
SAT-N	Underweight	31	18.65 $\pm$ 7.10	0.119 ^a
	Normal	520	22.31 $\pm$ 8.67	
SAT-R	Underweight	31	14.33 $\pm$ 4.57	0.050 ^a
	Normal	520	16.49 $\pm$ 4.70	

^a Mean comparisons were made by nonparametric Mann-Whitney U test.

^b Mean comparisons were made by parametric independent-samples t-test.

Table G4 Comparisons of cognitive test scores of the students classified by
malnutrition (Underweight-NCHS)

Cognitive scores	Malnutrition	n	Mean $\pm$ SD	p-value
IQ	Underweight	47	101.96 $\pm$ 6.10	0.173 ^a
	Normal	546	102.79 $\pm$ 8.23	
SAT-V	Underweight	46	19.98 $\pm$ 4.41	0.007 ^b
	Normal	505	22.08 $\pm$ 5.12	
SAT-N	Underweight	46	18.57 $\pm$ 6.82	0.007 ^a
	Normal	505	22.26 $\pm$ 8.67	
SAT-R	Underweight	46	14.41 $\pm$ 3.71	0.004 ^a
	Normal	505	16.45 $\pm$ 4.78	

^a Mean comparisons were made by nonparametric Mann-Whitney U test.

^b Mean comparisons were made by parametric independent-samples t-test.

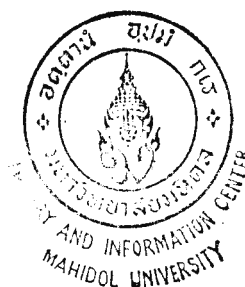
Table G5 Comparisons of cognitive test scores of the students classified by malnutrition (Thinness-WHO)

Cognitive scores	Malnutrition	n	Mean $\pm$ SD	p-value
IQ	Thinness	80	100.94 $\pm$ 8.25	0.027 ^a
	Normal	444	103.06 $\pm$ 7.97	
SAT-V	Thinness	75	20.08 $\pm$ 4.40	0.001 ^b
	Normal	422	22.22 $\pm$ 5.11	
SAT-N	Thinness	75	18.79 $\pm$ 8.15	0.001 ^a
	Normal	422	22.53 $\pm$ 8.45	
SAT-R	Thinness	75	14.68 $\pm$ 4.28	0.003 ^a
	Normal	422	16.50 $\pm$ 4.76	

^a Mean comparisons were made by nonparametric Mann-Whitney U test.

^b Mean comparisons were made by parametric independent-samples t-test.

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