

**NUTRITIONAL ASSESSMENT BY ANTHROPOMETRY IN  
THAI ELDERLY AND HEIGHT ESTIMATED EQUATIONS  
DEVELOPMENT**

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SUPRANEE CHANGBUMRUNG, Dr. agr.**ABSTRACT**

Malnutrition conditions such as underweight, overweight and obesity can occur in elderly people as a result of the aging process, which can lead to chronic diseases. Anthropometry, body size and body composition measurement to assess nutritional status, is an appropriate assessment method for elderly. Inaccurate height measurement can occur in elderly due to difficulties in measuring standing height, affecting the assessment of their nutritional status. The purpose of this study is to assess the nutritional status of the elderly by anthropometry, and to develop equations to predict height using knee length and arm span. The cross-sectional study was conducted between September 2013 and August 2014. Cluster sampling included 1,711 subjects in Bangkok and its vicinities. The nutritional status of 790 elderly was assessed by anthropometry. From total 1,711 subjects, 1,531 cases with complete data were selected to develop height predictive equations. Several equations were calculated in 1,403 subjects, whereas 128 subjects were put into a validation group. The study found that the subjects' age was negatively correlated with all anthropometric parameters. Underweight was more commonly found in men, whereas obesity and central obesity were higher in women. Malnutrition found in the study group requires interventions to prevent further complications. This study also proposes new height estimation equations for Thais using knee height and arm span. Prediction equations for female are "Height = 44.116+2.337(average knee height) - 0.07(age)" (adjusted R<sup>2</sup> = 0.805), and "Height = 53.951+ 0.660(arm span) -0.091(age)" (adjusted R<sup>2</sup>= 0.760), for male are "Height = 45.447+2.371(average knee height) - 0.059(age)" (adjusted R<sup>2</sup> = 0.790), and "Height = 39.563+0.756(arm span) - 0.086(age)" (adjusted R<sup>2</sup> = 0.765). The equation accuracy were higher than the previous studies conducted in Thailand and can thus be applied in clinics and community health settings - especially in elderly unable to measure their standing height.

**KEY WORDS: ELDERLY / ANTHROPOMETRY / NUTRITIONAL STATUS /  
PREDICTIVE HEIGHT EQUATION**

114 pages

การประเมินภาวะโภชนาการในผู้สูงอายุไทยโดยการวัดสัดส่วน และการพัฒนาสมการประเมินส่วนสูง  
 NUTRITIONAL ASSESSMENT BY ANTHROPOMETRY IN THAI ELDERLY AND HEIGHT  
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บทคัดย่อ

ภาวะน้ำหนักน้อย อ้วน หรืออ้วนลงพุง เป็นภาวะที่เกิดขึ้นได้บ่อยในผู้สูงอายุ ซึ่งเกิดจากกระบวนการของการสูงอายุ ทำให้ผู้สูงอายุมีโอกาสเกิดโรคเรื้อรังต่างๆ การวัดสัดส่วนร่างกายเพื่อประเมินภาวะโภชนาการ เป็นวิธีที่เหมาะสมในผู้สูงอายุ การที่ผู้สูงอายุไม่สามารถยืนตรงได้ตรงขณะวัดความสูง ทำให้ได้ค่าความสูงที่วัดได้ไม่ถูกต้อง จึงส่งผลต่อการประเมินภาวะโภชนาการ วัตถุประสงค์ของการศึกษา ได้แก่ การประเมินภาวะโภชนาการด้วยการวัดสัดส่วนร่างกาย และการพัฒนาสมการทำนายความสูงจากการวัดความยาวแขน และความสูงเข่า ได้ทำการศึกษาเก็บข้อมูลแบบภาคตัดขวางในช่วงเดือน กันยายน พ.ศ. 2556 ถึงเดือน สิงหาคม พ.ศ.2557 สุ่มกลุ่มตัวอย่างด้วยวิธีการสุ่มกลุ่มในกรุงเทพฯ และจังหวัดปริมณฑลจำนวนทั้งสิ้น 1,711 ราย ในจำนวนนี้มีผู้สูงอายุ 790 ราย และได้ทำการประเมินภาวะโภชนาการ สำหรับการพัฒนาสมการทำนายความสูง ใช้กลุ่มตัวอย่างทั้งหมด 1,531 ราย โดยที่กลุ่มตัวอย่างจำนวน 1,403 ราย นำไปสร้างสมการ และ 128 ราย นำไปทดสอบความแม่นยำของสมการ ผลการศึกษาพบว่า ความชุกของภาวะน้ำหนักน้อยพบในผู้ชายมากกว่าผู้หญิง ขณะที่ภาวะอ้วน และภาวะอ้วนลงพุงจะพบในผู้หญิงมากกว่าผู้ชาย พบความสัมพันธ์ระหว่างอายุและสัดส่วนร่างกายของผู้สูงอายุอย่างมีนัยสำคัญทางสถิติ ผู้สูงอายุที่มีน้ำหนักน้อยถึงจะพบไม่มาก แต่ยังคงให้ความสำคัญเนื่องจากมีภาวะแทรกซ้อนที่เป็นอันตราย สำหรับภาวะอ้วนและอ้วนลงพุงพบมากในผู้สูงอายุ โดยเฉพาะผู้หญิง ดังนั้นควรมีการจัดโปรแกรมการดูแลเรื่องภาวะโภชนาการในผู้สูงอายุในชุมชนอย่างต่อเนื่อง สมการความสูงที่พัฒนาจากความสูงเข่า และความยาวแขนที่มีอำนาจการทำนาย และความแม่นยำในการทำนายมากที่สุด คือ  $Height = 44.116 + 2.337(\text{average knee height}) - 0.07(\text{age})$  (adjusted  $R^2 = 0.805$ ) และ  $Height = 53.951 + 0.660(\text{arm span}) - 0.091(\text{age})$  (adjusted  $R^2 = 0.760$ ) สำหรับผู้หญิง และ  $Height = 45.447 + 2.371(\text{average knee height}) - 0.059(\text{age})$  (adjusted  $R^2 = 0.790$ ) และ  $Height = 39.563 + 0.756(\text{arm span}) - 0.086(\text{age})$  (adjusted  $R^2 = 0.765$ ) สำหรับผู้ชาย สมการความสูงที่พัฒนาในการศึกษานี้ พบว่ามีอำนาจในการทำนาย และมีความแม่นยำกว่าสมการที่มีผู้พัฒนาขึ้นมาก่อนหน้านี้ ซึ่งสามารถนำไปประยุกต์ใช้ในคลินิก หรือในชุมชนและสามารถเป็นสมการที่ใช้ในผู้สูงอายุที่ไม่สามารถวัดความสูงในท่ายืนได้

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## LIST OF ABBREVIATIONS

<b>Abbreviation or symbol</b>	<b>Term</b>
%	Percentage
$\geq$	Equal or more than
$\leq$	Equal or less than
$>$	More Than
$<$	Less Than
AC	Abdominal circumference
AHpR	Abdominal-hip ratio
AHtR	Abdominal-height ratio
AS	Arm span
BF	Body fat
BIA	Bioelectrical impedance analysis
BMI	Body mass index
BW	Body weight
CCK	Cholecystokinin
CI	Confidence interval
cm	Centimeter
CT	Computer tomography
CVD	Cardiovascular disease
DEXA	Dual X-ray absorptiometry
dL	Deciliter
DM	Diabetes mellitus
eq	Equation
et al.	Et cetera
F	F-test Statistic
FA	Female arm span
FFM	Fat free mass

## LIST OF ABBREVIATIONS (cont.)

<b>Abbreviation or symbol</b>	<b>Term</b>
FK	Female knee height
H	Height
ICC	Intra-class correlation coefficient
IDF	International Diabetic Federal
Kg	Kilogram
KH	Knee height
m	Meter
MA	Male arm span
MD	Mean difference
MK	Male knee height
MUAC	Mid upper arm circumference
n	Number
NIH	National Institutes of Health
r	Correlation coefficient
RMR	Resting metabolic rate
R <sup>2</sup>	R squared
SD	Standard deviation
SE	Standard error
SEE	Standard error of estimation
TEF	Thermic effect food
TF	Total body fat
VF	Visceral fat
WC	Waist circumference
WHO	World Health Organization
WHpR	Waist-hip ratio
WHtR	Waist-height ratio

# CHAPTER I

## INTRODUCTION

### 1. 1 Introduction

A person whose age is between 60 and 65 is generally considered as an older adult (1). In Thailand, one is considered an older adult when the person is 60 years old and older (2). Currently, this older adult population is the fastest growing segment in the Thai population. The census published that this elderly population increased to 7.3 % in 1990 and has continually risen to 13.9% in 2012. Its size has doubled in number since 1990. Moreover, it is expected to increase to 32% by 2050 (3). By then, Thailand will become an old population society whereby the elderly will outnumber the young population, becoming the predominant group in the society.

The process of aging is coupled with physical and psychological changes. These changes may lead to health-related nutritional disorders, consequently increasing susceptibility to chronic diseases such as abdominal obesity, cardiometabolic risks, physical disabilities and other related conditions.

The elderlies are most likely to suffer from Protein-Energy Malnutrition (PEM), a serious condition that is due to an inadequate intake of nutrients, particularly energy and protein. Physiological and psychological factors contribute to the inadequate food intake are commonly experienced by this aging population. Physical and physiological changes such as poor oral health and deteriorated dentition can result in poor appetite, loss of taste and smell, which diminishes the intake of food. Others major factor leading in the inadequate food intake among the elderly are dementia and depression. Depression is considered to be an important cause of weight loss, while dementia can result in elderly skipping meals due to forgetfulness. It is an established fact that undernutrition or underweight in older people has many adverse consequences. Not only are they at risk of an increased mortality, but also at risk of multiple medical complications that can have a significant impact on the overall quality of life. Moreover, undernutrition also leads to muscle wasting, thus an

increased risk of falling down, consequently increasing the risk of fractures and injury among the elderly. Immune dysfunction, increased infection susceptibility, poor wound healing and delayed recovery from surgery are other adverse effects. Aging causes body compositional changes, where muscle mass decreases and abdominal fat increases. Excess abdominal fat in older population is an independent risk of diseases related to obesity including type 2 diabetes mellitus (DM), hypertension, dyslipidemia and cardiovascular diseases (4-8).

Obesity or an excessive fat accumulation in the body is common in the aging population. Physical activity reduction, changes in the appetite-stimulating and appetite-inhibiting hormones and age-related body composition change can induce obesity in the elderly population. This nutritional disorder may be a major health hazard in the aging population (4, 5). The prevalence of obesity has been increasing in elderly, in which it will become a major public health problem. Several disorders related to obesity are osteoarthritis, hepatic steatosis, pulmonary dysfunction, urinary tract dysfunction, obstructive sleep apnea syndrome, and certain types of cancer, reduced cognitive skills, sexual dysfunction and depression.

Information on body composition of an elderly is required for a proper evaluation of their nutritional and functional status. The potential change in body composition may lead to changes in the risk factors of chronic diseases, especially for elderly persons. The health condition or nutritional status of a person is influenced by nutrients and non-nutrients ingestion and utilization. Therefore, it is important and necessary to routinely administer appropriate nutritional screening and assessment in this aging population group. Assessment of nutritional status can be achieved through dietary intake, clinical, biochemical and anthropometric methods. Each method has a different purpose appropriate for different circumstances, and likewise has both advantages and limitations (4-8). Initial stages of a nutrient deficiency can be identified through dietary intake method. The method acts as a monitoring tool in the food and beverage consumption, however, the method can be inaccurate and unreliable at times as the elderly often have an impaired memory. In the clinical assessment method, physical examination is performed to evaluate whether the elderly is present with signs and symptoms of nutrient deficiencies. The method may be inaccurate and unreliable as well due to the inability of the elderly to clearly report and

describe signs and symptoms pointing to a nutrient deficiency. Risk factors related to nutrition for some chronic diseases such as heart disease can be determined and monitored through biochemical method. This method requires more equipment and is too invasive, making it inappropriate for nutritional surveys in large-scale (4, 6 -7).

The anthropometric method utilizes the measurement of human body to monitor body size and determine body fat distribution (7), which facilitates in the assessment of risks for certain chronic diseases. The size of the body is measured through weight, height and body circumference including mid upper arm, waist and hip circumferences. Since height cannot be measured in disabled who cannot stand or an elderly, surrogate height measurements were developed. Knee height (KH) and arm span (AS) measurements are considered surrogate measurements in predicting a person's height (4, 7). Our body is mainly composed of fat and fat free mass. An anthropometric method that measures body fat percentage is the skinfold thickness technique and bioelectrical impedance analysis. Anthropometric measurements are common in clinical settings and in nutritional surveys because these are able to clearly detect malnutrition, specifically in cases where an imbalance in protein and energy is present.

Among the methods of assessing nutritional status, anthropometric method is the suitable choice in the aging population group. Not only the method is simple, portable, and inexpensive, it is also the least invasive and does not require complicated skills. Measurements taken can be precise if accurately done but they may be insensitive and are incapable in the detection of a nutritional status disturbance occurring in a short period of time.

Height is a representation of a person's body size. Accurately determining an individual's height is important as height is a crucial factor for predicting essential nutritional status indicators, including body mass index (BMI), basal metabolic rate and body composition. Height measurement among the elderly is present with difficulties. They are unable to recall height and provide accurate information due to memory loss. Moreover, it is difficult to measure standing height in this age group as they cannot stand up straight. Spinal deformities that are induced with aging usually lead to a drop in height as well. Alternatively, anthropometric method utilizes the measurement of the length of body organs such as the KH, legs, arms and AS for

predicting the height of the elderly (7 - 12). Various researchers have proposed predictive knee height and arm span equations in different countries for different groups of people (9 -11, 13-15). In Thailand, two studies have formulated knee height equations, however, there were some limitations to these studies. Jitapunkul and Benchajareonwong in 1998 studied a group of inpatients in Bangkok, while Chittawatanarat et al. in 2012 conducted a study using only volunteers in Northern region of Thailand (13, 14). Hence, the equations from the previous studies may not be appropriate for the whole country.

With regards to Thailand soon becoming an old society, health problems related to nutritional disorders in this aging population touch the researcher's interest. Therefore, this research is conducted to identify anthropometric characteristics of Thai elderlies, to determine obesity and underweight conditions and prevalence in this population, and to develop equations for estimating stature from knee height and arm span for aging population group in Thailand. The participants were chosen with cluster sampling from certain districts in Bangkok and the nearby provinces of Samut Prakan, Nakorn Pathom, Pathum Thani, Nonthaburi and Samut Sakorn. These provinces were selected as representatives because various people from different regions of Thailand migrated to these locations.

## **1.2 The objectives of study**

1. To determine the prevalence of obesity and underweight conditions of Thai elderly.
2. To identify the distribution and describe values for anthropometric characteristic of Thai elderly.
3. To develop equations to estimate stature for use in the community settings using a proxy indicator of standing height, namely knee height and arm span, categorized by gender and age group.
4. To validate height predictive equation derived from the study and compare to other previously developed equations.

## CHAPTER II

### REVIEW OF THE LITERATURES

#### 2.1 Older adult and population trend

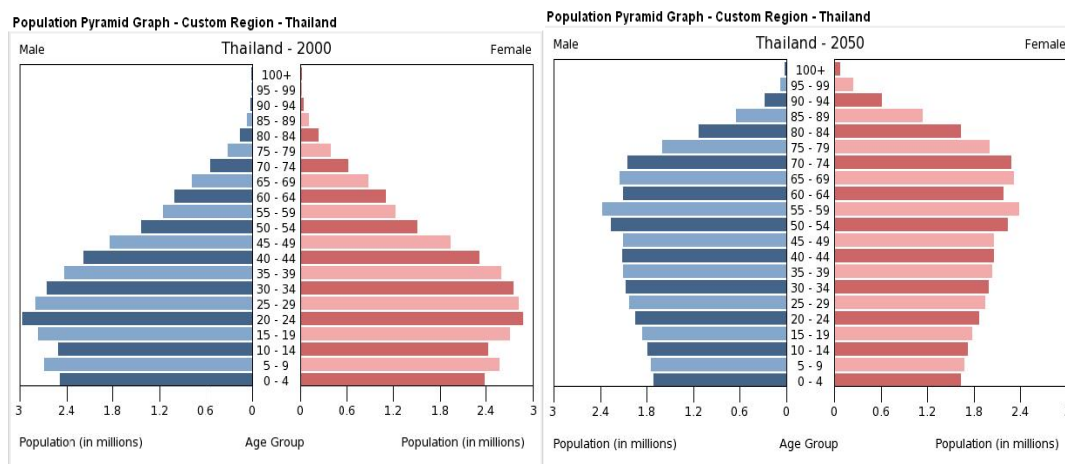
An older adult can be defined in several ways depending on biological, social, demographic and work-related factors. Generally, people aged 60 or 65 years and above are considered as older adults. The United Nations (UN) defined an older adult as a person whose age is 60 and older (1). Most research and those incorporated in most official policies and programmes in Thailand followed the UN definition for elderly (2). The number of old population has been rapidly increasing all over the world, including Thailand. The National Statistics of Thailand showed Thai elderly increased from 9.9% in 2000 to 13.9% in 2012 and is expected to continue to be 18.1% in 2020 (3). Table 2.1 showed the anticipated growth in number among the Thai elderly from 2000 – 2020.

**Table 2.1** Total population and older population by age in Thailand: 2000 and 2005 to 2020

Year	Total Population	Older Population					
		Total		Male		Female	
		Number	%	Number	%	Number	%
2000	61,904,273	6,145,055	9.9	2,840,172	9.3	3,304,883	10.6
2005	64,235,279	7,273,123	11.3	3,359,854	10.6	3,913,269	12.1
2006	64,677,487	7,507,497	11.6	3,467,034	10.8	3,467,034	12.4
2007	65,109,894	7,760,348	11.9	3,582,493	11.1	4,177,855	12.7
2008	65,531,043	8,034,328	12.3	3,707,281	11.4	4,327,047	13.1
2009	65,939,911	8,329,565	12.6	3,841,295	11.8	4,488,270	13.5
2010	66,336,258	8,646,221	13.0	3,984,512	12.2	4,661,709	13.9
2011	66,720,153	8,980,791	13.5	4,135,378	12.5	4,845,413	14.4
2012	67,091,089	9,330,352	13.9	4,292,350	13.0	5,038,002	14.8
2020	69,557,701	12,601,678	18.1	5,730,238	16.7	6,871,440	19.5

**Source:** The United States Census Bureau. (<http://www.census.gov/population/international/data/idb/region.php>)

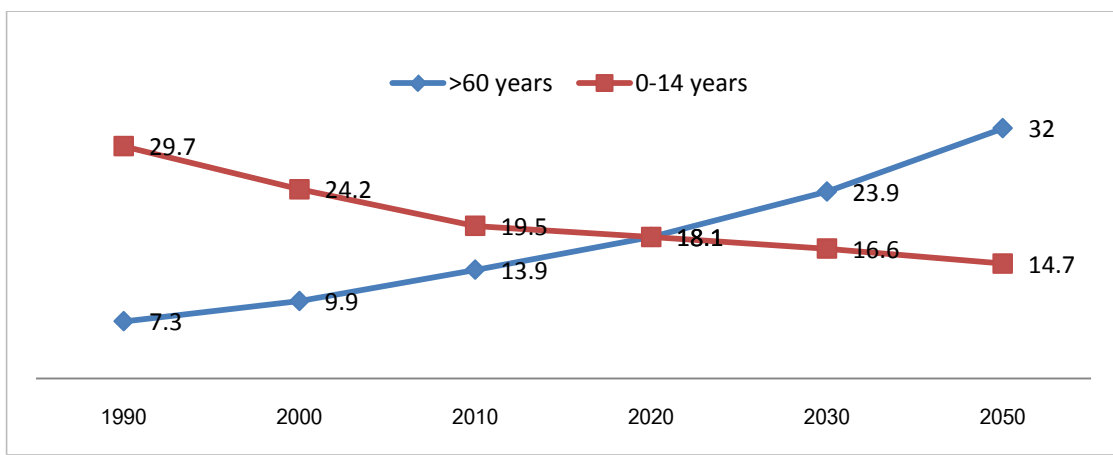
Thai population pyramids shown in Figure 2.1 reflected a decreasing trend in the young population, likely due to limited birth rate. Also, as the mortality and morbidity rates are reducing, Thai citizens are living longer. Thus, it is expected that there will be more elderly population than young population in the future. The base of the population pyramid in 2000 was narrow, which became a little wider at the middle then tapered off to point at the top. This implies that in 2000, huge proportions of the population were young people and a very small proportion was older people. By 2050, the shape of the expected pyramid is fairly different from that in 2000. Since the fertility rate is so low that the number of children born does not replace the young adult, the pyramid base is expected to be narrower. The middle part of the pyramid will gradually expand and become narrow again at the top, suggesting sizable proportion of older people in Thailand in the near future.



**Fig. 2.1** Projected population pyramid of Thailand in 2050  
 (<http://www.census.gov/population/international/data/idb/region.php>)

The trend implicated in Thai population shown in Figure 2.2 predicted that Thailand will become an aging society in the future. In 1990, only the elderly group comprised of 7.3% of the total population, whereas the percentage of young population was more than three times higher (29.7%). After a decade, percentage of elderly rose to 9.9%, and continued increasing to 13.9% in 2010. In contrary, the young population proportion declined from 29.7% in 1990 to 19.5% in 2010. The Thai graying rate then escalates continually in the next coming years, while the young

population steadily drops. It is forecasted that by 2020, the proportion of both old and young population in Thailand will be of equal to 18.1%. Following the crossing point, the population trend will diverge whereby the young population will decline and the elderly group will continue to rise. By 2050, the percentage of young population will drop to 14.7% and that of old population will rise to 32%, a twice of the young population (3).



**Fig.2.2** Proportion between the old and young population  
 (<http://www.census.gov/population/international/data/idb/region.php>)

## 2.2 Malnutrition problems among older adults

Schlenker (4) defined malnutrition as a nutritional deficit, excess, or imbalance. Overweight and underweight are examples of malnutrition. Hickson (5) defined the term malnutrition as the state of being poorly nourished and may be caused by the lack of one or more nutrients (undernutrition), or an excess of nutrients (overnutrition). Malnutrition by UNICEF (16) is a broad term commonly used as an alternative to undernutrition, but technically also refers to overnutrition. People are malnourished if their diet does not provide adequate calories and protein for growth and maintenance or they are unable to benefit from the food they eat fully due to illness (undernutrition). They are also malnourished if they consume too much calories (overnutrition).

Malnutrition is a condition when a nutritional imbalance occurs and undernutrition and overnutrition are the two types of malnutrition. Underweight can be considered as undernourished, whereas the overnutrition refers to being overweight and obese. This can either be due to an excess intake of nutrients or a deficit intake of nutrients. It may lead to cell mass deformation, metabolic disorders and malfunction of the body's physiological systems and organs. Health issues, lifestyle, psychological conditions and social environment are risk factors that can lead to malnutrition. Studies reveal that the old population is easily susceptible to malnutrition due to physiological changes that occur during the aging process.

### **2.2.1 Underweight**

Poor functional status, increased disease-related complications, increased severity of disability and a diminished quality of life that affects the graying population are associated with undernutrition. Undernutrition is defined as poor health resulting from the depletion of nutrients due to inadequate nutrient intake over time (7). Protein-Energy Malnutrition (PEM) is the most serious condition of undernutrition among the elderly population, a condition that results from an inadequate intake of macronutrients such as energy and protein. This adversely affects the well-being of the older persons and is usually correlated with a weight loss (4 – 5).

An unintentional 5 - 10% weight loss in the last 6 months, BMI less than  $18.5 \text{ kg/m}^2$ , or less than 3.5 g/dL protein albumin level in the serum indicate a protein and energy deficiency that may result to a negative effect on health (4 - 7). Statistical information published separately in the 5<sup>th</sup> National Food and Nutrition Survey in Thailand in 2006 and the 4<sup>th</sup> National Health Examination Survey (NHES IV) in 2008 and 2009 illustrated similar trends among the elderly group in Thailand (17 - 18). The Food and Nutrition Survey of Thailand in 2006 divided the elderly population into 2 groups: 60-69 and  $\geq 70$  years. Thai older adults belonging to the  $\geq 70$  age group has a higher underweight ( $\text{BMI} < 18.5 \text{ kg/m}^2$ ) percentage rate than the Thai older adults in the 60-69 age groups. Among the 60-69 years old adults, 17.1% of females and 18.2% of males were underweight. In the  $\geq 70$  age group, 23.5% and 24.8% of females and males were underweight, respectively. Two years later, the NHES IV divided the elderly population into 3 groups: 60-69, 70-79 and  $\geq 80$ . Underweight percentage rate

for males in the youngest elderly group was 11.2% and was 10.1% for females. For the middle age elderly group (70-79 years), underweight percentage rate was 18.9% for males and 16.8% for females. The underweight percentage rate was 30.9% for males and 27.6% for females in the  $\geq 80$  group. The results of both survey reports implied that Thai male older adults have a higher underweight percentage rates than their female counterparts in all age groups. In addition, the percentage of underweight is higher with age.

The following topics discuss and summarize the causes of an inadequate food intake among the elderly (5 -7, 19).

### **1) Physiological factors**

#### **Poor appetite**

The aging process induces changes in the endocrine system that regulates hunger, appetite and satiety. Decreased physical activity along with aging could reduce metabolic rate and result in a loss of appetite.

#### **Loss of taste and smell**

A perceived decline in the pleasantness in food is usually experienced when a person reaches the age of 60 and may also cause a reduced appetite. The aging process triggers a reduction in the number of taste buds and a decrease in the functioning of the receptors in the cell membrane involving taste sensations. Certain medications such as lipid lowering drugs, antihistamines, antibiotics, anti-inflammatory drugs, bronchodilator and asthma medications, antihypertensive, Parkinson's disease treatments and antidepressants commonly taken by the elderly can change taste and smell sensations.

#### **Oral health and dentition deterioration**

Healthy oral cavity and free from diseases are adequate for eating. Aging affects oral health and deteriorates dentition. As oral health deteriorates, there is an increased risk of oral diseases. The elderly population usually suffers from dry mouth or so called Xerostomia, an oral disease which is caused by a reduced saliva secretion, making eating difficult and inconvenient for the elderly. The other cause of a decreased saliva secretion is taking prescriptions such as antidepressants, antihypertensive agents and bronchodilators. Saliva plays a very important role in the

eating process. Mucins, found in the saliva, moisten the food and allow the food to be softer, making it easier to chew and swallow. As the food is chewed, the saliva binds the food particles together to form a bolus, which is then swallowed. Food intake is also greatly affected by one's dentition. Eating is enjoyable for people with complete dentition, but may be inconvenient for those people who are edentulous or people who wear dentures that do not fit well. Most of the older people belong to the latter group. Eating can be a huge challenge for edentulous people and there can be an extensive change in the dietary pattern. Mouth pain, teeth loss, ill-fitting dentures, sore gum, difficulty in chewing and swallowing all lead to a decreased food intake as eating becomes less enjoyable.

#### **Physiological anorexia of aging**

Some studies also revealed that the decline in the food intake among the elderly is due to the physiological anorexia of aging with an altered gastric signals resulting in an early satiation. Older people are less hungry and become satiated quicker after eating a normal meal. A number of endocrine factors contribute to inhibit feeding and induced anorexia in aging. Most notable anorexigenic hormones are cholecystokinin (CCK) and leptin. CCK is found in the hypothalamus, cortex and midbrain. It is released from the lumen of the intestine in response to nutrients, particularly fat and protein. CCK causes contraction of the gallbladder and relaxation of the sphincter of Oddi, releasing bile and pancreatic enzymes, respectively. Exogenous CCK administration suppresses food intake in humans and slows down gastric emptying. It has been found that plasma CCK concentrations are higher in healthy elderly than in young adults. Leptin, mainly produced from adipose tissues, suppresses appetite and food intake. Plasma leptin concentration in females increase with aging due to an increased fat mass that simultaneously occurs with aging. Plasma leptin concentration is also inversely related to plasma testosterone in males. Therefore, an increase may also happen in males, but may be because of circulating testosterone concentrations in men that decreases as men get older (5-7).

#### **Dysphagia**

The changes in the central nervous system and the breakdown in the neuromuscular control are experienced in mostly among older people, which results in dysphagia, a condition characterized by a difficulty in swallowing and passing food

from the oral cavity to the stomach. Moreover, a reduced secretion of the saliva contributes to dysphagia as food is not softened sufficiently. This condition triggers choking and coughing, inducing avoidance and limits certain types of food and liquids intake in elderly. As a result, an inadequate food intake occurs and brings about malnutrition.

### **Disease and disability**

The elderly population is more susceptible to a number of diseases and infections, consequently disorder of respiratory, gastrointestinal, endocrine and neurological systems. Effect of diseases and infections, as well as treatments for chronic diseases such as chemotherapy, are associated with increased energy expenditure and nutrient requirements, poor appetite, and with higher rates of malnutrition among the older population. Constipation is also highly prevalent in elderly population that can induce bloating and nausea, result in lost appetite. Furthermore, physical disability like arthritis and poor mobility leads to an inability to self-feed, shopping or to prepare food by themselves.

## **2) Psychological factors**

### **Dementia and depression**

Depression due to bereavement and isolation has also been shown to be associated with negative effects on eating behaviors and nutrient intake. Older adults with depression may also become suspicious with food, refusing to eat. These are usually manifested in a reduced appetite and weight loss among the graying population, and are considered as an important cause of weight loss and undernutrition in this age group. People with dementia suffer from memory loss, which can affect eating behavior. They often skip meals because they lost sense of time and thus, forgot to eat. Distractions during meal time is also a problem for adults with dementia; a distracted elderly can forget to eat meals right in front of them or even forgot to chew. In severe cases, elderly can suffer from unable to express and communicate hunger.

## **3) Social factors**

Many older people have limited financial means that results to a decreased intake of food. They cannot afford access to hygiene food with high nutritional

quality. Poverty is associated with a high rate of hunger and food insecurity. Most elderly live by themselves and loneliness reduces a person's desire to prepare and have balanced meals.

### **2.2.2 Overweight and obesity**

Overweight and obesity are both labeled as ranges of weight that are greater than what is generally considered healthy for a given height. World Health Organization (WHO) defines overweight and obesity as abnormal or excessive fat accumulation that may impair health and well-being. Overweight is a general term that refers to people with a BMI  $\geq 25$  kg/m<sup>2</sup> and a BMI of 30 kg/m<sup>2</sup> and above is categorized as obese (20).

There, however, has been a debate on BMI cut-off points for the Asian populations, and to date, there had been a prior attempt to determine WHO cut-off points for Asian and Pacific populations (21). WHO, the International Association for the Study of Obesity and the International Obesity Task Force proposed BMI cut-points 23.0 to 24.9 kg/m<sup>2</sup> for overweight and  $\geq 25.0$  kg/m<sup>2</sup> for obesity for Asian adults (21, 22). This is firstly due to the issues regarding the high prevalence of type 2 DM and cardiovascular risk factors among Asians even with BMI under 25 kg/m<sup>2</sup>. Secondly, the percentage of body fats and its distribution in Asian people are different from the other populations. The relationship between BMI and body fat percentage and fat distribution are less favorable in many Asian populations compared with their Caucasian or European counterparts.

In 2003, the Ministry of public health, Thailand, reported the total prevalence overweight (BMI 23-29.9 kg/m<sup>2</sup>) rate in the male older population was 28% and 37.7% for the older female population (17). The obesity prevalence rate was similar to the overweight prevalence rate whereby there was a higher prevalence rate in the older female population than in the older male. Obesity (BMI  $\geq 30$ kg/m<sup>2</sup>) prevalence rate for males was 2% and 6.3% for females (17), and the trend for prevalence of overweight and obesity were similar. There was a higher overweight and obesity prevalence rate in the 60-69 than  $\geq 70$  age group. From the NHES IV, overweight (BMI 25-29.9kg/m<sup>2</sup>) prevalence rate for older male population was between 10% and 22.1% and between 9.8% and 31.9% for older female population

(18). The obesity ( $\text{BMI} \geq 30 \text{ kg/m}^2$ ) prevalence rate for male older population was between 4.1% and 11.1% and between 1.3% and 4.3% for older female (18). Compared to the previous report, the overweight and obesity prevalence rates were similarly found higher in women than in men. It also shows that the young elderly has a higher prevalence rate of both overweight and obesity than the oldest group (Table 2.2). Statistics in both reports indicated that there has been an increasing obesity prevalence rate for both males and females, with females having higher prevalence rates than men, and young elderly female had higher prevalence rate than the oldest population.

**Table 2.2** Percentage of overweight and obesity in Thai elderly; classified by BMI

Year	Age group (years)	Samples		Overweight (BMI 23-29.9 $\text{kg/m}^2$ )		Obesity (BMI $\geq 30 \text{ kg/m}^2$ )	
		Male (n)	Female (n)	Male (%)	Female (%)	Male (%)	Female (%)
2006	60 – 69	413	519	29.8	40.3	2.4	7.1
	$\geq 70$	129	179	22.4	30.2	0.8	3.9
	All	542	698	28.0	37.7	2.0	6.3
2008 – 2009 <sup>a</sup>	60 – 69	2,487	2,539	22.1	31.9	4.3	11.1
	70 – 79	1,549	1,620	16.1	25.4	2.4	5.9
	$\geq 80$	432	452	10.0	9.8	1.3	4.1

<sup>a</sup> BMI = 25-29.9  $\text{kg/m}^2$

**Source:** Adapted from the 5<sup>th</sup> National Food and Nutrition Survey in Thailand, 2003, and the 4<sup>th</sup> NHES IV. (<http://www.hiso.or.th/hiso5/report/report1.php>)

Aging changes body composition, and as such, BMI measured in the elderly population may underestimate fatness. Muscle mass decreases upon aging while abdominal and intramuscular fat increases. This may lead to an underestimation in the BMI formula in the older adults. Conversely, the loss of height as a result of the compression of the vertebrae associated with aging leads to an overestimation of the body fat. Waist circumference (WC) and waist-hip ratio (WHpR) are other obese indicators that may be more appropriate for the elderly. WC is associated with abdominal fat mass and correlates closely with BMI and WHpR, though this indicator is unrelated to height. BMI measurement relates to general obesity while WC and WHR specifically correlate with central or abdominal obesity.

Excess abdominal fat is an independent risk and morbidity indicator in a number of diseases related to obesity, including type 2 DM, hypertension, dyslipidemia and cardiovascular diseases (CVD). WC is an approximate index of intra-abdominal fat mass. According to WHO (1998), WC of 102 cm and above in male, and 88 cm and above in female Caucasians infers a considerable increased risk of metabolic complications. Its subsequent report in 2000 suggested cut off points for males was 90 cm and 80 cm for females (22 - 23).

The NHES IV (2008-2009) reported the prevalence of WC over the cut-off points (90 cm and 80 cm for male and female, respectively) among the younger elderly male group aged from 60 to 69 was 23.3% and 53.3% for their female counterparts. The prevalence rate was 20.0% for the males aged from 70 to 79 and 45.1% for the females belonging to the same age group. The over cut-off prevalence rate belonging to the oldest group (80 years and over) was 13.4% for men and 28.6% for women (18). Clearly, this report suggested that females that had oversize abdomen were more prevalent than males in all elderly age groups, and especially the younger elderly which has the most WC prevalence rate over the cut-off point (Table 2.3).

**Table 2.3** Percentage of Thai elderly with waist circumference over the cut-off point

Year	Sample		Waist circumference		
	Age (years)	Male (n)	Female (n)	Male > 90 cm	Female > 80 cm
2008 – 2009	60 – 69	2,490	2,549	23.3	53.3
	70 – 79	1,559	1,635	20.0	45.1
	≥ 80	445	489	13.4	28.6

**Source:** Adapted from the NHES IV (<http://www.hiso.or.th/hiso5/report/report1.php>)

Waist to hip ratio (WHpR) greater than 1.0 and 0.85 in men and women, respectively, has recently been recognized internationally as a clinical method of identifying patients with abdominal fat accumulation. A cut off point of  $\geq 0.90$  for men and  $\geq 0.85$  for women is set by the WHO (23). In 2006, a survey was conducted among 538 and 694 elderly Thai men and women aged from 60 and above. The subjects were divided into 2 groups: 60-69 and 70 and over. Results of the study showed the prevalence of abnormal WHpR in the young elderly group (60-69) males was 5.6% and for females was 71.5%. This indicates that the condition is more strikingly prevalent among females than males. The older elderly group (70 year and

over) has a lower abnormal prevalence rate in both men and women; 3.1% in male and 69.1% in female (17) (Table 2.4), while abnormal WHpR was more common among the younger elderly population.

**Table 2.4** Percentage of Thai elderly with waist to hip Ratio (WHpR) over the cut-off point

Year	Sample		Abnormal WHpR		
	Age(year)	Male(n)	Female(n)	Male (%)	Female (%)
2006	60 – 69	411	516	5.6	71.5
	≥ 70	127	178	3.1	69.1
	All	538	694	5.0	70.9

**Source:** Adapted from the 5<sup>th</sup> National Food and Nutrition Survey in Thailand, 2003

Aging process in the elderly causes changes in the level of physical activity, calorie intake and energy regulation. Obesity in this age group is attributed to a number of factors in following topics. (4 - 5, 24 - 26)

### 1) Decreased energy expenditure

Physical inactivity is a major contributing factor of obesity in the elderly. Older males decrease their activity by 20% compared to younger males. Women showed decreased activity levels by 13%. An increase of chronic diseases that leads to disability results in impaired motor function and energy expenditure reduction. Aging contributes to the lowering of resting metabolic rate (RMR). People aged 60 and above have lower RMR than the younger individuals. The thermic effect food (TEF) also goes down with aging. This accounts for up to 10% of the total energy expenditure. Diminishing physical activity, lowering of RMR, TEF and energy expenditure increase the rate of obesity among the older population.

### 2) Food and energy intake stimulating system deficit

A complex system that involves appetite-stimulating and appetite-inhibiting hormones regulates food intake are changing in aging. Cholecystokinin, a hormone that is secreted from the proximal intestine in response to fat and protein ingestion and induces satiation is higher. It becomes weaker than expected effect in the

elderly. Normally, the leptin hormone produced in adipose tissue suppresses appetite and food intake. Aging may be accompanied by leptin resistance that would result in an increase of food intake.

### **3) Body composition changes in the aging process**

There is a significant loss of bone and muscle (lean mass/ fat free mass) and increase in adipose tissue in the process of aging together with central and visceral fats shifts in the regional distribution of adipose tissue store. A decrease of fat-free mass (mainly muscle) approximately 40% and increase in fat mass occurs between ages 20 and 70. After the age of 70, there is a parallel decrease in both fat-free mass and fat mass. The fat distribution in the body changes as a person ages with an increase in visceral fat. This is more apparent in females than in males. Moreover, skeletal muscle and liver are increasingly deposited with fat. Age-related body composition changes are associated with obesity in the elderly population.

### **4) Other factors**

Growth and sex hormones decrease with aging and are believed to contribute to the less favorable alterations in body composition that leads to a decrease in muscle mass and muscle strength. Consequently, physical activity is reduced facilitating weight gain. Ghrelin hormone level is usually high before meals and low after meals. However, due to a dysfunctional gut, there is a lack of ghrelin hormone suppression after food intake in the elderly allowing a lesser sensitivity to satiety.

### **2.2.3 Consequences of underweight and obesity in elderly**

It is an established fact that undernutrition in older people has many adverse consequences. They are not only at risk of an increased mortality but also at risk of multiple medical complications that have a significant impact on overall quality of life. Mortality rates are reported to be at 25% and higher for those frail elderly people living in nursing homes and 5-15% for those elderly who dwell within a community (6). Weight loss is considered a very serious condition, owing to the direct relationship with morbidity and mortality (6). Moreover, undernutrition also leads to muscle wasting and there is an increased risk of falling down, consequently risk of

fractures and injury among the elderly. Immune dysfunction, increased infection susceptibility, poor wound healing and delayed recovery from surgery are other significant adverse effects of PEM (4 – 5).

The prevalence of obesity has been increasing in all elderly. It is a trend will develop to become a major problem in the aging population and will lead to a number of medical complications, all of which can impair quality of life. There is an increased mortality risk among the elderly population at BMI exceeding 35 kg/m<sup>2</sup>. It implies that the relationship between BMI and mortality in this age group is a reverse J-shape or U-shape. A reverse J-shape or U-shape mean both a low BMI and a high BMI are associated with an increased risk of death from any cause and cause-specific death (25). In the Rotterdam Study, WC  $\geq$ 102 cm men and  $\geq$  88 cm women with normal BMI was associated with 20% higher mortality risk compared with normal WC (22). In a large study of community-dwelling adults aged 75 years and older, increasing WHR was associated with mortality from CVD, with WHpR exceeding 0.99 conferring the highest risk of mortality in non-smoking men, and WHpR > 0.90 in non-smoking women was associated with the greatest risk of death (22).

Obesity in the elderly leads to medical complications. It is thought that an increased body fatness and abdominal obesity is directly linked to an increased incidence of metabolic syndrome with glucose intolerance, hypertension and dyslipidemias and type 2 DM in the elderly population. Metabolic syndrome is a recognized risk factor for stroke. Other disorders related to obesity are osteoarthritis, hepatic steatosis, pulmonary dysfunction, urinary tract dysfunction, obstructive sleep apnea syndrome, and certain types of cancer, reduced cognitive skills, sexual dysfunction and depression. Obstructive sleep apnea also relates with abdominal obesity as respiratory compliance is reduced and breathing frequency as well as the weight on the chest wall increases. Central adiposity may be a risk factor for urinary tract dysfunction, which can affect urine storage and voiding type. Studies suggest that obesity and aging are also associated with depression (25 – 26).

### **2.3 Nutrition assessment in older adults**

Nutritional status is the health condition of an individual or a population influenced by the ingestion and utilization of nutrients and non-nutrients. Schlenker defines nutritional assessment as the integration and interpretation of anthropometric, biochemical, clinical, and dietary data to determine the nutritional and health status of individuals and population groups (4).

Anthropometric method in nutritional assessment is the gross composition measurement of human body such as weight, height and body circumference, waist, hip circumference and mid upper arm circumference.

Biochemical method is used to determine and monitor nutritional risk for selected chronic conditions such as heart disease, the level of recent dietary intakes of selected nutrients, nutrient stores, obtain functional measures of nutritional adequacy or deficiency, confirm or deny nutritional diagnoses based on other assessment measures and determine immune functions. Example of the measurements include cholesterol levels, folate status, iron status and protein status. This method of assessment may not be appropriate for a large-scale nutritional survey as it is too invasive needs more equipment, and time-consuming (7).

A clinical assessment comprises of a medical history and physical examination to determine the presence of physical or diagnostic signs and symptoms of nutritional diseases, both deficiency and toxicity. The assessment also determines and monitors the ability to perform activities of daily living, particularly skills related to purchasing, preparing and eating foods. Furthermore, it also facilitates in the evaluation of an intervention for specific nutritional problems (4, 7). The challenges present when utilizing the method are that the older population do not always report symptoms or changes in functional status. The elderly may accept their conditions as normally occurring with age. Due to dementia and impaired cognitive function, information provided by elderly may be unreliable as elderly may forget or unable to clearly describe the signs and symptoms associated with advanced stages of nutritional deficiency.

Dietary intake method allows the identification of an initial stage of a nutrient deficiency. This method both assesses food consumption patterns, food security or insecurity, food storage and cooking facilities and the use of therapeutic

diets and supplements (4, 7). The method assesses the actual food and beverage intakes, monitors food consumption patterns of individuals or groups to identify changes and trends over time, determines usage of supplements and their effect on nutrient intake and evaluates feeding practices of institutionalized older adults. It may be difficult to assess dietary intakes of older adults because the elderly often have an impaired memory and reduced appetite (4, 7). The 24-h recall method in the dietary intake assessment relies mainly on memory and is an unreliable method in the elderly population (4, 7).

### **2.3.1 Anthropometric measurement in nutritional assessment**

Anthropometry was defined by different authors as follows; Jelliffe (1996) defined anthropometry as the measurement of the variations of the physical dimensions and the gross composition of the human body at different age levels and degrees of nutrition (7). Another definition by WHO in 1995 are anthropometric methods involves measurement of physical dimension and gross composition of the body (7). Bernstein and Luggen defined anthropometry as the measurement of body size, weight, and proportions to assess the physiological effects of either undernutrition or overnutrition (8).

Anthropometric methods in nutritional assessment are used for a number of reasons. First, this method determines and monitors changes in body weight in detecting changes in weight. Secondly, the method determines and monitors body composition, particularly body fat. Lastly, anthropometric method is able to determine body fat distribution in the assessment of risk for selected chronic conditions (4, 7 - 8). Anthropometric measurement in nutritional assessment is categorized into two types. The first type assesses body size and the second type determines body composition. Body size measurement includes weight, height and body circumference, including mid upper arm, waist & hip circumference measurements. Surrogate measurement for predicting height such as arm span (AS), knee height (KH) and others are also measures of body size. The second type of anthropometric measurement that determines body composition is further divided into fat and fat free mass (FFM) measurements. Fat and FFM are major components of body composition. Skinfold

thickness is an anthropometric method for measuring the percentage of human body fat (7).

Anthropometric measurements which are used often in clinical settings and nutritional surveys are weight, height, skinfolds and circumferences. These anthropometric measurements are useful for detecting moderate and severe degrees of malnutrition, particularly imbalances of protein and energy.

### **2.3.2 Advantages and limitations of anthropometry**

Anthropometric measurements have been widely used in nutritional assessment for various reasons. The measurement is safe and utilizes a non-invasive technique that can be used at the bedside of a single patient and is also applicable to large sample sizes. It is a technique that requires simple and inexpensive equipment, and low skilled personnel are able to perform the measurement procedures. Measurements can be precise and accurate if correctly done by trained personnel with appropriately verified and calibrated equipment. Finally, screening tests allow identification of individuals as being at risk for undernutrition or overnutrition, or is currently malnourished (7 - 8).

Though anthropometric measurements are increasing popular, these have their own limitations. These measurements are insensitive and are unable to detect disturbances in nutritional status over short periods of time. Moreover, the methods cannot identify and specific nutrient deficiency such as zinc deficiency. Some non-nutritional factors like disease, genetic influences, diurnal variation, and reduced energy expenditure lower the specificity and sensitivity of anthropometric measurements (7 - 8).

## **2.4 Anthropometric methods for older adults**

Anthropometric methods used in nutritional assessment are specific for the age and circumstances of the patient, particularly beneficial in older population group. As aging occurs, the biochemical indicators of the nutritional status in adults may change as a normal process, but can be falsely classified as abnormal. The body can also deteriorate that is neither due to anything unusual nor abnormal nutrition.

Limitations in the accuracy of the use of anthropometric methods in the older population are due to many physiological changes in body size and composition that comes with normal aging. A misclassification of nutritional status in this age group is therefore likely to happen. Interpretation of results in anthropometric measures needs to be handled with care. Physical disabilities that are common in this age group make it difficult to obtain adequate and reproducible data (4, 6 – 8, 29).

### **2.4.1 Measurement of weight and height**

#### **1) Weight measurement**

The sum of the protein, fat, water, and bone mass in the body all amasses the body weight. Weight measurement is collected after the bladder is emptied and before a meal using a beam balance with non-detectable weights or spring balances and electronic scales. The scale should be placed on a hard, flat surface and checked for zero balance before each use. The person being weighed should stand on the scale looking straight ahead, relaxed and still, and be either nude or wearing light clothing. Electronic digital scale should be set in the kilogram mode and the digital LED readout should show a 0.00 kg prior to weighing (29). Measurements are recorded to the nearest 0.1 kg. Visible edema and time of weighing should be recorded to ensure consistency. Subsequent measurements and scales are calibrated at regular intervals throughout the year and whenever they are moved to a different location.

It is not easy to obtain regular and accurate measures of body weight especially in those who are frail. Chair or bed scales can be used for those who cannot stand for measurement on an upright balance beam scale and similar procedures to ensure accuracy and consistency should be followed. There is a tendency in normal adults for an increased fat deposition with age concomitant with a reduced muscle mass. A negative energy balance may occur in conditions of chronic and acute illness leading to a decline in body weight. A weight change represents recent changes in nutritional status and is thus sensitive. This may be caused by fluid shifts that are common with other older adults using diuretics. Body weight is the most important parameter in clinical practice.

## **2) Height measurement**

A person's height is a parameter of age. It decreases with aging due to thoracic spine kyphosis, compression of the vertebrae, diminished extension of the hips and knees and abdominal muscle mass relaxation in the older population. They lose stature because of vertebral compression, postural slump and loss of muscle tone. Height measurement in this age group may be difficult because of the inability or the unwillingness of the elderly to stand straight as a result of vertebral compression, postural slump and muscle tone loss.

A stadiometer that is free standing is used to measure standing height in the older population. The sampled person should stand straight with head facing forward and shoulders relaxed, arms hanging loosely at sides with palms facing forwards and feet together and knees straight. The heels, buttocks and shoulder blades should touch the vertical backboard of the free standing stadiometer. Minimal clothing should be worn and shoes and socks must be removed. During measurement, the person should take a deep breath and stand tall. Then, the movable headboard is lowered to touch the crown of the head. Measurement is recorded to the nearest and the time of the day the measurement is also noted since diurnal variations can present. Subsequent measurements should be done at similar times and in the afternoons if possible.

## **3) Surrogate measures of height**

An accurate height measurement of an elderly subject is often difficult to obtain because the aging process leads to thinning of vertebrae discs, thus a change in the body posture. This contributes to height reduction or even kyphosis or curvature of spine, a condition common the older population suffering from osteoporosis. Therefore, it may be impossible to obtain accurate height measurement in this age group and the measurements may not necessarily reflect their actual height.

Hence, there is a need for a simple and reliable method of height measurement in the older population. As the length of long bones in the arms and legs are not affected by aging (7-8, 12) AS and KH measurements have been utilized as alternative measures of height in the elderly group.

### **3.1) Arm span and demi span**

Arm span (AS) highly correlates with a person's stature and can be used as a surrogate measure of height in cases when a person's actual height cannot be measured. Measurement of the AS is done when both arms the person are stretched at shoulder height parallel to the floor, and the length is recorded from the tip of one arm to the tip of another arm, crossing breadth of shoulders.

According to WHO, AS measurement should be carried out against a flat wall with a fixed marker board at the zero end of a horizontal scale, and a vertical sliding board which moves along the scale positioned above the shoulders of the person. The feet should be together and back against the wall. The arms should be at shoulder height and extended laterally across the wall and the palms faced forward. The measurement should be taken with the tip of the middle finger on the right hand in contact with the fixed marker board and the tip of the middle finger on the left hand on the sliding board. For accurate measurements, two recordings of each measurement to the nearest 0.1 cm are noted.

Another alternative method is the measurement of demi-span. The person measured outstretches his arms perpendicular to his body and the measuring tape is placed between the middle and ring fingers and runs along the arm to the center of the sternal notch.

### **3.2) Knee height**

The height of a person's knee may be used to estimate height as it is associated with stature. Because of this, it is usually beneficial and applicable in people who are unable to stand or those who suffer with severe spinal curvature. When measuring knee height (KH), a caliper with an adjustable measuring stick is used. To measure KH, the sample may be in a sitting or supine position with the knee bent at a 90 degree angle. The immovable blade of the caliper is positioned under the heel of the foot while the movable blade is placed above the anterior surface of the left thigh above the condyles of the femur proximal towards the patella. The shaft of the caliper is held parallel to the shaft of tibia. Measurements should be done twice and are recorded to the nearest 0.1 cm. In cases where there is a difference of less than 5 mm between the two measurements, the mean of the two measurements is used.

#### **4) Body circumference**

##### **4.1) Mid upper arm circumference**

Subcutaneous fat and muscle comprise the arm. A change in mid upper arm circumference (MUAC) means a change in muscle mass, subcutaneous fat, or both. As such, MUAC measurement can be a very useful tool in diagnosing protein-energy malnutrition or starvation. The measurement of MUAC is done with a flexible inelastic tape made of fiberglass or steel and starts at the midpoint of the upper arm between the acromion process and the tip of the olecranon. The measurement is recorded to the nearest 0.1 cm.

##### **4.2) Waist circumference**

Waist circumference (WC) is associated with abdominal fat and atherogenic metabolic disturbances that are likewise associated with abdominal obesity. A stretch-resistant tape that provides a constant 100g tension is used to measure the circumference. Placements of tape for WC were different according to health institution protocols, which described as follows;

1. The midpoint; at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest (30).
2. The top of iliac crest (31).
3. The umbilical level point/the abdominal circumference (32).
4. The minimal waist level point (23).

A systematic review of 120 studies examined whether measurement protocols influenced the relationship of WC with morbidity from CVD and DM, and mortality from CVD and all causes. Most protocols measured at the midpoint (36%), umbilical level (28%) and minimal waist level (25%), and concluded that the WC's protocol had no substantial influence on the association between WC, all-cause and CVD mortality, CVD and diabetes mellitus (24). Partry-Parisien et al. conducted study in 6,306 respondents aged 3 to 79 from the Canadian Health Measures Survey and compared between WC at the top of iliac crest (National Institutes of Health: NIH protocol) and midpoint between the lower margin of the least palpable rib and the top of the iliac crest (WHO protocol) (33). The WC measurement of NIH protocol significantly exceeded than the WHO protocol. In another study, WC at the minimal

waist was significantly shorter than abdominal circumference at the umbilicus in both genders, with the mean difference being greater in women (34).

WC measurement in elderly people of 25 studies showed 8 studies using the WHO protocol, 8 studies measured at umbilicus level, 2 studies at smallest part of the trunk, 1 at between umbilicus and xyphoid process (smallest three parts of the breastbone; articulates with the corpus sternum and the seventh rib), and 7 studies did not specify the methods of measurements (Table 2.21 – 2.22). Normally, the person being measured is asked to fast overnight prior to the measurement. During measurement, the subject wears little clothing and stands erect with the abdomen relaxed. Arms are placed at the sides, feet together and the weight being equally divided over both legs. To determine the midpoint, the tape is placed between the lower margin of the least palpable rib and the lateral iliac crest, and then is firmly tied to stay in position around the abdomen. The tape defines the level of the WC. The measurement is taken without the tape compressing the skin and measurement reading is noted to the nearest millimeter. During the measurement, the person is directed to breathe normally and breathe out gently.

#### **4.3) Hip circumference**

To measure hip circumference (HC), the tape is placed around the widest part of the buttocks, positioned parallel to the floor, touching the skin but not pressing the soft tissue. The area is located at the pubic symphysis level at the anterior and isheal tuberosity at the posterior. The measurement is noted to the nearest millimeter. The person being measured should be relaxed and are taken at the end of a normal expiration. Each measurement is done twice and the average is used in cases when a difference of less than 1 cm is noted.

#### **5) Percentage of body fat**

The two compartment model assumes that the total body mass is composed of two major compartments including body fat and the fat-free mass (FFM) (32). FFM contains no lipid and is referred to as the body cell mass composes the skeletal muscle, non- skeletal muscle, soft lean tissues, and the skeleton. The body fat content is the most variable component of the body, differing among individuals of the

same sex, height, and weight. Women generally have a higher percentage of body fat than men. The fat content of women is higher than of men, representing 26.9% of their total body weight compared with 14.7% for men (7). The mean percentage of body fat for normal-weight women is similar to the percentage body fat of obese men (35 - 36). Obesity, defined as an excessive amount of total body fat, is identified when the body fat is in excess of 38% for women and 25% for men (37). The progressive loss of muscle and bone mass, increased extracellular fluid volumes, reduced body cell mass and increased body fat are associated with aging. Body composition assessment techniques used in the elderly should account for these variations. Elderly individuals tend to have loose connective tissue, and storage fat becomes less subcutaneous, making it difficult to accurately assess body composition using skinfold measurements.

Bioelectrical impedance analysis (BIA) is method for determining body impedance, which is based on the nature of the conduction of an applied electrical current in an organism (35, 38), and relies on relationship between the volume of a conductor and its impedance. BIA also depends on the differences in electrical conductivity of fat-free mass and fat. The FFM contains virtually all the body's conducting electrolytes and the impedance value is combined with anthropometric data into a prediction equation to give body compartment measures (39). This technique measures the impedance of an electrical current (typically 800  $\mu$ A; 50 KHz), passed between two electrodes, generally located on the right ankle and the right wrist of an individual. BIA measures the resistance of an electric current that is proportional to the amount of FFM, which correlates with  $\text{height}^2/\text{resistance}$ . Hydration status, recent physical activity, consumption of food and beverages, ambient air and skin temperature, menstrual status, and body position are among the factors that can affect the validity of the measurement. This method has practical features similar to anthropometry, i.e. safe, convenient, and the equipment is portable and inexpensive (7).

## 2.5 Anthropometric indices

It is not simple to interpret single anthropometric measurement data, for example, weight and skinfold thickness alone may not truly represents a person's nutritional status. Thus, there is a need for these raw anthropometric data to be modified for better interpretation. Mathematical and statistical methods are used in order to calculate these data.

Body mass index (BMI) and WHpR are the most common types of anthropometric indices, and both are used in epidemiological studies. BMI is an indicator for defining overweight and obesity while WHpR is an indicator for defining abdominal obesity in adults.

BMI, WC, WHpR, and waist to height ratio (WHtR) are associated with the risk of diseases as shown in Table 2.5. WHpR has the strongest positive relationship for the overall CVD risk factors. Studies conducted by Yusuf et al. (40) suggests that BMI, WC and WHpR are all strongly and linearly associated with myocardial infarction risks. According to Gelber et al. (41), BMI, WC, WHpR and WHtR possess similar magnitudes to CVD risks. In a meta-analysis by Vazquez et al. (42), all of these anthropometric measures (BMI, WC, and WHpR) have similar associations with incidence of Type 2 DM. Out of all parameter, the weakest positive relationship with risk of Type 2 DM is BMI. Conversely, all parameters strongly relate to hypertension and overall mortality (23).

**Table 2.5** Associations of BMI, WC, WHpR and WHtR with disease risk

	Relationship			
	Overall CVD risk factors <sup>a</sup>	Type 2 DM <sup>b</sup>	Hypertension <sup>b</sup>	Overall mortality <sup>c</sup>
1. Body Mass Index	++	+++	+++	+++
2. Waist Circumference	+++	++++	+++	+++
3. Waist-Hip Ratio	++++	++++	+++	+++
4. Waist-Height Ratio	+++	++++	+++	+++

<sup>a</sup> From STEPS analysis is presented in the WHO meeting

<sup>b</sup> In cross-sectional data

<sup>c</sup> Without mutual adjustment of the anthropometric parameters.

Relationship: + to ++++ = positive association, mild to strong

**Source:** Adapted from WHO (2011). Waist circumference and waist-hip Ratio: report of a WHO expert consultation, Geneva, 8 – 11 December 2008

### 2.5.1 Body mass index

The weight to height ratio indicates the relationship between body weight and height and is particularly useful in providing nutritional status measurement in the adult population. The BMI or Quetelet's index is currently the common method used. This method is more likely used than other methods such as weight to height ratio, the Ponderal index and Benn's index as shown in Table 2.6 (6, 43).

**Table 2.6** Indices for weight relative to height

Index	Formula
Weight/height ratio	Weight/height
Body mass index (Quetelet's index)	Weight/(height) <sup>2</sup>
Ponderal index	Height/ <sup>3</sup> $\sqrt{weight}$
Benn's index	Weight/(height) <sup>p</sup>
Height weight difference index (HWDI)	Height - weight

**Note:** The power p in Benn's index is calculated to minimize the direct relationship with height.

**Source:** Adapted from Gibson. 2005; Benn, 1971

The BMI is a simple, inexpensive technique and is a noninvasive surrogate measure of body fat. It is calculated as weight in kilograms divided by the square of height in meters (kg/m<sup>2</sup>). Since the measurement only relies on height and weight of the person, accurately measuring height and weight will allow the BMI to be accurately calculated. Studies have shown that BMI correlates with direct measures of body fat and future health risks, and high BMI predicts future morbidity and death. The widespread and longstanding application of BMI contributes to its utility at the population level. The other direct measurements of body fat were underwater weighing and dual energy x-ray absorptiometry (28).

Though the BMI is gaining popularity internationally as the method preferred in the classification of overweight and obesity in adults, the method possesses a number of limitations. Firstly, it can be difficult if used in adults with low education in developing countries. BMI requires a device for accurate calculation such as calculator or monogram (7). Secondly, BMI interpretation possesses a concern where it does not distinguish between weight associated with muscle and weight associated with body fat. In some cases, a high BMI may be due to excessive adiposity, muscularity or edema (6 - 7, 28). Age, gender, ethnicity, and muscle mass

may influence the relationship between BMI and body fat. Older adults usually have more body fat than younger adults with the same BMI. More so, it is often for women to have more total fat than men with similar BMI. Highly trained athletes or muscular people usually have increased muscle mass than normal, making them more heavy. As mentioned, it may also be difficult to measure height in the elderly because of kyphosis. Finally, BMI interpretation in the elderly group does not follow the same standard and excess fat and a high BMI in old age is not as harmful (6). The WHO Expert Consultation reported that the proportions of Asian people with high risks of type 2 DM and CVD are observed to be at a substantially lower BMI than the current WHO cut-off point for overweight (25 kg/m<sup>2</sup>). However, the cut-off points for observed risk varies from 22 kg/m<sup>2</sup> to 25 kg/m<sup>2</sup> in different Asian populations and for high risk, it varies from 26 kg/m<sup>2</sup> to 31 kg/m<sup>2</sup>. The Consultation therefore recommended that the current WHO BMI cut-off points should be retained as the international classification. But the cut-off points of 23, 27.5, 32.5 and 37.5 kg/m<sup>2</sup> are to be added as points for public health action. It was, therefore, recommended that countries should use all categories (i.e. 18.5, 23, 25, 27.5, 30, 32.5 kg/m<sup>2</sup>, and in many populations, 35, 37.5, and 40 kg/m<sup>2</sup>) for reporting purposes, facilitating international comparisons (Table 2.7).

**Table 2.7** Classifications of adult underweight, overweight and obesity according to BMI

Classification	BMI(kg/m <sup>2</sup> )		
	Principal cut-off points <sup>a</sup>	Additional cut-off points <sup>b</sup>	Asian population cut-off points <sup>c</sup>
Underweight	<18.50	<18.50	<18.50
Normal range	18.50 - 24.99	18.50 - 22.99	18.50 - 22.99
		23.00 - 24.99	
Overweight	≥25.00	≥25.00	23.00 - 24.99
Pre-obese	25.00 - 29.99	25.00 - 27.49	
		27.50 - 29.99	
Obese	≥30.00	≥30.00	≥25.00

<sup>a</sup> WHO. 1995

<sup>b</sup> WHO. 2004

<sup>c</sup> Kanazawa et al. 2002

### **2.5.2 Waist to hip ratio**

WHpR is an alternative measurement that reflects abdominal adiposity. It is believed to be a more superior method than BMI in predicting CVD risks, though the latter has been the chosen indicator for measuring body size and composition, and in diagnosing underweight and overweight. This is based mainly on the rationale that increased visceral adipose tissue is associated with a range of metabolic abnormalities that are considered to be risk factors for CVD and type 2 DM. These metabolic abnormalities include decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profile (23). WHpR is done by calculating the quotient between the WC and HC, thus distinguishes the fat composition in the hips and buttocks area (lower trunk), which are mainly subcutaneous fat, from the fat composition in the waist and abdomen area (upper trunk) which are largely visceral fat. WHpR assesses subcutaneous and visceral fat depots. Subcutaneous adipose tissues are found largely in the hips and buttocks area and visceral adipose tissues in the waist and abdomen.

Gynoid obesity is a term that refers to an individual with an increased lower trunk fat composition. Conversely, android obesity describes a person that has larger upper trunk or central fatness. The gynoid obesity is more typical of the female while android obesity is typical of male, but obese men and women may belong to either category. The total body fat mass is highly correlated with WHpR. It has been established that accumulation of visceral or intra-abdominal fat results in an elevated WHpR, which increases risks of diseases related to obesity and metabolic disorders. Disturbances in lipoprotein metabolism and plasma insulin-glucose homeostasis are consequences of metabolic disorders in obese people. This is believed to be associated with an android distribution of adipose tissue rather than a gynoid distribution of adipose tissue (7). Huxley et al., suggested that WHpR is positively correlated with mortality following adjustments of other variables such as smoking, alcohol and estrogen use (44). In a meta-analysis by Koning et al., WHpR and WC are significantly associated with the risk of incident CVD events (45).

Bjorntorp in 1987 was the first who suggested that WHpR  $> 1.0$  for men and  $> 0.85$  for women represents an accumulation of abdominal fat with a high risk of CVD complications and mortality (46). These cut-off figures are now widely used. However, these cut-off figures have been debated in response to its appropriateness in

terms of assessing health risks among ethnic groups with variations in their body fat distribution. WHO reported a substantial increase of metabolic complications risks and recommended a WHpR of  $\geq 0.90$  for men and  $\geq 0.85$  for women (Table 2.8) (23).

**Table 2.8** WHO cut-off points and risk of metabolic complications

Indicator	Cut-off points	Risk of metabolic complications
Waist circumference	> 94 cm (M); > 80 cm (W)	Increased
Waist circumference	> 102 cm (M); > 88 cm (W)	Substantially increased
Waist-hip ratio	$\geq 0.90$ cm (M); $\geq 0.85$ cm (W)	Substantially increased

M =men; W= women

**Source:** Adapted from WHO (2011).Waist circumference and waist-hip Ratio: report of a WHO expert consultation, Geneva, 8 – 11 December 2008

The cut-off points adapted for use in each country vary considerably. The chosen cut-off points seem to be based on risks of CVD and type 2 DM and to some extent, mortality. Table 8 shows the chosen cut-off points adapted in certain countries such as Mexico, Chile, France and Oman (Table 2.9) (23).

**Table 2.9** WHpR cut off points adapted in certain countries

	Cut – off	
	Male	female
WHO	0.90	0.85
Mexico	0.90	0.85
France	0.96	0.83
Chile	N/A	0.84
Oman	0.91	0.91

**Source:** Adapted from WHO (2011).Waist circumference and waist-hip Ratio: report of a WHO expert consultation, Geneva, 8 – 11 December 2008

Aging affects the whole body fat distribution. Fat is further accumulated in the abdominal area with advancing age, so WHpR might cause misinterpretation in this age group. WC is a better indicator of abdominal fat content. Both the total body fat and visceral fat content can be measured by computer tomography (CT) scan or by dual X-ray absorptiometry (DEXA) scan. This is also associated with potential metabolic disturbances leading to abdominal obesity. WHO suggested using WC as

the preferred anthropometric assessment tool of abdominal fat than WHpR (23). Moreover, practical consideration seems to favor WC as an alternative to BMI. WC measurement is a simple, cheap, practical and an easy method to conduct. Measuring waist is easier and more accurate than measuring height. Males generally have higher WC values than females in all age groups. WC is a useful measure in predicting diseases such as CVD, type 2 DM, hypertension and mortality. An increase in the value of WC means a higher risk of diseases. Cut off point of WC in Table 2.10, International Diabetes Federation (IDF) criteria defined central obesity for ethnic or country specific values for WC; European countries > 94 cm for male and > 80 cm for female, South Asian, and Chinese people > 90 cm for male and > 80 cm for female (47).

**Table 2.10** International Diabetes Federation (IDF) criteria for ethnic or country specific values for waist circumference

Country or ethnic group	Waist circumference (cm)	
	Men	Women
Europid	> 94	> 80
South Asian and Chinese	> 90	> 80

**Source:** Adapted from IDF, 2006 ([http://www.idf.org/webdata/docs/MetS\\_def\\_update2006.pdf](http://www.idf.org/webdata/docs/MetS_def_update2006.pdf))

### 2.5.3 Waist to height ratio

WHtR measures the distribution of an individual body fat. This anthropometric index predicts a wide range of cardiovascular risk factors and health related conditions. The method was first proposed in the mid-1990s and is associated with metabolic risk factor. Both European and Asian studies confirm that this index is a better predictor of metabolic risks than BMI. WHtR also correlates with abdominal obesity. The person's WC reflects the amount of visceral fat depots within the abdominal cavity. With that being said, a greater amount of visceral fat stored within the abdominal cavity means a higher WHtR (48 - 50).

WHtR is a noninvasive and simple screening technique. It simply requires the measurements of height and WC and is further calculated by dividing the individual WC by height. Studies reveal that WHtR is a better method than BMI in assessing cardio-metabolic risks. In a study among Taiwanese adults, the technique

proved to be an effective indicator of abdominal obesity and cardio-metabolic risks even to individuals whose BMI and WC were considered as “normal” (48).

Table 2.11 tabulates WHtR cut-off values for the risks of diseases such as DM, CVD, hypertension, dyslipidemia and metabolic syndrome for both males and females.

**Table 2.11** WHtR cut-off values by gender and risks of diseases

Risk	Cut-off	
	Male	Female
Diabetes mellitus	0.52	0.53
Cardiovascular disease	0.53	0.50
Hypertension	0.50	0.50
Dyslipidemia	0.49	0.49
Metabolic syndrome	0.50	0.49

**Source:** Adapted from Ho et al. (2003).

Generally, WHtR 0.50 boundary value is used to indicate an increase in health risks. This WHtR 0.5 boundary value also represents a more accurate cut-off point for both men and women. WHtR 0.60 indicates central obesity or a more severe risk, and WHtR < 0.40 indicates a likelihood of being underweight as shown in Table 2.12 (48-50).

**Table 2.12** WHtR classification

WHtR	Cut – off point
Might be underweight	<0.40
Normal (OK)	0.40 – 0.49
Increase in health risks (Consider take care)	0.50 – 0.59
central obesity or a more severe risk (Take care)	≥ 0.60

**Source:** Adapted Ashwell. (2011)

## 2.6. Study in anthropometric measurement in nutritional assessment in older adult

### 2.6.1 Height and weight measurement

The average height and weight of the elderly male and female from different studies are shown in Tables 2.13 and 2.14. The data showed that body height and weight among the elderly people can be influenced by genetics, gender, socio-economic status, geographical region and ethnicity. Females tend to be shorter and lighter than their male counterparts.

**Table 2.13** Summary of the average height and weight of elderly males from various countries

Countries	Age (years)	n	Height (cm)	Weight (kg)
Thailand. 2001 (51)	≥ 60	105	160.8 (5.7)	53.3 (9.25)
Malaysia. 2009 (52)	≥ 60	129	162.3 (7.5)	66.6 (11.3)
India. 2004 (53)	≥ 60	171	160.8 (4.8)	55.7 (6.5)
Bangladesh. 2010 (54)	≥ 60	129	158.8 (7.1)	54.2 (10.7)
Chinese. 2002 <sup>a</sup> (55)	≥ 70	999	1.62 (0.1)	56.7 (10.1)
Brazil. 2007 (56)	≥ 60	881	164.9 (0.3)	69.3 (0.6)
Brazil. 2012 (57)	≥ 60	85	161 (5.9)	N/A
Chile. 2004 (58)	≥ 60	411	164.6 (7.1)	73.2 (13.0)
Chile. 2007(56)	≥ 60	446	165.3 (0.5)	75.0 (0.7)
Mexico. 2005 (59)	≥ 60	1,090	163.2 (8.5)	70.3 (12.3)
Mexico. 2007 (56)	≥ 60	507	162.4 (0.4)	71.2 (0.6)
Cuba. 2007 (56)	≥ 60	708	166.3 (0.3)	64.4 (0.6)
Uruguay. 2007 (56)	≥ 60	528	168.9 (0.4)	73.5 (0.8)
USA (whites). 2007 (56)	≥ 60	1,491	174.5 (0.2)	86.4 (0.4)
USA (Non-Hispanic white). 2008 <sup>b</sup> (60)	≥ 60	957	174.6 (0.2)	87.2 (0.58)
USA (Blacks). 2007 (53)	≥ 60	393	174.0 (0.4)	84.7 (1.0)
USA (Non-Hispanic black). 2008 <sup>b</sup> (60)	≥ 60	264	174.3 (0.52)	85.7 (1.21)
USA (Mexican American). 2007 (56)	≥ 60	514	168.5 (0.3)	79.9 (0.8)
USA (Mexican American). 2008 <sup>b</sup> (60)	≥ 60	281	167.8 (0.42)	79.8 (1.15)
England. 2008 (61)	≥ 65	956	170.8 (6.6)	79.8 (12.1)
England. 2010 (62)	≥ 65	452	171.5 6 6.9	N/A
Italy. 2002 (63)	≥ 65	1,674	165.7 (6.7)	72.6 (10.7)
Italy. 2010 (64)	≥ 65	120	166.2 (7.2)	70.7 (13.4)
Netherlands. 2006 (65)	≥ 65	193	175.6 (6.5)	79.3 (10.34)
Germany. 2000 <sup>a</sup> (66)	≥ 60	82	1.73 (6.4)	77.9 (9.3)

<sup>a</sup> Height in meter, <sup>b</sup> Mean (SE), N/A=not applicable

**Table 2.13** Summary of the average height and weight of elderly males from various countries (Cont.)

Countries	Age (years)	n	Height (cm)	Weight (kg)
Turkey. 2011 (68)	≥ 65	129	163.7 (6.89)	64.1 (17.73)
Turkey. 2012 (67)	≥ 60	69	165.24 (4.44)	78.33 (10.06)
South African. 2011 <sup>a</sup> (69)	≥ 60	303	1.67 (0.08)	68.93 (15.16)
Uganda. 2005 (70)	60 – 90	81	163.87 (4.84)	53.34 (9.19)
Nigeria. 2010 <sup>a</sup> (71)	≥ 50	110	1.65 (0.08)	70.55 (12.07)

<sup>a</sup> Height in meter, <sup>b</sup> Mean (SE), N/A=not applicable

**Table 2.14** Summary of the average height and weight of elderly females from various countries

Countries	Age (years)	n	Height (cm)	Weight (kg)
Thailand. 2001 (51)	≥ 60	177	151.2 (5.8)	49.2 (10.5)
Malaysia. 2009 (52)	≥ 60	101	149.0 (5.8)	60.0 (13.8)
India. 2004 (53)	≥ 60	161	143.2 (5.7)	43.5 (8.5)
Bangladesh. 2010 (54)	≥ 60	188	148.6 (6.4)	46.7 (10.3)
Chinese. 2002 <sup>a</sup> (55)	≥ 70	1,033	1.48 (0.1)	48.6 (10.1)
Brazil. 2007 (56)	≥ 60	1,262	151.8 (0.2)	63.4 (0.5)
Brazil. 2012 (57)	≥ 60	177	149 (5.6)	N/A
Chile. 2004 (58)	≥ 60	809	149.8 (6.3)	63.6 (13.4)
Chile. 2007(56)	≥ 60	855	150.2 (0.3)	64.0 (0.5)
Mexico. 2005 (59)	≥ 60	870	152.6 ( 7.5)	62.7 (11.6)
Mexico. 2007 (56)	≥ 60	740	148.4 (0.3)	62.9 (0.5)
Cuba. 2007 (56)	≥ 60	1,197	152.8 (0.3)	59.9 (0.5)
Uruguay. 2007 (56)	≥ 60	916	154.8 (0.3)	71.3 (0.6)
USA (whites). 2007 (56)	≥ 60	1,528	159.9 (0.2)	71.8 (0.4)
USA (Non-Hispanic white). 2008 <sup>b</sup> (60)	≥ 60	944	160.2 (0.27)	72.0 (0.60)
USA (Blacks). 2007 (56)	≥ 60	445	174.0 (0.4)	84.7 (1.0)
USA (Non-Hispanic black). 2008 <sup>b</sup> (60)	≥ 60	275	160.6 (0.32)	82.0 (1.33)
USA (Mexican American). 2007 (56)	≥ 60	543	154.3 (0.4)	69.4 (0.9)
USA (Mexican American). 2008 <sup>b</sup> (60)	≥ 60	283	153.9 (0.48)	69.4 (1.01)
England. 2008 (61)	≥ 65	1,126	156.8 (6.4)	67.2 (12.8)
England. 2010 (62)	≥ 65	516	157.7 6 6.1	N/A
Italy. 2002 (63)	≥ 65	1,462	152.2 (7.5)	63.8 (13.1)
Italy. 2010 (64)	≥ 65	164	153.0 (6.6)	58.1 (12.9)
Netherlands. 2006 (65)	≥ 65	206	163.3 (6.5)	71.1 (10.5)
Germany. 2000 <sup>a</sup> (66)	≥ 60	122	1.60 (5.2)	67.0 (9.7)
Turkey. 2011 (68)	≥ 65	137	153.8 (9.34)	64.1 (17.18)
Turkey. 2012 (67)	≥ 60	150	153.04 (5.05)	73.02 (12.16)
South African. 2011 <sup>a</sup> (69)	≥ 60	930	1.67 (0.08)	65.06 (15.01)
Uganda. 2005 (70)	60 – 90	81	152.18 (5.23)	48.24 (8.91)
Nigeria. 2010 <sup>a</sup> (71)	≥ 50	66	1.55 (0.12)	71.70 (16.76)

<sup>a</sup> Height in meter <sup>b</sup> Mean (SE), N/A=not applicable

Table 2.15 shows that the aging process affects a person's body height and weight regardless of gender, ethnicity or geographical region. As age advances, a person's height and weight starts to decline.

**Table 2.15** Average height and weight of older adults in specific countries, classified by age groups

Countries	Age (years)	n		Height (cm)		Weight (kg)	
		M	FM	M	FM	M	FM
Thailand. 2006 (17)	60 – 64	224	279	161.3 (6.54)	150.5 (5.55)	58.9 (30.52)	52.7 (11.41)
	65 – 69	191	239	161.0 (5.82)	150.7 (5.42)	56.8 (12.27)	51.8 (11.62)
	70 – 74	129	180	158.5 (5.84)	149.3 (5.83)	52.3 (9.39)	48.1 (10.81)
Indonesia. 2012 (15)	55 – 59			159.5 (6.2)	149.2 (5.0)	57.2 (10.5)	56.5 (11.0)
	60 – 64			158.5 (6.5)	148.9 (5.6)	58.1 (11.1)	53.9 (10.8)
	65 – 69	812		158.3 (6.4)	147.3 (5.3)	55.0 (9.9)	51.9 (11.1)
	> 69			158.4 (5.9)	146.3 (5.7)	54.5 (8.9)	49.4 (9.9)
Malaysia. 1998 (72)	60 – 69	80	127	159.2 (7.23)	147.4 (5.56)	58.7 (11.84)	51.7 (10.85)
	70 – 79	44	59	157.5 (7.61)	146.3 (5.19)	54.1 (10.04)	48.4 (10.66)
	80 – 89	16	18	155.7 (7.12)	144.3 (4.93)	53.5 (12.81)	43.3 (12.17)
Japan. 2003(73)	60 – 69	644	340	165.8	153.1	62.7	52.0
	≥ 70	117	52	164.9	150.3	60.1	48.7
England. 2008 (61)	65 – 69			173.2 (6.2)	158.8 (5.9)	83.2 (11.6)	70.6 (12.8)
	70 – 74			170.5 (6.2)	157.5 (6.3)	80.0 (12.1)	68.0 (12.5)
	75 – 79	956	1,12	169.2 (6.6)	156.1 (5.8)	77.4 (12.2)	65.8 (11.7)
	≥ 80		6	167.1 (6.3)	153.0 (6.4)	73.6 (10.1)	61.3 (12.0)
Italy. 2002 (63)	65 – 69	466	418	167.1 (7.5)	154.1 (6.7)	74.6 (11.2)	66.2 (12.0)
	70 – 74	451	370	166.3(64)	152.3 (6.5)	74.4 (11.9)	64.8 (12.5)
	75 – 79	392	361	163.8 (6.6)	150.6 (6.4)	69.5 (10.7)	61.1 (10.6)
USA. 2008 (60) (National survey 2003 – 2006) <sup>a</sup>	80 – 84	365	313	162.7 (7.2)	149.3 (7.0)	66.7 (10.7)	60.0 (11.7)
	60 – 69	668	691	175.4 (0.28)	161.8 (0.33)	90.0 (0.98)	77.3 (0.91)
	70 – 79	555	463	173.8 (0.42)	159.2 (0.34)	85.0 (0.92)	70.6 (1.07)
	≥ 80	349	412	170.7 (0.36)	156.0 (0.37)	76.3 (0.62)	64.5 (0.69)
Mexico. 2005 (59)	60 – 64	317	371	163.8 (7.5)	153.9 (7.2)	71.8 (12.5)	64.3 (11.7)
	65 – 69	319	209	163.8 (8.1)	152.6 (7.6)	71.8 (11.9)	63.6 (10.4)
	70 – 74	217	141	163.3 (8.7)	151.3 (7.1)	69.6 (12.2)	61.9 (11.1)
	75 – 79	152	91	161.3 (10.1)	150.5 (7.4)	67.7 (12.9)	58.2 (11.7)
	≥ 80	93	58	162.0 (9.4)	150.4 (8.2)	66.1 (10.4)	57.4 (12.2)
Netherlands. 2006 (65)	60 – 69	136	211	1.67 (0.61)	1.55 (0.48)	70.5 (1.00)	63.7 (0.84)
	70 – 79	87	130	1.65 (0.73)	1.53 (0.72)	67.6 (1.25)	60.2 (1.02)
	≥ 80	25	44	1.65 (1.61)	1.51 (1.09)	65.5 (1.92)	57.3 (1.54)
	60 – 64	155	223	1.65 (0.07)	1.53 (0.06)	70.8 (13.26)	66.4 (13.17)
Brazil. 2005 <sup>b</sup> (74)	65 – 69	104	204	1.66 (0.05)	1.53 (0.06)	71.2 (12.81)	63.9 (12.75)
	70 - 74	108	180	1.64 (0.07)	1.51 (0.06)	68.4 (12.00)	63.3 (13.60)
	75 – 79	181	235	1.64 (0.06)	1.51 (0.07)	67.7 (12.50)	61.9 (11.83)
	≥ 80	186	229	1.63 (0.08)	1.48 (0.06)	62.9 (11.50)	57.4 (12.14)

<sup>a</sup>Mean (SE) <sup>b</sup> Height in meter, M=male, FM=female

**Table 2.15** Average height and weight of older adults in specific countries, classified by age groups (cont.)

Countries	Age of subjects (years)	Number of subjects		Height (cm)		Weight (kg)	
		M	FM	M	FM	M	FM
Chile. 2004 (58)	60 – 64	96	178	165.8 (7.2)	151.2 (6.0)	78.0 (13.1)	67.8 (13.5)
	65 – 69	121	186	165.3 (7.2)	151.0 (5.8)	73.4 (14.0)	66.8 (14.0)
	70 - 74	79	149	164.7 (6.8)	150.1 (6.1)	72.0 (10.5)	64.1 (11.6)
	75 – 79	62	134	163.5 (6.8)	149.4 (6.5)	71.7 (11.8)	62.0 (12.4)
	80 – 84	31	87	162.5 (7.9)	147.7 (6.0)	69.1 (13.0)	58.5 (11.6)
	≥ 85	22	75	161.6 (5.7)	145.7 (6.8)	64.6 (11.0)	53.1 (10.7)
Cuba. 2009 <sup>b</sup> (75)	60 – 64	195	234	1.68 (0.07)	1.55 (0.07)	68.8 (12.05)	64.9 (13.84)
	65 – 69	148	217	1.67 (0.07)	1.54 (0.07)	65.2 (12.56)	62.9 (14.81)
	70 - 74	109	213	1.67 (0.06)	1.53 (0.07)	63.0 (11.84)	59.2 (12.30)
	75 – 79	85	180	1.65 (0.07)	1.52 (0.06)	60.7 (14.69)	56.7 (12.51)
	≥ 80	95	196	1.63 (0.08)	1.50 (0.07)	59.3 (10.48)	53.2 (11.56)

<sup>a</sup>Mean (SE) <sup>b</sup> Height in meter, M=male, FM=female

There are a number of factors that contribute to a person's BMI. These factors include genetics, gender, socio-economic status, geographical region and ethnicity. BMI value was higher in females than in males. BMI values ranged from 20.7 to 25.8 kg/m<sup>2</sup> for males and 20.3 to 25.1 kg/m<sup>2</sup> for females in the Asian countries. When compared to people in Europe and the USA, BMI of the Asians was lower than BMI of the Europeans (25.6 to 28.3 kg/m<sup>2</sup> for males and 24.8 to 28.8 kg/m<sup>2</sup> for females), North Americans (27.9 to 28.6 kg/m<sup>2</sup> for males and 28.0 to 31.8 kg/m<sup>2</sup> for females) and Latin Americans (23.2 to 27.4 kg/m<sup>2</sup> for males and 25.6-29.8 kg/m<sup>2</sup> for females) (Table 2.16).

As shown in Table 2.17, the average BMI value for males generally declined with advancing age except for countries like Italy, Chile and Brazil. For Italian males, BMI value increased with age particularly in the 65-69 years old age group at 26.8 kg/m<sup>2</sup> and 27.0 kg/m<sup>2</sup> for the 70-74 years old age group (63). In Chile, average BMI of 26.5 kg/m<sup>2</sup> was reported in males belonging to the 70-74 years old age group, the 75-79 years old age was 26.8 kg/m<sup>2</sup> (58). Brazilian males BMI were 25.81 kg/m<sup>2</sup> and 25.92 kg/m<sup>2</sup> for 65-69 and 65-69 years old age group respectively (74). The same trend was true to the female counterparts except in Mexico. There was a BMI value of 27.1 kg/m<sup>2</sup> for 60-64 years old age group and 27.3 kg/m<sup>2</sup> for 65-69 years old age group.

**Table 2.16** Summary of BMI values of populations in Thailand and other countries

Countries	Age (years)	n		BMI (Kg/m <sup>2</sup> )	
		Male	Female	Male	Female
Thailand. 2001 (51)	≥ 60	105	177	20.7 (3.2)	21.9 (3.6)
Thailand. 2010 (18)	≥ 60	9,638	10,607	23.1 (4.1)	24.4 (4.8)
Thailand. 2012 (13)	≥ 60	500	503	22.6 (3.4)	23.5 (4.1)
India. 2004 (53)	≥ 60	171	161	21.2 (2.1)	20.3 (3.2)
Bangladesh. 2010 (54)	≥ 60	129	188	21.8 (3.5)	21.1 (4.4)
Chinese. 2002 <sup>a</sup> (55)	≥ 70	999	1,033	21.7 (3.7)	22.2 (4.2)
Japan. 2009 (76)	50 – 74	3,405	4,326	23.6 (2.8)	22.6 (3.1)
Korea. 2012(77)	≥ 65	294	313	23.6 (3.3)	23.8 (3.5)
Brazil. 2007 (56)	≥ 60	881	1,262	25.4 (0.2)	27.4 (0.2)
Brazil. 2012 (57)	≥ 60	85	177	26.4 (4.4)	27.2 (5.5)
Chile. 2004 (58)	≥ 60	410	806	27.0 (4.2)	28.3 (5.4)
Chile. 2007(56)	≥ 60	446	855	27.4 (0.2)	28.4 (0.2)
Mexico. 2002 (81)	≥ 60	38	101	26.3 (3.2)	28.2 (5.3)
Mexico. 2007 (56)	≥ 60	507	740	27.0 (0.2)	28.6 (0.2)
Mexico. 2007 (57)	≥ 60	1,090	870	26.4 (4.4)	26.8 (4.4)
Mexico. 2008 (82)	≥ 60	131	156	26.4 (3.6)	27.8 (4.5)
Cuba. 2007 (56)	≥ 60	708	1,197	23.2 (0.2)	25.6 (0.2)
Uruguay. 2007 (55)	≥ 60	528	916	25.7 (0.3)	29.8 (0.3)
USA (80% white). 2009 (80)	70 – 79	530	659	26 (3.6)	26 (4.7)
USA (whites). 2007 (56)	≥ 60	1,491	1,528	28.4 (0.1)	28.0 (0.2)
USA (Non-Hispanic white). 2008 <sup>c</sup> (60)	≥ 60	956	934	28.6 (0.16)	28.0 (0.21)
USA (Blacks). 2007 (56)	≥ 60	393	445	27.9 (0.3)	27.9 (0.3)
USA (Non-Hispanic black). 2008 <sup>c</sup> (60)	≥ 60	263	273	28.1 (0.30)	31.8 (0.44)
USA (Mexican American). 2007 (56)	≥ 60	514	543	28.1 (0.2)	29.2 (0.3)
USA (Mexican American). 2008 <sup>c</sup> (60)	≥ 60	280	281	28.2 (0.33)	29.2 (0.44)
Sweden. 2008 <sup>b</sup> (78)	≥ 75	181	190	25.1 (23.5 – 27.1)	25.8 (23.4–28.4)
England. 2008 (61)	≥ 65	956	1,126	27.3 (3.5)	27.3 (4.8)
England. 2010 (62)	≥ 65	1,674	1,462	26.4 (3.7)	27.6 (5.7)
Italy. 2010 (64)	≥ 65	120	164	25.6 (4.4)	24.8 (5.3)
Netherlands. 2006 (65)	≥ 65	193	206	25.7 (2.8)	26.7 (3.7)
Germany. 2000 <sup>a</sup> (66)	≥ 60	82	122	26.0 (2.6)	26.3 (3.6)
Poland. 2012 (79)	≥ 60	64	174	28.3 (5.0)	28.5 (5.0)
Turkey. 2011 (68)	≥ 65	129	137	27.5 (4.48)	30.6 (5.52)
Turkey. 2012 (67)	≥ 60	69	150	28.66(3.19)	31.20 (4.65)
Uganda. 2005 (70)	60 – 90	81	81	19.81(2.96)	20.80 ( 3.49)
Nigeria. 2010 <sup>a</sup> (71)	≥ 50	110	66	25.90(4.21)	29.79 (6.70)

<sup>a</sup> Median (range) <sup>b</sup> Median (interquartile range) <sup>c</sup> Mean (standard error)

**Table 2.17** BMI of elderly by age groups

Countries	Age (years)	n		BMI (Kg/m <sup>2</sup> )	
		Male	Female	Male	Female
Japan. 2003 (73)	60 – 69	644	340	22.8	22.2
	≥ 70	117	52	22.1	21.5
England. 2008 (61)	65 – 69			27.7 (3.4)	28.0 (4.9)
	70 – 74	956 / 1,126		27.5 (3.8)	27.4 (4.9)
	75 – 79			27.0 (3.6)	27.0 (4.4)
	≥ 80			26.3 (2.9)	26.1 (4.7)
Italy. 2002 (63)	65 – 69	466	418	26.8 (4.2)	28.0 (5.2)
	70 – 74	451	370	27.0 (3.9)	27.9 (5.0)
	75 – 79	392	361	26.0 (3.6)	27.1 (5.2)
	80 – 84	365	313	25.2 (3.6)	27.1 (5.8)
Chile. 2004 (58)	60 – 64	96	178	28.4 (4.3)	29.6 (5.2)
	65 – 69	121	186	26.9 (4.5)	29.3 (5.6)
	70 - 74	79	149	26.5 (3.4)	28.5 (5.1)
	75 – 79	62	134	26.8 (4.4)	27.9 (5.4)
	80 – 84	31	87	26.0 (3.7)	26.8 (4.8)
	≥ 85	22	75	24.7 (4.0)	25.2 (5.2)
Brazil. 2005 (74)	60 – 64	155	223	25.81 (4.28)	28.34 (5.34)
	65 – 69	104	204	25.92 (3.92)	27.32 (4.90)
	70 - 74	108	180	25.39 (4.11)	27.63 (5.79)
	75 – 79	181	235	25.01 (3.95)	27.12 (4.71)
	≥ 80	186	229	23.58 (3.70)	26.01 (5.06)
Brazil. 2011(83)	60 – 69	N/A	50	N/A	27.80 (4.58)
	70 – 80	N/A	31	N/A	26.73 (3.94)
Netherlands. 2006 (65)	60 – 69	136	211	25.2 (0.32)	26.3 (0.33)
	70 – 79	87	130	24.5 (0.42)	25.5 (0.41)
	≥ 80	25	44	24.0 (0.64)	24.9 (0.68)
Cuba. 2009 (75)	60 – 64	195	234	24.35(4.04)	27.23 (5.59)
	65 – 69	148	217	23.32 (4.16)	26.57 (6.12)
	70 - 74	109	213	22.70 (3.98)	25.15 (4.89)
	75 – 79	85	180	22.20 (5.09)	24.53 (5.11)
	≥ 80	95	196	22.20 (3.76)	23.58 (4.84)
USA. 2008 <sup>a</sup> (60)	60 – 69	665	691	29.2 (0.29)	29.5 (0.33)
	70 – 79	554	463	28.1 (0.25)	27.8 (0.40)
	≥ 80	348	411	26.2 (0.19)	26.4 (0.27)
Mexico. 2007 (59)	60 – 64	317	371	26.8 (4.4)	27.1 (4.5)
	65 – 69	319	209	26.7 (3.9)	27.3 (4.2)
	70 – 74	217	141	26.0 (4.1)	27.0 (4.4)
	75 – 79	152	91	26.0 (5.0)	25.5 (4.2)
	≥ 80	93	58	25.3 (5.0)	25.2 (4.4)

<sup>a</sup> Mean (SE), N/A = not applicable

According to the BMI reported in Table 2.18, underweight were more prevalent in Asian countries, ranging from 3.9% to 21.7%. The trend was reversed in

Western countries. There were more obese elderly people regardless of gender. Obesity prevalence rates ranged from 19.5% to 38.5% in Latin America, 20.8% to 38.8% in the US and 20.7% to 25.3% in England.

**Table 2.18** Percentage of underweight and obesity among elderly

Countries	Age (years)	n		Underweight (BMI < 18.5 Kg/m <sup>2</sup> )		Obesity (BMI > 30 Kg/m <sup>2</sup> )	
		Male	female	Male	female	Male	female
Mexico. 2007 (82)	≥ 60	131	156	N/A	N/A	8.4	15.3
Mexico. 2007 (59)	60-64	1,090	870	1.2	1.6	N/A	N/A
England. 2008 (61)	≥65	956	1,126	0.6	1.2	20.7	25.3
Malaysia. 2009 (52)	≥ 60	129	101	3.9	6.9	10.1	26.7
Malaysia. 2011(85)	≥60	135	N/A	14.8	N/A	3.0	N/A
Bangladesh. 2010 (54)	≥ 60	129	188	21.7	27.7	2.3	3.2
Thailand.2006 (17)	≥ 60	542	698	19.7	18.8	2.0	6.3
Thailand.2011 (14)	≥ 60	500	500	9.4	10.7	2.4	8.4
Thailand.2010 (18)	60 – 69	2,487	2,539	11.2	10.1	4.3	11.1
	70 – 79	1,549	1,620	18.9	16.8	2.4	5.9
	≥ 80	432	452	30.9	27.6	1.3	4.1
Barbados. 2007 (56)	≥ 60	588	920	N/A	N/A	38.5	33.8
Brazil. 2007 (56)	≥ 60	881	1,262	N/A	N/A	33.2	28.8
Chile. 2007 (56)	≥ 60	446	855	N/A	N/A	22.9	19.5
Cuba. 2007 (56)	≥ 60	708	1,197	N/A	N/A	30.9	26.7
Mexico. 2007 (54)	≥ 60	507	740	N/A	N/A	37.0	32.4
Uruguay. 2007 (56)	≥ 60	528	916	N/A	N/A	24.9	21.2
USA (whites). 2007 (56)	≥ 60	1,491	1,528	N/A	N/A	24.4	20.8
USA (Blacks). 2007 (56)	≥ 60	393	445	N/A	N/A	38.8	34.0
USA (Mexican American) .2007 (56)	≥ 60	514	543	N/A	N/A	41.1	36.2

N/A=not applicable

### 2.6.2 Surrogate measures of height; AS, demi span and KH

Different authors propose several predictive equations of height. These equations are listed in Table 2.19 and are derived from studies among the adult population group. AS, demi-span, and age were considered to be independent variable in these predictive equations. Samples of the studies undertaken in Thailand and Indonesia were older adults (14-15).

**Table 2.19** Height estimation equations derived from arm span or other measurements

Countries	Age (years)	n	Arm span or others	
			Equation	R <sup>2</sup>
Australia. 1998 (85) (Melbourne Chinese)	≥ 30	Men = 130	39.56 + 0.75 AS	0.69
		Female = 117	37.67 + 0.76AS + 0.015Age	0.69
			38.21 + 0.76AS	0.71
			37.86 + 0.76AS + 0.0026Age	0.72
Malaysia. 2003 (10)	30 - 49	Male =49	47.56 + 0.681 AS	0.75
		Female =51	51.28 + 1.438 DS	0.72
			18.78 + 0.851 AS	0.81
			41.35 + 1.549 DS	0.70
Sri Lanka. 2011 (86)	20-26	Male =101	48.801+ 0.6784 AS	N/A
		Female =95	47.451+ 0.678 AS	N/A
Indonesian. 2012 (15)	55 – 85	Male =295	23.247 + 0.826 AS	0.822
	55 – 65	Male =203	22.575 + 0.830 AS	0.842
	55 – 85	Female =517	28.312 + 0.784 AS	0.789
	55 – 65	Female =415	29.761 + 0.776 AS	0.785
Thailand. 1998 (13) (Medical inpatients admitted)	15 – 79	Male = 107	46.38 + 0.7 ASL	N/A
			44.31 + 0.72 ASS	N/A
			52.29 + 1.34 HAL	N/A
			56.69 + 1.3 HAS	N/A
		Female = 293	44.77 + 0.71 ASL	N/A
			49.01 + 0.69 ASS	N/A
			63.74 + 1.18 HAL	N/A
			56.49 + 1.28 HAS	N/A
India. 2011 (87)	18 – 59	Male = 132	62.78 + 0.61 AS	0.67
Thailand. 2012 (14)	≥ 60	Male=250	83.80 + 0.92 DS	0.51
		Female=250	96.82 + 0.70 DS	0.57

AS= arm span, DS= demi-span, ASL = arm span in supine position, ASS= arm span in erect position, HAL= left half span in erect position, HAS= left haft span in supine position, N/A=not applicable

Table 2.20 shows a number of equations used for estimating the stature of the elderly from KH. Age was included as a variable in the studies from Latin America, Australia, Korea, and USA (11, 84, 88-90). Equations were derived from different age groups. There were two equations formulated in Thailand. The first equation was formulated in 1998 among inpatients aging 15 to 79 years old (13), and the other was in 2012, conducted among the elderly volunteers in the Northern region of the country (14).

**Table 2.20** Height estimation equations derived from knee height

Countries	Age (years)	n	Knee height	
			Equation	R <sup>2</sup>
Australia.1998 (85) (Melbourne Chinese)	≥ 30	Men = 130	67.78 + 2.01 KH	0.59
			71.70 + 1.98 KH - 0.044 Age	0.59
		Female = 117	74.08 + 1.81 KH	0.55
			78.46 + 1.79 KH - 0.066 Age	0.56
Malaysia. 2003 (10)	30 - 49	Male =49	69.38 + 1.924 KH	0.66
		Female =51	50.25+ 2.225 KH	0.70
Turkey. 2012 (67)	19 – 97	Male = 183	51.44 + 2.24KH	0.778
		Female = 368	52.46 + 2.21KH	0.878
Sri Lanka. 2011 (86)	20-26	Male =101	73.945+ 1.784 KH	N/A
		Female =95	73.945+ 1.784 KH	N/A
Indonesian. 2012 (15)	55 – 85	Male =295	56.343 + 2.102 KH	0.732
	55 – 65	Male =203	52.853 + 2.175 KH	0.756
	55 – 85	Female =517	62.682 + 1.889 KH	0.634
	55 – 65	Female =415	64.938 + 1.845 KH	0.634
Thailand. 1998 (13) (Inpatients admitted)	15 – 79	Male =107	65.16 + 2.01 KH	N/A
		Female = 293	71.61 + 1.81 KH	N/A
Thailand. 2012 (14)	≥ 60	Male = 250	80.31 + 1.73 KH	0.92
		Female = 250	87.49 + 1.50 KH	0.87
Korea. 2009 (88)	20 – 69	Male =2,020	74.63 + 1.95 KH - 0.09 Age	0.73
		Pre-menopausal female =1,425	66.13 + 1.99 KH - 0.07 Age	0.68
		Postmenopausal female =596	70.87 + 1.96 KH - 0.14 Age	0.69
Brazil. 2005 (11)	≥ 60	Male = 713	67.2 + 1.96 KH - 0.08 Age	0.69
		Female = 944	69.87+ 1.85 KH - 0.11 Age	0.58
Chile. 2005 (11)	≥ 60	Male = 389	64.88+2.09 KH - 0.10 Age	0.7
		Female = 615	75.17+ 1.78 KH - 0.10 Age	0.54
Mexico. 2005 (11)	≥ 60	Male = 388	63.88+1.99 KH - 0.06 Age	0.67
		Female = 607	73.09+ 1.87KH - 0.19 Age	0.59
USA (Hispanic).1999 (89) Northeastern	≥ 60	Male =128	70.28 + 1.81KH	0.72
			76.02 + 1.79KH - 0.07Age	0.72
		Female =166	59.29 + 1.92 KH	0.71
USA (Puerto Rican). 1999 (89) Northeastern	≥ 60		68.68 + 1.90 KH - 0.123 Age	0.73
		Male =81	53.42 + 2.13 KH	0.77
			52.95+ 2.13 KH - 0.006 Age	0.77
USA (Non – Hispanic white). 1998 (9)	≥ 60	Female =87	55.98 + 1.99 KH	0.68
			66.80+ 1.94 KH- 0.123 Age	0.70
USA (Non – Hispanic black). 1998 (9)	≥ 60	Male = 1,369	78.31 + 1.94 KH – 0.14 Age	0.69
		Female = 1,472	82.21 + 1.85 KH – 0.21 Age	0.64
USA (Mexican – American). 1998 (9)	≥ 60	Male = 474	79.69 + 1.85 KH – 0.14 Age	0.70
		Female = 481	89.58 + 1.61 KH – 0.17 Age	0.63
USA (Mexican – American). 1998 (9)	≥ 60	Male = 497	82.77 + 1.83 KH – 0.16 Age	0.66
		Female = 457	84.25 + 1.82 KH – 0.26 Age	0.65

N/A = not applicable, KH=knee height

### 2.6.3 Waist & hip circumference

A person’s waist circumference is influenced by gender and the country of origin. The average WC and standard deviation for older adults both males and females in specific countries are listed in Table 2.21. Older female adults tended to have a smaller WC than older male adults. McDowel et al. in 2008 conducted studies among the elderly in the US aging from 60 to 80 years old and older, and the samples were divided into three groups: 60-69, 70-79 and the 80 and older age group. The study revealed that WC declines with advancing age in both men and women. The average WC for an American ranged from 101.4 to 106.3 cm for women and 96.5 to 102.4 cm for men (60).

WC of Latin Americans ranged from 89.5 to 98.4 cm for males and 87.2 to 94.9 cm for females. Studies conducted in the European countries revealed that WC value ranged from 97.5 to 103.7 cm for males and 88.9 to 96.3 cm for females. In Asia, WC values ranged from 77.4 to 94.1 cm and 72.2 to 84.4 cm for males and females respectively.

**Table 2.21** Summary of the average waist circumference of elderly

Countries	Age (years)	n		Waist circumference (cm)	
		Male	Female	Male	Female
USA. 2008 <sup>a</sup> (60)	60 – 69	649	670	106.7 (0.74)	98.6 (0.62)
	70 – 79	530	441	105.4 (0.73)	96.2 (0.91)
	≥ 80	319	346	100.4 (0.38)	94.0 (0.72)
USA (Non-Hispanic white). 2008 (60)		904	864	106.3 (0.41)	96.6 (0.51)
USA (Non-Hispanic black). 2008 (60)	≥ 60	255	248	102.0 (0.86)	102.4 (0.75)
USA (Mexican American). 2008 (60)		274	270	103.0 (0.89)	98.4 (0.82)
USA (whites). 2007 (56)		1,491	1,528	105.3 (0.3)	96.5 (0.4)
USA (Mexican American). 2007 (56)	≥ 60	514	543	102.4 (0.6)	97.9 (0.9)
USA (Blacks). 2007 (56)		393	445	101.4 (0.8)	101.3 (0.9)
USA (80% white). 2009 (80)	70 – 79	530	659	97.7 (9.9)	88.0 (12.1)
	≥ 60	1,090	870	95.5 (11.4)	93.7 (13.4)
	60 – 64	317	371	95.5 (11.6)	93.8 (13.8)
Mexico. 2007 (59)	65 – 69	319	209	96.1 (10.8)	95.3 (14.0)
	70 – 74	217	141	95.4 (10.8)	93.2 (11.9)
	75 – 79	152	91	94.1 (12.5)	91.1 (11.5)
	≥ 80	93	58	95.7 (12.2)	92.8 (15.1)

<sup>a</sup> Mean (standard error)

<sup>b</sup> Median (interquartile range)

**Table 2.21** Summary of the average waist circumference of elderly (cont.)

Countries	Age (years)	n		Waist circumference (cm)	
		Male	Female	Male	Female
Mexico. 2002 (81)	≥ 60	38	101	96.4 (16.0)	91.6 (13.4)
Mexico. 2007 (56)	≥ 60	507	740	96.9 (0.5)	94.9 (0.5)
Brazil. 2007 (59)	≥ 60	881	1,262	95.9 (0.5)	93.7 (0.6)
Brazil. 2005 (90)	60 – 69	136	211	89.9 (1.08)	86.7 (0.08)
	70 – 79	87	130	90.1 (1.28)	85.2 (1.09)
	≥ 80	25	44	90.5 (1.94)	85.2 (1.73)
Chile. 2007 (59)	≥ 60	446	855	99.2 (0.6)	92.8 (0.5)
Chile. 2004 (58)	≥ 60	411	819	98.4 (9.9)	93.0 (11.8)
Uruguay. 2007 (59)	≥ 60	528	916	97.1 (0.7)	91.0 (0.6)
Barbados. 2007 (59)	≥ 60	588	920	90.9 (0.6)	91.3 (0.3)
Cuba. 2007 (59)	≥ 60	708	1,197	89.5 (0.5)	87.2 (0.5)
Netherlands. 2006 (65)	≥ 65	193	206	96.3 (8.3)	89.4 (10.9)
Sweden. 2008 <sup>b</sup> (78)	≥ 75	181	190	94 (89–100)	87 (80–95)
Poland. 2012 (79)	≥ 60	64	174	103.7 (10)	96.3 (11)
England. 2008 (60)	≥ 60	956	1,126	100.5 (10.2)	88.9 (11.5)
Italy. 2002 (63)	≥ 65	1,729	1,550	97.5 (9.9)	96.9 (14.1)
Korea. 2012 (77)	≥ 65	294	313	88.4 (8.3)	86.3 (9.2)
Japan. 2009 (76)	50 – 74	3,405	4,326	85.7 (7.6)	83.0 (9.5)
Japan. 2008 (91)	51 – 70	315	314	84.8 (8.0)	80.4 (8.5)
Japan. 2003 (73)	60 – 69	644	340	85.0	78.2
	≥ 70	117	52	84.0	78.2
Chinese. 2002 (55)	≥ 70	999	1,033	83.4 (10.0)	82.7 (11.3)
Malaysia. 2009 (52)	≥ 60	129	101	94.1 (5.6)	88.4 (4.5)
Bangladesh. 2010 (54)	≥ 60	129	188	80.4(10.5)	72.2 (12.8)
Thailand. 2001 (51)	≥ 60	105	177	77.4 (9.9)	76.8 (14.4)

<sup>a</sup> Mean (standard error)

<sup>b</sup> Median (interquartile range)

According to the WC values in Table 2.22, abnormal WC for male is defined as  $\geq 102$  cm and for female is  $\geq 88$  cm. Studies in 2007 suggested that the abnormal WC prevalence rate ranged from 20.4% to 37.7% for males and 14.6% to 68.9% for females in Latin American countries (54). Other studies conducted in 2012 pointed out those women had higher abnormal WC prevalence rates than men. Prevalence rate for women ranged from 48.5% to 72.7% and 12.5% to 32.5% for men (93). In the Brazilian people, the prevalence rate of over cut point WC (male  $\geq 94$  and female  $\geq 80$  cm) found elderly males were 39.2% and elderly females were 65.9% (91).

**Table 2.22** Percentage of abnormality waist circumference in elderly

Countries	Age of subjects (years)	Number of subjects		Waist circumference (cm)	
		Male	female	Male $\geq$ 102	Female $\geq$ 88
Bangladesh. 2010 (53)	$\geq$ 60	129	188	0.8	10.6
Chile. 2007 (54)	$\geq$ 60	446	855	21.4	15.4
Chile. 2012 (92)	$\geq$ 65	281	563	32.5	64.3
Barbados. 2007 (54)	$\geq$ 60	588	920	37.1	28.3
Barbados. 2012 (92)	$\geq$ 65	393	601	12.5	63.0
Cuba. 2007 (54)	$\geq$ 60	708	1,197	28.2	20.8
Cuba. 2012 (92)	$\geq$ 65	355	718	15.2	48.5
Mexico. 2007 (54)	$\geq$ 60	507	740	34.5	26.1
Mexico. 2007 (59)	$\geq$ 60	1,090	870	26.1	68.9
Mexico. 2012 (92)	$\geq$ 65	264	411	25.8	72.7
Uruguay. 2007 (54)	$\geq$ 60	528	916	23.3	16.9
Uruguay. 2012 (92)	$\geq$ 65	328	587	26.6	58.4
USA (whites). 2007 (54)	$\geq$ 60	1,491	1,528	20.4	14.6
USA (Blacks). 2007 (54)	$\geq$ 60	393	445	35.1	26.6
USA (Mexican American). 2007 (54)	$\geq$ 60	514	543	37.7	28.8
Brazil. 2007 (54)	$\geq$ 60	881	1,262	29.0	21.5
Brazil. 2012 (92)	$\geq$ 65	517	768	25.0	65.2
Brazil. 2005 <sup>a</sup> (90)	$\geq$ 60	248	385	39.2	65.9
	60 – 69	136	211	43.7	67.2
	70 – 79	87	130	34.2	64.3
	$\geq$ 80	25	44	31.3	65.2

<sup>a</sup> Men  $\geq$  94 cm and women  $\geq$  80 cm

The WHpR values are shown in Table 2.23. Generally, males have higher WHpR than females. In Asian countries, WHpR values ranged from 0.90 to 0.94 for males and 0.82 to 0.93 for females. The U.S. and Latin American countries showed WHpR ranging from 0.91 to 0.95 for males and 0.89 to 0.92 for females. The WHpR of European ranged from 0.94 to 0.97 kg/m<sup>2</sup> for males and 0.83 to 0.94 for females.

**Table 2.23** Summary of the average waist to hip ratio among elderly

Countries	Age (years)	n		WHpR	
		Male	Female	Male	Female
Thailand. 2000 (99)	60 – 94	55	329	0.92 (0.76 – 1.05)	0.82 (0.67 – 1.12)
Japan. 2008 (91)	51 – 70	315	314	0.91 (0.05)	0.87 (0.07)
Korea. 2012 (77)	≥ 65	294	313	0.94 (0.07)	0.93 (0.09)
China. 2002 (55)	≥ 70	999	1,033	0.90 (0.07)	0.89 (0.08)
Mexico. 2007 (59)	≥ 60	1,090	870	0.95 (0.06)	0.90 (0.08)
Mexico. 2002 (82)	≥ 60	131	156	0.91 (0.07)	0.92 (0.90)
USA (80% white). 2009 (80)	70 – 79	530	659	0.94 (0.06)	0.84 (0.07)
Turkey. 2011 (68)	≥ 65	129	137	0.94 (0.09)	0.90 (0.09)
Netherlands. 2006 (65)	≥ 65	193	206	0.97 (0.06)	0.87 (0.05)
Germany. 2000 (66)	≥ 60	82	122	0.95 (0.04)	0.83 (0.04)
Italy. 2002(63)	≥ 65	1,674	1,462	0.97 (0.05)	0.94 90.08)

WHpR = waist to hip ratio

#### 2.6.4 Waist to height (WHtR)

Studies in Japan, Sri Lanka, and Turkey indicated in average that female's WHtR was higher than in males. It ranged from 0.49 to 0.59 for males and 0.51 to 0.63 for females (Table 2.24).

**Table 2.24** Summary of the average waist to height ratio among elderly

Countries	Age of subjects (year)	Number of subjects		WHtR	
		Male	female	Male	Female
Japan. 2008 (91)	51 – 70	315	314	0.52 (0.05)	0.53 (0.06)
Japan. 2003 (73)	60 – 69	644	340	0.51	0.51
	≥ 70	117	52	0.51	0.52
Sri Lanka. 2012 (93)	60 – 69	N/A	N/A	0.482 (0.063)	0.520 (0.84)
	≥ 70	N/A	N/A	0.490 (0.071)	0.519 (0.89)
Turkey. 2012 (67)	≥ 60	69	150	0.59 (0.04)	0.63 (0.07)
Turkey. 2011(68)	≥ 65	129	137	0.58 (0.07)	0.62 (0.08)
Netherlands. 2006 (65)	≥ 65	193	206	0.55 (0.05)	0.55 (0.07)

WHtR = waist to height ratio

### 2.6.5 Percentage of body fat

Percentage body fat of male ranged from 22.36 to 38.4 and 24.45 to 40.0 in female. In most of studies, percentage body fat in female was higher than male except Suriah et al. (70) in 80 – 89 age groups (Table 2.25).

**Table 2.25** Mean and SD of percentage body fat (%BF) in elderly

Countries	Age (years)	Gender	n	Percentage body fat
Spain. 2011 (94)	54 – 74	Male	148	27.05 (9.50)
		Female	278	38.20 (7.14)
UK. 2005 (95)	60 - 79	Male	2,744	34.5 (8.0)
Italy. 2011(96)	67 – 78	Male	97	28.38 (5.96)
India. 2004(53)	≥ 60	Male	171	29.6 (2.16)
		Female	161	38.7 (4.4)
UK. 2010 (97)	60 – 69	Male	754	26.2 (6.7)
		Female	670	26.6 (6.8)
	≥ 70	Male	176	38.4 (8.3)
		Female	140	40.0 (9.4)
Sweden. 2003(98)	70 – 74	Male	155	29.5 (5.8)
		Female	180	27.3 (6)
	≥ 75	Male	115	36.3 (6.4)
		Female	138	34.1 (6.1)
Brazil. 2011(83)	60 – 69	Female	50	36.83 (5.04)
	70 – 80	Female	31	37.97 (3.46)
Malaysia. 1998 (70)	60 – 69	Male	80	24.38 (7.70)
		Female	127	24.45 (8.13)
	70 – 79	Male	44	22.36 (6.70)
		Female	59	24.50 (7.82)
	80 – 89	Male	16	24.92 (8.15)
		Female	18	22.24 (10.12)

In summary of the literature review in this study, malnutrition can have a significant impact on the overall quality of life at all stages of life. Aging population, a continually growing sector of the population in Thailand and in many countries globally, can suffer from both overnutrition and undernutrition as a result from various factors involving physiological and psychological disabilities. It is therefore becoming a global concern that requires attention as both conditions are associated with medical complications, as well as mortality. Nutritional status can be assessed in multiple ways, each with their own advantages and limitations. In older population, however,

anthropometric measurements may be more appropriate over other methods due to its simple, non-invasive and sensitive nature, and specifically allows the determination of whether a person is underweight or overweight. Other methods of nutritional assessments may also be hindered by the effects of aging on biochemical status and cognitive functions, as mentioned. Although initial data from anthropometry (e.g. weight) may not necessarily provide full insights to the person's general well-being, manipulation and conversion of data (e.g. BMI) enables them to evaluate the risks of developing various chronic diseases, which is important for both screening and intervention alike.

Comparing Asian countries with the rest of the world, Asian population were generally shorter with lower weight. As such, underweight is more common in Asian countries, whereas overweight is more prevalent in the Western countries. With regards to equations for estimating height, many equations have been published in Asian countries, but few were from South-East Asian countries. To date, only two studies have been published these equations, but the samples were unlikely to be representative of the whole country.

## CHAPTER III

### MATERIALS AND METHODS

#### 3.1. Study Design

The study design was an observational study and utilizes survey methods. Anthropometric assessment was conducted without any sample manipulation.

#### 3.2. Subjects

##### 3.2.1 General inclusion criteria

The selected participants were free-living adults, age  $\geq 18$  years old, living in Bangkok and nearby provinces such as Samut Prakan, Nakorn Pathom, Pathum Thani, Nonthaburi and Samut Sakorn. General inclusion criteria were age  $\geq 18$  years old and able to participate with consent. Exclusion criteria depended on objectives, which were explained in Table 3.1.

##### 3.2.2 Calculation of sample size

Formula

$$n = \frac{Z^2 \alpha/2 PQ}{d^2}$$

Where;

n = sample size,

$Z^2 \alpha/2$  = Z statistic for a level of confidence = 1.96

P = expected prevalence or proportion = 49.4 % = 0.494 [Prevalence of waist to hip ratio abnormality in Thai elderly (14)]

Q = 1 – P

d = precision = 0.04

Sample size in calculation = 600 cases, adding 10% = 660 cases (Table 3.2)

**Table 3.1** The objectives and exclusion criteria for subject recruitments

Objectives	Age group (years)	Exclusion criteria
(1) To identify anthropometric characteristic of Thai elderly	≥ 60	none
(2) To determine the prevalence of obesity and underweight conditions of Thai elderly	≥ 60	none
(3) To develop equations to estimate stature for use in community settings using a proxy indicator of standing height, categorized by sex and age group;	≥ 18	- Kyphosis present or unable to stand for height measurement - Severe pre - existing conditions
(3.1) Equations derived from knee height	≥ 18	- Kyphosis present or unable to stand for height measurement - Amputated limbs - Unable to stretch out their arms - Severe pre - existing conditions
(3.2) Equations derived from arm span	≥ 18	- Kyphosis present or unable to stand for height measurement - Amputated limbs - Unable to stretch out their arms - Severe pre - existing conditions
(4) To validate height predictive equations derived from the study and compare with previously reported equations	≥ 60	- Kyphosis present or unable to stand for height measurement - Amputated limbs - Unable to stretch out their arms - Severe pre - existing conditions

**Table 3.2** The objectives and sample size of each objectives

Objectives	Age group (years)	Sample		
		Male	Female	All
(1) To identify anthropometric characteristic of Thai elderly	≥ 60	254	484	738
(2) To determine the prevalence of obesity and underweight conditions of Thai elderly	≥ 60	254	484	738
(3) To develop equations to estimate stature for use in Thai adults in community settings using a proxy indicator of standing height categorized by sex, and age group	≥ 18	449	970	1,419
(4) To validate height predictive equations derived from the study and compare with previously reported equations <sup>a</sup>	≥ 60	41	87	138

<sup>a</sup> Random 20% from elderly subjects (88)

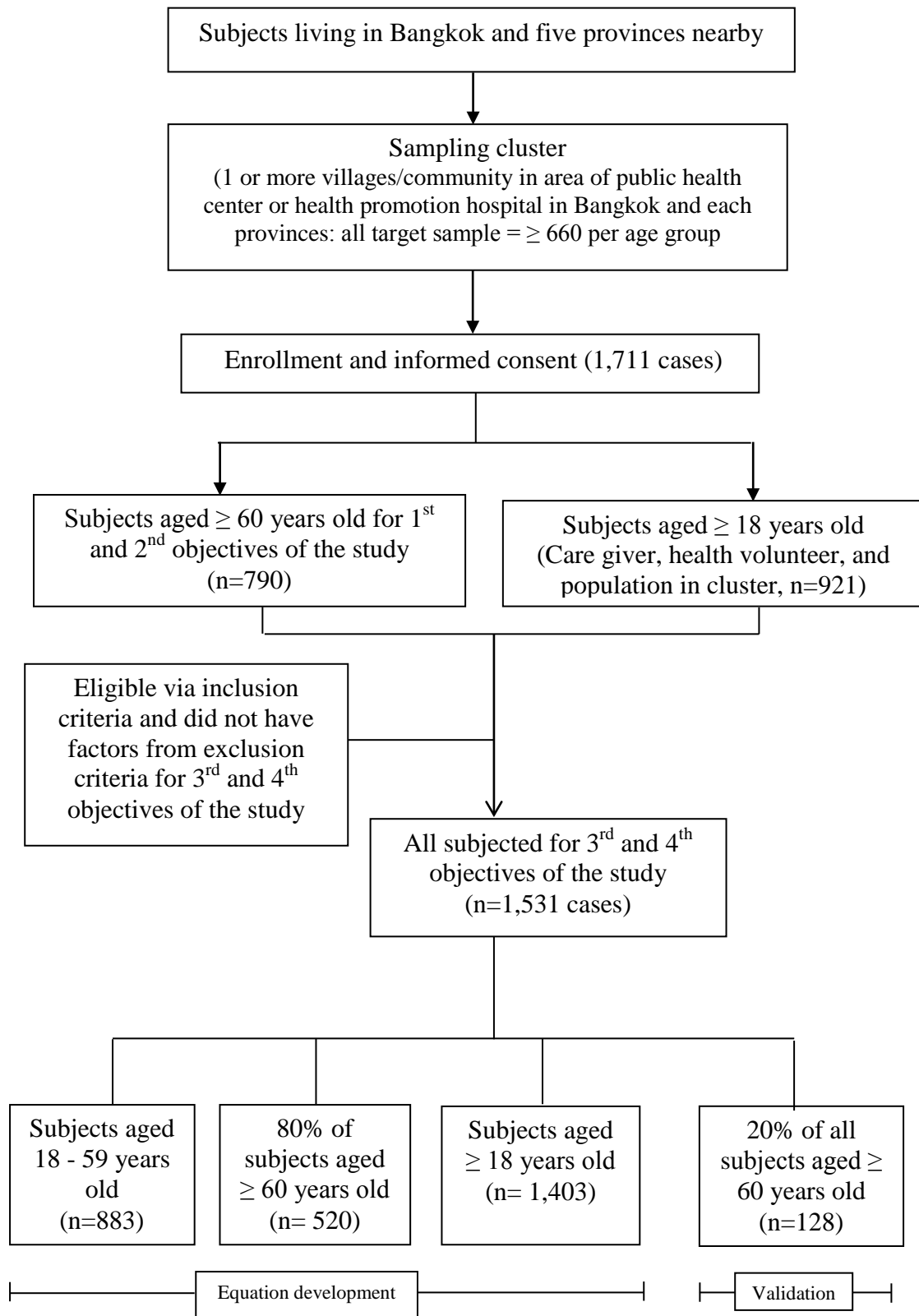
### 3.2.3 Sample selection

Cluster (area) sampling was used as the sampling method. In this study, Bangkok and other aforementioned provinces were selected as the clusters representative of Thailand's population, to which one district was randomly selected from each provinces/clusters. In Bangkok, the district was represented further represented by a randomly selected public health center, while in the other provinces, the districts were represented by a health promotion hospital, also selected by simple random sampling. Simple random sampling method was also used to select one community, representing the Bangkok cluster, and ten villages, representing the other five clusters. All potential subjects from the selected villages/community were invited by the staffs of the hospitals and public health center to participate in the study, and were informed of the initial information of the study. Interested participants were invited to a designated area for providing explanation of the study, obtaining consent forms, and assessing nutritional status by anthropometry and demographic data. Data of any interested participants who were unable to come to the area were collected by individual home visits (n = 790). As shown in Figure 3.1, the subjects for development and validating predictive height equation were also enrolled by cluster (area) sampling and convenient sampling in each cluster;

- 1) Most elderly subjects (n=493 from 790 cases) were recruited from the subjects for assessing nutritional status absent of factors in exclusion criteria. Additional elderly subjects were recruited from convenient sampling in other community in the same cluster.

- 2) The elderly subjects were separated by gender, and were sorted ascending by age. Random numbers were generated by Microsoft excel and were again sorted ascending but by random number. 20% of elderly subjects based on the sorting number were assigned into validating equation group in each gender (n=87 for female, 41 for males).

- 3) The subjects aged 18 – 59 years old were recruited from the schools, universities and community in the area of cluster (n=631 for female, 252 for male).



**Fig.3.1** Flow chart of sample allocation

### **3.3 Ethical issues**

3.3.1 The study protocol was approved by the Ethics Committee of the Faculty of Tropical Medicine (TMEC 13 – 039, approved date 28 August 2013).

3.3.2. Invitation brochures for participating in the research were distributed through public health care centers and health promoting hospital at primary level.

3.3.3 Each volunteers signed informed consent to participate in this study with a witness. In case of volunteers who cannot sign informed consent, substitute decision maker was considered.

3.3.4 Anonymity is an important requirement for individual data. All the information was evaluated and published representing the whole sample.

### **3.4 Anthropometric measurement protocol**

#### **3.4.1 Weight measurement**

Weight was measured using a digital scale and the collection should be done after the bladder is emptied and before a meal, and in light clothing.

- 1) Position the scale on a hard flat surface.
- 2) Place the scale on a zero balance before each use.
- 3) The sample stands on the scale looking straight ahead.
- 4) The sample should relax and not move.
- 5) Measurements are recorded to the nearest 0.1 kilogram.
- 6) Time of measurements and visible edema are recorded.
- 7) Weighing scale is calibrated whenever it is moved to another location.

#### **3.4.2 Height measurement**

Standing height is measured using a free standing stadiometer. When measuring a person's standing height, the guidelines re as follows;

- 1) The sample stands straight with the head facing forward and shoulders relaxed.
- 2) Arms are to hang loosely at the sides with the palms facing forwards.

- 3) Feet are placed together and knees straightened.
- 4) Heels, buttocks and shoulder blades of the sample should touch the vertical backboard of the stadiometer.
- 5) The sample is barefoot without wearing any socks.
- 6) Make sure that the Frankfurt plane is horizontal.
- 7) During measurement, the subject takes a deep breath and stands still.
- 8) Measurements are recorded to the nearest millimeter.
- 9) The time of measurement is recorded.

### 3.4.3 Knee height

A knee height caliper (Fig. 3.2) is used to measure the knee height of a person. Both right and left knees are measured. In cases where both legs cannot be measured due to cast, amputation or sores, only one leg is measured. During measurements, the following are recommended:

- 1) The sample sits on a chair with knee on a 90 degree angle.
- 2) The fixed caliper is positioned under the heel of the foot while the movable caliper is positioned on the anterior surface of the thigh above the femoral condyles and proximal to the patella.
- 3) Measurements are recorded to the nearest 0.1 centimeter.
- 4) Both left and right knee height measurements are performed.
- 5) Measurements are repeated in cases when the results differ by greater than 0.4 centimeter.



**Fig. 3.2** Knee height caliper

#### **3.4.4 Arm span**

A non-stretchable tape is used to measure the arm span of a person. The followings are the guidelines for arm span measurement:

- 1) The sample stands straight against a flat wall and feet together with arms stretched at a 90 degree angle and palms facing forward.
- 2) Measurements are taken from the tip of the middle finger to the tip of the middle finger on the opposite side.
- 3) Measurements are recorded to the nearest 0.1 centimeter.

#### **3.4.5 Abdominal and waist circumference**

Two locations of waist circumferences will be measured in this study; (1) at the point between last rib and top of iliac crest and, (2) at umbilicus level or abdominal circumference. An ordinary tape is used to measure the abdominal or waist circumference of a person. The tape used is narrow, flexible and does not stretch. The guidelines of measuring the waist circumference are described as follows;

- 1) The sample is in a standing position with feet together.
- 2) Locate the point of measurement.
  - 2.1) Palpate the high point of the iliac crest indicating the mid-axillary line and the last palpable rib of the body of the sample
  - 2.2) Locate the umbilicus.
- 3) Mark the midpoint between the high point of the iliac crest and the last palpable rib on both sides/ umbilicus.
- 4) Place the measuring tape around the trunk at the marked points.
- 5) The measuring tape must be parallel to the floor and the tape is snug but not compressing the skin.
- 6) Measurements are made at the minimal respiration and are recorded to the nearest 0.1 centimeter.

#### **3.4.6 Hip circumference**

To measure hip circumference, the guidelines are

- 1) The sample is in a standing position with feet together.
- 2) The tape is placed at the maximum extension of the buttocks.

- 3) The sides of the tape are adjusted ensuring a horizontal position.
- 4) The tape is held snug but not tight.
- 5) Measurements are recorded to the nearest 0.1 centimeter.

### **3.4.7 Percentage of body fat**

Using a bioimpedance analyzer (Omron, model HBF-375 ), the body fat percentage is calculated with a formula that uses the measured body water along with five factors; electric resistance, height, weight, age and gender.

- 1) After measuring weight and height, those values and gender were entered into bioimpedance analyzer.
- 2) Step on the main unit bare-footed and stand with knees and back straight, looking straight ahead. Make sure both heels are positioned on a heel electrode.
- 3) Raise the arms horizontally, and extend elbow straight.
- 4) Hold the electrodes on display unit using both hands and extend the arms straight at 90 degree angle to the body until analysis is complete.

## **3.5 Data Analysis**

### **3.5.1 Descriptive statistics**

Continuous data were analyzed with statistical mean and standard deviation. Categorical data were analyzed with statistics, frequency and percentage. Data were analyzed using the software package SPSS version 21.

### **3.5.2 Analytic statistics**

3.5.2.1 Comparison between means was performed by using an independent sample t-test and a one-way analysis of variance (ANOVA).

3.5.2.2 The associations between outcome variables were determined by using Pearson's correlation coefficients.

3.5.2.3 The prevalence of nutritional status based on anthropometric indices between the genders and age groups were compared using chi-square test or likelihood ratio

3.5.2.4 Predictive height equation developing was formulated by multiple regressions. R squared ( $R^2$ ) and standard error of the estimate (SEE) were analyzed to determine the predictive ability of the formula.

3.5.2.5 Mean difference and Intra-class correlation coefficient (ICC) with 95% confidence interval (95% CI) were used to validate height predictive equation. Mean different between measured height and estimated height from equation is a crude way for checking for difference or agreement between two measurements. ICC was computed to demonstrate the strength of the relationship (agreement) between two measurements.

### **3.6 Research fund**

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## **CHAPTER IV**

### **RESULTS**

#### **4.1 Nutritional status of elderly participants**

##### **4.1.1 Demographic data**

Two hundred and fifty four elderly males, age ranged 60 – 93 years, and four hundred and eighty four elderly females, age ranged 60 – 95 years, were recruited in this study to analyze for the nutritional status of older population in Thailand. The demographic data such as age, education level, underlying conditions, smoking and alcohol consumption status, as categorized by gender, were presented in Table 4.1. Most male and female participants (77.7% and 83.4%, respectively) graduated in primary school level. In addition, hypertension was the most commonly found underlying conditions in both males and females and other conditions such as diabetes and dyslipidemia, were also common occur in elderly population. Elderly males were more likely to drink alcohol and smoke than elderly females.

**Table 4.1** Demographics data and health status<sup>a</sup>

Variables	Male (n=254)	Female (n=484)
Age (years) <sup>b</sup>	71.13±8.24	69.86±7.85
Education		
Illiterate	14(6.5)	73(17.3)
Primary	181(83.4)	328(77.7)
Secondary school	14(6.4)	16(3.8)
Higher Secondary school	8(3.7)	3(0.7)
Pre-existing conditions		
Hypertension	116(44.4)	269(54.6)
Dyslipidemia	67(25.7)	194(39.4)
Diabetes	53(19.9)	140(28.4)
Heart disease	15(5.7)	45(9.1)
Cerebral vascular disease	10(3.8)	20(4.1)
Thyroid	4(1.5)	21(4.3)
Kidney disease	6(2.3)	12(2.4)
Carcinoma	3(1.1)	14(2.8)
Liver disease	4(1.5)	4(0.8)
Smoking	90(35.4)	39(8.1)
Alcohol consumption		
Always	21(8.3)	7(1.4)
Sometimes	53(20.9)	39(8.1)

<sup>a</sup> Data presented as n (%) unless stated otherwise

<sup>b</sup> Data presented as mean ± SD (min-max)

## 4.1.2 Anthropometric characteristics and nutritional status

### 4.1.2.1 Height

From Table 4.2, elderly males were significantly taller than females in all age groups ( $P < 0.0001$ ). The average height for elderly males aged 60 to 69 years, 70 to 79 years, and 80 years and older were 162.5, 161.7, and 159.8 cm, respectively, whereas the average height for elderly females were 151.1, 150.4, and 146.8 cm, respectively. Comparison between the male aged 80 and above and male aged 60 – 69 years, the latter group were taller, albeit insignificant ( $P = 0.073$ ), whereas there was a significant negative correlation between age and height ( $r = -0.187$ ,  $P = 0.004$ ) in males. As for height and age in female elderlies, we found significant negative correlation ( $r = -0.211$ ,  $P < 0.001$ ) and also the height of females aged 80 and above were shorter compared to female aged 60-69 years.

#### 4.1.2.2 Knee height

Elderly males also had longer knee height (KH) than females in all age groups ( $P < 0.001$  for both knees). The mean right KH of elderly males aged 60 to 69 years, 70 to 79 years, and 80 years and older were 51.1, 51.2, and 50.9 cm, respectively and for elderly females were 48.0, 48.0, and 47.1 cm, respectively. Similarly, the mean left KH of elderly males aged 60 to 69 years, 70 to 79 years, and 80 years and older were 51.0, 51.1, and 50.8 cm, respectively, and for elderly females were 47.9, 47.8, and 47.1 cm, respectively.

KH of elderly males showed no significant difference between age groups ( $P = 0.883$  for right KH,  $P = 0.775$  for left KH) and also showed no significant correlation between age and left or right KH ( $r = -0.050$ ,  $P = 0.442$  for left KH,  $r = -0.046$ ,  $P = 0.477$  for right KH). Age groups comparison showed KH of elderly females aged 80 and above were significantly shorter than KH of female aged 60 -69 years ( $P = 0.046$  for left KH,  $P = 0.020$  for right), but there were no significant negative correlation between age and both KH ( $r = -0.50$ ,  $P = 0.118$  for left KH,  $r = -0.083$ ,  $P = 0.081$  for right KH).

#### 4.1.2.3 Arm span

Gender comparison showed longer arm span (AS) for males than females ( $P < 0.001$ ). The mean AS of the elderly males aged 60 to 69 years, 70 to 79 years, and 80 years and older were 169.6, 169.7, and 168.3 cm, respectively, and for elderly female for were 156.7, 156.7, and 154.2 cm, respectively. Both elderly males and females showed no significant negative correlation between age and AS ( $r = -0.087$ ,  $P = 0.197$  for male,  $r = -0.090$ ,  $P = 0.062$ ), as well as showed no difference when comparing AS by age groups ( $P = 0.629$  for male,  $P = 0.066$  for female).

#### 4.1.2.4 Body weight

Elderly males were heavier than elderly females in all age groups ( $P < 0.001$ ). In both groups, we found that the body weight of both elderly males and females aged 80 and above were lower than those of age 60 – 69 years ( $P < 0.001$ ). For males, the mean weight of elderly males decreased from 63.99 kg at the age of 60 to 69 years to 55.09 kg at age over 80 years. The mean weight of elderly

females also decreased from 59.67 kg at the age of 60 to 69 years to 51.63 kg at age over 80 years.

**Table 4.2** Height, knee height (KH), arm span (AS) and body weight of elderly participants and the correlations between these characteristics and age

	Age group (years)	n	Mean	SD	F	P <sup>a</sup>
<b>Height (cm)</b>						
Elderly male	$r = -0.187$ $P = 0.004^b$					
	All <sup>c</sup>	241	161.8	6.8	2.651	0.073
	60-69	122	162.5	6.2		
	70-79	75	161.7	6.5		
	80 up	44	159.8	8.4		
Elderly female	$r = -0.211$ $P < 0.001^b$					
	All	455	150.5	5.5	12.310	<0.001
	60-69	264	151.1	5.3		
	70-79	147	150.4	5.3		
	80 up	44	146.8	6.3		
<b>Right KH (cm)</b>						
Elderly male	$r = -0.046$ $P = 0.477^b$					
	All <sup>b</sup>	237	51.1	2.4	0.125	0.883
	60-69	116	51.1	2.3		
	70-79	79	51.2	2.4		
	80 up	42	50.9	2.4		
Elderly female	$r = -0.083$ $P = 0.081^b$					
	All	438	47.9	2.0		
	60-69	253	48.0	1.9		
	70-79	141	48.0	2.0		
	80 up	44	47.1	2.0		
<b>Left KH (cm)</b>						
Elderly male	$r = -0.050$ $P = 0.442^b$					
	All <sup>c</sup>	238	51.0	2.4	0.255	0.775
	60-69	117	51.0	2.3		
	70-79	79	51.1	2.4		
	80 up	42	50.8	2.4		
Elderly female	$r = -0.074$ $P = 0.118$					
	All	442	47.8	2.1	3.096	0.046
	60-69	256	47.9	2.0		
	70-79	142	47.8	2.1		
	80 up	44	47.1	2.2		

<sup>a</sup>  $P$  value by one way ANOVA comparison between age groups

<sup>b</sup>  $P$  value by Pearson correlation

$P < 0.001$  by independent t-test comparison between genders

**Table 4.2** Height, knee height (KH), arm span (AS) and body weight of elderly participants and the correlations between these characteristics and age (cont.)

	Age group (years)	n	Mean	SD	F	<i>P</i> <sup>a</sup>
<b>AS (cm)</b>						
Elderly male	<i>r</i> = - 0.087 <i>P</i> = 0.197 <sup>b</sup>					
	All <sup>c</sup>	220	169.4	8.0		
	60-69	112	169.6	7.9	0.465	0.629
	70-79	70	169.7	7.9		
	80 up	38	168.3	8.6		
Elderly female	<i>r</i> = - 0.090 <i>P</i> = 0.062 <sup>b</sup>					
	All	427	156.5	6.7		
	60-69	250	156.7	6.8	2.735	0.066
	70-79	135	156.7	6.2		
	80 up	42	154.2	7.5		
<b>Body weight (kg)</b>						
Elderly male	<i>r</i> = - 0.277 <i>P</i> <0.001 <sup>b</sup>					
	All <sup>c</sup>	225	61.58	12.33		
	60-69	117	63.99	12.21	8.155	<0.001
	70-79	69	61.16	12.72		
	80 up	39	55.09	9.52		
Elderly female	<i>r</i> = - 0.241 <i>P</i> <0.001 <sup>b</sup>					
	All	437	57.97	11.41		
	60-69	251	59.67	11.24	10.646	<0.001
	70-79	142	56.91	11.23		
	80 up	44	51.63	10.44		

<sup>a</sup> *P* value by one way ANOVA comparison between age groups

<sup>b</sup> *P* value by Pearson correlation

*P* < 0.001 by independent t-test comparison between genders

#### 4.1.2.5 Body mass index (BMI) and classification

The prevalence rate of underweight, overweight, and obese, and also association between BMI classifications and age groups were presented in Table 4.3. Generally, elderly males had higher BMI than the elderly females (*P* < 0.001). The mean BMI of the elderlies aged 60 to 69 years were significantly higher than those aged over 80 years (24.09 vs 21.39 kg/m<sup>2</sup>, *P* = 0.001 for males, 26.14 vs 23.87 kg/m<sup>2</sup>, *P* = 0.005 for females). We also found significant negative correlation between age and BMI in both male and female (*r* = -0.252 and -0.173, respectively, *P* < 0.001 for all).

Because the cut-off point for BMI classified as underweight was identical for the International classification and the Asian classification, the study

found that that the prevalence of underweight in the older male population was 10.4% and 4.8% for the older female population. On the other hand, the prevalence of obese as  $\text{BMI} \geq 30 \text{ kg/m}^2$  in females increased from 7.0% to 54.3% when using the classification for Asian population ( $\text{BMI} \geq 25\text{kg/m}^2$ ), which was higher than males ( $P < 0.001$ ), where it increased from 6.1% to 33.5%. Following an increase in age, the prevalence of obesity were decreased in both elderly males ( $P = 0.043$ ) and females ( $P = 0.070$ ).

**Table 4.3** Body mass index (kg/m<sup>2</sup>) by age groups and genders, and the prevalence of each BMI classifications

Age group	n	Mean	SD	P <sup>a</sup>	BMI classification					P
					<18.50	18.50 – 22.99	23.00 – 24.99	25.00 – 29.99	≥ 30	
Elderly male										
All <sup>c,d</sup>	230	23.31	4.10		24(10.4%)	95(41.3%)	34(14.8%)	63(27.4%)	14(6.1%)	
60-69	119	24.09	4.23		8(6.7%)	45(37.8%)	17(14.3%)	39(32.8%)	10(8.4%)	0.043 <sup>e</sup>
70-79	71	23.11	4.09	0.001	9(12.7%)	28(39.4%)	12(16.9%)	18(25.4%)	4(5.6%)	
80 up	40	21.39	3.00		7(17.5%)	22(55.0%)	5(12.5%)	6(15.0%)	0	
Elderly female										
All	440	25.60	4.71		21(4.8%)	108(24.5%)	72(16.4%)	177(40.2%)	62(14.1%)	
60-69	254	26.14	4.81		8(3.1%)	55(21.7%)	37(14.6%)	112(44.1%)	42(16.5%)	
70-79	143	25.17	4.60	0.005	10(7.0%)	37(25.9%)	26(18.2%)	53(37.1%)	17(11.9%)	0.070 <sup>f</sup>
80 up	43	23.87	3.98		3(7.0%)	16(37.2%)	9(20.9%)	12(27.9%)	3(7.0%)	

<sup>a</sup> P value by one way ANOVA comparison of mean BMI between age groups

<sup>b</sup> P value of Pearson correlation

<sup>c</sup> P < 0.001 by independent t-test comparison between genders

<sup>d</sup> P < 0.001 by Chi square test comparison between genders

<sup>e</sup> P value by Likelihood ratio comparison of BMI classifications between elderly male age groups

<sup>f</sup> P value by Chi square test comparison of BMI classifications between elderly female age groups

#### 4.1.2.6 Abdominal, waist and hip circumference (AC, WC and HC)

The AC of elderly females were greater than of males in all age groups ( $P = 0.018$ ). The AC of elderly male aged 80 and above were significantly narrower compared to elderly male aged 60 -69 years ( $P = 0.045$ ), and there was a negative correlation between age and AC ( $r = -0.129$ ,  $P = 0.046$ ) as shown in Table 4.4. In contrast, there was no significant difference in the WC between both genders ( $P = 0.166$ ). For males aged 80 and above, the WC were significant wider when compared to the males aged 60 – 69 years ( $P = 0.028$ ), and WC was significantly and negatively correlated with age in male ( $r = -0.159$ ,  $P = 0.014$ ).

Elderly females AC and WC showed atypical pattern. There was no significant correlation between age and AC in elderly female ( $r = 0.013$ ,  $P = 0.078$ ), and with no significant difference in AC when compared within age groups ( $P = 0.574$ ). WC between age group showed also no difference.

Regarding HC, elderly females had wider HC than males ( $P < 0.001$ ). Comparing between the HC of elderly males aged 80 and above and aged 60 – 69 years, the results showed the older group had narrower HC ( $P = 0.006$ ), and showed significant negative correlation between age and HC ( $r = -0.185$ ,  $P = 0.004$ ). As for the HC of elderly female, we found significant negative correlation between age and HC ( $r = -0.153$ ,  $P = 0.001$ ), and found no significant difference HC when compared within age groups ( $P = 0.368$ ).

From Table 4.4, elderly females showed higher prevalence of abnormal WC and AC than males ( $P < 0.001$  for both WC and AC), being approximately doubled in females than males. There were, however, no difference in the prevalence of abnormal WC and AC between age groups in both males ( $P = 0.131$  for AC,  $P = 0.059$  for WC) and females ( $P = 0.949$  for AC,  $P = 0.785$  for WC).

**Table 4.4** Abdominal, waist and hip circumference by age groups and genders, correlation between circumferences and age, and prevalence of abnormal circumferences

Age group	n	Mean	SD	F	$P^a$	Normal (n, %)	Abnormal (n, %)	$P^e$
<b>AC (cm)</b>								
Elderly male	r = - 0.129 $P = 0.046^b$							
All <sup>c</sup> ( $P = 0.018$ )	241	86.38	11.43			159(66.0)	82(34.0) <sup>d</sup>	
60-69	122	87.27	11.69	2.991	0.045	75(61.5)	46(38.5)	0.131
70-79	77	87.13	12.10			51(66.2)	26(33.8)	
80 up	42	82.40	8.41			33(78.6)	9(21.4)	
Elderly female	r = 0.013 $P = 0.078^b$							
All	454	88.55	12.09			120(26.4)	334(73.6)	
60-69	261	88.16	11.98	0.555	0.574	69(26.4)	192(73.6)	0.949
70-79	147	89.45	12.31			38(25.9)	109(74.1)	
80 up	46	88.30	11.56			13(28.3)	33(71.7)	
<b>WC (cm)</b>								
Elderly male	r = - 0.159 $P = 0.014^b$							
All <sup>c</sup> ( $P = 0.166$ )	240	85.81	11.47			166(69.2)	74(30.8) <sup>d</sup>	
60-69	120	87.16	11.96	3.511	0.028	76(63.3)	44(36.7)	0.059
70-79	79	85.92	11.68			56(70.9)	23(29.1)	
80 up	41	81.63	8.45			34(82.9)	7(17.1)	
Elderly female	r = - 0.022 $P = 0.961^b$							
All	452	87.15	11.81			122(27.0)	330(73.0)	
60-69	260	87.03	11.83	1.002	0.368	70(26.9)	190(73.1)	0.785
70-79	147	87.46	11.99			38(25.9)	109(74.1)	
80 up	45	86.80	11.34			14(31.1)	31(68.9)	
<b>HC (cm)</b>								
Elderly male	r = - 0.185 $P = 0.004^b$							
All <sup>c</sup> ( $P < 0.001$ )	241	90.92	8.40					
60-69	121	91.95	8.84	5.200	0.006			
70-79	79	91.29	8.49					
80 up	41	87.18	5.56					
Elderly female	r = - 0.153 $P = 0.001$							
All	457	96.83	10.74					
60-69	263	97.49	9.60	1.002	0.368			
70-79	148	96.50	9.73					
80 up	46	96.93	17.82					

AC=abdominal circumference, WC=waist circumference, HC=hip circumference

<sup>a</sup>  $P$  value by one way ANOVA comparison of mean between age groups<sup>b</sup>  $P$  value by Pearson correlation<sup>c</sup>  $P$  value by independent t-test comparison of mean between genders<sup>d</sup>  $P < 0.001$  by chi-square test comparison of prevalence of abnormal circumferences between genders<sup>e</sup>  $P$  value by chi-square test comparison of prevalence of abnormal circumferences between age groups

#### 4.1.2.7 Abdominal/hip ratio (AHpR) and waist/hip ratio (WHpR)

AHpR and WHpR of elderly males were significantly greater than elderly female ( $P < 0.001$  for both, Table 4.5). Age group comparison showed no difference in the WHpR in both genders ( $P = 0.551$  for males,  $0.062$  for females), as well as AHpR for males ( $P = 0.885$ ). As for elderly female, there were significant difference in AHpR between age groups ( $P = 0.003$ ), and there were significant correlation between age and AHpR ( $r = 0.193$ ,  $P < 0.001$ ). There was a correlation between age and WHpR in females ( $r = 0.127$ ,  $P = 0.007$ ).

In this study, the AHpR and WHpR cut-off points of  $\geq 0.90$  for males and  $\geq 0.85$  for females were used (23). Based on this classification, the prevalence of abnormal AHpR ( $P = 0.108$ ) and WHpR ( $P = 0.728$ ) were similar between males and females (Table 31). Comparing between age groups, approximately 70% of every age groups (both males and females), had AHpR and WHpR above the cut-off points, but significance was only observed between age groups of female AHpR ( $P = 0.034$ ).

Focus on abnormality of AHpR and WHpR ratio, the abnormal AHpR pattern of elderly male and female was increase from young elderly, highest in middle elderly and decline in the oldest. Dissimilarly, the abnormal WHpR was increasing from young elderly up to the oldest.

**Table 4.5** Abdominal/hip ratio (AHpR) and waist/hip Ratio (WHpR) by age groups and genders, correlation between AHpR and WHpR and age, and prevalence of abnormal indices

Age group	n	Mean	SD	F	<i>P</i> <sup>a</sup>	Normal (n,%)	Abnormal (n,%)	<i>P</i> <sup>e</sup>
<b>AHpR (cm)</b>								
Elderly male	<i>r</i> = - 0.009 <i>P</i> = 0.886 <sup>b</sup>							
All <sup>c</sup>	231	0.95	0.07			62(25.9)	177(74.1) <sup>d</sup>	
60-69	121	0.95	0.07	0.122	0.885	31(25.6)	90(74.4)	0.858
70-79	77	0.95	0.07			19(24.7)	58(75.3)	
80 up	41	0.94	0.07			12(29.3)	29(70.7)	
Elderly female	<i>r</i> = 0.193 <i>P</i> < 0.001 <sup>b</sup>							
All	449	0.91	0.08			93(20.7)	356(79.3)	
60-69	259	0.90	0.07	5.966	0.003	64(24.7)	195(75.3)	0.034
70-79	145	0.93	0.07			20(13.8)	125(86.2)	
80 up	45	0.93	0.11			9(20.0)	36(80.0)	
<b>WHpR (cm)</b>								
Elderly male	<i>r</i> = - 0.063 <i>P</i> = 0.329 <sup>b</sup>							
All <sup>b</sup>	239	0.94	0.07			69(28.9)	170(71.1) <sup>d</sup>	
60-69	120	0.95	0.06	0.598	0.551	30(29.0)	90(71.0)	0.299
70-79	79	0.94	0.07			24(26.2)	55(73.8)	
80 up	40	0.93	0.07			15(25.0)	25(75.0)	
Elderly female	<i>r</i> = 0.127 <i>P</i> = 0.007 <sup>b</sup>							
All	448	0.90	0.08			124(27.7)	324(72.3)	
60-69	259	0.89	0.07	2.790	0.062	75(29.0)	184(71.0)	0.769
70-79	145	0.90	0.08			38(26.2)	107(73.8)	
80 up	44	0.92	0.11			11(25.0)	83(75.0)	

<sup>a</sup> *P* value by one way ANOVA comparison of mean between age groups

<sup>b</sup> *P* value by Pearson correlation

<sup>c</sup> *P* value by independent t-test comparison of mean between genders

<sup>d</sup> *P* < 0.001 by chi-square test comparison of prevalence of abnormal circumferences between genders

<sup>e</sup> *P* value by chi-square test comparison of prevalence of abnormal circumferences between age groups

#### 4.1.2.8 Abdominal/height ratio (AHtR) and waist/height ratio (WHtR)

The average AHtR and WHtR of all elderly females were significantly (*P* < 0.001) greater than males (Table 4.6), but there were no significant difference between age groups in both males (*P* = 0.219 for AHtR and = 0.160 for WHtR) and females (*P* = 0.220 for AHtR and = 0.445 for WHtR). There were no

significant correlation between age and AHtR or WHtR in both elderly males ( $r = -0.078$ ,  $P = 0.235$  for AHtR,  $r = -0.110$ ,  $P = 0.091$  for WHtR) and females ( $r = 0.077$ ,  $P = 0.104$  for AHtR,  $r = 0.058$ ,  $P = 0.223$  for WHtR).

Based on AHtR, 2.5% of all elderly male subjects were underweight ( $< 0.40$  AHtR) and was 0.2% for females. WHtR showed 0.4% of males were underweight and none for females. Furthermore, we also observed a similar trend between AHtR and WHtR when they were used to classify subjects as increased health risk (0.50 – 0.59) and central obesity ( $\geq 0.6$ ). Both indicators showed that approximately 50% of males were at an increased health risk and over 15% as having central obesity. For females, there was over 40% increased health risk and central obesity.

Nevertheless, we found no significant association in the prevalence of abnormal weight status between age groups when classified by AHtR ( $P = 0.484$  for males and 0.144 for females) or WHtR ( $P = 0.499$  for males and 0.492 for females).

**Table 4.6** Abdominal/height ratio (AHtR) and waist/height ratio (WHtR) by age groups and genders, correlations between AHtR and WHtR and age, and prevalence of abnormal indices

Age group	n	Mean	SD	F	$P^a$	Classification			$P^e$	
						<0.40	0.40 – 0.49	0.50 – 0.59		≥ 0.60
<b>AHtR</b>										
Elderly male		$r = -0.078$								
All <sup>c</sup>	236	0.53	0.07			6(2.5%)	61(25.8%)	125(53.0%)	44(18.6%)	
60-69	121	0.54	0.07	1.528	0.219	3(2.5%)	31(25.6%)	61(50.4%)	26(21.5%)	0.484
70-79	73	0.54	0.08			2(2.7%)	18(24.7%)	38(52.1%)	15(20.5%)	
80 up	42	0.52	0.06			1(2.4%)	12(28.6%)	26(61.9%)	3(7.1%)	
Elderly female		$r = 0.077$								
All	446	0.59	0.08			1(0.2%)	57(12.8%)	186(41.7%)	202(45.3%)	
60-69	259	0.58	0.08	1.519	0.220	1(0.4%)	35(13.5%)	114(44.0%)	109(42.1%)	0.499
70-79	144	0.59	0.08			0	17(11.8%)	59(41.0%)	68(47.2%)	
80 up	43	0.60	0.08			0	5(11.6%)	13(30.2%)	25(58.1%)	
<b>WHtR</b>										
Elderly male		$r = -0.110$								
All <sup>c</sup>	236	0.53	0.07			1(0.4%)	69(30.3%)	119(52.2%)	39(17.1%)	
60-69	120	0.54	0.07	1.845	0.160	0	36(31.3%)	53(46.1%)	26(22.6%)	0.144
70-79	75	0.53	0.07			1(1.4%)	21(29.2%)	40(55.6%)	10(13.9%)	
80 up	41	0.51	0.06			0	12(29.3%)	26(63.4%)	3(7.3%)	
Elderly female		$r = 0.058$								
All	445	0.58	0.08			0	69(16.0%)	177(41.0%)	186(43.1%)	
60-69	258	0.58	0.08	0.812	0.445	0	39(15.6%)	109(43.6%)	102(40.8%)	0.492
70-79	144	0.58	0.08			0	24(17.1%)	55(39.3%)	61(43.6%)	
80 up	43	0.59	0.08			0	6(14.3%)	13(31.0%)	23(54.8%)	

<sup>a</sup>  $P$  value by one way ANOVA comparison of mean between age group

<sup>b</sup>  $P$  values of Pearson correlations

<sup>c</sup>  $P < 0.001$  by independent t-test comparison of mean between gender

<sup>d</sup>  $P < 0.001$  by chi-square test comparison of prevalence of abnormal indices between genders

<sup>e</sup>  $P$  value by chi-square test comparison of prevalence of abnormal indices between age groups

#### 4.1.2.9 Percentage total body fat (%TF) and visceral fat (VF)

As expected, %TF of elderly females were significantly higher than the elderly male ( $p < 0.001$ ), while males had more visceral fat than females ( $P = 0.023$ , Table 4.7). There was a significant correlation between age and %TF in elderly male ( $r = 0.157$ ,  $P = 0.017$ ), but was not significantly different between age groups ( $P = 0.065$ ). %TF of female elderly aged 80 and above was not significantly lower than elderly female aged 60 – 69 years ( $P = 0.166$ ), and %TF did not correlated with age in females ( $r = 0.070$ ,  $P = 0.141$ ).

On the other hand, there were no significant difference between age group and %VF in both male and female ( $P = 0.156$  and  $0.335$ , respectively). In case of correlation between age and %VF, we found negative correlation in both males and females, but was only significant in elderly females ( $r = -0.121$ ,  $P = 0.067$  for male,  $r = -0.095$ ,  $P = 0.047$  for female).

The %TF cut-off points used in this study were  $\geq 20\%$  for male and  $\geq 30\%$ , and the results were presented in Table 4.7. The prevalence of abnormal TF in elderly males was significantly lower than female (81.6% vs. 92.7%,  $P = 0.005$ ). Although we did not find significance between age groups for both males and females, regardless of age 80% abnormal TF was found.

For VF, the cut-off points were  $\geq 10$  (Omron cut off point) in both male and female. The prevalence of abnormal VF in elderly male were significantly higher than elderly female (55.2 % vs 45.9%,  $P = 0.005$ ). As seen in Table 4.7, there were no significant associations between abnormal VF and age groups of both male and female ( $P = 0.644$  for male and  $P = 0.453$  for female) but gender difference was present ( $P = 0.020$ ).

**Table 4.7** Total body fat and visceral fat by age groups and genders, correlations between fat and age, and prevalence of abnormal total body fat and visceral fat

Age group	n	Mean	SD	F	<i>P</i> <sup>a</sup>	Normal (n,%)	Abnormal (n,%)	<i>P</i> <sup>e</sup>
<b>TF (%)</b>								
Elderly male	r = 0.157 <i>P</i> = 0.017 <sup>b</sup>							
All <sup>c</sup>	230	26.80	5.85			31(13.9)	193(86.1) <sup>d</sup>	
60-69	119	25.93	5.72	2.772	0.065	22(18.5)	95(81.5)	0.084
70-79	73	27.68	5.85			6(9.6)	63(90.4)	
80 up	38	27.82	5.96			3(7.9)	34(92.1)	
Elderly female	r = 0.070 <i>P</i> = 0.141 <sup>b</sup>							
All	440	37.13	4.67			32(7.3)	408(92.7)	
60-69	255	36.80	4.55	1.876	0.166	21(8.2)	234(91.8)	0.388
70-79	143	37.44	4.92			10(7.0)	133(93.0)	
80 up	42	38.07	4.36			1(2.4)	41(97.6)	
<b>VF (%)</b>								
Elderly male	r = - 0.121 <i>P</i> = 0.067 <sup>b</sup>							
All <sup>c</sup> ( <i>P</i> = .023)	230	11.03	6.00			103(44.8)	127(55.2)	
60-69	119	11.59	6.38	1.876	0.156	51(42.7)	68(57.1)	0.644
70-79	73	10.95	5.99			32(43.8)	41(56.2)	
80 up	38	9.43	4.41			20(52.6)	18(47.4)	
Elderly female	r = - 0.095 <i>P</i> = 0.047 <sup>b</sup>							
All	436	10.10	5.24			236(54.1)	200(45.9)	
60-69	252	10.38	5.34	1.098	0.335	130(51.6)	122(48.4)	0.453
70-79	142	9.90	5.21			80(56.3)	62(43.7)	
80 up	42	9.20	4.64			26(61.9)	16(38.1)	

<sup>a</sup> *P* value by one way ANOVA comparison of mean between age groups

<sup>b</sup> *P* value by Pearson correlation

<sup>c</sup> *P* value by independent t-test comparison of mean between genders

<sup>d</sup> *P* < 0.001 by chi-square test comparison of prevalence of abnormal circumferences between genders

<sup>e</sup> *P* value by chi-square test comparison of prevalence of abnormal circumferences between age groups

## **4.2 Developing and validation of predictive height model**

### **4.2.1 General characteristics of all participants**

The participants included for developing predictive height model equations were free-living adults, aged  $\geq 18$  years old, living in Bangkok and nearby provinces including Samut Prakan, Nakorn Pathom, Pathum Thani, Nonthaburi and Samut Sakorn. We developed predictive height model and validating model from these participants. Although the regions studied were Bangkok and the surrounding areas, some of the enrolled participants were originally from other regions of the country (female aged 18 – 59 years old = 57.3%, female aged  $\geq 60$  years old = 25.2%, male aged 18 – 59 years old = 10.3%, and male aged  $\geq 60$  years old = 15.9%). They were good representative for the whole country.

The majority of female aged 18-59 years (83.1%) graduated from secondary school, while most of the old female population (aged 60 and above years) graduated from primary school (73.4%). For the male population, the majority of subjects, aged 18-59 years, graduated from secondary school (44.2%) while most of the older population (77.6%) graduated from primary school. The young generations in this study were in higher education class. Hypertension and dyslipidemia were most common among participants, as shown in Table 4.8.

**Table 4.8** General characteristics of participants for developing predictive height equations

	Female		Male	
	Age group		Age group	
	18 – 59 years	60 – 105 years	18 – 59 years	60 – 113 years
<b>Province n (%)</b>				
Bangkok	271(42.7)	43(10.0)	72(28.6)	7(3.1)
Samut Prakan	224(35.3)	129(30.1)	106(42.1)	80(35.2)
Pratum Tani	48(7.6)	70(16.3)	14(5.6)	54(23.8)
Nontaburi	32(5.0)	88(20.5)	2(0.8)	40(6.6)
Nakorn prathom	45(7.1)	55(12.8)	35(13.9)	29(12.8)
Samut Sakorn	14(2.2)	44(10.3)	23(9.1)	17(7.5)
All	634	429	252	227
Immigration from other provinces	363(57.3)	108(25.2)	26(10.3)	36(15.9)
<b>Education n (%)</b>				
Illiterate	3(0.5)	36(11.3)	1(0.4)	4(2.4)
Primary school	67(10.9)	234(73.4)	59(24.6)	132(77.6)
Secondary school	513(83.1)	35(11.0)	106(44.2)	20(11.8)
Higher Secondary school	34(5.4)	14(4.3)	74(30.9)	14(8.2)
<b>Diseases n (%)</b>				
No pre-existing diseases	564(89.0)	145(33.8)	212(84.1)	104(45.8)
Hypertension or dyslipidemia	37(6.0)	257(63.5)	25(9.9)	108(52.7)
Diabetes	12(1.9)	91(23.0)	11(4.4)	47(22.4)
Thyroid	10(1.6)	19(4.9)	1(0.4)	2(1.0)
Liver disease	3(0.5)	-	1(0.4)	4(1.9)
Kidney disease	1(0.2)	8(2.1)	1(0.4)	2(1.0)
Coronary artery disease	6(1.0)	28(8.0)	2(0.8)	8(4.3)

#### 4.2.2 Characteristics of participants used for developing equations

All measured parameter of 1,531 participants were completed to be selected for further analysis. The 1,403 participants were enrolled for developing equation and 128 elderlies ( $\geq 60$  years) were used as the validated group. Anthropometric parameters especially height and surrogate height was shown in Table 4.9. All 1,403 participants classified by gender and age groups were included. New generation tended to be taller than old generation.

**Table 4.9** Height, left, right, and average knee height, and age of subjects for developing predictive height equation<sup>a</sup>

Age groups (years)	Height (cm)	Left KH (cm)	Right KH (cm)	Average KH (cm)	AS (cm)
<b>Female</b>					
18 – 59 (n=631)	157.4±5.4	49.3±1.9	49.3±1.8	49.3±1.8	160.1±6.4
< 20 (n=152)	159.7±4.7	50.0±1.6	49.9±1.6	49.9±1.6	160.6±6.2
20 – 29 (n=295)	158.1±5.2	49.5±1.8	49.5±1.7	49.5±1.8	160.7±6.3
30 – 39 (n=42)	156.2±4.9	48.9±1.7	48.9±1.7	48.9±1.7	159.2±5.9
40 – 49 (n=62)	154.9±5.4	48.6±1.9	48.6±1.9	48.6±1.9	159.2±6.2
50 – 59 (n=82)	153.4±4.7	48.1±1.8	48.1±1.8	48.1±1.8	157.4±7.0
60 – 105 (n=339)	150.7±5.3	47.7±2.0	47.8±2.0	47.7±2.0	156.3±6.7
60 – 69 (n=214)	151.3±45.1	47.8±1.9	47.9±1.9	47.9±1.9	156.5±6.5
70 – 79 (n=101)	150.2±5.1	47.7±2.0	47.7±2.0	47.7±2.0	156.4±6.4
≥ 80 (n=22)	146.9±45.2	46.5±2.0	46.6±2.0	46.6±2.1	152.6±7.1
<b>Male</b>					
18 – 59 (n=252)	168.5±6.6	52.7±2.4	52.7±2.4	52.7±2.4	174.4±7.0
< 20 (n=34)	171.6±5.3	54.0±2.2	54.0±2.1	54.0±2.1	177.6±6.7
20 – 29 (n=78)	169.8±6.3	53.3±2.4	53.3±2.4	53.3±2.4	175.3±6.4
30 – 39 (n=54)	169.5±7.8	52.7±2.5	52.7±2.5	52.7±2.5	174.6±8.0
40 – 49 (n=41)	166±5.3	51.7±2.1	51.7±2.1	51.7±2.1	172.0±6.2
50 – 59 (n=45)	164.8±5.7	51.7±2.1	51.6±2.0	51.6±2.0	172.5±6.8
60 – 113 (n=181)	162.2±6.4	51.1±2.3	51.2±2.3	51.2±2.3	170.5±7.1
60 – 69 (n=98)	163.0±5.9	51.3±2.2	51.4±2.2	51.4±2.2	170.5±7.4
70 – 79 (n=53)	161.4±7.3	51.0±2.5	51.0±2.5	51.0±2.5	171.3±7.1
≥ 80 (n=22)	160.4±5.9	50.6±2.0	50.9±2.0	50.9±2.0	168.8±5.0

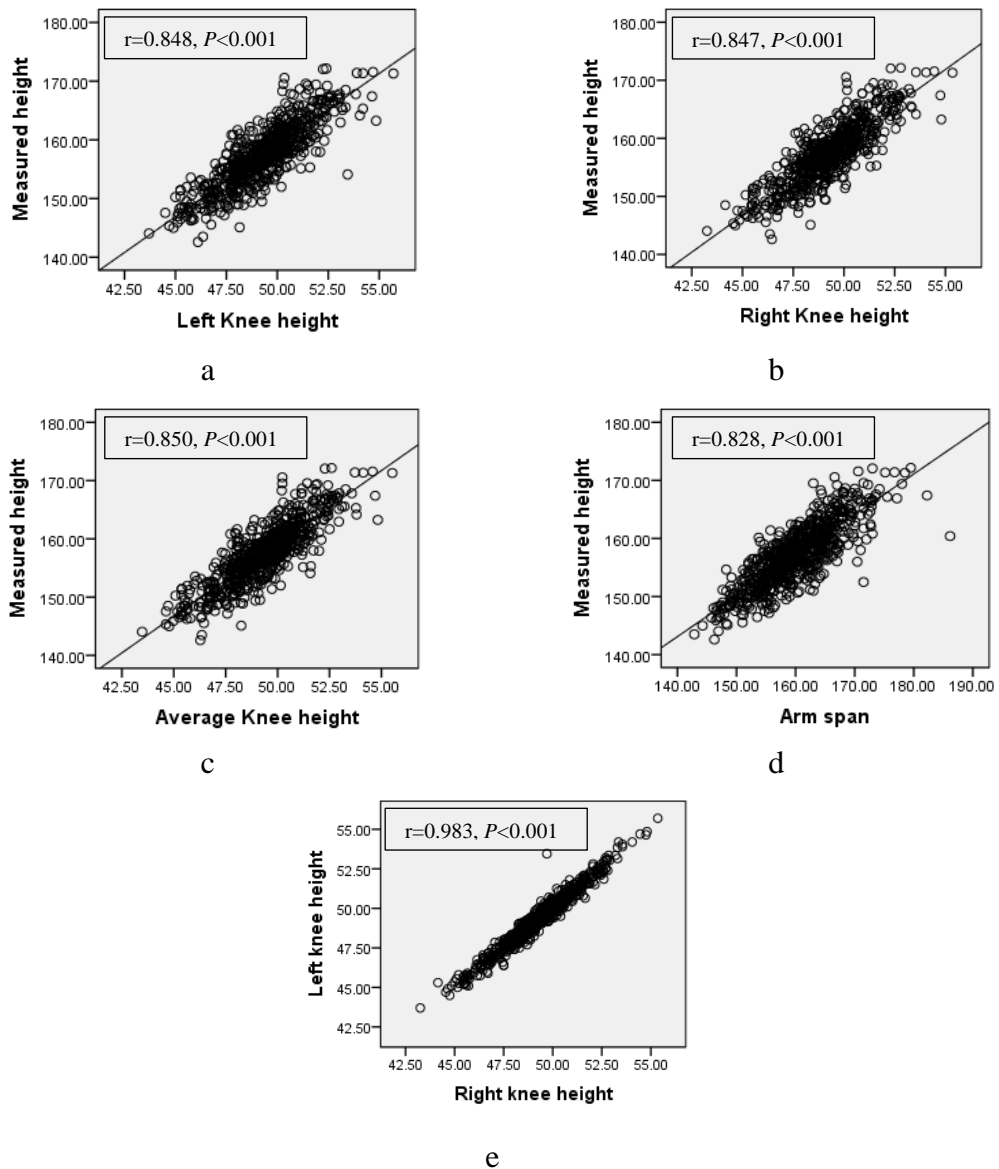
<sup>a</sup> Data presented as mean±SD

KH=knee height, AS=arm span

### 4.2.3 Correlation between height, age, and surrogate of height

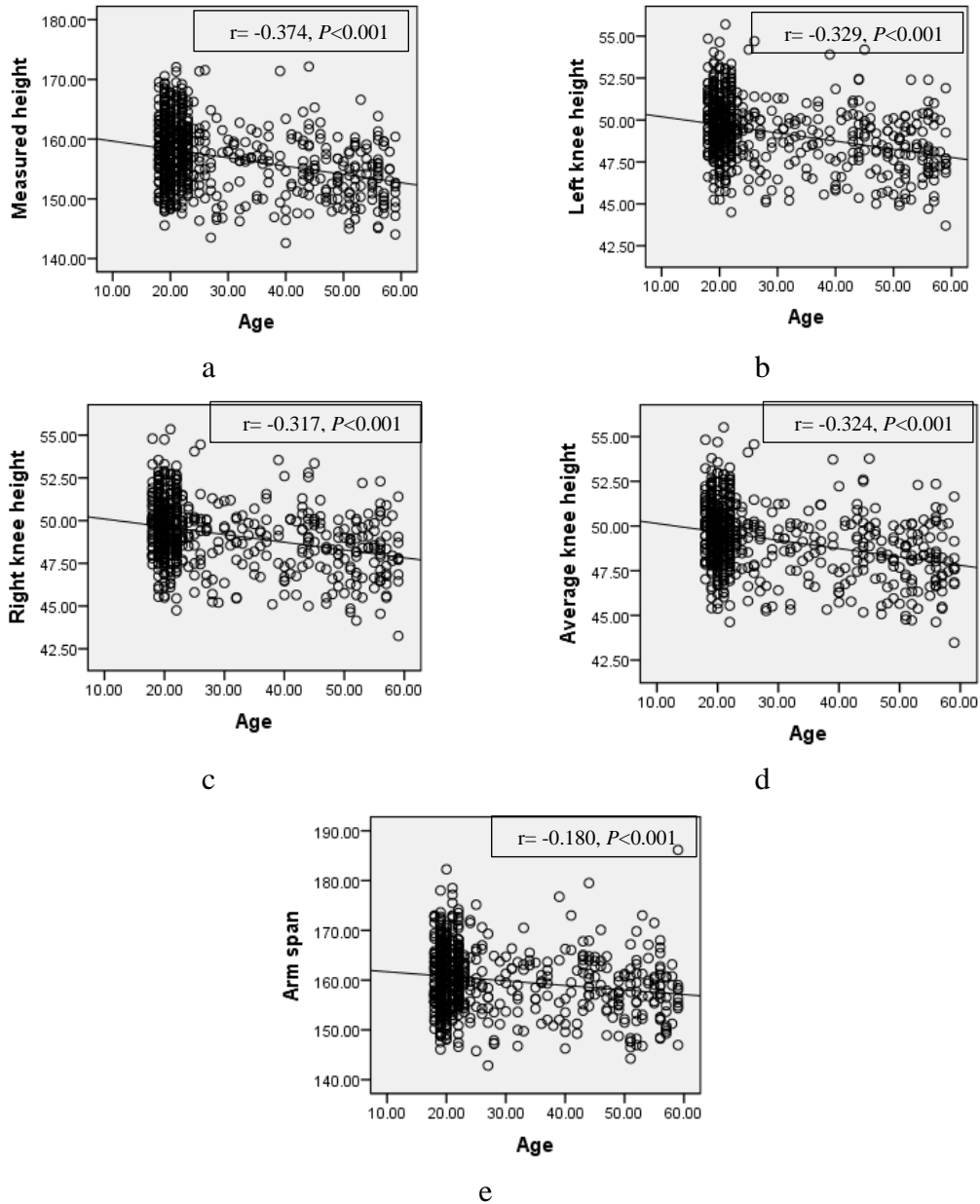
#### 4.2.3.1 Female aged 18 – 59 years

The measured height of adult female aged < 60 years showed strong positive correlation with left, right, average KH, and AS ( $r = 0.848$ ,  $0.847$ ,  $0.850$ , and  $r = 0.828$ ,  $P < 0.001$  for all pairings, respectively). Left KH was strongly and positively correlated with right KH ( $r = 0.983$ ,  $P < 0.001$ ) (Fig.4.1).



**Fig.4.1** Scatter diagrams showing correlations between measured height and (a) left knee height, (b) right knee height, (c) average knee height, (d) arm span, and (e) between left and right knee height in female group (aged < 60 years)

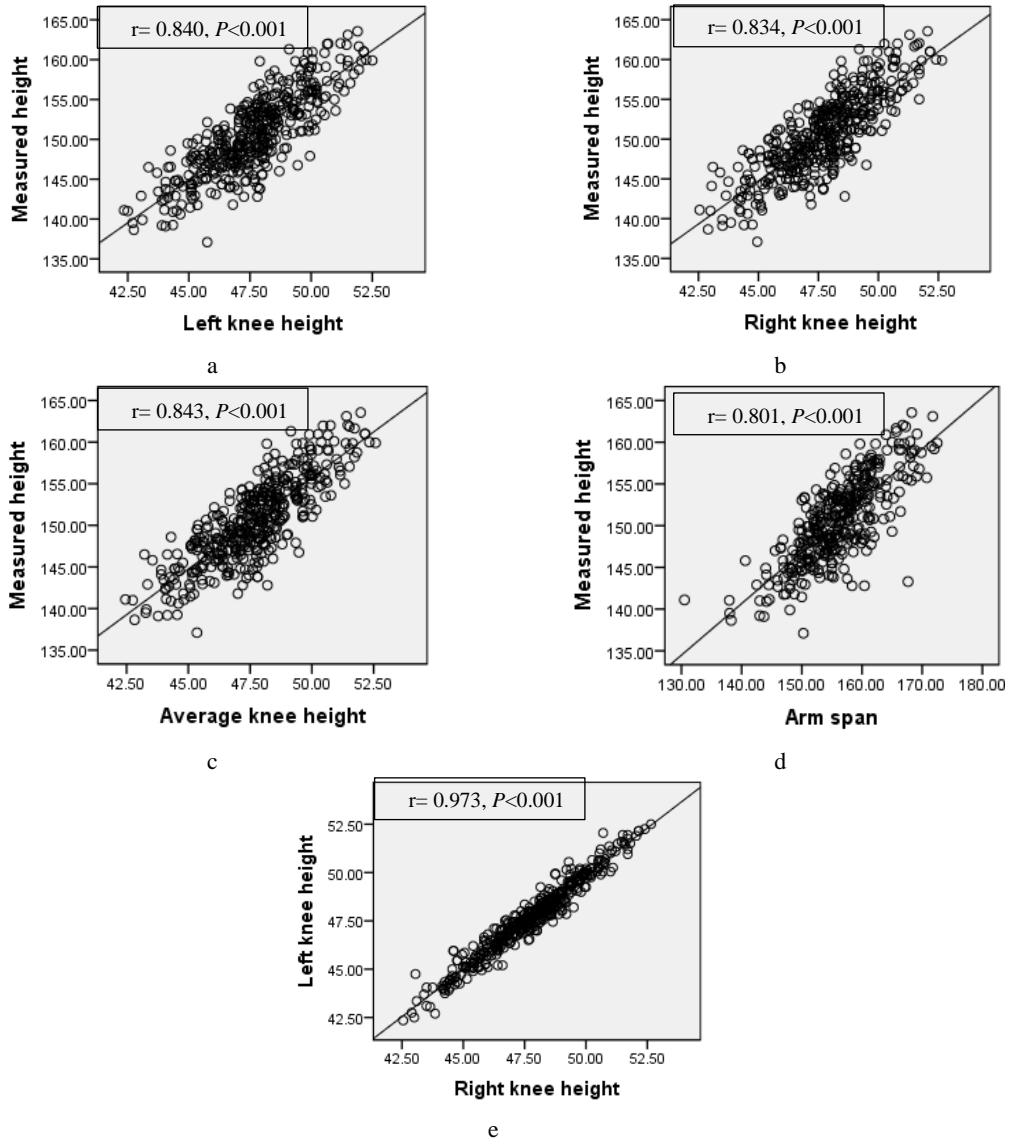
Concerning aging and height, age of subjects (< 60 years) in this study showed negative correlation with actual height, left, right, average KH, and AS ( $r = -0.374, -0.329, -0.317, -0.324, \text{ and } =-0.180, P < 0.001$  for all, respectively) (Fig.4.2).



**Fig.4.2** Scatter diagrams showing correlations between age and (a) measured height, (b) left knee height, (c) right knee height, (d) average knee height, and (e) arm span in female group (aged < 60 years)

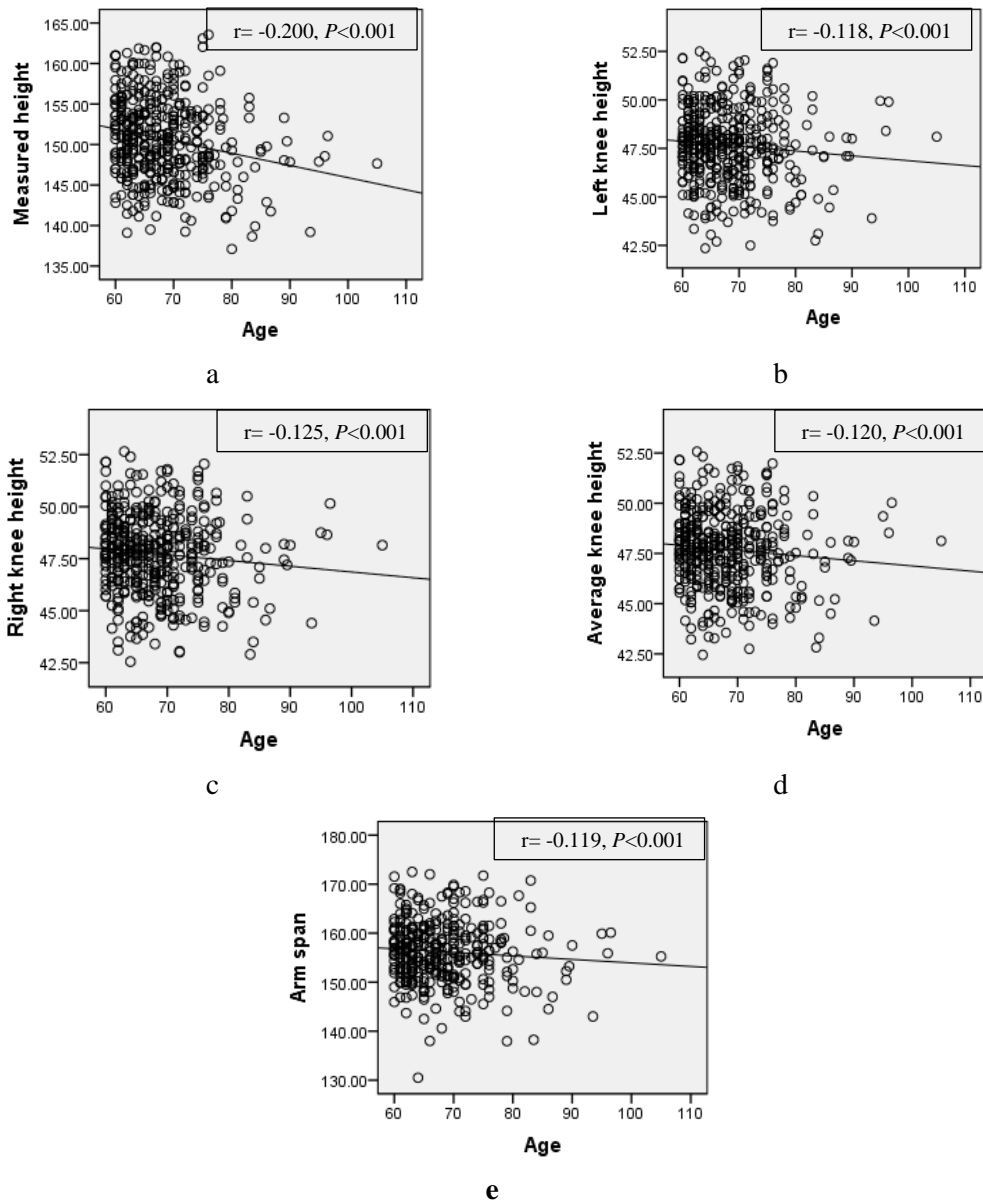
#### 4.2.3.2 Female aged $\geq 60$ years

In case of older females ( $\geq 60$  years), the actual height similarly showed significant strong positive correlation with left, right, average KH, and AS ( $r = 0.840, 0.834, 0.843, \text{ and } 0.801, P < 0.001$  respectively). Left KH was also strongly and positively correlated with right KH ( $r = 0.973, P < 0.001$ ) (Fig.4.3).



**Fig.4.3** Scatter diagrams showing correlations between measured height and (a) left knee height, (b) right knee height, (c) average knee height, (d) arm span, and (e) between left and right knee height in equation developing group (female aged  $\geq 60$  years)

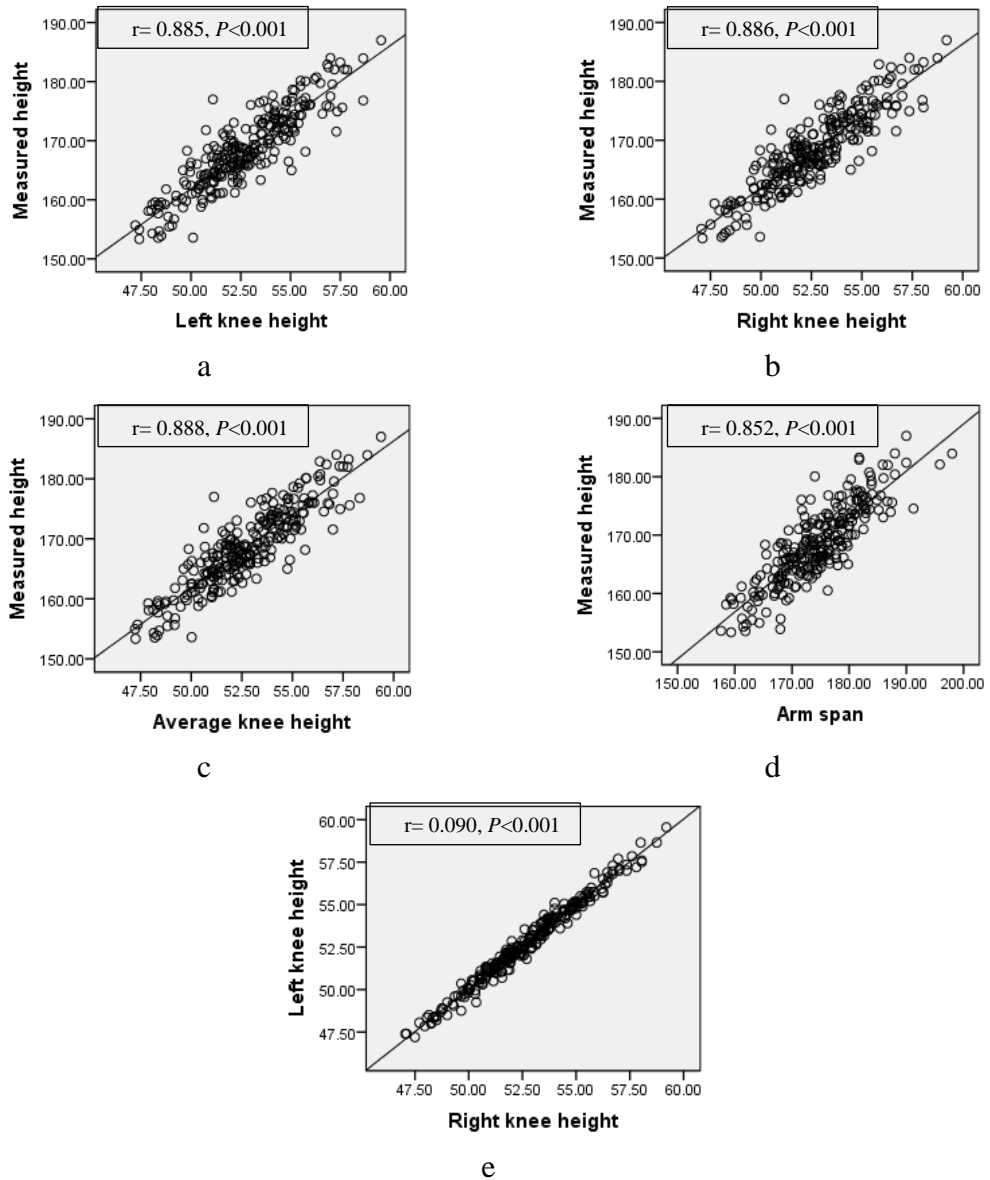
Compared to Fig. 4.2, age of older female subjects (aged  $\geq 60$  years) in Fig. 4.4 showed significant, but weaker negative correlation with actual height, left, right, average KH, and AS ( $r = -0.200, -0.118, -0.125, -0.120,$  and  $-0.119, P < 0.001$  for all respectively). The correlation of age, height, and surrogate height of young and old female participants were in the same pattern.



**Fig.4.4** Scatter diagrams showing correlations between age and (a) measured height, (b) left knee height, (c) right knee height, (d) age and average knee height, and (e) arm span in equation developing group (aged  $\geq 60$  years)

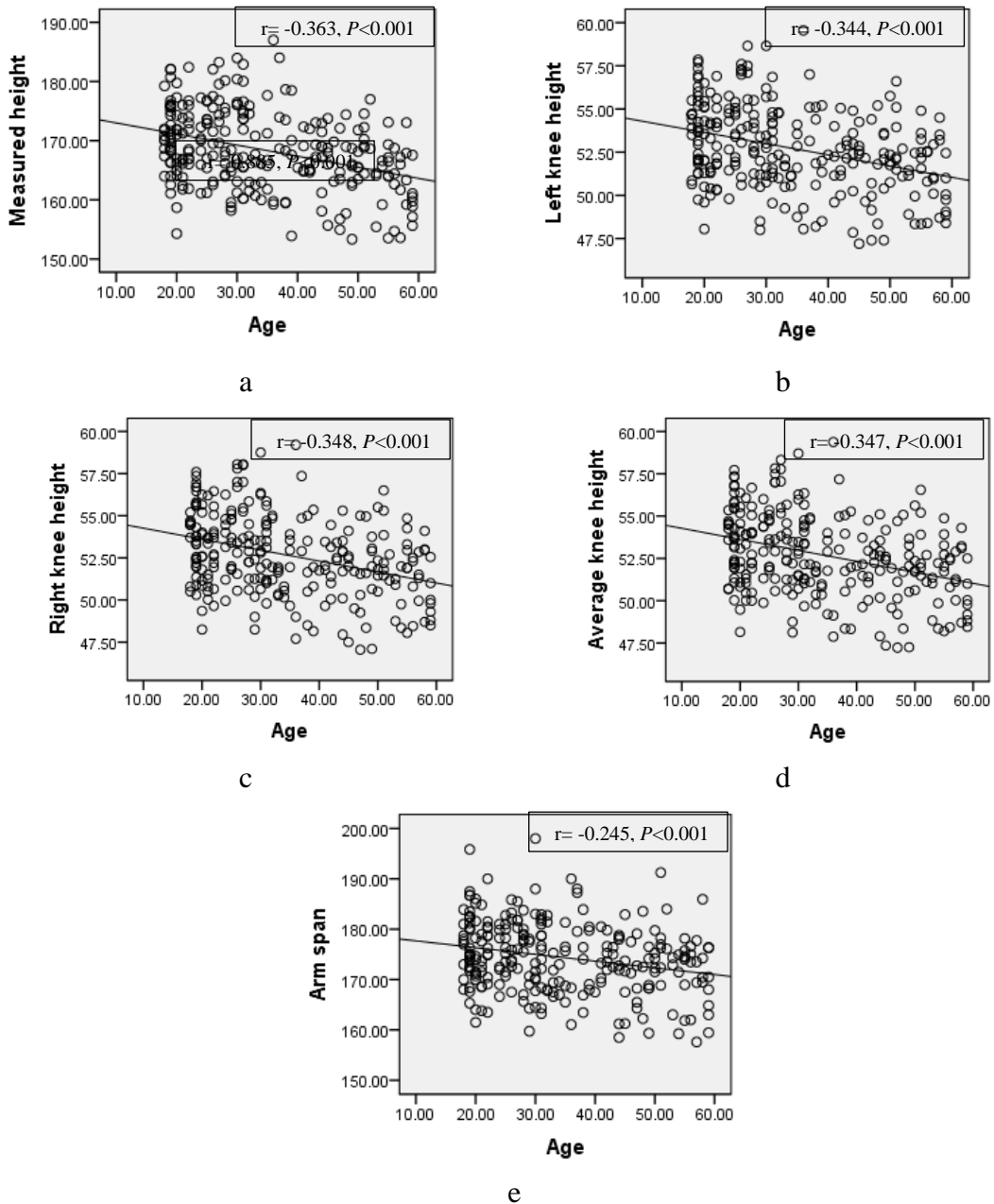
#### 4.2.3.3 Male aged 18 – 59 years

The measured height of adult male showed significant strong positive correlation with left, right, average KH, and AS ( $r = 0.885, 0.886, 0.888,$  and  $r = 0.852,$  all  $P < 0.001,$  respectively). Left KH correlated with right KH positively strong ( $r = 0.990, P < 0.001$ ) (Fig.4.5).



**Fig.4.5** Scatter diagrams showing correlations between measured height and (a) left knee height, (b) right knee height, (c) average knee height, (d) arm span, and (e) between left and right knee height in male group (aged < 60 years)

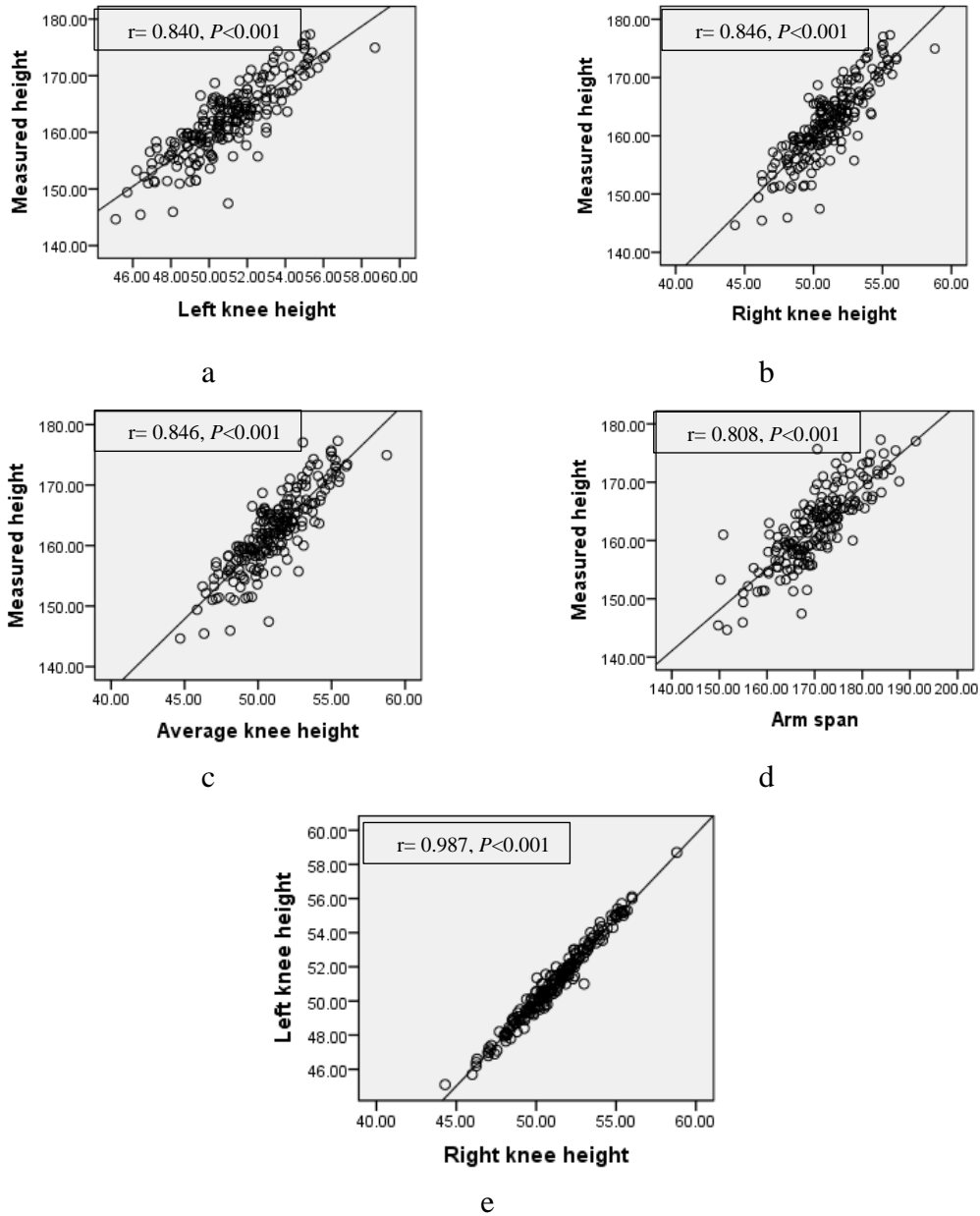
Concerning aging and height, age of subjects in this study showed significant negative correlation with actual height, left, right, average KH, and AS ( $r = -0.363, -0.344, -0.348, -0.347,$  and  $r = -0.245$   $P < 0.001$  for all, respectively) (Fig.4.6).



**Fig.4.6** Scatter diagrams showing correlations between age and (a) measured height, (b) left knee height, (c) right knee height, and (d) average knee height, and (e) arm span in male group (aged < 60 years)

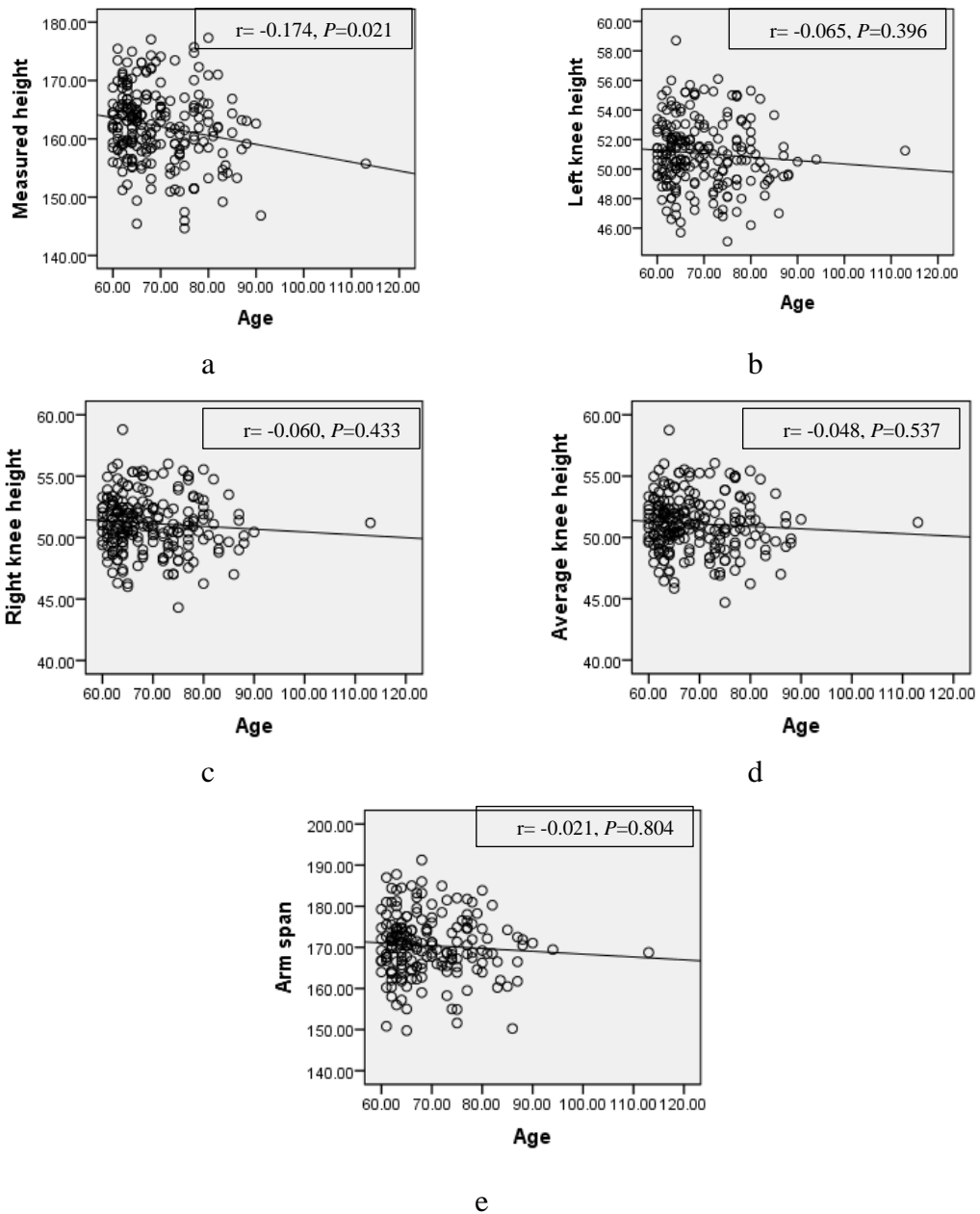
#### 4.2.3.4 Male aged $\geq 60$ years

In case of older male, the actual height of also showed significant strong positive correlation with left, right, average KH, and AS ( $r = 0.840, 0.846, 0.846$  and  $r = 0.808, P < 0.001$  respectively). Left KH correlated with right KH positively strong ( $r = 0.987, P < 0.001$ ) (Fig.4.7).



**Fig.4.7** Scatter diagrams showing correlations between measured height and (a) left knee height, (b) right knee height, (c) average knee height, (d) arm span, and (e) between left and right knee height in equation developing group (aged  $\geq 60$  years)

The age of older male subjects showed significant negative correlation with actual height ( $r = -0.174, P = 0.021$ ) but were not significant with left, right, average KH, and AS ( $r = -0.065, -0.060, -0.048$  and  $r = -0.021, P = 0.396, 0.443, 0.537,$  and  $P = 0.804,$  respectively) (Fig. 4.8).



**Fig. 4.8** Scatter diagrams showing correlations between age and (a) measured height, (b) left knee height right knee height, (c) right knee height, (d) average knee height, and (e) arm span in equation developing group (aged  $\geq 60$  years)

Correlation between height, age, and surrogate height of female and male participant showed the same direction, but old male correlation between age and height, and surrogate height could not found statistical evidence.

#### 4.2.4 Model development derived from female KH

##### 4.2.4.1 Female aged 18 – 59 years

A total of 631 participants aged between 18 and 59 years old were used to develop these predictive equations and regression models specific to this age group, as shown in Table 4.10.

Comparing between left, right, and average KH equation, equation developed from average KH (Model FK3) was the most accurate ( $R^2 = 0.725$ ,  $SEE = 2.850$ ). Since height reduces with age, we assumed that incorporating age to the equation will improve the power of the equation. As predicted, all of equations that involve age in addition to KH showed height prediction with high accuracy, especially the Model FK6 equation which exhibited the best height prediction (adjusted  $R^2 = 0.735$ ,  $SEE = 2.796$ ).

**Table 4.10**  $R^2$  and SEE of Equation developing for female aged < 60

Model	Equation	Adjusted $R^2$	SEE
FK1	$H = 35.867 + 2.466 \text{ KH (L)}$	0.719	2.877
FK2	$H = 33.357 + 2.519 \text{ KH (R)}$	0.717	2.887
FK3	$H = 33.599 + 2.513 \text{ KH (Av)}$	0.725	2.850
FK4	$H = 42.190 + 2.363 \text{ KH (L)} - 0.045\text{Age}$	0.729	2.827
FK5	$H = 40.238 + 2.408 \text{ KH (R)} - 0.050\text{Age}$	0.729	2.825
FK6	$H = 40.092 + 2.408 \text{ KH (Av)} - 0.047\text{Age}$	0.735	2.796

H= height, KH = knee height, L=left, R=right, Av=average, FK=Female knee height model

##### 4.2.4.2 Female aged $\geq 60$ years

Old female 430 participants were divided into a validating group and a predictive equation development group. Participants were initially allocated with a random number. The subjects in the first 20% of the sorted set of random numbers were then assigned to be the validating group ( $n = 87$ ), with and rest of subjects assigned to the predictive equation development group ( $n = 343$ ). We then excluded the 4 outliers in the developing equation group, resulting in 339 cases for this group. Regression models derived from this group was shown in Table 4.11.

Out of the three KH measurements, the average KH (Model FK9) showed the most accurate prediction power (adjusted  $R^2 = 0.709$ ,  $SEE = 2.814$ ). Inclusion of age into the equation further increased the accuracy in all equations, with

the Model FK12 exhibited the most accuracy prediction (adjusted  $R^2 = 0.718$ , SEE = 2.773).

**Table 4.11**  $R^2$  and SEE of Equation developing for female aged  $\geq 60$  years

Model	Equations	Adjusted $R^2$	SEE
FK7	H = 44.032+2.237 KH (L)	0.705	2.829
FK8	H = 44.125+2.231 KH (R)	0.695	2.883
FK9	H = 42.595+2.265 KH (Av)	0.709	2.814
FK10	H = 50.609+2.204 KH (L) - 0.074Age	0.714	2.784
FK11	H = 50.375+2.199 KH (R) - 0.069Age	0.703	2.846
FK12	H = 48.982+2.233 KH (Av)- 0.071Age	0.718	2.773

H= height, KH = knee height, L=left, R=right, Av=average, FK= female knee height model

#### 4.2.4.3 All females

Regression models derived from 838 females were shown in Table 4.12. Alike previous equations, the average KH (Model FK15) showed the most accurate prediction power (adjusted  $R^2 = 0.755$ , SEE = 3.136), which further increased when age was included in the Model FK18 equation (adjusted  $R^2 = 0.805$ , SEE = 2.800).

**Table 4.12**  $R^2$  and SEE of Equation developing for all females

Model	Equation	Adjusted $R^2$	SEE
FK13	H = 26.577+2.633 KH (L)	0.751	3.159
FK14	H = 23.770+2.690 KH (R)	0.744	3.208
FK15	H = 23.804+2.689 KH (Av)	0.755	3.136
FK16	H = 46.486+2.287 KH (L) - 0.070Age	0.798	2.841
FK17	H = 44.799+2.326 KH (R) - 0.075Age	0.799	2.837
FK18	H = 44.116+2.337 KH (Av)- 0.071Age	0.805	2.800

H= height, KH = knee height, L=left, R=right, Av=average, FK= female knee height model

Notably, the Model FK18, which involved predicting height from average KH with age, had the highest adjusted  $R^2$  out of all derived equations for female KH.

#### 4.2.4.4 Validation of female KH predictive height model

There were no significant differences in age, height, left, right and average KH between equation developing group and validating group, shown in Table 4.13.

**Table 4.13** Comparison between physical characteristics of the female aged  $\geq 60$  years in the equation developing group and the validating group<sup>a</sup>

Variables	Eq. developing group (n=339)	Validating group (n=87)	<i>P</i> <sup>b</sup>
Age (years)	68.3(7.1)	68.0(6.9)	0.691
Height (cm)	150.7(5.2)	150.6(4.5)	0.868
Left. KH (cm)	47.7(1.9)	47.5(1.7)	0.439
Right. KH (cm)	47.8(1.9)	47.6(1.7)	0.555
Average KH (cm)	47.7(1.9)	47.6(1.7)	0.496

<sup>a</sup> Data presented as mean (SD), Eq=equation

<sup>b</sup> *P* value by independent t-test

Table 4.14 showed estimated heights, which were calculated from the three equations (ModelFK6, FK12, FK18) with highest  $R^2$  from each age group and the other two previously reported equations (13, 14). The estimated height from two previously reported equations were rather different from the actual height than the estimates from our three predictive power equations formulated during this study, with our results being more comparable to the actual height. Furthermore, the mean difference from our present equations were much smaller than the previously reported equations (1.62 to 4.54 cm difference compared to 7.12 to 8.25 cm difference), suggesting that the equations accurred more than the previous existing equations, both of which possess higher mean differences.

The correlation coefficient (*r*), as shown in Table 40, indicated the relationship between actual height and estimated height derived from KH equations, while the intra-class correlation coefficient (ICC) further indicates the degree of agreement. Despite all models, including the previously reported equations, showed identical correlation, our models possess considerably higher ICC (0.810 to 0.827) compared to 0.229 and 0.318), demonstrating higher degree of agreement. Of all equations, the predictive model developed from all female participants showed the highest ICC value (Model FK18).

**Table 4.14** Validation of developed equations for female knee height, as assessed by actual and estimated heights (n=87)

	Mean±SD	95% CI of mean		MD ± SE	95% CI of mean difference		r	ICC	95% CI of ICC	
		Lower	upper		Lower	upper			Lower	upper
Actual height	150.6±4.5	149.6	151.6							
Estimated height										
Present study										
Model FK6 <sup>a</sup>	154.6±4.2	153.7	155.5	-4.00±0.34	-4.68	-3.32	0.728	0.810	0.741	0.857
Model FK12 <sup>b</sup>	155.1±3.9	154.3	156.0	-4.54±0.34	-5.21	-3.88	0.728	0.823	0.798	0.851
Model FK18 <sup>c</sup>	152.2±4.1	151.4	153.1	-1.62±0.34	-2.30	-0.95	0.728	0.827	0.795	0.855
Thai previous studies										
Jitapunkul & Benchajareonwong.1998	157.7±3.1	157.0	158.4	-7.12±0.33	-7.77	-6.46	0.728	0.318	-0.066	0.668
Chittawatanarat et al.2012	158.9±2.6	158.3	159.4	-8.25±0.34	-8.92	-7.58	0.728	0.229	-0.058	0.566

MD = Mean difference, SE = Standard error of mean, r = Pearson correlation, ICC = Intra-class correlation

<sup>a, b, c</sup> Equations with the highest R<sup>2</sup>, derived from females aged 18 – 59 years, ≥ 60 years, and all females, respectively

### 4.2.5 Model development derived from female AS

#### 4.2.5.1 Female aged 18 – 59 years old

The participants aged between 18 and 59 years old ( $n = 676$ ) were used to develop the height predictive equations from AS (Model FA1 – FA2, Table 4.15). The actual height that was predicted by AS and age in multiple linear regression model (Model FA2; adjusted  $R^2 = 0.722$ , SEE = 2.91, Table 4.15) exhibited better height prediction than model with only AS (Model FA1; adjusted  $R^2 = 0.690$ , SEE = 3.07).

#### 4.2.5.2 Female aged $\geq 60$ years old

Similarly in the predictive height equations (Model FA3 - FA4) derived from female aged 60 and above ( $n = 274$ ), the model that includes age as variable (Model FA4) showed better height prediction than model with only AS (Model FA3) by increasing adjusted  $R^2$  from 0.641 to 0.648 (Table 4.15).

#### 4.2.5.3 All age groups

Out of all the derived equations, the Model FA6 that was derived from all female participants ( $n=950$ ) showed the highest prediction power (adjusted  $R^2 = 0.767$ , SEE = 2.947), as shown in Table 4.15.

**Table 4.15**  $R^2$  and SEE of Equation developing by female arm span

Model	Equations	Age group (years)	Adjusted $R^2$	SEE
FA1	$H = 42.039 + 0.719AS$	18 – 59	0.690	3.07
FA2	$H = 49.082 + 0.689AS - 0.082Age$		0.722	2.91
FA3	$H = 50.372 + 0.642AS$	$\geq 60$	0.641	3.138
FA4	$H = 56.044 + 0.633AS - 0.063Age$		0.648	3.109
FA5	$H = 35.881 + 0.751AS$	All	0.672	3.499
FA6	$H = 53.951 + 0.660AS - 0.091Age$	(18 – 103)	0.767	2.947

FA= Female arm span model, H=height, AS=arm span

#### 4.2.5.4 Validating female AS predictive height model

There were no significant differences of age, height, and AS between equation developing group and validating group, shown in Table 4.16.

**Table 4.16** Comparison between physical characteristics of the female aged  $\geq 60$  years, between equation developing group and validating group<sup>a</sup>

Variables	Eq. developing group (n=247)	Validating group (n=78)	<i>P</i> <sup>b</sup>
Age (years)	68.5(7.4)	68.1(7.0)	.664
Height (cm)	150.7(5.2)	150.8(4.4)	.852
Arm span (cm)	156.2(6.5)	156.2(5.8)	.988

<sup>a</sup>Data presented as mean (SD)<sup>b</sup>*P* value by independent t-test,

The best three formulated AS equation (Model FA2, FA4, FA6) in present study and a previously reported equation (13) were used to estimate height (Table 4.17). Compared to our three equations, the estimation from the previously reported model showed the most deviation from the actual height. As a result, the mean difference between the actual height and the estimated heights from the presently derived equations (ranged -0.08 to 0.14) were much smaller and showed more accuracy than the previously existing equation.

The ICC of present equations ranged 0.72 to 0.781, demonstrating a high degree of agreement and all model had similar correlation coefficient. Specifically, the predictive height model developed from all female participants (Model FA6) showed the highest ICC value.

**Table 4.17** Mean SD and 95% CI of mean of actual height and estimated heights from female AS (n=78)

	Mean±SD	95% CI of mean		MD±SE	95% CI of MD		r	ICC	95% CI of ICC	
		Lower	upper		Lower	upper			Lower	upper
Actual height	150.8±4.4	149.8	151.8							
Estimated height										
Present study										
Model FA2. <sup>a</sup>	151.1±4.0	150.2	152.0	-0.35±0.37	-1.08	0.38	0.707	0.781	0.736	0.819
Model FA4 <sup>b</sup>	150.6±3.7	149.8	151.5	0.14±0.36	-0.58	0.86	0.703	0.772	0.726	0.811
Model FA6 <sup>c</sup>	150.8±3.9	150.0	151.7	-0.08±0.36	-0.80	0.64	0.712	0.780	0.735	0.818
Thai previous study										
Jitapunkul & Benchajareonwong,1998	156.8±4.0	155.9	157.7	-6.02±0.40	-6.79	-5.24	0.672	0.422	0.089	0.745

MD = Mean difference, SE = Standard error of mean, r = Pearson correlation, ICC = Intra-class correlation

<sup>a, b, c</sup> Equations with the highest R<sup>2</sup>, derived from females aged 18 – 59 years, ≥ 60 years, and all females, respectively

### 4.2.6 Model development derived from male KH

#### 4.2.6.1 Male aged 18 – 59 years

A total of 252 participants aged between 18 and 59 years old were used to develop these predictive equations and regression models specific to this age group, as shown in Table 4.18. Regarding the three KH, the most accurate prediction equation for this age group was derived from the average KH (Model MK3, adjusted  $R^2 = 0.788$ , SEE = 3.061). After including age in the multiple linear regression models, all demonstrated increment in predictive power, as shown and especially in Model MK6 which has the highest predictive power (adjusted  $R^2 = 0.790$ , SEE = 3.042).

**Table 4.18**  $R^2$  and SEE of Equation developing

Model	Equation	Adjusted $R^2$	SEE
MK1	$H = 40.927 + 2.419 \text{ KH (L)}$	0.783	3.095
MK2	$H = 39.509 + 2.448 \text{ KH (R)}$	0.784	3.085
MK3	$H = 39.556 + 2.446 \text{ KH (Av)}$	0.788	3.061
MK4	$H = 45.382 + 2.357 \text{ KH (L)} - 0.034\text{Age}$	0.786	3.074
MK5	$H = 43.726 + 2.388 \text{ Knee KH (R)} - 0.032\text{Age}$	0.787	3.066
MK6	$H = 43.809 + 2.386 \text{ KH (Av)} - 0.032\text{Age}$	0.790	3.042

H= height, KH = knee height, L=left, R=right, Av=average, MK=male knee height model

#### 4.2.6.2 Male aged $\geq 60$ years

All participants aged 60 and above were randomly assigned to be in either the predictive equation development group (n = 181) and validating group (n = 41). Model MK7 - MK9 were produced from the predictive development group, in which Model 9 exhibited the highest prediction power ( $R^2 = 0.715$ , SEE = 3.393) out of the three KH. The predictive height model from average KH (Model MK9) showed an increase in prediction power when age is additionally used one of the predictors (Model MK12, adjusted  $R^2 = 0.717$ , SEE = 3.377) (Table 4.19)

**Table 4.19** R<sup>2</sup> and SEE of Equation developing of the male group (aged ≥ 60 years)

Model	Equations	Adjusted R <sup>2</sup>	SEE
MK7	H = 41.914+2.357 KH (L)	0.704	3.458
MK8	H = 40.799+2.375 KH (R)	0.713	3.401
MK9	H = 40.229+2.388 KH (Av)	0.715	3.393
MK10	H = 47.660+2.339 KH (L) - 0.069Age	0.710	3.424
MK11	H= 45.111+2.362 KH (R) - 0.052Age	0.716	3.387
MK12	H= 44.926+2.373 KH (Av)- 0.056Age	0.717	3.377

H= height, KH = knee height, L=left, R=right, Av=average, MK= male knee height model

#### 4.2.6.3 All males

Regression models MK13 – MK18 derived from 424 males were shown in Table 4.20. When KH was used as the sole predictor, Model MK15 showed the highest predictive power (adjusted R<sup>2</sup> = 0.779, SEE = 3.366). Model MK18, which included both KH and age as the predictors demonstrated an even higher prediction power when compared KH alone (adjusted R<sup>2</sup> = 0.803, SEE = 3.178).

**Table 4.20** R<sup>2</sup> and SEE of Equation developing of the all males

Model	Equation	Adjusted R <sup>2</sup>	SEE
MK13	H= 33.972+2.536 KH (L)	0.777	3.396
MK14	H= 32.439+2.565 KH (R)	0.774	3.406
MK15	H=32.462+2.565 KH(Av)	0.779	3.366
MK16	H = 46.982+2.340 KH (L) - 0.058Age	0.798	2.841
MK17	H = 45.799+2.366 KH (R) - 0.062Age	0.800	3.203
MK18	H= 45.447+2.371 KH (Av)- 0.059Age	0.803	3.178

H= height, KH = knee height, L=left, R=right, Av=average, MK= male knee height model

#### 4.2.6.4 Validating male KH predictive height model

There were no significant differences in age, height, left, right and average KH between equation developing group and validating group, as shown in Table 4.21.

**Table 4.21** Comparison between physical characteristics of the male aged  $\geq 60$  years in the equation developing group and the validating group<sup>a</sup>

Variables	Eq. developing group (n=181)	Validating group (n=41)	<i>P</i> <sup>b</sup>
Age (years)	70.0 (8.3)	69.0 (7.8)	0.498
Height (cm)	162.2 (6.4)	162.0 (6.6)	0.855
Left. KH (cm)	51.1 (2.3)	50.8 (2.4)	0.432
Right.KH (cm)	51.1 (2.3)	50.8 (2.4)	0.276
Average KH (cm)	51.1 (2.3)	50.8 (2.3)	0.257

<sup>a</sup>Data presented as mean (SD), Eq=equation, KH=knee height

<sup>b</sup>*P* value by independent t-test

The three equations with highest  $R^2$  developed from KH and age in this study were selected to validate along with the other two previously reported equations (13 - 14) (Table 4.22).

When the equations were used to estimate the height of elderly male subjects, our three equations showed that the mean difference between the actual height and the estimated height from KH ranged between -0.769 to 0.423 cm. The estimations from the two previously existing models, however, were strikingly different from the actual height.

Although we observed very similar *r* value among the five equations, which indicated similar relationship between actual height and estimated height, the ICC was high for all the equations developed in this study (ICC = 0.856 - 0.860), suggesting large agreements, and low for the previously reported equations (ICC = 0.585 and 0.198).

**Table 4.22** Mean SD and 95% CI of mean of actual height and estimated heights (cm) (n=41)

	Mean±SD	95% CI of mean		MD±SE	95% CI of MD		r	ICC	95% CI of ICC	
		Lower	upper		Lower	upper			Lower	upper
Actual height	162.1±6.4	160.0	164.1							
Estimated height										
Present study										
Model MK6 <sup>a</sup>	162.8±5.8	161.0	164.7	-0.769±0.460	-1.698	0.161	0.889	0.856	0.747	0.920
Model MK12 <sup>b</sup>	161.7±5.8	159.8	163.5	0.423±0.461	-0.509	1.354	0.889	0.858	0.750	0.921
Model MK18 <sup>c</sup>	161.9±5.8	160.0	163.7	0.209±0.461	-0.722	1.141	0.889	0.860	0.752	0.923
Thai previous studies										
Jitapunkul & Benchajareonwong,1998	167.3±4.8	165.8	168.8	-5.211±0.482	-6.186	-4.236	0.888	0.585	-0.088	0.850
Chittawatanaarat et al.2012	168.2±4.2	166.9	169.5	-6.134±0.522	-7.190	-5.078	0.888	0.198	-0.070	0.714

MD = Mean difference, SE = Standard error of mean, r = Pearson correlation, ICC = Intra-class correlation

<sup>a, b, c</sup> Equations with the highest R<sup>2</sup>, derived from females aged 18 – 59 years, ≥ 60 years, and all females, respectively

### 4.2.7 Model development derived from male AS

#### 4.2.7.1 Male aged 18 – 59 years old

The predictive height equations Model MA1-MA2 were derived from AS by the participants aged between 18 and 59 years old (n = 252, Table 4.23), where Model MA2 exhibited better height estimation than Model MA1 which only considered AS (adjusted R<sup>2</sup> = 0.749, SEE = 3.329).

#### 4.2.7.2 Male aged ≥ 60 years old

The male group aged 60 and above (n = 143) was used to develop these AS predictive equations (Model MA3-MA4). Height that was predicted by both AS and age also appeared closer to the actual height than the model with only AS (adjusted R<sup>2</sup> = 0.659, SEE = 3.777) (Table 4.23).

#### 4.2.7.3 All age groups

Furthermore, a total of 395 participants aged ≥ 18 years old were used to develop these AS predictive equations Model MA5-MA6. Model MA6 exhibited better height prediction than Model MA5 with only AS as well as the others predictive models developing from male AS in this study (adjusted R<sup>2</sup> = 0.765, SEE = 3.484) (Table 4.23).

**Table 4.23** R<sup>2</sup> and SEE of Equation developing by arm span in males

Model	Equations	Age group (years)	Adjusted R <sup>2</sup>	SEE
MA1	H = 28.093 + 0.805 AS	18 - 59	0.725	3.487
MA2	H = 37.605 + 0.767 AS – 0.085Age		0.749	3.329
MA3	H = 50.372 + 0.642 AS	≥ 60	0.650	3.828
MA4	H = 56.044 + 0.633 AS – 0.063Age		0.659	3.777
MA5	H = 22.301 + 0.832 AS	18 - 115	0.712	3.857
MA6	H = 39.563+ 0.756 Arm AS –0.086Age		0.765	3.484

MA= male arm span model, H=height, AS=arm span, SEE=standard error of estimate

#### 4.2.7.4 Validating male arm span predictive height model

There were no significant differences in age, height, and AS between equation developing group and validating group as shown in Table 4.24.

**Table 4.24** Comparison physical characteristics of the male groups (aged  $\geq 60$  years) between the equation developing group and the validating group<sup>a</sup>

Variables	Eq. developing group (n=147)	Validating group (n=38)	<i>P</i> <sup>b</sup>
Age (years)	69.9(8.4)	68.3(7.6)	0.310
Height (cm)	162.4(6.5)	162.7(6.7)	0.811
Arm span (cm)	170.5(7.1)	170.1(9.4)	0.828

<sup>a</sup>Data presented as mean (SD)

<sup>b</sup>*P* value by independent t-test,

The Table 4.25 showed the mean difference between actual height and estimated heights of the best three equations from this study and from a previously reported equation. Our equations showed lower mean difference than the previously reported (0.354 to 3.230 vs. 4.114 cm). This result suggests higher power in estimating height of our models. Our models also had ICC ranged between 0.778 and 0.875, demonstrating a higher degree of agreement than the previous model. Unexpectedly, Model MA4, which was derived specifically from older male adults, showed the lowest ICC out of the three equations that aim to estimate height in older adults that could be resulted from small validated male sample.

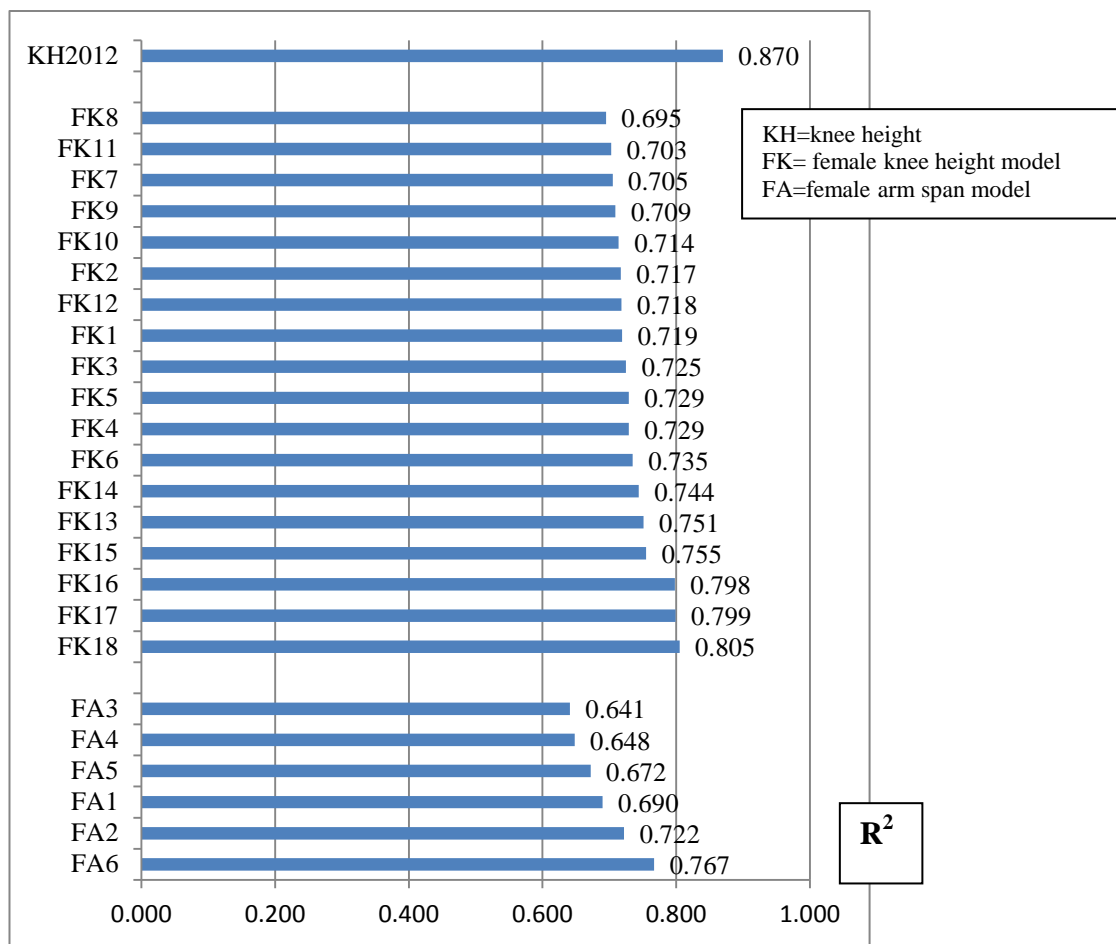
**Table 4.25** Mean SD and 95% CI of mean of actual height and estimated heights (cm) (n=38)

	Mean±SD	95% CI of mean		MD±SE	95% CI of MD		r	ICC	95% CI of ICC	
		Lower	upper		Lower	upper			Lower	upper
Actual height	162.7±6.7	160.5	164.9							
Estimated height										
Present study										
Model MA2 <sup>a</sup>	162.3±7.4	159.9	164.7	0.372±0.580	-0.803	1.547	0.877	0.874	0.771	0.932
Model MA4 <sup>b</sup>	159.4±6.1	157.4	161.5	3.230±0.520	2.176	4.285	0.878	0.778	0.194	0.919
Model MA6 <sup>c</sup>	162.3±7.3	159.9	164.7	0.354±0.573	-0.808	1.517	0.877	0.875	0.773	0.933
Thai previous study										
Jitapunkul & Benchajareonwong,1998	166.8±6.9	164.6	169.0	-4.144±0.518	-5.195	-3.094	0.888	0.748	0.004	0.918

MD = Mean difference, SE = Standard error of mean, r = Pearson correlation, ICC = Intra-class correlation

<sup>a, b, c</sup> Equations with the highest R<sup>2</sup>, derived from females aged 18 – 59 years, ≥ 60 years, and all females, respectively

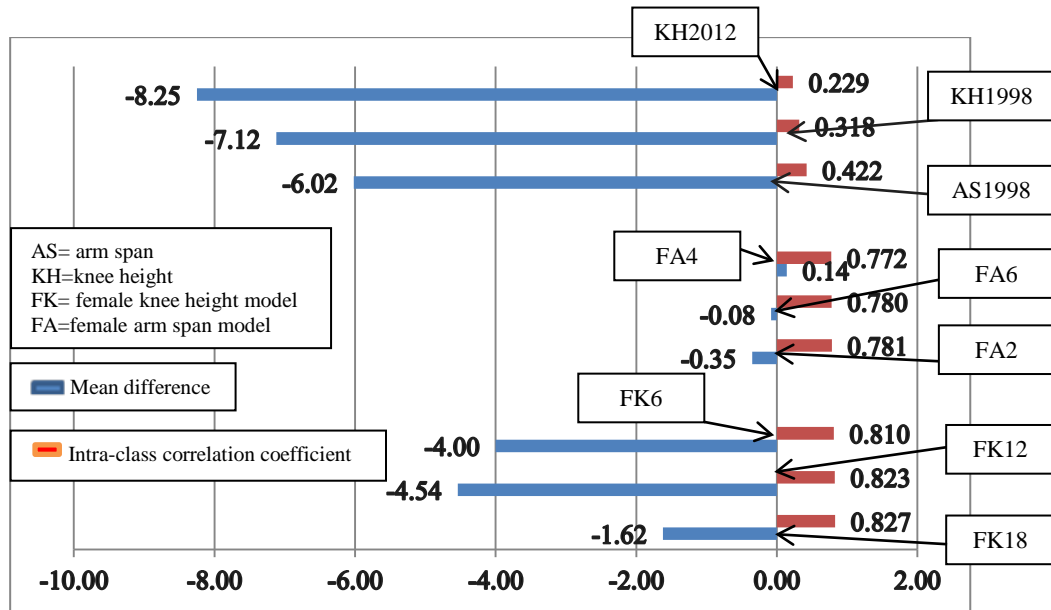
Summary of the predictive power of the developed equations, derived from KH and AS for predicting height in women, are shown in Figure 4.9. Based on R<sup>2</sup>, the Model FK18 illustrated the best predictive power to estimate height of all KH equations, and also of all 24 developed equations for females in this study. The model, however, was slightly weaker than the previously reported equation. The Model FA6 showed the highest predictive power of all AS equations to predict height.



**Fig.4.9** The predictive power (R<sup>2</sup>) of predictive height equations for female

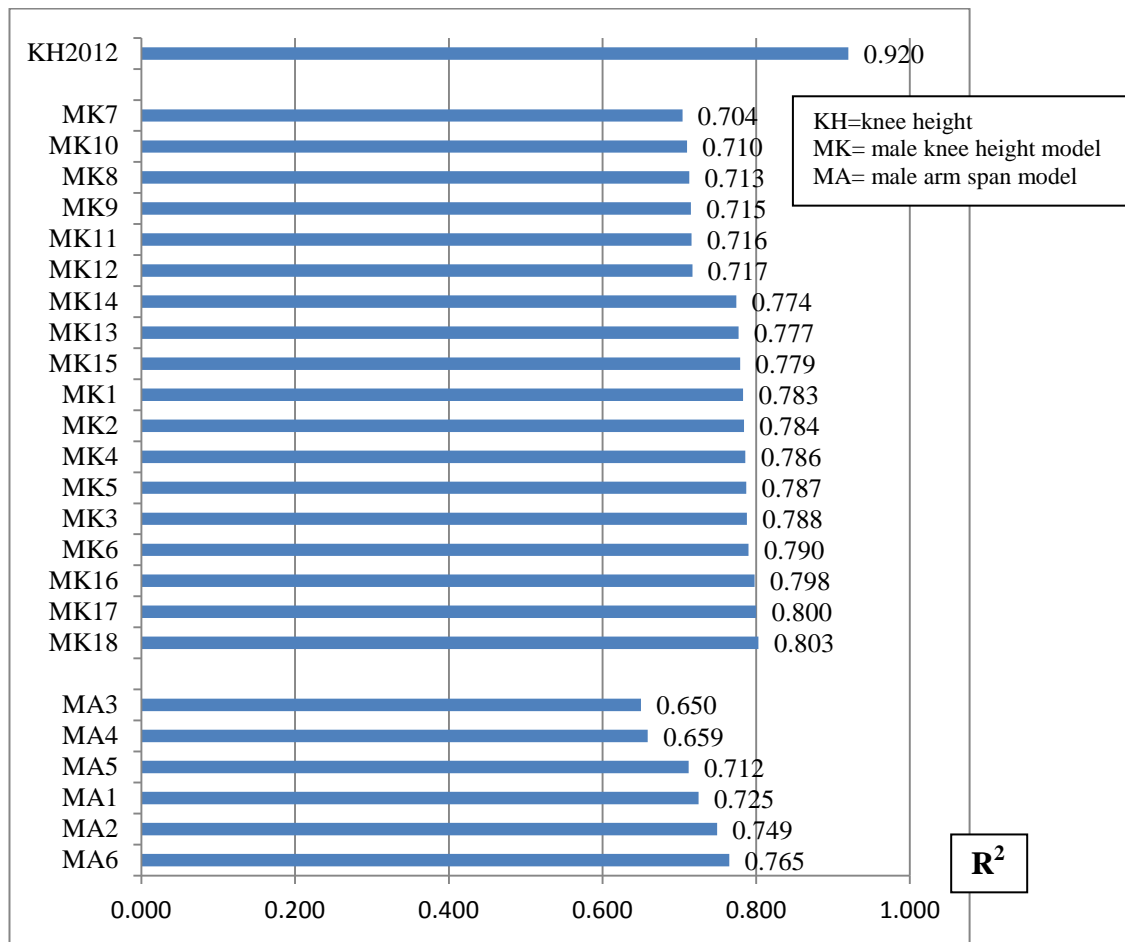
When applying the three equations with highest predictive power formulated from each age group, Model FA6 showed the lowest mean difference, and Model FK18 showed the highest ICC, when compared to others equations. All the equations from this study showed lower mean difference compared to the three previously reported equations in Thailand. In conclusion, Model FK18 and FA6 have

high predictive power and precision when used to predict height of elderly females (Fig.4.10).



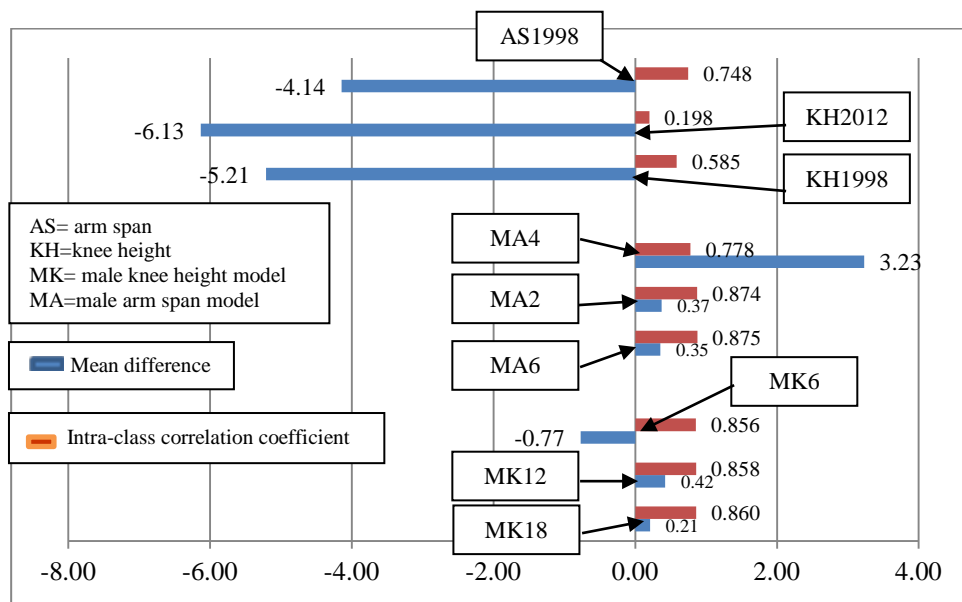
**Fig.4.10** Mean difference (cm) between actual height and estimated height of elderly females, and intra- class correlation coefficient of predictive height equations for female

Summary of the predictive power of the developed equations, derived from KH and AS for predicting height in men, as shown in Figure 4.11. Based on  $R^2$ , the Model MK18 illustrated the best predictive power to estimate height of all KH equations, and also of all 24 developed equations for males in this study. The model, however, was also slightly weaker than the previously reported equation. The Model MA6 showed the highest predictive power of all AS equations to predict height.



**Fig. 4.11** The predictive power ( $R^2$ ) of predictive height equations for male

When applying the three equations with highest predictive power formulated from each age group, Model MK18 showed the lowest mean difference, and Model MA6 showed the highest ICC, when compared to others equations. All the equations from this study showed lower mean difference compared to the three previously reported equations in Thailand. In conclusion, Model MK18 and MA6 have high predictive power and precision when used to predict height of elderly males (Fig. 4.12).



**Fig. 4.12** Mean difference between actual height and estimated height, and intra- class correlation coefficient of predictive height equations for male

## **CHAPTER V**

### **DISCUSSION**

A cross-sectional study was conducted between September 2013 and August 2014. The participants aged between 18 and 115 years old, living in Bangkok and nearby provinces were enrolled in to the study. At the present time, this study can be considered a good representation for the whole country, as the people from different regions of country move into Bangkok and its vicinity. The two major objectives of the study were illustrating descriptive nutritional status by anthropometric data, and developing and validating the predictive height equations.

#### **5.1 The nutritional status and anthropometric characteristics**

##### **5.1.1 Height and surrogate height measurement**

The elderly participants included in the 1<sup>st</sup> objective were investigated for their nutritional status by anthropometric measurements. There were higher proportion of females, and age of the participants ranged from 60 – 115 years (female = 484 and male = 254). The average height of both male and female elderly participants in our study were similar to the Thailand's National Food and Nutrition Survey (17), but were different from the results from Chittawatanarat et al. (14). In comparison with the data from Chittawatanarat et al (14), we found that in average our elderly male subjects were 0.4 cm taller, and our elderly female subjects were 1.5 cm shorter. Unlike the study by Chittawatanarat et al. where they recruited participants to represent the Northern region of Thailand, our participants in our study were recruited from Bangkok and its vicinity in specific settings and conditions to represent the whole country.

The body shape changes naturally as aging occurs. Our male and female subjects showed lower height at older age, and is in accordance with the data from

other countries in the literature reviews (17, 58-60, 62-63, 71 -75). The present study showed mean differences in height between the younger elderly (aged 60-69 years) and the oldest group (aged 80 years and above) were 2.8 cm in males and 4.0 cm in females. This loss of stature in older population can be explained by various factors including vertebral compression, postural slump and abdominal muscle mass relaxation, which can be more prominent in women as a result of higher rate of osteoporosis (4, 7-8, 58). Since this is a cross-sectional data, the growth rate between the three age groups in the past might be different as diet and living conditions might differ, which were not compared in this study.

KH and AS showed weak and insignificant negative relationship with increasing age in both elderly males and females, suggesting no association between age and KH or AS. When we separated subjects into age groups, we found that elderly aged 80 and above had shorter KH and AS than the other two younger age groups. To our knowledge, there were no other studies supporting this finding. As the length of long bones in the arms and legs are not affected by aging, KH and AS measurement have been utilized as alternative measured of height in the elderly group (4, 7, 9, 13, 17, 93). In general, elderly male had higher average knee height (KH) compared to elderly female, and was supported by other studies (10, 58, 69, 85, 101, 103). Furthermore, AS was longer than height in both males and females and our results were consistent with other studies (10, 71, 102).

## **5.1.2 Nutritional status by consider different anthropometric data**

### **5.1.2.1 Underweight**

In our study, gender comparison showed lower BMI in elderly male when compared to elderly females. Reduction in muscle mass appearing at a lower BMI in older males is an important determinant of impaired physical function and metabolic rate, which can lead to the clinical issues. As age increases, body weight reduction is caused by a reduction in body water content and muscle cell mass, which is more pronounced in men and may be due to increase sedentary activities (12). Unlike men, woman can accumulate more subcutaneous fat. Menopause is an aging phenomenon that influences specifically women's health and is often accompanied by an increase in weight and adiposity (12). Higher BMI in women can

also be explained with lower height (58). According to previous reports in Thailand in 2009 and 2011, the BMI of old women were greater than old men (14, 18). Although the data from our current study is comparable with these data, it is inconsistent with the data from some other countries. In India (53), Bangladesh (54), Japan (76), Italy (64), as well as Portugal (104), the BMI of male elderly was greater than female, but the data from Korea (77), Brazil (56), England (61), and USA (60) were reported as opposite.

BMI is associated significantly with age, where increasing age significantly reduces body weight and BMI in all elderly subjects. This finding is in line with other countries (58, 60, 74, 83). Because BMI measurement solely relies on accurate measurements of height and weight of the person, kyphosis, a common condition found in the elderly, may interfere with height measurement among this group, in turn results in an inaccurate calculation of BMI.

As for the prevalence of underweight, our results are in accordance with the past reports in Thailand (13, 17 -18), but contradicted with some Western countries (59, 61). As with the Thai's National Survey (18), we found that the age group with highest prevalence of underweight is 70 – 79 years in females, and 80 and above in males.

#### **5.1.2.2 Obesity**

Obesity is considered as when BMI is above the healthy range. The International cut off point for obesity is  $BMI \geq 30 \text{ kg/m}^2$  and for the Asian BMI classification is  $BMI \geq 25 \text{ kg/m}^2$ . There were higher prevalence of obesity in both males and females in this study, compared to the National survey in 2006 (17), and the recent study in year 2012 (14). There has been a debate on BMI cut-off points for the Asian populations due to the high prevalence of type 2 DM and cardiovascular risk factors among Asians with BMI under  $25 \text{ kg/m}^2$ , as well as the relationship between BMI and fat in Asian populations (23). Although the elderly are being diagnosed as obese, several studies in Western or Asian countries as well as in Thailand showed that overweight or mild obesity in elderly is not a high mortality risk. The Tromso and HUNT studies in Norway, showed individuals in the 25 - 29.9 BMI categories had lowest all-cause mortality (106). Hong et al., studied the Korean elderly in community

and concluded that mortality started increasing from BMI of 27.5 kg/m<sup>2</sup> or above (107). A study in Thailand (108), also concluded the risk of all-cause mortality increased when BMI <18.5 kg/m<sup>2</sup> and decreased in the middle BMI group and increased again in the obesity group especially for BMI ≥ 35 kg/m<sup>2</sup>. Since the body composition of the elderly population can be different from that of healthy younger adults, BMI alone may not be appropriate for assessing nutritional status (109 - 110).

The average BMI of elderly females were significantly greater than elderly males. This result is in accordant with the previously reported in Thailand (14, 18), Korea (77) and Latin America countries (11, 56 – 59). The prevalence of BMI ≥ 25 kg/m<sup>2</sup> of elderly female were higher than elderly male in our study. Thus, elderly women with higher body weight and higher prevalence of overweight or obesity could be contributed to more fat deposits rather than skeletal weight as women had more energy stores than the men, a shorter stature or a combination of both (12, 105).

We found significantly negatively correlation between age and BMI in both elderly males and females, and all subjects aged 60 – 69 years were significantly more overweight or obese than the other age groups. Decreased physical activity and decreased energy expenditure associated with aging predispose to fat accumulation and fat redistribution, but also muscle loss, so BMI may not only necessarily depend on adiposity (12, 105).

### **5.1.2.3 Abdominal or central obesity**

While BMI measurement relates to obesity, AC, WC, AHpR, WHpR, both AHtR and WHtR correlate with central or abdominal obesity. In contrast to other studies, the AC and WC of elderly females were greater than males in our study (141 - 142.5 cm for female, and 123.5 - 125.8 for male), with greater proportion of females having AC or WC > 100 cm than men (11.3 - 13.6% for female, 8.3 - 10.4% for male). Declination of AC and WC with age was only observed in men. According to International Diabetes Federation (IDF), which set WC cut off point criteria for specific South Asians, Chinese and Japanese were > 90 cm for male and > 80 cm for female. The prevalence rate of abnormal abdominal or waist circumference in elderly females was significantly greater than elderly males in this

study. This result corresponds to Thai National Survey, which reported the prevalence of WC over the cut-off point among the female group is 28.6 - 53.3% and 13.4 - 23.3% for their male (18). dos Santos and Sichieri in 2005 found more than 50% of women in all age groups had WC out of the normal range in Brazilian elderly population (90). This result implied to higher health risk in female elderly.

As for the correlation between age and AC or WC, we found significant negative relationship in elderly male. This result corresponds with studies in Mexican, Brazilian, Cuba and Japanese elderly population (59, 73, 75, 90). When comparing the proportions of abnormal AC or WC, we also found female aged 70-79 years old had the highest prevalence of abnormal AC and WC, but were not significantly different between age groups. There were no significant differences in AC or WC between age groups of males.

The study found that AHpR and WHpR in males greater than in females, consistent with other studies. In this study, the AHpR and WHpR cut off point of  $\geq 0.90$  for males and  $\geq 0.85$  for females was used. There were similar high prevalence ( $>70\%$ ) of abnormal fat distribution in both males and females. The average AHtR and WHtR of all elderly females were significantly greater than males. Almost 50% of elderly female had central obesity, while almost 20% of elderly male were centrally obese, when defined by AHtR and WHtR  $\geq 0.60$ . Abnormality found in elderly study group result from deteriorate health. Ageing process is contributing factor of obesity in the elderly (4 - 6). From late middle age until the 80s or over, there is a decline in the volume of subcutaneous fat, and a redistribution of fat from subcutaneous to visceral adipose tissue. This age-associated decline in the size of adipose tissue is accompanied by the accumulation of fat outside adipose tissue (in muscle, liver and bone marrow), and loss of lean body mass (23). The prevalence of obesity has been increasing in elderly. This trend will continue to become a major problem in this population.

Based on AHpR and WHpR, we found significant positive correlation between them and age, in elderly female indicates the oldest group could be more abnormality in AHpR and WHpR. Gynoid obesity is typical in female, described as when an individual accumulates lower trunk fat, while android obesity means an individual with upper trunk or central fatness, a typical condition in male, to

explain the principal of waist to hip circumference ratio for fat distribution (7). Elderly female subjects in this study was found AHP<sub>R</sub> and WHp<sub>R</sub> greater than male, that may resulted from mixed type gynoid and android obesity.

#### **5.1.2.4 Total body fat and visceral fat level**

Obesity, defined as an excessive amount of total body fat, is identified as body fat is in excess of 30% for women and 20% for men (37). Bioelectrical impedance (BIA) is a method that determines body impedance, which based on the nature of the conduction of an applied electrical current in an organism, thus allows the determination of body fat (38). The subjects are examined by CT scan and a visceral fat area  $\geq 100 \text{ cm}^2$  is diagnostic for obesity disease (111). Bosy-Westphal et al. changed visceral fat area to visceral fat level by dividing by 10, which equates to 10 (112), a cut-off point used in this study.

In our study, elderly females group showed %TF significantly higher than males, while visceral fat area of older males were significantly greater than females. The prevalence of abnormal TF in elderly female was significantly higher than elderly males. Most of studies also found female body fat percentage higher than male, with the exception of a study by Suiah et al., who found that male aged 80 – 89 had higher body fat than females (53, 72, 83, 94-98).

In the contrary, abnormal visceral fat level prevalence rate was found higher in males (55.2%) than in females (45.9%). This result imply that women had a higher percentage of body fat than men, while visceral fat tended be to higher and accumulated more in the elderly male than the elderly female.

The fat distribution in the body changes as a person ages, where there is an increase in total body fat and reduce in visceral fat. This is more apparent in females than in males, where body fat becomes accumulated in the skeletal muscle and liver (4, 7, 26). The increase in fat tissue that is generally thought to be a hallmark of aging was attenuated in the oldest women (105). Generally, women also accumulate more subcutaneous fat than men and menopause is an aging process that is further accompanied by an increase in adiposity (12).

Only in elderly male showed significant correlated between age and %TF, and there was significantly negatively correlated between age and

visceral fat level only in female elderly. There were no significant differences in %TF and visceral fat level between age groups for both males and females. The decreased energy expenditure due to decrease physical activity with increasing age in elderly population consequence to fat accumulation and fat distribution, those are explanations in this situation (12, 105). Older male decrease their activity by 20%, while women decrease activity levels by 13% compared to younger population (4). An increase of chronic disease common condition in elderly leads to disability results in motor function and energy expenditure reduction. A decrease of fat free mass (mainly muscle) and increase in adipose tissue in the process of aging together with central and visceral fats shifts in the regional distribution of adipose tissue store (4, 6, 8).

## **5.2 Predictive height equation developing and validating**

Height is one of the anthropometric variables that best reflects skeleton size and has a good association with bone and muscular mass. Although height alone is not proper for monitoring nutritional conditions, its measurement is a crucial factor to predict essential nutritional status, which includes determining BMI, basal metabolic rate and body composition. Standing height is the gold standard of height measurement, but it is impossible to be measured in individuals who are physically disabled or cannot stand. Especially elderly, height measurement in this group may be difficult because of the inability or the unwillingness of the elderly to stand straight as a result of vertebral compression, postural slump and muscle tone loss. Therefore, there is need for a simple and reliable method of height measurement to be developed for older population. As the length of long bones in the arms and legs are not affected by aging, KH and arm span (AS) measurement have been utilized as alternative measures of height in the elderly group.

Several published studies have explored KH and AS as alternate methods for estimating height (9, 11, 13 - 14, 51, 67, 71, 85-86, 88-89). Since 1998, Chumlea et al. have developed models to predict stature with KH and age as predictor variables, specific for each gender and racial/ethnic groups (9). Lera et al. later developed predictive equations based on KH and age to estimate height in people from 60 years and older in Latin America (Mexico, Brazil, Chile) (11). Zhang et al. developed

stature predictive equations using AS and KH with age in an elderly Chinese in Australia (85). Hwang et al., Shahar and Pooy, and Fatmah developed stature predictive equation for Asian populations, using AS and KH in an elderly population in Korea, Malaysia, and Indonesia, respectively (51, 71, 88). There were two studies that formulate predictive height equations in Thailand. The first study was formulated in 1998 among inpatients aging 15 to 79 years old (13) and another was conducted in 2012 among elderly volunteers in the northern region of the country (14). Construction of a predictive equation requires validation and should be developed by selecting suitable subjects, with considerations of the influences of all factors.

In the present study, new equations were developed after considering possible factors and were successfully validated. A total of 886 participants aged between 18 and 59 years old, and 598 participants aged  $\geq 60$  years living in Bangkok and five nearby provinces were enrolled in to the study. We selected the KH and AS as the surrogate of height measurements for developing predictive height equation, specific for sex and age group. Age, as another variable, was added into predictive height equation in both KH and AS equations.

Mean actual height found was significantly and positively correlation with the KH in which the strength of the correlation was remarkably high. This finding is in line with the studies performed in Indonesian elderly (15) as well as in Thailand (14), and Portugal (101). In addition, AS was found to be strongly associated with height across all the age groups. Similarly, strong associations between height and AS have been found by studies from various countries. High correlation ( $r=0.72-0.89$ ) was observed between AS and height in India (102) and in Malaysia ( $r= 0.72 - 0.78$ , (58). A study conducted among elderly residents in Indonesia also showed AS significantly associated with height (15).

Almost all previous studies have measured only left KH (11, 64, 67, 69). Chumlea et al. (9) was the first study to develop equations to estimate height using the right knee, and the right side of the body was recommended in anthropometric measurement (10). Berger et al. further reported that right and left KH were practically identical (100). Therefore, this study assessed both the left and right KH, and found no any statistical difference.

Aging was shown to be associated with height reduction, supported by the significant negative correlations between age and actual height, KH, and AS. With regards to age increments in elderly population, height, KH, and AS decreased in both male and female subjects in present study but the relationship was weak, and not significant between KH or AS with increasing age. For male and female adult groups (aged 18 – 59 years), KH and AS showed significantly negative correlation with age. These negative correlations found were in the same direction with other studies (13, 15, 51, 69, 71 85).

Therefore, it can be concluded that the relationship between age and actual height should be considered when developing predictive height models, and that age should be used as a variable estimate height in the equation, and should exhibit higher predicting power.

### **5.2.1 Predictive height equation developing and validating in female**

A total of 970 participants included in developing predictive model aged between 18 and 105 years old (aged 18 -59 years old =631, aged  $\geq 60$  years old =339). The measured height showed significant strong positive correlation with left, right, average KH, and AS in all female participants.

Comparing between equations developed from left and right, averages KH, and AS, the equation developed from average KH was the most strongly powered. Without age factor, the equations that use only KH or AS appeared to have lower  $R^2$  power. When age was included in the multiple linear regression models, most of all, average KH equation derived from female aged 18-103 years (n = 838) exhibited the best height prediction (adjusted  $R^2 = 0.805$  and  $SEE = 2.800$ );

$$“H = 44.116 + 2.337 \text{ KH (Av)} - 0.071 \text{ Age}”$$

that derived from female aged 18 -103 years (n=838). The equation derived from AS of female aged 18 -103 years showed the best predictive power (adjusted  $R^2 = 0.767$  and  $SEE = 2.947$ );

$$“H = 53.951 + 0.660 \text{ AS} - 0.091 \text{ Age}”$$

In present study, it was reasonable to include age as a parameter as age is significantly related to height and increased  $R^2$ .

There were no significant differences in height, KH, AS as well as age between the developing equation group and validating group. The two previously reported predictive height equations in Thailand (13-14), and the three best new equations based on KH were applied, all showed a general overestimation of the height. The previously reported equations produced an average excess of 7.12-8.25 cm, whereas the all new equation produced an average excess of 1.62 – 4.54 cm. This implies that the all new equations appeared more accurate than two Thai previous equations.

Considering the AS equation, validation of the previously reported predictive height equations in Thailand (13), and the three best new equations based were applied, also showed a general overestimation of the height. The previous equations produced an average excess of 6.79 cm, whereas the all new equation produced an average excess of 0.58 – 1.08 cm. This also implies that the all new equations using AS appeared more accurate than the previous equations in Thailand.

According to absolute agreement (ICC value), all new models developed in this study (both KH and AS) showed higher ICC than the Thai previously reported models (13 -14). This implies that all the new equations appeared more reliable than two Thai previous equations.

### **5.2.2 Predictive height equation developing and validating in male**

A total of 433 male participants included in developing predictive model aged between 18 and 113 years old (aged 18-59 years old = 252, aged  $\geq$  60 years old = 181). The measured height showed significant strong positive correlation with left, right, average KH, and AS in all male participants. Comparing between equations developed from left and right, averages KH, and AS, the equation developed from average KH was the most strongly powered. Without age factor, the equations that use only KH or AS appeared to have lower  $R^2$  power. When age was included in the multiple linear regression models, most of all, average KH equation derived from male aged 18-115 years ( $n = 424$ ) exhibited the best height prediction (adjusted  $R^2 = 0.790$  and  $SEE = 3.042$ );

$$“H = 45.447 + 2.371 \text{ KH (Av)} - 0.059 \text{ Age}”$$

that derived from male aged 18 -115 years (n=424). The equation derived from AS of male aged 18 -115 years showed the best predictive power (adjusted  $R^2 = 0.765$  and  $SEE = 3.484$ );

$$“H = 39.563 + 0.756AS - 0.086Age”$$

In present study, it was reasonable to include age as a parameter as age is significantly related to height and increased  $R^2$ .

There were no significant differences in height, KH, AS as well as age between the developing equation group and validating group. The two previously reported predictive height equations in Thailand (13-14), and the three best new equations based on KH were applied, all showed a general overestimation of the height. The previously reported equations produced an average excess of 5.21-6.13 cm, whereas the all new equation produced an average excess of 0.21 – 0.77 cm. This implies that the all new equations appeared more accurate than two Thai previous equations. Considering the AS equation, validation of the previously reported predictive height equations in Thailand (13), and the three best new equations based were applied, also showed a general overestimation of the height. The previous equations produced an average excess of 4.14 cm, whereas the all new equation produced an average excess of 0.35 – 3.23 cm. This also implies that the all new equations using AS appeared more accurate than the previous equations in Thailand.

According to absolute agreement (ICC value), all new models developed in this study (both KH and AS) showed higher ICC than the Thai previously reported models (13 -14). This implies that all the new equations appeared more reliable than two Thai previous equations.

### **5.3 Strengths of the study**

The result of this study provided:

- 1) Information of the nutritional status and risk factors for chronic disease among the elderly in the community.
- 2) Elderly nutritional problems or risk factors for chronic diseases have been kept and forwarded to the relevant authorities to carry out further care and interventions.

3) Height prediction equations developed in this study is appropriate for Thai populations and can be applied to individual who are difficult in standing height measurement.

#### **5.4 Limitations of the study**

Although our results may be considered reliable, this study has some limitations to be taken into account:

1) Due to the cross-sectional nature of this study, it did not allow evaluation of temporal changes for anthropometric characteristics.

2) Since not all anthropometric measurements could be obtained from all elderlies due to the presence of disability, the data we obtained for certain measurements might not be representative of the whole elderly population.

3) Only subjects who were apparently healthy by primary health assessment were included in the equation developing and validation groups.

4) The number of subjects used for validation of KH and AS model equation were small (less than 100 subjects for all equations), which might not be statistically appropriate for application to the general population. External validation should be performed in more participants in future studies.

If the limitations in this study could be overcome, in clinical and field settings, this equation can be applied to obtain an accurate height estimate for those whose height cannot be measured.

## **CHAPTER VI**

### **CONCLUSION**

This study aims to deliver two important aspects. Firstly, the present study provides information that can be used for comparison, evaluation, and surveillance of the nutritional status in the elderly population, whether in the clinical practice or in epidemiologic studies. Except abdominal and waist to hip ratio, there were no difference in other anthropometric measurements between males and females. Many nutritional studies and including our study revealed that age had negative impact on many anthropometric parameters. Height, knee height, body weight, AC, WC, and AHpR is negatively associated with age in female elderly while only body weight and HC is associated with age in male elderly. Many anthropometric measurements, such as AC, WC, and the prevalence of abnormality were high in both males and females, but we also found that some indexes, such as AC, WC, BMI, AHtR or WHtR, were markedly higher in female subjects than those in male subjects, indicating a higher risk of developing chronic diseases. Furthermore, we also found that only a small proportion of elderly were found underweight, however, it is still a condition that adversely and severely affects the well-being of the old persons. Therefore, the overweight and obese subjects, it is also important to consider the lifestyle and nutrition of this underweight group.

Secondly, we developed a new predictive equation to calculate height from KH and AS in elderly population. Our equations illustrated estimated height that is closer to actual height with better predictive power than the previously reported equations. This study found that the equation that consider KH or AS in combination with age were the best predictor to estimate total height. To further validate the model equation, further study will be required to recruit more subjects from different geographical locations of Thailand

We developed a new predictive equation for height, by collecting more samples than previous studies. The present model showed a higher degree of agreement than existing models, especially when using age as a variable.

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## **APPENDIX**

MUTM 2013-048-01



**CERTIFICATE OF ETHICAL APPROVAL**  
Ethics Committee of the Faculty of Tropical Medicine, Mahidol University  
420/6 Ratchawithi Rd., Ratchatheewee, Bangkok 10400, Thailand

This Certificate of Ethical Approval (MUTM 2013-048-01) applies to the

**Project entitled:** Nutritional assessment by anthropometry in Thai elderly and height estimated equations development

**EC Submission No.:** TMEC 13-039

with the following relevant documents:

- 1) Research proposal (FTM ECF-019-02); Thai version date 22 July 2013
- 2) Participant Information Sheet (FTM ECF-020-00); Thai version (date not affixed)
- 3) Informed Consent Form; Thai version (date not affixed)
- 4) Case Record Form for participants aged 18-59 years; Thai version (date not affixed)
- 5) Case Record Form for participants aged 60 years and over; Thai version (date not affixed)

**Principal Investigator:** Mr. Nopphanath Chumpathat

**Advisor:** Assoc. Prof. Dr. Karunee Kwanbunjan

**Affiliation:** Department of Tropical Nutrition and Food Science,  
Faculty of Tropical Medicine, Mahidol University

**This project has been approved for the period**  
**From 27 August 2013 to 26 August 2014**

The Ethics Committee of Faculty of Tropical Medicine certify that we are in compliance with Declaration of Helsinki, ICH Guidelines for Good Clinical Practice and other International Guidelines for Human Research Protection.

Signature .....  
(Prof. Dr. Srisin Khusmith)

Chairperson (Panel 2)  
Ethics Committee of the  
Faculty of Tropical Medicine

Date ..2.8..AUG..2013..

Signature .....  
(Mrs. Pornpimon Adams)

Member and Secretary  
Ethics Committee of the  
Faculty of Tropical Medicine

Date ..2.8..AUG..2013..

### Case Record Form

ID .....
----------

#### I. Demographic data

1. Sex	<input type="checkbox"/> 1) Male <input type="checkbox"/> 2) Female
2. Year of birth	.....
3. Education level	<input type="checkbox"/> 1) Illiterate <input type="checkbox"/> 2) Primary school <input type="checkbox"/> 3) Secondary school <input type="checkbox"/> 4) Higher secondary school
4. Province	<input type="checkbox"/> 1) Bangkok, how long? (Years) ..... <input type="checkbox"/> 2) Samut Prakan, how long? (Years) ..... <input type="checkbox"/> 3) Nonthaburi, how long? (Years) ..... <input type="checkbox"/> 4) Pathum Thani, how long? (Years) ..... <input type="checkbox"/> 5) Nakorn Pathom, how long? (Years) ..... <input type="checkbox"/> 6) Samut Sakhorn, how long? (Years) .....
4.1) Where are currently you living?	
4.2) Have you been living in any other provinces previously?	<input type="checkbox"/> 1) Yes, specify province..... How long? (Years)..... <input type="checkbox"/> 2) Not applicable
5. Do you drink alcohol?	<input type="checkbox"/> 1) No <input type="checkbox"/> 2) Sometimes <input type="checkbox"/> 3) Always
6. Do you smoke?	<input type="checkbox"/> 1) No <input type="checkbox"/> 2) Sometimes <input type="checkbox"/> 3) Always
7. Are you currently pregnant, or recently had a child within 6 months? (Women adult only)	<input type="checkbox"/> 1) No <input type="checkbox"/> 2) Yes

**II. Pre-existing Conditions**

1. Diabetes	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
2. Hypertension	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
3. Dyslipidemia	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
4. Carcinoma	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
5. Liver diseases	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
6. Kidney diseases	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
7. Thyroid	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
8. Cerebrovascular accidents	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
9. Heart diseases	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
10. Bone problems or history of bone surgery	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
11. Others	<input type="checkbox"/> 1)Yes	<input type="checkbox"/> 2)No	<input type="checkbox"/> 3) Unknown
	If yes, specify .....		

**III. Anthropometric Data**

	1 <sup>st</sup> time	2 <sup>nd</sup> time	3) Not done
1. Standing height (cm)			
2. Body weight (kg)			
3. Knee height (cm)			
3.1 Right knee			
3.2 Left knee			
4. Arm span (cm)			
5. Abdominal circumference <sup>a</sup> (cm)			
6. Waist circumference <sup>a</sup> (cm)			
7. Hip circumference <sup>a</sup> (cm)			
8. Total body fat <sup>a</sup> (BIA unit)			
9. Visceral fat level <sup>a</sup>			

<sup>a</sup>Subjects aged < 60 years old not done

## **BIOGRAPHY**

<b>NAME</b>	Nopphanath Chumpathat
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