Chapter 1

Introduction

1. General consideration

1.1. Definition

Anthropometry is a combination of ancient Greek language comprised of "anthropo-" which means human and "-metry" which mean measurement. Therefore the literal meaning is measurement of human.

Most of anthropometry involves measurements of the physical dimensions and gross composition of the body. Most of these measurements have been utilized in nutritional status evaluation. The term "nutritional anthropometry" first appeared in the Brozek article (1956) of "Body measurement and human nutrition"[1] and was later defined by Jelliffe (1966) as "measurements of the variations of the physical dimensions and the gross composition of the human body at different age levels and degrees of nutrition".[2]

Subsequent publications suggest specific body measurements for characterizing nutritional status, standardized measurement techniques as well as suitable reference data.[2-3] Currently, anthropometric measurements are widely used in the assessment of nutritional status. These measurement techniques were recommended by the World Health Organization (WHO) in 1995.[4]

The benefits of anthropometric measurements can be divided into two levels, individual and population level. For the individual level, anthropometry is particularly useful especially in chronic imbalances between intake of protein and energy especially in low socioeconomic children in developing countries. In addition, these parameters are also used for clinical variables in developed countries to diagnose both failure to thrive and overweight children. At the population level, anthropometry plays an important role in screening and assessment to indentify malnutrition status as well as in the subsequent conduction of nutritional surveillance. However, most of content in the following chapters focused on the adult application of anthropometric measurement. The usefulness of anthropometric measurement in pediatrics is beyond the primary objective of this thesis.

Applications of anthropometric parameters in adult are useful in two aspects. First, the application of direct measurement raw data is used in the clinical setting such as body weight and height. Second, a combination of direct raw measurements data which is converted into anthropometric indices such as weight for age, sum of triceps and subscapular skinfolds, and waist-hip circumference ratio. These indices are essential for the interpretation of measurements. The most popular combination of indices such as body mass index, ratio of body weight in kilograms and square height in meters, and waist-hip circumference ratio are used in population studies as indicators of obesity and intra-abdominal fat mass respectively.[5]

1.2. Anthropometry and body composition relationships

Anthropometry and body composition are closely related to each other. Anthropometric measurements can be divided into two groups. One group of measurements assesses body size and body dimensions such as body height, length, body span as well as body circumferences. The other group determines body composition. Body composition is subdivided into two major components of body fat and fat free mass, the latter is commonly known as lean body mass. Most of body composition estimations use body skinfold thickness as one of covariate predictive parameters such as using the combination of anthropometric measurement of the triceps skinfold and the mid upper arm circumference to estimate the mid upper arm muscle area. These parameters surrogates for the total body fat content and muscle mass of the body respectively.[5] An alternative approach involves using anthropometric measurements or indices in regression equations to predict body density and to calculate body fat and the fat free mass. These points are discussed in details in chapter 4.

1.3 Advantages and limitations of anthropometric assessments

Anthropometric measurements play an important role in nutritional assessment due to the advantages listed below.[5-6]

1. Simple, safe, noninvasive techniques are involved, which can be used at the bedside of a single patient, and are also applicable to large sample sizes.
2. Inexpensive equipment is required which is portable and durable and can be made or purchased locally
3. Relatively unskilled personnel can perform the measurement procedures.
4. Methods can be precise and accurate, if standardized techniques and trained personnel are used
5. Retrospective information is generated regarding long term nutritional history, which cannot be obtained with equal confidence using other techniques.
6. Mild to moderate undernutrition, as well as severe states of under- or overnutrition, can be identified.
7. Changes in nutritional status over time and from one generation to the next, a phenomenon known as the secular trend, can be evaluated.
8. Screening tests that identify individuals at high risk to under- or overnutrition can be devised.
9. Monitoring changes in both growth and body composition (e.g., hospital patients) and in population groups can be used with these measurements. These records provide sources of measurement error and the effects of confounding factors are minimized.

Although there are many advantages of anthropometric measures but also some inevitable limitations can be summarized as follows:

1. Anthropometric measures are relatively insensitive and cannot detect disturbances in nutritional status over short periods of time.
2. Specific nutrient deficiency cannot be identified by nutritional anthropometry. Therefore, distinguishing disturbances in growth and body composition induced by nutrient deficiencies from those caused by imbalances in protein and energy intake is not possible.

3. Certain non-nutritional factors such as diseases, genetic influences or ethnic differences and diurnal variation can lower the specificity and sensitivity of anthropometric measurements, although such effects generally can be excluded or taken into account by appropriate sampling and experimental design.

Even though some of the limitations noted above, the benefits and advantages of these measurements are indicated in both the individual and population level. Consideration of these limitation and their precisions are the most critical step for the selection of anthropometric assessments parameters or indices for evaluation in clinical applications. Proper selection of anthropometric parameters and their limitations might increase the validity of measurements and the resulting interpretations.

2. Application of anthropometric measurements

In clinical practice, anthropometric parameters are used in many clinical aspects such as nutrition screening and assessment, drug dose adjustment, physiologic testing, mortality prediction and peri-operative prediction. The following topics discuss and summarize the value of anthropometric measurements in each clinical aspect.

2.1 Clinical applications

2.1.1 Nutrition screening and assessment

Nutritional screening and assessment for identifying hospitalized patients who had malnutrition or future risk of protein calorie malnutrition used three aspects of data which were comprised of medical and dietary history, physical examination and laboratory results. Anthropometric measurements are an important part of the physical examination. Body weight, height, triceps skinfold, mid arm muscle and waist circumference are used for these evaluations.

Basic parameters of weight and height provide general information about the patient's nutrition status as well as body fat. The measurement of weight over time is essential for trend alteration and risk stratification. An individual is considered at risk for malnutrition if there is unintentional weight loss of more than 10 percent of usual body weight in the preceding 3 months or if body weight is less than 90 percent of ideal body weight.[7] The more popular anthropometric indices of body weight and height is body mass index (BMI) or the Quetelet's index which could be calculated by body weight in kilogram divide by square height in meters. This index is a quick and simple tool to assess body adiposity in relationship to height and weight independent of body frame size. The classification of BMI by WHO were demonstrated in Table 1.1.[4] However, limitation of BMI include potential overestimation of body fat in athletes or those with increased muscle mass and it may underestimate body fat in older persons or individuals who have lost muscle mass.

Table 1.1 Body mass index classifications

Weight classification	Body mass index (kg/m^2)
Underweight	< 18.5
Normal	18.5 – 24.9
Overweight	25.0 – 29.9
Obesity (Class 1)	30.0 – 34.9
Obesity (Class 2)	35.0 – 39.9
Extreme obesity (Class 3)	> 40

The precise determination of the amount of body fat requires sophisticated and technical methods that are usually inconvenient for use in clinical practice. Simple measurement with anthropometric measurements based on skinfold thickness, height and weight are recommended. These methods will be discussed in detail in Chapter 3.

2.1.2 Drug dose adjustment

Anthropometric measurements play an important role in drug dose adjustment. The most direct parameters of measurement are body weight and height. In addition, their widely used derived parameters for dosing and organ function calculation are body mass index, ideal body weight, adjusted lean body weight or dosing weight in obese patient and body surface area.

In adult, ideal body weight (IBW, Table 1.2) is used for the calculation of an initial dose of certain medications distributed primarily to non-adipose tissues such as penicillins, cephalosporins, digoxin, rocuronium, vecuronium and aminoglycosides. IBW is recommended only in overweight patients.[8-9] In non-obese and underweight patients, the actual body weight is used for dose calculation. However, in a morbid obese patient commonly defined as 200% or more IBW[10], could not use IBW for dose calculation. Dosing weight is suggested for these patients.[8](Table 1.2)

Body surface area is commonly used in pharmacological calculation such as chemotherapy and renal calculation for creatinine clearance. Two methods widely utilized are the Du Bois method and Mosteller or square root method.[11-12] Both formulas are calculated using height and body weight for input parameters.

Patients suffering from acute or chronic renal insufficiency need pharmacological adjustment for appropriate doses especially in renal excretory drugs. The most common bedside equation used in clinical practice is Cockcroft – Gault formula (Table 1.2).[13] This formula uses lean body weight for input parameters but it is not adjusted for body surface area. Therefore, distortion occurred in overweight and obese person who is no linear correlation between lean body mass and body surface area.

Estimated lean body weight could be calculated by the Janmahasatian formula (Table 1.2).[14] This formula used actual body weight and body mass index. This formula is based on gender and is not applicable for individuals with abnormal body water composition such as fluid overload and has not been validated in individuals at extremes of height and those with a high muscular build or in underweight individuals.[14]

Table 1.2 Predicted formula using anthropometric parameter for drug dose adjustment

Predicted value	Formula
Ideal body weight (Devine method)[15]	Male: IBW(kg) = 50kg + 2.3kg for each inch over 5 feet* Female: IBW(kg) = 45.5kg + 2.3kg for each inch over 5 feet* * 0.91 kg for each cm over 152.4 cm
Dosing weight (Morbid obesity)[8]	Dosing weight = IBW + (ABW – IBW) x 0.4
Body surface area (Du Bois method)[12]	BSA = 0.007184 x [Ht(cm)]$^{0.725}$ x [ABW(kg)]$^{0.425}$
Body surface area (Mosteller method)[11]	BSA = sqr[Ht(cm) x ABW(kg)/3600]
Lean body weight (Janmahasatian method) [14]	Male: LBW(kg) = [9270 x ABW(kg)] / [6680 x (216xBMI)] Female: LBW(kg) = [9270 x ABW(kg)] / [8780 x (244xBMI)]
Creatinine clearance (Cockcroft – Gault method)[13]	Male: CCr(mL/min) = [(140-age) x LBW(kg)] / [Cr(mg/dL)x72] Female: CCr(mL/min) =[(140-age) x LBW(kg)x 0.85] / [Cr(mg/dL)x72]

Abbreviation: IBW, Ideal body weight; ABW, Actual body weight; BSA, Body surface area; Ht, Height; LBW, lean body weight; sqr, Square root; BMI, Body mass index(kg/m^2); CCr, Creatinine clearance.

2.1.3 Physiologic testing and estimation

Pulmonary function test is the most common physiologic examination in clinical practice. Anthropometric factors are independent factors besides age, gender and race in pulmonary testing of healthy persons. These include height, weight and body mass index. Taller persons have larger lung volumes, higher maximal flow rates and a greater ability to take up oxygen and carbon monoxide per minute. Body weight is another independent factor. However, this is much less important than the standing height when predicting most pulmonary function values. Therefore, weight is not included in spirometry prediction equations. However, extremes in weight are associated with lower lung volumes.[16] Malnutrition causes reduced diaphragm strength, so that the patient cannot take as deep a breath while truncal obesity restricts the expansion of the chest cage.

In addition, estimated tidal volume in acute respiratory distress syndrome also uses the ideal body weight to set initial tidal volume on a mechanical ventilator. The recommended initial tidal volume is set to 8 mL/kg of IBW and the initial respiratory rate is set to meet the patient's minute ventilation requirements. Over the next one to three hours the tidal volume is reduced to 7 mL/kg of IBW and then 6 mL/kg of IBW.[17-18]

2.1.4 Mortality prediction

BMI is the most popular of anthropometric indices for mortality prediction. It also is an indicator of mortality risk. A large cohort population study in U.S. revealed the lowest risk of death when the BMI was from 23.5 to 24.9 in men and from 22.0 to 23.4 in woman.[19] In addition, the BMI has been used in several international population studies to assess disease risk among adults. Increasing BMI is clearly associated with a high risk of high blood pressure, type 2 diabetes mellitus, other cardiovascular disease risk factors, and increase mortality.[20-22] In addition, increasing of the BMI associated with musculoskeletal disorders, impairments in respiratory and physical functioning and quality of life have been reported.[23]

Of these evidences, BMI is the preferred index to classify body status and to estimate relative risk of mortality and diseases.

However, there are many limitations for using BMI as a single variable. First, the BMI could potentially produce an inaccurate diagnosis of overweight and obesity in some special populations such as athletes or body builders and elderly patients.[24-26] Second, BMI associated mortality in specific situations were controversial.[19,27-28] A large retrospective study in critically ill patients demonstrated that only underweight patients are associated with poor outcomes in contrast with overweight and obese patients.[29] These results had the same direction in a large prospective study of non bariatric surgical patients.[30] This difference might be explained by the fat mass (FM) and fat free mass (FFM) proportions. The decrease of FFM and increase of FM had a negative impact to the overall mortality in an epidemiologic study especially in males.[27-28] Therefore, a combination both of BMI and FM might be clinically prognostic indicators as well as obesity diagnostic criteria.[31]

2.1.5 Peri-operative prediction

Anthropometric measurements have become a part of peri-operative prediction of morbidity and mortality. One of the commonly mentioned formulas is the prognostic nutritional index (PNI) by Buzby et al in 1980.[32] This formula was developed in gastrointestinal surgical patients using four variable to predict composite outcomes of perioperative morbidity and mortality. In addition to laboratory testing of albumin, transferin and delayed cutaneous hypersensitivity, the formula used anthropometric measurement of triceps skin fold as a covariate. The formula is demonstrated below.[32]

PNI = 158 – 16.6(serum albumin;g/dL) – 0.768(triceps skin fold; mm) – 0.2(serum transferring; mg/dL) – 5.8(Delayed cutaneous hypersensitity).

In present data, using anthropometric indices of body mass index to predict of peri-operative morbidity and mortality is not consistent in all weight categories except in underweight patients (BMI less than 18.5 kg/m^2).[30,33-39] Interestingly, a large population study in patients undergoing non-bariatric general surgery found that overweight and moderately obese patient have lower mortality compared with normal weight patient and call this phenomenon an “Obesity paradox”.[30] This finding corresponded to the previous study in major abdominal cancer surgery in which obesity was not a risk factor of postoperative morbidity and mortality.[37] However, there were contrary reports in non cardiac moderate or major surgery, colorectal surgery, pancreatoduodenectomy, thoracic surgery which revealed increasing risk of peri-operative complication and mortality.[35-36,38-39]

2.2 Limitation of measurement in special populations and estimation methods

As previously mentioned, basic anthropometric measurement of height, body weight as well as anthropometric indices of BMI is widely used in clinical practice both in the individual and public health level. However, these parameters are difficult to assess in elderly people, emergency non ambulatory patients as well as in critically ill patients. In elderly people, height is a parameter that have variable on age. It may decrease with aging as a result of thoracic spine kyphosis, compression of the vertebrae, diminished extension of the hips and knees and abdominal muscle mass relaxation. Knee height, an indirect measurement technique for estimating height of elderly people who cannot stand or who have extreme spinal curvature has been proposed. In emergency or intensive care patients, visual estimation is one of the most common methods to guess the patient height. However, this method has an unreliable result. A study of pre-operative supine patients used visual estimation for height by different observers demonstrating marked variation in the ability to assess these characters accurately.[40] A more scientific method was recommended by the prediction of patient stature via the anthropometric measurement model. Although there were many suggested formulas for height prediction with some selected anthropometric measurements such as ulnar length, knee height, hand dimension, demispan and arm span, and an inaccurate prediction may occur due to the relationship between the anthropometric measurement and height depending on ethnic specific differences, gender and age.[4,41-50]

According to height, there are many limitations for obtaining body weight in some clinical practice situations as previously mentioned. A special instrument is required for direct measurement in these patients. Nevertheless, it might be unavailable. Although visual estimation is the most common method of estimating weight, current literature has reported great inaccuracies of this method compared with the actual body weight. In addition, the precision of this method is operator-dependent.[40,51-53] To diminish predictive error, one study that was performed in an emergency department (ED) setting that demonstrated anthropometric measurement with greater accuracy of around 20% within a 10% error threshold than visual estimation by ED providers.[54] Although these more scientific anthropometric measurements to estimate body weight have been proposed but ethnic differences and measurement parameter distinctions might impact predicted validity.[55-58] In addition, some parameters used in equations are hard to assess in general practice especially requiring skin fold thickness.[54,59-60]

In our best knowledge, there is no recommended formula suggestion to predict body weight and height in the Thais. Therefore, the aims of this thesis were to summary previously recommended formulas and the appropriate and precise methods to estimate actual body weight and height using anthropometric parameters from different parts of the body as well as to propose a simple estimation equation with acceptable validity which could be applied conveniently for general medical practice.

3. Scope of the thesis

3.1 Anthropometric and body composition measurement methods

The author discussed this topic in chapter 2 which reviewed methods of recommended adult anthropometric measurement and body composition measurement methods as well as limitations and points of concern in each measurement.

3.2 Height, body weight and body fat prediction by anthropometric measurements

Height and body weight are commonly used in clinical practice. Some difficult clinical situations might have unavailable data. In Chapter 3 would be discussed the recommended formula for different ages, gender and sex as well as a recent study of Thai people using anthropometric measurement for a predicted formula. At the end of chapter 3, the authors summarized body fat prediction using anthropometric measurement performed both in Thai and other ethnicities.

3.3 Variation and error in anthropometric measurement and body composition prediction

Although these anthropometric measurements are simple and non-invasive methods, there are some issue of concern regarding the variation and error during measurement, individual alteration of physical properties, invalid assumption, ethnic difference and age spectrum effects. In Chapter 3 discusses these aspects in detail.

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