DEVELOPMENT OF DEMI-SPAN EQUATIONS FOR PREDICTING HEIGHT IN INSTITUTIONALISED MALAYSIAN ELDERLY

by

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
BMI	Body mass index
BSA	Body surface area
CHI	Creatinine height index
CV	Coefficient of variation
CI	Confident interval
FFM	Fat-free mass
FVC	Forced vital capacity
HSE	Health Survey for England
ICU	Intensive care unit
ISAK	International Society for the Advancement of Kinanthropometry
MNA	Mini Nutritional Assessment
MUST	Malnutrition Universal Screening Tool
MAFF	Ministry of Agriculture, Fisheries and Food
NHANES	National Health and Nutrition Examination Survey
NDNS	National Diet and Nutrition Survey
NLSAA	Nottingham Longitudinal Study of Activity and Ageing
PBW	Predicted body weight
REE	Resting energy expenditure
RSK	Rumah Seri Kenangan
SD	Standard deviation
SE	Standard error
SEE	Standard error of estimate
SHeS	Scottish Health Survey
SSM	Skeletal muscle mass
TOOTH	Tokyo Oldest Old Survey on Total Health
VIF	Variance inflation factor
WHO	World Health Organization

LIST OF TERMINOLOGY

$Height_{measured}$	Measured height
$Height_{new}$	Predicted height from equations developed in present study
$Height_{Suzana\text{-}Ng}$	Predicted height from equations Suzana and Ng (2003)
$Height_{Bassey}$	Predicted height from equations Bassey (1986)
$BMI_{measured}$	BMI calculated from measured height $BMI_{measured} = \frac{\text{weight (in kg)}}{height_{measured}\text{ (in m}^2\text{)}}$
BMI_{new}	BMI calculated from $height_{new}$ $BMI_{new} = \frac{\text{weight (in kg)}}{height_{new}\text{ (in m}^2\text{)}}$
$BMI_{Suzana\text{-}Ng}$	BMI calculated from $height_{Suzana\text{-}Ng}$ $BMI_{Suzana\text{-}Ng} = \frac{\text{weight (in kg)}}{height_{Suzana\text{-}Ng}\text{ (in m}^2\text{)}}$
BMI_{Bassey}	BMI calculated from $height_{Bassey}$ $BMI_{Bassey} = \frac{\text{weight (in kg)}}{height_{Bassey}\text{ (in m}^2\text{)}}$

LIST OF SYMBOLS

R	Multiple correlation coefficient
R^2	Coefficient of multiple determination
r	Correlation coefficient
σ	Standard deviation
α	Significant level
B	Unstandardised regression coefficients
kg	Kilogramme
cm	Centimetre
mm	Millimetre
n	Total number of individuals

PEMBENTUKAN PERSAMAAN DEMI-SPAN UNTUK MENGANGGAR KETINGGIAN WARGA TUA YANG DITEMPATKAN DI INSTITUSI PENJAGAAN WARGA TUA DI MALAYSIA

ABSTRAK

Demi-span merupakan salah satu kaedah alternatif yang digunakan untuk menganggar ketinggian warga tua. Namun begitu, penggunaan kaedah ini masih tidak dapat dikenalpasti ketepatannya dalam kalangan warga tua di Malaysia. Justeru, kajian ini bertujuan untuk (1) menentukan perbezaan antropometri daripada segi jantina, etnik dan umur dalam kalangan warga tua Malaysia; (2) membentuk persamaan demi-span untuk menganggar ketinggian warga tua Malaysia; (3) membandingkan ketepatan persamaan demi-span yang dibentuk daripada orang dewasa; (4) menilai ketepatan indeks jisim tubuh (BMI) yang diperoleh menggunakan ketinggian anggaran daripada persamaan demi-span. Kajian hirisan lintang ini telah melibatkan 331 orang warga tua Malaysia yang terdiri daripada kumpulan etnik Melayu, Cina dan India yang berusia 60 tahun dan ke atas. Subjek kaijian merupakan penghuni di lapan buah rumah orang tua di Semenanjung Malaysia. Berat badan, ketinggian dan demi-span diukur dengan menggunakan prosedur piawai. Data dianalisa dengan menggunakan SPSS, versi 18.0. Keputusan menunjukkan bahawa profil antropometri subjek (berat badan, ketinggian, demi-span dan BMI) berbeza mengikut umur dan jantina ($p<0.001$), tetapi bukan pada etnik ($p>0.05$). Persamaan demi-span kajian ini adalah seperti berikut: untuk lelaki, ketinggian (cm) = 67.51 + (1.29 x demi-span) - (0.12 x umur) + 4.13, dan untuk perempuan, ketinggian (cm) = 67.51 + (1.29 x demi-span) - (0.12 x umur).

Ketinggian anggaran daripada persamaan baru ini mempunyai persetujuan (*agreement*) yang baik dengan ketinggian sebenar dan menghasilkan kiraan BMI yang tepat. Akan tetapi, ketinggian anggaran daripada persamaan demi-span orang dewasa gagal untuk menghasilkan persetujuan (*agreement)* yang baik dan adalah kurang tepat jika digunakan untuk mengira BMI warga tua. Kesimpulannya, persamaan demi-span yang dihasilkan dalam kajian ini dapat menganggar ketinggian and BMI dengan agak tepat. Namun begitu, ujian ketepatan pada sampel warga tua yang lain adalah diperlukan. Kajian ini juga membataskan penggunaan persamaan yang dibentuk daripada golongan dewasa perlu diambil kira mengenai perbezaan antropometri yang wujud berbanding dengan golongan warga tua.

DEVELOPMENT OF DEMI-SPAN EQUATIONS FOR PREDICTING HEIGHT IN INSTITUTIONALISED MALAYSIAN ELDERLY

ABSTRACT

Demi-span measurement can be used as an alternative method to predict height for elderly people. However, there is little data on the accuracy of this method to be used in institutionalised Malaysian elderly. Therefore, the objectives of this study were (1) to determine the anthropometric differences among gender, ethnicity and age groups in institutionalised elderly; (2) to develop a demi-span equation for predicting height in institutionalised elderly; (3) to evaluate the accuracy of published demi-span equations derived from younger adults; and (4) to assess the accuracy of the body mass index (BMI) calculated using the predicted height from published demi-span equations and that from the new equation developed in this study. A cross-sectional study was conducted on institutionalised Malaysian elderly aged 60 and older. Subjects were residents of eight shelter homes in Peninsular Malaysia; 205 men and 126 women (331 totals), from Malays, Chinese and Indians ethnic groups were recruited. Measurements of weight, height and demi-span were obtained using standard procedures. Data were analysed using SPSS, version 18.0. Results revealed that anthropometric measurements of the subjects (weight, height, demi-span and body mass index) differ by age and gender ($p<0.001$), but not ethnicity ($p>0.05$). The demi-span equations obtained were as follows: for men, height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age) + 4.13, and for women, height (cm) = 67.51 + (1.29 x demi-span) – (0.12 x age). Bland-Altman agreement analysis demonstrated good agreement between measured height and predicted height from new equations and was valid for BMI assessment. However, the predicted height from published demi-span equations derived from younger adults failed to yield good agreement with measured height and was less accurate for assessing BMI. In conclusion, the new demi-span equations allow prediction of height and BMI with sufficient accuracy in institutionalised Malaysian elderly. However, further testing on other elderly samples is needed. Also, we recommend caution when using adult-derived equations in elderly people by considering the extent of anthropometric differences that may exist between the adults and elderly.

CHAPTER 1

INTRODUCTION

1.1 Background

Height is an important determinant of several clinical parameters related to patient care, most of which rely on accurate recording of body weight and height. For example, in nutritional assessment, height is needed to calculate the body mass index (Garrow & Webster, 1985), resting energy expenditure (Harris & Benedict, 1919) and creatinine height index (Walser, 1987). Height is also used to determine body surface area for drug dosage adjustment (Sawyer & Ratain, 2001; Felici *et al.,* 2002; Verbraecken *et al.,* 2006) and to calculate renal clearance (Peters *et al.,* 2000). In addition, height is necessary for estimating body composition such as fat-free mass (Kyle *et al.,* 2004) and skeletal muscle mass (Janssen *et al.,* 2000); for predicting lung volumes (Singh *et al.,* 1993; Fulambarker *et al.,* 2004; Smolej Narancić *et al.,* 2009; Golshan *et al.,* 2009) and for ideal body weight calculation (Bollen *et al.,* 2005).

However, height measurement in the elderly may be affected by the physiologic changes in height and body composition that occur with normal ageing. Reduction in height in elderly people has been attributed to postural changes, thinning of the intervertebral discs, shrinkage of the vertebrae and osteoporotic vertebral collapse. Height measurement can be further complicated by kyphoscoliosis, which affects the curvature of the vertebrae (Mitchell & Lipschitz, 1982a; Kuczmarski, 1989). Therefore, measurements of other body segments, such as knee height (Chumlea *et al.,* 1985), arm length (Mitchell & Lipschitz, 1982b), arm span (Kwok & Whitelaw, 1991), demi-span (Bassey, 1986) and ulna length (Elia, 2003) have been proposed as alternative methods of predicting height in elderly people. All these surrogate measures of height are based on long bones because the length of long bones is less affected by ageing (Mitchell & Lipschitz, 1982b).

Among these surrogate measures of height, demi-span, which is defined as the distance between the midpoint of the sternal notch and the finger roots with the arm outstretched laterally, is becoming the preferred alternative measure of height in nutritional studies for the elderly (Hughes *et al.,* 1995; Chan *et al.,* 2010; Nishiwaki *et al.,* 2011; Lorefält *et al.,* 2011). Demi-span has been used in national-level longitudinal studies (Morgan, 1998; Arai *et al.,* 2010; Gray *et al.,* 2010) and is included in nutrition screening tools such as the Mini Nutritional Assessment (MNA) and the Malnutrition Universal Screening Tool ('MUST') to estimate height for BMI calculation when height measurement cannot be obtained (Guigoz *et al.,* 1997; Todorovic *et al.,* 2003). The demi-span measurement has been chosen over other proxy measures of height in the Health Survey for England (HSE) and the Scottish Health Survey (SHeS) because it can be easily obtained without causing discomfort or distress (Bromley *et al.,* 2005; Craig & Mindell, 2007).

The prediction of height from demi-span has been described by several investigators. Bassey (1986) used equations derived from 125 Europeans with an average age of 35 years (men) and 34 years (women). Suzana and Ng (2003) used equations derived from 100 middle-aged Malaysian adults aged between 30 and 49 years. Weinbrenner and associates (2006) used equations derived from 592 elderly Spanish people aged 65 years and older, and Hirani and colleagues (2010) used equations derived from 1421 English people aged 25 to 45 years. Demi-span equations by Bassey (1986), Suzana and Ng (2003) and Hirani *et al.* (2010) were developed from adult data rather than data from the elderly population. However, Weinbrenner *et al.* (2006) developed demi-span equations to predict current height in older people based on data obtained from the elderly population.

1.1.1 Rationale to predict height from demi-span

Although there are several methods for prediction of height, however, in this study, demi-span has been selected for equations development because of its practical and simple measurement. As aforementioned, demi-span is measured from the midpoint of the sterna notch to the finger roots (between middle and ring fingers) with the arm outstretched laterally (Bassey, 1986). The demi-span is accessible and its landmarks are readily identified. There is no adjustment of indoor clothing needed for demi-span measurement, unlike the knee height measurement that need to bare lower leg and ulna length measurement that need to bare forearm, which might caused less acceptability among Muslims due to cultural sensitivity, especially in Malay women where *Aurat* issues can be the reason for measurement rejection. Besides, there is practical advantage of using demi-span as compared to arm-span, because demi-span can be measured by one observer easily, whereas arm-span requires two observers for measurement. Also, demi-span is more readily accepted by elderly because this measurement can be obtained when the person is bedridden or in a wheelchair.

Therefore, to avoid the cultural sensitivity and to consider the practical advantages of measuring method, we choose demi-span for equation development in this study.

1.1.2 Rationale to derive equations from elderly

Currently, the most frequently used demi-span equations to predict height in elderly individuals is extrapolated from those of younger adults, for example the Bassey equations (1986). However, these adult-derived equations may not be applicable in elderly people, if there has been a significant secular increase in body sizes (Kwok *et al.*, 2002). Way back to 16 years ago, findings from National Health and Morbidity Survey II (NHMS II) in year 1996 have reported secular increase in height among younger cohort in Malaysia, where height of younger generation (20 to 49 years old) remarkably greater than older generation (50 to 70 years and above) for all ethnic groups, possibility due to better nutrition that brought on by the socio-economic development in Malaysia during the last four decades (Lim *et al.,* 2000). In other words, the accuracy of elderly height that is predicted using equations derived from adult populations might be questionable due to the anthropometric differences that emerged from the secular increase in body sizes. Alternatively, the predictive equations can be derived from elderly people. The reasons to support the use of elderly people to derived equations in this study is that equations should be specific to target group which refer to the cohort of interest, in this case elderly in Malaysia aged 60 years and above, for better accuracy in height prediction.

1.1.3 Rationale to choose which equations for comparisons

Despite the array of available demi-span equations, there is a need to investigate which of the several equations is the most accurate for determining height among elderly in Malaysia. In this study, both the Bassey (1986) and Suzana and Ng (2003) equations were chosen for comparative purposes. Bassey equations were selected because of its widely used in the clinical setting and in nutritional studies since these equations had been included in Mini Nutritional Assessment (MNA) tools to estimate height in elderly when standing height is impossible to obtain (Guigoz *et al.,* 1997). Suzana and Ng equations were chosen for comparison in this study because these equations were derived locally to predict height in Malaysian elderly and the findings might give impact to local study.

Both the Bassey and Suzana and Ng equations were derived from adult populations. These equations have not been verified for accuracy using validation procedures in a sample of Malaysian elderly, although Suzana and Ng equations had been tested on elderly (*n*=100) using percentage (%) of differences between measured and predicted height, which in statistical point of view, is inadequate to prove its accuracy due to the lack of proper validation procedures to showed the significant differences between the compared height variables. Therefore, the ability of these adult-derived demi-span equations to accurately predict height in Malaysian elderly still remains doubtful and there is a need to verify the extent of accuracy of both the Bassey (1986) and Suzana and Ng (2003) equations to predict height among elderly population in Malaysia.

There are reasons why demi-span equations developed by Hirani *et al.* (2010) and Weinbrenner *et al.* (2006) were not selected for comparative purposes in this study. First, Hirani *et al.* (2010) in their paper already mentioned that their demi-span equations were only suitable to predict height of young adults in England (aged in their 20s to 40s), but not for contemporary elderly individuals. Therefore, direct comparison between Hirani's equations with ours equations is not possible. Second, demi-span equations by Weinbrenner *et al.* (2006) were derived from Spanish elderly aged 65 and above. The lack of homogeneity in age categories between Weinbrenner's study and ours made us difficult to directly compare their equations with ours because our sample were those elderly aged 60 years and above. Although Weinbrenner's equations have been designed for used in elderly, concerns still exist because their equations only applicable specifically to Spanish elderly, but might not to other population, such as Asians who might have different in body proportions and appear to be shorter as compared to Caucasians (Pheasant, 2003).

Therefore, we choose demi-span equations by Bassey (1986) and Suzana and Ng (2003), instead of equations by Hirani *et al.* (2010) and Weinbrenner *et al.* (2006) for comparisons, because we believed their application in Malaysian elderly will be of greater interest and influence, which will eventually give impact to future local study.

1.2 Problem statements

1.2.1 Problem statement 1

Currently, there is no corresponding elderly-derived demi-span equations for predicting height in elderly people in Malaysia. The published demi-span equations by Bassey (1986) and Suzana and Ng (2003) are developed from adult data rather than data from the elderly population. There is not clear whether these adult-derived equations can be used as an alternative method to predict height for elderly people in Malaysia. Meanwhile, these published demi-span equations are gender-specific, but not age-specific. There is little data on the accuracy of these equations and no published data comparing this method in the elderly population in Malaysia.

1.2.2 Problem statement 2

It is not yet clear whether the predicted height from demi-span can be used for body mass index (BMI) calculation. Given that BMI is calculated as weight divided by the square of height, a small change in the height (denominator) will have a substantial effect on the BMI result, independent of any change in the weight (numerator) (Sorkin *et al.,* 1999a; Sorkin *et al.,* 1999b). If BMI is to be calculated from the predicted height, then, there is a need to determine the usefulness of demi-span as an alternative measurement in the assessment of body mass index (BMI) in elderly Malaysians aged 60 and above.

1.3 Objectives

1.3.1 General objective

To develop a new demi-span equation for predicting height in institutionalised Malaysian elderly aged 60 and above.

1.3.2 Specific objective

(a) To determine the anthropometric differences according gender, ethnicity and age groups among institutionalised Malaysian elderly.

(b) To develop a gender-, ethnic- and age-specific demi-span equation for predicting height in institutionalised Malaysian elderly.

(c) To evaluate the accuracy of adult-derived demi-span equations (Bassey's and Suzana-Ng's equations) for predicting height in institutionalised Malaysian elderly.

(d) To assess the accuracy of body mass index (BMI) as calculated by predicted height from published demi-span equations and from the new equation developed in this study.

1.4 Research questions

(a) To what extend the anthropometric measurements in elderly such as weight, height, demi-span and BMI decrease with age and differ between gender and ethnicity?

(b) Are demi-span, age, gender and ethnicity the good predictor towards the height in institutionalised Malaysian elderly?

(c) Are the adult-derived demi-span equations (Bassey's and Suzana-Ng's equations) valid to predict height in institutionalised Malaysian elderly?

(d) Are demi-span equations derived from elderly, as compared to adults, a useful height predictor to accurately determine the BMI in institutionalised Malaysian elderly?

1.5 Hypotheses

(a) Anthropometric characteristics of elderly differ significantly by age, gender and ethnicity.

(b) Demi-span, age, gender and ethnicity are significant predictors of height in elderly people.

(c) The adult-derived demi-span equations (Bassey's and Suzana-Ng's equations) are less accurate to predict height in elderly people.

(d) Body mass index (BMI) as calculated by predicted height from adult-derived demi-span equations (Bassey's and Suzana-Ng's equations) is less accurate as compared to those of calculated from elderly-derived demi-span equations.

1.6 Significance of study

The findings of this study are important to help the health professionals to predict height in elderly persons when a measure of height cannot be obtained, for example, in persons with leg amputations, spinal curvature or those who confined to bed. Furthermore, having an accurate height estimate is important for use in equations related to patient care, since most of the clinical indicators rely on accurate recording of not only body weight but also height, for example, body mass index (BMI), body surface area (BSA), resting energy expenditure (REE), fat-free mass (FFM), skeletal muscle mass (SMM), forced vital capacity (FVC) and predicted body weight (PBW).

The results of this study will be useful to provide evidence to prove that there are no universally applicable equations for height prediction from demi-span as the relationship between them is influenced by the age, gender and ethnicity of an individual from a particular population. If these results could be confirmed, this study will add to the available literature of the accuracy of different height prediction equations and their impact on BMI calculation in the context of geriatric health.

1.7 Definition of terms

Demi-span: The measurement from the finger root between middle and ring fingers to the midpoint of the sternal notch with the left arm horizontally abducted in neutral flexion and the wrist in neutral rotation (Bassey, 1986).

Height: The measurement of someone from head to foot in an upright position (Oxford Dictionary of English, 2006).

Elderly: The elderly in Malaysia are defined as those who are 60 years old and above (Department of Social Welfare Malaysia, 2011).

Regression equation: A mathematical equation that is derived from statistical analysis which is performed by simple or multiple linear regression. The common equation for simple (univariate) linear regression is $y = a + bx \pm \text{SEE}$. For multiple linear regression, it takes the form y = a + $y = a + b_1x_1 + b_2x_2 + \ldots b_nx_n \pm \text{SEE}$, where '$y$' is the dependent variable, 'x_i' is the predictor variables, 'a' is the intercept or constant, 'b_i' is the slope or regression coefficients and 'SEE' is the standard error of estimate (Field, 2009).

Predicted height: The value of height calculated from regression equation used to provide an estimate of an individual's actual height.

CHAPTER 2

LITERATURE REVIEW

2.1 Elderly population in Malaysia

The elderly in Malaysia are defined as those who are 60 years old and above in accordance with the United Nations World Assembly on Ageing held in Vienna in 1982 (United Nations, 1982). In Malaysia, policy makers have officially use this cut-off age in formulating and implementing plans for elderly citizens, such as those demonstrated in National Policy For The Elderly 1995 (Department of Social Welfare Malaysia, 2011).

The percentage of the elderly population in Malaysia has increased over the past five decades: 5.2% in the year 1970, 5.7% in the year 1980, 5.9% in the year 1991, 6.2% in the year 2000 and 8.4% in year 2010 (Department of Statistics Malaysia, 2011). Population ageing in Malaysia is a result of declining fertility and mortality rates, reduction in infectious diseases and improvement in health care system (Pala, 1998). Nowadays, people are living longer due to socio-economic developments and medical technology advancements; meanwhile, declining in fertility rates have been attributed to current trend of families that having fewer children due to reasons such as an increase of working women and limiting offspring to provide a better quality of life for their children (Sharmilla, 2010).

Currently, there are about 2.2 million elderly populations in Malaysia. According to Balasundram (2006), Malaysia is likely to reach an ageing nation status by year 2035, with 14% of its population are elderly aged 60 years and above. Generally, any nation with 10% of its population above the age of 60 years is categorised as an ageing nation (National Council for Senior Citizens Organisation Malaysia, 2007). A medium projection by the United Nations (2009) reported that, the proportion of elderly people in Malaysia will rise to 22% or 8.7 million in year 2050. Although the rate of increase of its ageing population is not as phenomenal as in countries such as China and Singapore (United Nations, 2009), the considerably rapid increase in the proportion of elderly people in recent years has received primary attention from Malaysia's government on issues related to ageing problem (Krishnamoorthy, 2006).

2.2 Prevalence of malnutrition (undernutrition)

Findings from the third National Health and Morbidity Survey (NHMS III) showed that the prevalence of underweight in elderly Malaysians increased with age with almost 26.3% of those in the older age group (80 years and above) being underweight (Suzana *et al.,* 2010). Meanwhile, a study conducted on several local publicly funded shelter homes ('*Rumah Seri Kenangan*') had found a high proportion of institutionalised elderly being underweight with 14.3% of them recording a body mass index (BMI) less than 18.5 kg/m^2 and a further 18.2% recording a BMI between 18.5 and $20kg/m^2$; the authors further summarised that almost one-third (32.5%) of the subjects were at risk of being undernourished, with BMI less than $20kg/m^2$ (Visvanathan *et al.,* 2005). Malnutrition is also very common to occur among hospitalised elderly patients. A recent study reported that 18.0% of the hospitalised elderly patients who admitted to University Malaya Medical Centre were underweight (Sakinah *et al.,* 2010). In addition, another study showed that almost 38.5% of elderly people residing in the rural areas of Malaysia were malnourished with BMI less than 18.5kg/m^2 (Suzana *et al.,* 2002).

2.3 Ageing and malnutrition

Ageing is a growing public health concern in the Malaysia, as indicated by the considerably high prevalence of malnutrition among elderly in Malaysia (see section 2.2). The elderly are, on the whole less healthy than the non-elderly (Mafauzy, 2000). The ageing process involves anatomical, physiological and nutritional changes that are manifested by height and weight loss, an increase in body fat and a decrease in muscle mass and bone mass (Cavanaugh & Blanchard-Fields, 2002). These body composition changes that occur during ageing increased susceptibility to several chronic diseases and consequently, malnutrition is expected to be a major problem in the elderly (Visvanathan, 2003; Hickson, 2006).

2.4 Role of anthropometry in nutritional assessment

Since malnutrition is expected to be a major problem in the elderly (Visvanathan, 2003; Hickson, 2006), to manage nutritional problem, assessment of nutritional status is the first step. Anthropometric measurement is the preferred option used to determine the nutritional status of the elderly, because it is considered to be simple, quick and inexpensive (Mitchell & Chernoff, 2006). The usefulness of anthropometry as predictors of nutritional status in the elderly is confirmed by Kuczmarski and colleagues (2000), who reported that anthropometry (e.g. height, weight, skinfold thinkness and circumferences) is the most reliable and specific indicator to assess malnutrition in elderly, with their conclusion draw from a study involved a total of 5700 elderly (60 years and older) from a nationally representative sample of US civilian examined in the third National Health and Nutrition Examination Survey (NHANES III).

Height and weight are two of the most easily obtained anthropometric measures and often used for screening of malnutrition through the calculation of BMI (Visvanathan *et al.,* 2004; Visvanathan *et al.,* 2005). Therefore, BMI calculation is considered as a simple and quick method for an early identification of elderly persons at nutritional risk, allowing the clinicians to provide a more comprehensive nutritional intervention, as well as to improve the quality health care in elderly patients.

Apart from BMI calculation, height is also an important determinant of several clinical parameters related to patient care, most of which rely on accurate recording of body weight and height. The following sections will provide a brief explanation regarding the importance of height as clinical indicators.

2.5 Importance of height as clinical indicators

Height measurement is important in clinical setting because it is required for the calculation of some clinical indices, such as body mass index (BMI), body surface area (BSA), creatinine height index (CHI), resting energy expenditure (REE), fat-free mass (FFM), skeletal muscle mass (SMM), forced vital capacity (FVC) and predicted body weight (PBW). Eight clinical indicators that required height in calculation are discussed below.

2.5.1 Body mass index

Body mass index (BMI) is calculated from weight and height measurements using the formula as below (Garrow & Webster, 1985):

$$\text{BMI}= \frac{\text{weight (in kilogramme, kg)}}{\text{height (in metre squared, m}^2\text{)}}$$

BMI is a widely accepted gold standard for determining whether an individual is underweight or overweight (Cook *et al.*, 2005). In clinical practice, BMI is commonly used as a screening tool to identify potential weight problem in patients.

2.5.2 Body surface area

Body surface area (BSA) can be calculated from an individual's weight and height. Different formulas can be applied to calculate BSA, but the most commonly used one is that developed by Du Bois and Du Bois (1916):

$$\text{BSA (m}^2\text{)} = 0.007184 \text{ x weight (kg)}^{0.425} \text{ x height (cm)}^{0.725}$$

BSA plays a crucial role in determining the glomerular filtration rate (Peters *et al.,* 2000) and drug dosage (Verbraecken *et al.,* 2006; Felici *et al.,* 2002; Sawyer & Ratain, 2001). Glomerular filtration rate (GFR) provides an excellent measure of the kidneys function. A low or decreasing GFR indicates the presence of chronic kidney disease (Gaspari *et al.,* 1997). In addition, estimation of GFR in clinical practice allows proper dosing of drugs excreted by glomerular filtration to avoid potential drug toxicity (Sawyer & Ratain, 2001). BSA is widely used in medical oncology, particularly to calculate doses of chemotherapeutic agents. It is customary to adjust the drug dose on the basis of the patient's body surface area (BSA) in order to normalize the effects of antineoplastic agents (Felici *et al.,* 2002).

2.5.3 Creatinine height index

The creatinine height index (CHI) compares the actual 24-hour creatinine excretion of a patient with the expected value for a person of the same height, given the equation as followed (Lagua & Claudio, 1996):

$$\text{CHI (\%)} = \frac{\text{Actual 24-hour urinary creatinine excretion (mg)}}{\text{expected 24-hour urinary creatinine excretion (mg)}} \times 100$$

This calculation results in a percentage which can indicate protein depletion, since creatinine is an end product of muscle metabolism (Driver & McAlevy, 1980). The CHI indicates mild or no protein depletion when it is above 80 %; moderate protein depletion is indicated at a CHI of 60 % to 80 %, and severe depletion is indicated by a CHI below 60 % (Alpers *et al.,* 2008). Table 2.1 shows expected 24-hour urinary creatinine excretion by adults of various heights for use in calculation of the creatinine height index.

Table 2.1 Expected 24-hour urinary creatinine excretion by adults of various heights for use in calculation of the creatinine height index.

Height		**Expected creatinine excretion (mg)**	
in	**cm**	**Adult women**	**Adult men**
58	147.3	830	-
59	149.9	851	-
60	152.4	875	-
61	154.9	900	-
62	157.5	925	1288
63	160.0	949	1325
64	162.6	977	1359
65	165.1	1006	1386
66	167.6	1044	1426
67	170.2	1076	1467
68	172.7	1109	1513
69	175.3	1141	1555
70	177.8	1174	1596
71	180.3	1206	1642
72	182.9	1240	1691
73	185.4	-	1739
74	188.0	-	1785
75	190.5	-	1831
76	193.0	-	1891

Adapted from Blackburn, G. L., Bistrian, B. R., Maini, B. S., Schlamm, H. T. & Smith, M. F. (1977). Nutritional and metabolic assessment of the hospitalized patient. *JPEN J Parenter Enteral Nutr,* **1(1),** 11-22; cited in Alpers, D. H., Stenson, W. F., Taylor, B. & Bier, D. M. (2008). Manual of nutritional therapeutics. 5th ed. Philadelphia: Lippincott Williams & Wilkins.

2.5.4 Resting energy expenditure

Height is also needed for calculating energy expenditure, which is important in the medical nutritional therapy. An individual’s resting energy expenditure (REE) can be determined using the equation by Harris and Benedict (1919):

REE (men) = 66 + 13.7 x weight (kg) + 5 x height (cm) – 6.76 x age (years)

REE (women) = 655 + 9.6 x weight (kg) + 1.8 x height (cm) – 4.7 x age (years)

2.5.5 Fat-free mass

Body composition can be assessed by using bioelectrical impedance analysis (BIA). This approach allows the determination of the fat-free mass (FFM) and total body water (TBW) in subjects without significant fluid and electrolyte abnormalities (Kyle *et al.,* 2004). Houtkoope *et al.* (1996) found that the volume of FFM or TBW is directly proportional to height^2/body resistance (Ht^2/R), and hence accurate height measurement is important to avoid erroneous result in bioelectrical impedance analysis. FFM for healthy individuals are calculated according to the formula developed by Deurenberg *et al.* (1991):

$$FFM = (0.34 \text{ x height}^2/R_{50}) + (0.1534 \text{ x height}) + (0.273 \text{ x weight}) - (0.127 \text{ x age}) + (4.56 \text{ x sex}) - 12.44$$

where FFM in kilogramme; height in centimetres; R_{50} is the resistance at 50 kHz in Ohm; weight in kilogram; age in years; sex = 1 for men and 0 for women.

2.5.6 Skeletal muscle mass

Sarcopenia, which is the age-related loss in skeletal muscle (Evans, 1995), can be identified through the calculation of skeletal muscle mass (SMM) and expressed as skeletal muscle mass index (SMI = $\frac{Skeletal\ Muscle\ Mass}{Body\ Mass} \times 100$), as proposed by Janssen *et al.* (2002). The predictive equation for calculating SMM is as follows (Janssen *et al.*, 2000):

$$SMM\ (kg) = [(Ht^2/R \text{ x } 0.401) + (\text{gender x } 3.825) + (\text{age x } -0.071)] + 5.102$$

where Ht is height in centimetres; *R* is BIA resistance in ohms; gender = ‘1’ for men and ‘0’ for women; age is in years.

2.5.7 Forced vital capacity

Normal lung volumes are predicted on the basis of sex, age and height (Smolej Narancić *et al.,* 2009; Golshan *et al.,* 2009; Fulambarker *et al.,* 2004; Singh *et al.,* 1993). The first set of equations for prediction of forced vital capacity (FVC) in Malaysians aged above 20 years had been proposed by Singh *et al.* (1993):

FVC (L), men = (0.0407 x height) - (0.0296 x age) - 2.343

FVC (L), women = (0.031 x height) - (0.022 x age) - 1.64

These height-derived spirometric reference equations help in the interpretation of lung function test and provide a more comprehensive diagnosis in lung diseases.

2.5.8 Predicted body weight

In intensive care unit (ICU), traditional approaches to mechanical ventilation use tidal volumes of 10-15 ml per kilogram of body weight (Marini, 1996). However, patients with acute lung injury or acute respiratory distress syndrome (ARDS) have to make adjustment in tidal volumes based on the predicted body weight (Sevransky *et al.,* 2004). The predicted body weight depends on individual's height for calculation, as showed below:

Predicted body weight (kg), men = 50 + 0.91 x (height in cm - 152.4)

Predicted body weight (kg), women = 45 + 0.91 x (height in cm -152.4)

Adjustment in tidal volumes based on predicted body weight (which is the function of height) is important to ensure the improvement in lung function and a better survival in ICU patients (The Acute Respiratory Distress Syndrome Network, 2000).

2.6 Problems of height measurement in elderly

Obtaining an accurate height measurement for elderly individuals can be difficult due to vertebrae deformity (e.g. kyphosis) as the effect of ageing, as well as the effects of diseases such as osteoporotic vertebral fractures, osteoarthritis, disc degeneration and muscle weakness (Osman *et al.,* 1994; Wasnich, 1996; Goh *et al.,* 1999; Kado *et al.,* 2007). Height measurement also poses a greater problem for elderly with mobility impairments such as limb amputations, fractures and bed-bound. These barriers typically preclude elderly from standing erect, and as a result, height cannot be reliably measured.

Longitudinal studies have been consistent in showing that height loss tends to progress with ageing (Sorkin *et al.,* 1999a; Dey *et al.,* 1999). A 35-year Baltimore Longitudinal Study that involved 2084 subjects aged 17 – 94 years old showed that height loss began at about age of 30 years, with the rate of decline at -0.161cm/year for women and -0.091cm/year for men (Sorkin *et al.,* 1999a). Another 25-year longitudinal study that involved 973 Swedish elderly aged 70 years old showed that the mean height decreased by 4.0cm in men and 4.9cm in women over the 25-year follow-up period (Dey *et al.,* 1999). Recognition of this problem has prompted research into the use of long bones to predict height, since the length of long bones has been reported to be less affected by ageing (Mitchell & Lipschitz, 1982b).

2.7 Alternative measurements for predicting height

Height can be predicted by applying mathematical methods. It is a widely used approach for calculating the height based on the regression coefficients that represent proportional relationship to the bone length. The mathematical method makes use of any segment of skeleton to predict the height of an individual through regression equation.

2.7.1 History of height prediction

Height prediction has become an area of interest in forensic anthropology for decades ago, with the purpose mainly for the identification of an individual from dismembered skeletal remains (Byers, 2002; Komar & Buikstra, 2008). The World War II increased the interest of height prediction from skeletal remains that helps in the identification of unknown individuals. The science of reconstructing height from long bones has been established since the mid-twentieth century, following the studies done by Trotter and Gleser (1952, 1958) who contributed much to the developing of height prediction equations for American Whites and Blacks, as well as for Asian males, using the long bones of the limbs such as humerus, radius, ulna, femur, tibia and fibula, that obtained from skeletons of military personnel killed during World War II and Korean war. A brief introduction to Mildred Trotter and total length for long limb bones is presented in Figure 2.1.

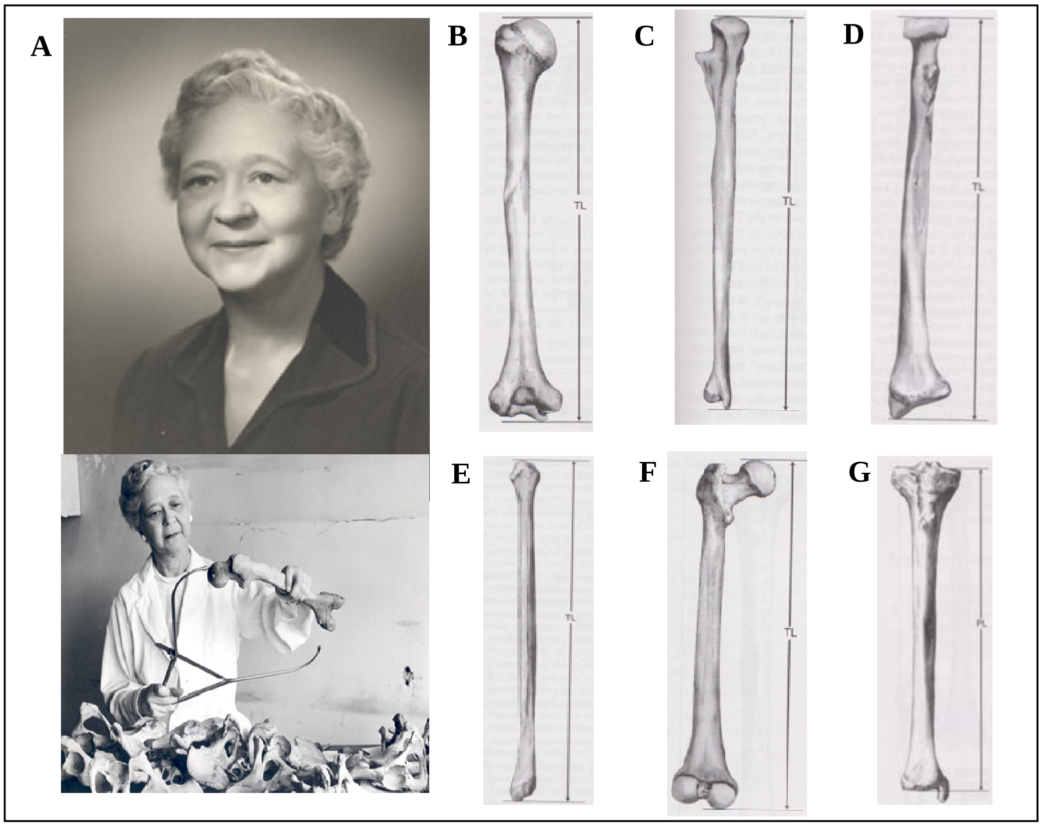

Figure 2.1 History of height prediction: (**A**) Mildred Trotter (1899-1991) was an important forensic anthropologist in 20th century. She contributed much to the development of regression equations for height prediction from human long bones. (**B**) Total length of the humerus (**C**) Total length of the ulna (**D**) Total length of the radius (**E**) Total length of the fibula (**F**) Total length of the femur (**G**) Physiological length of the tibia. (Adapted from: Byers, 2002).

Since Trotter and Gleser's publications, extensive work on regression equations for height prediction have been developed throughout the world. The relationship between long bone length and living human height has been documented in some early studies, such as those of arm-span (Harris *et al.,* 1930), arm length (Mitchell & Lipschitz, 1982b), knee height (Chumlea *et al.,* 1985) and demi-span (Bassey, 1986). Their pioneering works have given rise to a recent increase in publications using similar theory to study different populations. The theory is that height of an individual is proportionate to various body parts (Özaslana *et al.*, 2003). Table 2.2 presented the published regression equations for height prediction in different populations.