ESTIMATION OF HEIGHT OF ADULT MALAYS ATTENDING HOSPITAL UNIVERSITI SAINS MALAYSIA (HUSM) USING CALCANEUS BONE MEASUREMENT ON PLAIN RADIOGRAPH

BY
DR. AHMAD TARMIZI BIN MUSA

Dissertation Submitted in Partial Fulfilment of the Requirement for the Degree of Master Of Medicine (RADIOLOGY)

UNIVERSITI SAINS MALAYSIA

ACKNOWLEDGEMENT

This dissertation is the result of the guidance and the help of several remarkable individuals, who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

First and foremost, my utmost gratitude to Allah The Almighty, for answering my prayers for giving me the strength to plod on despite my constitution wanting to give up. Thank you so much Dear Lord.

I am heartily thankful to my main supervisor, Associate Professor Dr. Meera Mohaideen Hj. Abdul Kareem, my main supervisor whose sincerity and encouragement I will never forget. AP Dr. Meera has been my inspiration as I hurdle all the obstacles in the completion of this research work. He helped me come up with the dissertation topic and guided me over almost five years of development. And during the most difficult times when writing this dissertation, he gave me the moral support and the freedom I needed to move on.

I am pleased to record my deep appreciation to University of Science Malaysia for providing me with the incentive grant in encouraging me to pursue professional growth. I thank Department of Radiology, School of Medical Sciences, University of Science Malaysia for the wonderful opportunity enabling me to utilize the facilities provided.

I wish to extend my sincere thanks and appreciation to Mr. Nataraja Moorthy, my co-supervisor, for his patience and steadfast encouragement to complete this study, Associate Professor Dr. Mohd. Shafie Abdullah, former Head Department of Radiology who had kind concern and consideration regarding my academic requirements, and also Dr. Nik Munirah Nik Mahdi, current Head Department of Radiology, for the moral support and the insights she has shared despite her just being newly appointed.

I have incurred debt to my lecturers and seniors, in particular Dr. Roshila, Dr. Norzila and Dr. Khairil Amir, for their unselfish and unfailing support for being accommodating to my queries. They have shared valuable insights in the relevance of the dissertation.

I am also grateful to many of my colleagues, Hadif, Rizal and Chandran, whom I have engaged in various discussions relating to the dissertation which have benefited me immensely. They have made available their support in a number of ways from the initial to the final level enabled me to develop an understanding of the dissertation objectives.

It is a pleasure to thank those who made this dissertation possible, the supporting staffs of the Department of Radiology, Science Malaysia University especially radiographers and attendants for all the help not only in taking the consent from the subjects but also in measuring the height and doing the ankle radiograph of the subjects.

Special mention must be made to my parents, Haji Musa Hamzah and Hajjah Che Rahmah Che Lah, as well as my parents-in-law, Dr. Haji Hassan Abdul Rahman and Hajjah Noraini Abdul Ghani, who provide me with strength, love and affection and for having secured for me a congenial environment for me to carry out this dissertation.

Last but not the least, there is one other person who merits special mention. This work would not have seen the light of the day without her untiring and dedicated effort in coming out with this dissertation, spotting the grammatical and spelling errors and have made various suggestions for changes much of which I have incorporated. She is my beloved wife, Hasni Muniati Binti Hassan who has been the pillar of support throughout my career and had patiently endured me when I was preparing the completion of this dissertation. I shall never stop thanking her and so blessed to have her in my life.

TABLE OF CONTENTS

CONTENTS

LIST OF FIGURES AND TABLE

LIST OF TABLE

LIST OF FIGURE

ABBREVIATION

ABBREVIATION

SEE	**Standard Error of Estimation**
SD	**Standard Deviation**
MaxL	**Maximum calcaneus length**
MaxH	**Maximum Calcaneus Height**
BH	**Body Height (Calcaneus)**
LaL	**Load arm Length**
HUSM	**Hospital Universiti Sains Malaysia**
TSH	**Total skeletal height**
ELS	**Estimating Living Stature**
PACS	**Picture Archiving Computerised System**
GCF	**Ground compression force**
FEM	**Fine elimen model**
TC	**Talocalcaneal**
CC	**Calcaneocuboid**

ABSTRACT

Abstrak

Tajuk

Anggaran Ketinggian berdasarkan Ukuran Dimensi tulang Tumit (Calcaneal) pada paparan radiograf dikalangan orang dewasa Melayu yang datang ke HUSM

Pengenalan

Dalam Penyiasatan Forensik mediko-legal, mewujudkan identiti peribadi mangsa adalah penting. Formular anggaran ketinggian adalah penting dalam menyediakan anggaran ketinggian seseorang individu daripada tinggalan rangka atau tulang yang dijumpai. Persamaan regerasi yang khusus untuk sesuatu populasi perlu diterbitkan daripada ukuran tulang yang serupa. Ukuran tulang aksis utama *(Long Bone)* telah lama digunakan bagi pengangaran ketinggian individual dan sudah lama terbukti keberkesanan dalam kajian terdahulu. Dengan peningkatan kadar jenayah serta keganasan di bandar ditambah pula dengan kecelakaan yang serius yang sering berlaku di dunia, kebayakkan daripada tubuh anggota mangsa adalah dalam keadaan terpisah atu tidak sempurna. Maka formular persamaan bagi anggaran ketinggian perlu diterbitkan daripada serpihan tulang aksis atau tulang-tulang ynag lebih kecil. Formular regerasi ketinggian daripada ukuran tulang tumit telah dibuat oleh Bidmos dan telah memaparkan kolerasi yang sinifikan dan julat ketidak tepatan yang rendah. Walau bagaimana pun, tiada lagi kajian yang serupa dilakukan bagi populasi masyarakat melayu.

Objektive

Untuk menganggar ketinggian individu Melayu dewasa yang menghadiri di Hospital Universiti Sains Malaysia berdasarkan pengukuran tulang calcaneus pada paparan radiograf.

Kaedah

Kajian telah melibatkan 68 pesakit yang telah secara suka rela memberi kebenaran untuk melakukan pemeriksaan radiograf leteral sendi bukulali. Pembaris yang *Radiopaque* disertakan bersama pemeriksaan radiograph bagi mengurangkan julat perbezaan pemprosesan digital. Daripada 68 peserta 39% adalah lelaki (berumur antara 20-61 tahun) dan 61% adalah perempuan (berumur antara 20-54 tahun). Empat pembolehubah diambil sebagai pengukuran calcaneus iaitu MaxL, MaxH, BH dan LaL. Nilai Mean dan SD telah dikira bersama bag tiap-tiap pemboleh ubah. Daripada empat pemboleh ubah, persaman *univariable* dan *multivariable* telah dibentuk.

Keputusan

Kebanyakan pengukuran calcaneus mempunyai perkaitan dengan ketinggian (p <0.05) iaitu bagi lelaki daripada 0.166 hingga 0,528 dan bagi wanita adalah diantara 0.274 hingga 0.654. Kajian menunjukkan perbezaan antara kolerasi antara *univariable* dengan *multivariable*. Formula *multivariable* menunjukkan kolerasi yang lebih tinggi atau sama dengan *univariable*. Selain daripada itu persamaan *univariable* mumpunyai nilai SEE yang rendah berbanding *multiivariable.* Maka

persamaan univariable menunjukkan kejituan daripada sudut pengangaran ketianggian.

Kesimpulan

Pengukuran calcaneus boleh dijadikan sebagai salah satu daripada persamaan bagi mengangarkan ketinggian yang hampir jitu. Dengan faktor-faktor tambahan daripada multivariable, ketepatan menganggarkan daripada pengukuran calcaneus adalah sebaik persamaan ukuran *long bone.*

ABSTRACT

Topic

Estimation of height of adult Malays population attending Hospital Universiti Sains Malaysia (HUSM) using calcaneus bone measurement on plain radiograph

Introduction

In medico-legal forensic investigation, establishing personal identity of a victim is important. Stature reconstruction is important in providing estimated height of a person from their skeletal remains. Population specific regression equations for stature estimation need to be establishing from the identical bone. Long bone measurement had been used in stature estimation with proved accuracy in many previous studies. With the rise of violence in major cities and mass disaster occurring around the world resulting dismembered human parts and long bones, there was a need for derivation equation from the small bone or long bone fragment for stature estimation. Stature estimation from the regression analysis from the calcaneus measurement had been done by Bidmos which showed significant correlation coefficient and low SEE value. However there is no such study performed with Malay population.

Objective

To estimate the height of individual Malay adult attending Hospital Universitie Sains Malaysia based on the measurement of calcaneus bone on plain radiograph.

Methods

These studies have 68 volunteers for underlying lateral ankle radiograph with radiopaque ruler as references calibration during the procedure to reduce digital discrepancy during measurement in PACS. Out of 68 subjects 39 % are male (from 20-61 years old) and 61 % are female (from 20-54 years old). Four variables were taken as calcaneus measurements that are MaxL, MaxH, BH and LaL. Mean and SD of the variables was calculated. Univariate and multivariate regression equation were derived from all these four calcaneus measurement.

Results

Most of the calcaneus measurement had correlation with height ($p < 0.05$) with range of 0.166 to 0.528 for male and 0.274 to 0.654 for female. The study shows multivariable equation has higher or equal correlation with univariate equation. However in this study univariable shows smaller SEE compare to the multivariate which shows univariable has more accuracy in estimation stature.

Conclusions

Calcaneus measurement can provide reliability in estimation of stature of an individual. With the additional factors from multivariable, the accuracy of estimating stature from the calcaneus measurement will be as good as long bone.

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

Estimation of individual's stature is an important parameter in forensic examination, contributing to the identification of missing person. Due to the biometrical relationship between body and segment length and total body height, estimation of person's living stature can be concluded by measuring the length of only one long bone (Sagar and Sharma, 2010).

The problem is encountered in cases of in as disasters, explosions, and assault where the body is dismembered to conceal the identity of the victims. Anthropometric technique are commonly used by anthropologist and adopted by medical scientist to estimate a body size for the purpose of identifications. When the bodies are discovered, forensic anthropologist can measure long bones and apply their measurements to linear regression to estimate a stature.

Many studies have been conducted to determine stature by taking measurements of the long bones and various percutaneous body measurements. The relationship between specific body dimension and proportion can be used to identify and aid in solving crimes in absence of complete evidence. For example, stature can be estimated from imprint external body parts or shoes or shoes marks left at scene of crime. Similarly, the stature of the victim can be estimated when apart of such as long bones, carpals or tarsal bone, is all remain (Sanli *et al*., 2005). Estimation of height with mathematical method, which is one of the most frequently used method today, is the method of estimating height by taking the mathematical regression coefficients obtained through the measurements of various bones of the body. It has been a custom in studies of stature estimation to derive a regression formula separately between males and females, which owing to statistically significant differences in stature and dimensions of various body parts between males and females. Determination of sex, hence become critical requirement in applicability of specific regression models in stature estimation (Kanchan *et al.*, 2010a).

It has been noted that lower extremity has a greater correlation with body height than the upper extremity (Kanchan *et al.*, 2008). Ossifications and maturation in foot occurs earlier than long bones, therefore, during adolescence age, height could be more accurately predicted from foot measurement as compared to those long bones (Moudgil *et al.*, 2008)

The foot has been extensively studied to provide valuable information about an individual when an individual foot is recovered and brought for forensic examination. Researchers have attempted sex determination from foot measurements (Ashizawa *et al.*, 1997; Fessler *et al.*, 2005; Ozden *et al.*, 2005; Sanli *et al.*, 2005; Agić *et al.*, 2006; Moudgil *et al.*, 2008; Sen and Ghosh, 2008; Zeybek *et al.*, 2008; Kanchan *et al.*, 2010b; Singh *et al.*, 2010; Tharmar *et al.*, 2011; Hisham *et al.*, 2012; Patela *et al.*, 2012) *and Foot Index* (Moudgil *et al*., 2008). However few studies have been done for sex determination using single foot bone such as calcaneus (Steele, 1976; Bidmos and Asala, 2003).

Many years ago anthropologists commonly did stature estimation of human based on individual bone. Bones begin from the skull, long bone of upper and lower limb until the talus are measured and investigated. Anthropologists manage to estimate diet, activity and even sex determination from the individual bone (Jadar and Shah, 2004).

A.M.C Murphy reported a study on prehistoric New Zealand population which shows that there is an existence of significant sexual differentiations with the individual talus bone (Murphy, 2002b). Other similar study done by Bidmos and Asala (2004) reported that measurement of talus bone of the white South African can be used in sexual determination and shows significant correlation. Murphy (2002a) in his other study reported that calcaneus is the most durable bone in foot. This study shows that calcaneus also can be used in determining sex differentiation.

In estimating the human stature, a study done by Bidmos (2006a) has shown significant correlation between calcaneus bone measurement and stature estimation on South African population. However stature estimation using calcaneus is not yet established in Malaysia.

Zaslan *et al.* (2003) reported that anthropometric technique was commonly used by the anthropometrologists and had been adopted by medical researcher in estimating the human height for many years ago. The study shows that stature estimation can be based on the thigh length, lower leg length, trochanter length, foot length and foot height (Zaslan *et al.*, 2003). Jadav and Shah (2004) reported that stature estimate can be done by measuring head length. However, the study shows no significant correlation (H.R Jadav and G.V Shah, 2004).

Radoinova *et al* (2002) shows the significant correlation between the length of femur, tibia and fibula with the stature estimation. The study reported that minimal standard error of estimation in both sexes in Bulgarian is around 1 to 2 cm (D.Radoinova *et al.*, 2002). Mubarak Bidmos (2005) reported that adult stature estimation can be measured by calcaneus measurement on cadaver with the standard error of estimation around 4 to 5 cm. The stature estimation can be calculated from the individual bone measurement or using combination of variables (Bidmos, 2006b).

However, no other similar study done based on calcaneus bone measurement using plain radiograph was done in Asian group of population. Tharmar *et al.* (2011) measuring foot length of Malay adult Malaysian for stature estimation which showed high correlation value.

CHAPTER TWO

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 HUMAN FOOT

The human foot is an organ of the most under and on the lower end of human limb. The human foot is a complex and strong structure and able to sustain the burden and impact. This is because the structure of the foot consists of 23 bones, 33 joints and more than 100 muscles, tendons and ligaments that form complex structures. This complex structure of the foot is helping the complex movement such as walking, running or jumping. These components work together to provide stability and flexibility in helping the movement and provide support to the feet. Failure of one of these components will interfere or give complications to the structure of the body, such as back pain or knee joint pain. But the failure of the body structure can also give complications to the feet.

Foot structure is divided into three main sections, the forefoot, the midfoot and the hindfoot. Forefoot consists of five components phalanges bones and five metatarsal bones. The joints between the metatarsal bones and phalanges bones called metatarsal phalanges joints where lies the ball of the foot. Here, half of which lays the weight and pressure when a person is standing and one hundred percent to 80 percent when a person is running a sprint.

Midfoot consists of five tarsal bones; a cuboidal, three curnieforms and a navicular bone that make up the foot arch that serves to absorb shock. Midfoot and hindfoot connects the fore foot. The structure is connected to the plantaris muscle and plantar fascia in plantar surface of the foot.

Hindfoot is composed of three joints and links the midfoot to the ankle (talus). Superior articulation of the talus bone is connected to the two long bones of the lower leg (tibia and fibula), forming a hinge that allows the foot to move up and down. The heel bone (calcaneus) is the largest bone in the foot. It joined the talus to form the subtalar joint. The bottom of the heel bone is cushioned by a layer of fat.

2.2 CALCANEUS ANATOMY AND DEVELOPMENT

In the process of development of the foot, the first primary ossification center for the metatarsal and phalanges are within 5th first month of perinatal period. After that, the second groups of the primary center ossification derived from talus bone; rest of ossification which will form after postnatal (two or three will appear after birth). Normal sequences of appearances of the tarsals are relatively constant and well documented. The calcaneus has a flatten area just distal to the centre of the dorsal surface. This is the tore rumour of calcaneus grow that form the fencelike the sinustarsi. At the early stage of development it displays a large nutrient foramen. Within the first month post natal, the calcaneus can be identified as a pisiform-shape nodule with shallow grove. Calcaneus appears first follow by the talus and lateral cuboidal (Meschan, 1974-1976).

Calcaneus is the largest tarsal bone and form heel of the foot. Anteriorly, it articulates with the cuboid. Superiorly, it articulates with the talus. Anteromedially, marked process from the calcaneus supported the talus known as the sustentaculum tali. This articulation form three basic joint surface also known as superior, medial and anterior articulations or facet. Superior and medial facet also known as talocalcaneal (TC) joint and anterior articular facet known as calcaneocuboid (CC) joint. Posteriorly, prominent tuberosity of the calcaneus also knows as calcaneus tuberosity. It is the insertion site of the biggest and strongest tendon in human structure known as Achilles’ tendon (Meschan, 1974-1976).

Radiographic anatomy of the calcaneus

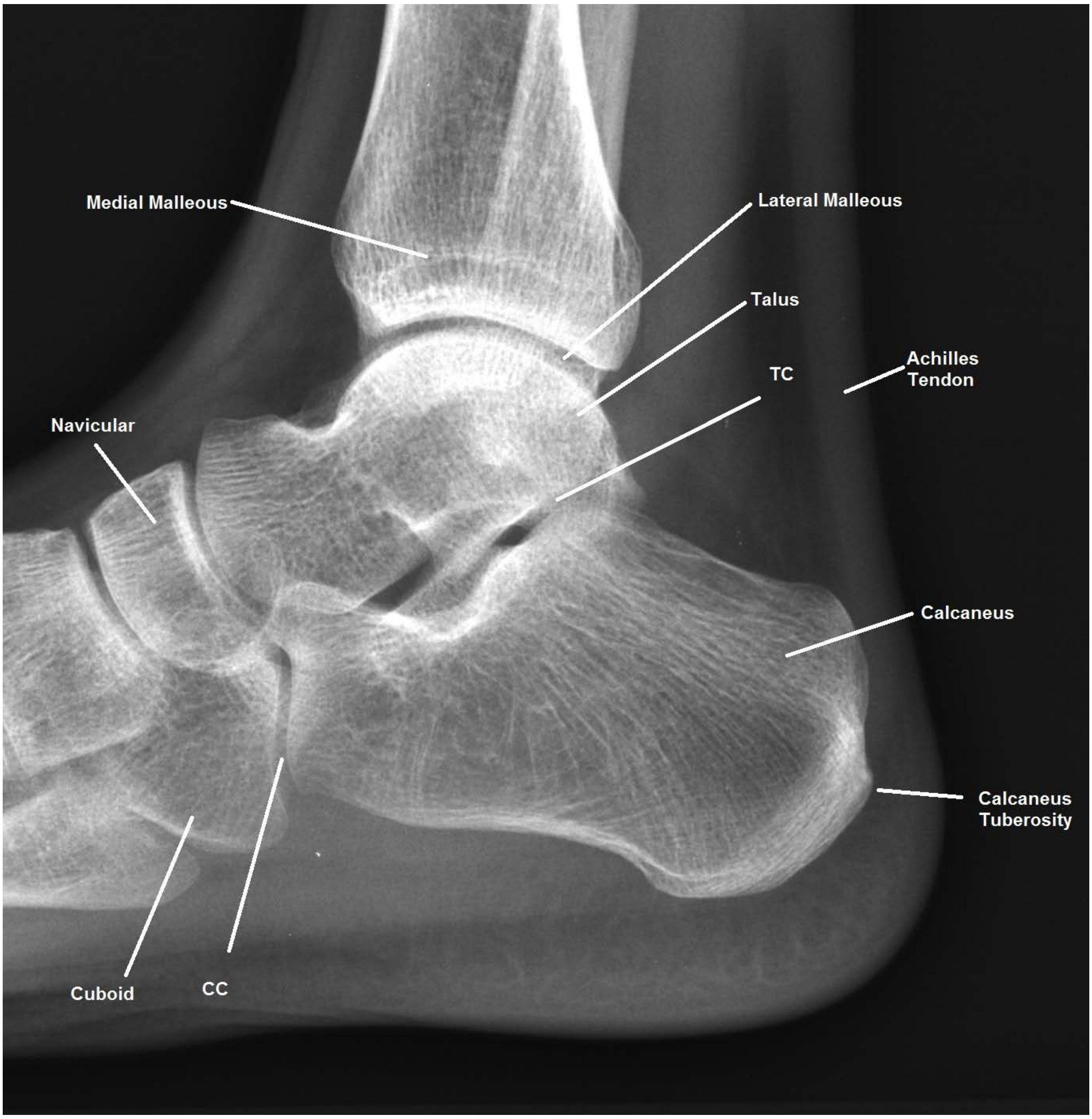

Figure 2.0: Lateral radiograph of Calcaneus

2.3 BIOMECHANICAL FUNCTION OF FOOT AND CALCANEUS

In the foot, calcaneus act as fulcrum for foot movement and simultaneusly as ground assoption force during simial activites. Base on the 2 dimention (2D) Fine elimen model (FEM) (Fig 2.1) show that Ground pressure distributed in two places that is at the calcaneus base and at the metatarsal head. In the model show most of tensile forced at to the calcanel via the achiles tendon from the soleus and gastrocnemius muscle during foot flextion (Giddings *et al.*, 2000). Ground compression force (GCF) act to the base of calcaneus from the plantar lingamnet and plantar fascia.

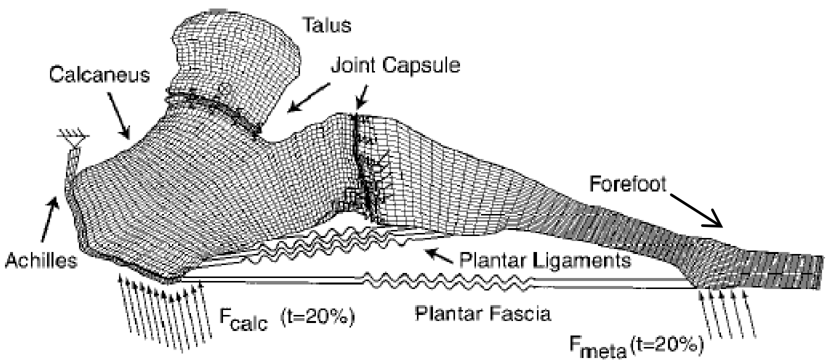

Figure 2.1 : FEM model with boundaries condition show 20% body weight (BW) stance during walking. Forces distibuted into two at the calcaneus base and metatarsal head. (Giddings *et al.*, 2000)

This model (fig 2.1) shows two friction contact surfaces that act to the calcaneus one at the talocalcaneal (TC) joint and one at Calcaneocuboid (CC) joint. The articulation surface is covered by cartilage and sarrounded by joint capsule. It promote siliding, arbitrary contact and seperation between the deformable bodies.

The total joint contact, ground force pressure, plantar ligament and plantar fascia and Achilles tendone forced all contribute to loads on the calcaneus during gait.

Figure 2.2 shows that the this forces contribute to the equilibrium configuration at 70% of stance at walking and 60 stance at running.

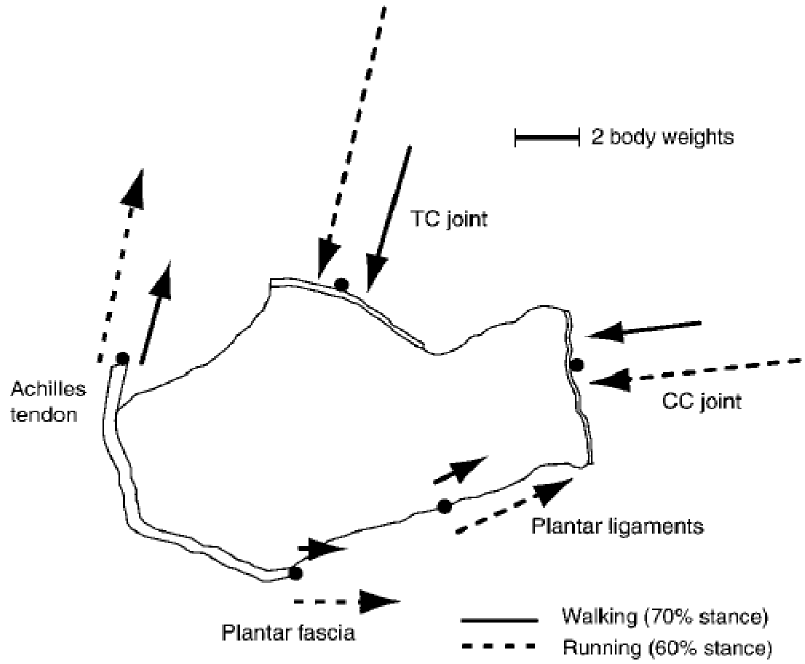

Figure 2.2 : Vector act on calcaneus during walking and Running (Giddings *et al.*, 2000).

The diagram of the calcaneus showing tendon, ligament and joint forces acting on the calcaneus at 70% of stance during walking and 60% of stance during running. The vectors are slightly of set from the actual site of forces applied that been indicated by a dot. Predicted TC joint capsule and CC joint capsule load at peak loading were small and not been shown within this diagram.

2.4 HISTORY OF STATURE ESTIMATION

A number of methods have developed in the last few centuries for stature estimation. Stature is usually estimated by employing either the anatomical or the mathematical method (Lundy, 1985). The mathematical method makes use of one or more bone length to estimate the stature of individual. This method employs bone length and stature table and regression formula to estimate total skeletal height or living stature from long bone length (Krishan and Sharma, 2007). In the first study of its kind, Rollet assessed the correlation between stature and long bone length (Trotter and Gleser, 1952). He measures the length of radius, ulna, humerus, fibula, tibia and femur of adult French cadavers and publishes report with methods of measurements, the individual measurement and tables stature of estimation. Pearson use Rollet's data to create a regression formulae for estimating stature (Pearson, 1894; Pearson, 1899). He contributed greatly to the advancement of stature estimation, and discussed the applicability using equation for stature estimation on many populations. Using the mathematical method, the bone length measurement is substituted into the regression equation. The outcome of the equations calculated give the total skeletal height or stature of living person. This depends upon the equations employed and whether the soft tissue and ageing correction factors were included into the equation. The obvious advantage of this method is that a single bone can be used to determine estimated stature of a living individual. The main disadvantages of the mathematical method is that different formula are required for different population, for each different bony structure and also separately for each gender. This is because variation in body proportion exists, making these formulae population and gender specific (Sanli *et al.*, 2005; Krishan, 2007).

According to Dupertuis and Hadden (1951), Pearson's formulae were derived from measurements of populations that were particularly short in stature (Dupertuis and Hadden, 1951). It became necessary to create a new formulae representative of taller or normal stature in that population. They were, like Pearson, unsure if formulae derived from one race would be applicable to other races. Dupertious and Hadden calculated their new formula using cadavers of tall Euro Americans and Africans (Dupertuis and Hadden, 1951). They found that using two or more long bone lengths is more reliable than just one. Using long bone from lower extremity is more accurate than using bones from upper limb. They also noted that, just as Pearson did, that estimation formulae apply best to the population from which it was derived (Shields, 2007). Later, Mildred Trotter and Goldine Glesser (1977) developed equations that are still used for stature estimation today. They took advantages of repatriated deceased from World War II and Korean War by measuring long bone length from male cadavers and comparing them to the military records containing living stature (Trotter and Gleser, 1958b; Trotter and Gleser, 1977). According to Trotter and Gleser, the evidences indicates that in order to develop accurate estimates of stature, the equations used on unknown individual must be derived from 'a representative sample of the population of the same race, age, geographical area and time period to which the unknown is believed to belong'. However in difficulties to get same age, geographical area and physiological feature, mathematically can determine the standard differences or know as standard error of estimations (Trotter and Gleser, 1977). The equation they developed is primarily of American white and blacks and should be used to compare with these populations.

However, this equation is currently being applied worldwide because of the scarcity of stature data.

The anatomical method estimates total skeletal height was initially introduced by Dwinght in 1894 (Krishan, 2007). In 1956, Fully reintroduced the method with slight variation and it became known as Fully's procedures (Raxter *et al.*, 2007). This method is based on the summed heights of skeletal elements at that contribute to stature measurement in human. The skeletal elements measured in this method are cranium, vertebrae, femur, tibia, talus and calcaneus. This represents the elements that contribute to stature and their measurements are summed to calculate total skeletal height. To calculate the living stature of an individual using anatomical method, correction factors that compensate for soft tissue also need to be added. The main disadvantage of the anatomical method is that a nearly complete skeleton is needed for stature estimation (Krishan, 2007; Krishan and Sharma, 2007). This method is rarely used because longer duration of time in measurement and requires a nearly complete skeletons (Kelly Jean Field, 2007).

2.5 EFFECTS OF AGING ON STATURE

It is generally accepted that stature declines with age. According to Giles and Hutchinson (1991), it is a reasonable assumption that populations, particularly those in the united states, will begins to decrease in stature starting in theirs midforties. This minimal decrease begins for males at about 1mm/year and for female at about 1.25mm/year. These factors must be accounted for when estimating in and older individual, generally including over the age of 45 years old (Giles and Klepinger, 1988). Galloway found that height reduces average by 0.16 cm per years after age

45 (Galloway, 1988). She suggested correction of the maximum height -0.16 cm (age 45), incorporated into the stature estimation equation when analysing older individuals. Trotter stated that stature decrease from age 30 by 0.06 cm per year (Trotter and Gleser, 1977).

2.6 ESTIMATION OF STATURE FROM VARIOUS PARTS OF HUMAN BODY

Estimation of stature in victim is a one of the major concern in Forensic Investigation and anthropology. Every part of the human body is unique in its determination ration to the height. It is amazing to discover that every part of the body is different in its own way for a similar body component in other person. There is also relationship between each part of the body and the whole body. Nothing epitomises this truth more than the relationship that various parts of the body have to stature and gender identity on a person. Many authors have studied estimation from mutilated body parts can be done based on ratio of the body part concerned in relation to entire body. The relationship between humerus, radius, ulna, femur, tibia, fibula and clavicle with the stature estimation have been a topic of research for decades (Nath and Badkur, 2002; Oberoi *et al.*, 2006).

There is an established relationship between stature and various body parts of the body. This allows a forensic scientist to estimate stature from different part of the body. With the increasing trend of mass disasters, homicides cases with dismembered body part, air plane crashes, road traffic and train accidents and so on. There is always need for such studies which helps in identifying the deceases from dismembered and fragmentary body part.

Some authors have successfully tried to estimate stature from percutaneous body measurements, some from the isolated long bone and other bones and some focused their attention on the estimation of stature using radiographic material (Krishan, 2007).

It is possible to determine the height of dead body by two methods defined as anatomical and mathematical methods (Ozden *et al.*, 2005). The most easiest and reliable method is by regression analysis. Mathematical method, which is one of the most frequently used one nowadays, is the method for calculating the height by considering the mathematical regression coefficients obtained from the measurements of many bones of the body (Karaman *et al.*, 2008).

Various studies conducted on the estimation of stature indicate that every part of the skeleton has been use for estimation. One of the foremost and famous studies on estimation of stature from the long bone measurement of the American white and black is by Trotter and Gleser. Trotter and Gleser, who contributed much to establishing and developing the mathematical method and that the use of the equation they establish still continues in our days also, studied particularly the American population. In Totter and Gleser study, they made comparison among various groups in this population with different structure. The basic principle of the Trotter and Gleser equations is the comparison measure of part of the skeleton to the equivalent in living individuals or cadavers. Since then, the researcher and the scientists have carried out extensive work on the estimation of stature from a variety of bones throughout the world.

Kate and Majumdar successfully estimated stature from length of femur and humerus by regression method and autometry in an Indian sample (Kate and Mujumdar, 1976). Trotter and Gleser statistically evaluated the prediction of stature from length of the long bones in American negroes (Trotter and Gleser, 1958a). Rother et al (1979) conducted a study on estimation of the stature from fragments of femur and devised some regression formulae (Rother *et al.*, 1979). Mysorekar et al also estimated stature on the basis of lower end of femur and upper end of radius (Mysorekar *et al.*, 1984). Badkur and Nath reconstructed stature by measuring 12 anthropometric parameters on ulnar and multi-linear regression equations were computed (Badkur and Nath, 1990). Simmonsa *et al.* provided regression equations for the estimation of maximum femur length and stature from three well define and easy to measure segments of the femur in a sample from Terry collection (Simmons *et al.*, 1990). Holland (1992) calculated strong linear regression equations for estimation of stature from measurements of condyles of tibia in a sample from Harmann-Todd collection (Holland, 1992).

Introna *et al.* correlated stature with several parameters of the skull and obtained multiple linear regressions for estimation stature. The study is consisted of 119 adult black and white males from the terry collection (Introna Jr *et al.*, 1993). Jantz and Jantz (1999) developed regression equation from two sample of metacarpal specimens (Jantz and Jantz, 1999). One from 212 individuals from the Terru colletions and other 55 modern males and concluded that in spite of differences noted, The Terry equation perform acceptably on modern individuals. Jantz *et al.* presented results in estimation of stature from tibia (Jantz *et al.*, 1995). Jantz *et al.* critically commented upon the method of measurement of tibia by Trotter and Gleser. Ousley recommended that forensic stature estimation is generally less precise than Trotter and Gleser stature estimation but is more accurate for modern forensic cases because a forensic stature is the only stature available for a missing person (Ousley, 1995).

Compobasso *et al.* (1998) used scapula measurements for estimation of stature. They took seven anthropometric parameters of scapula and developed multiple and linear regression equation (Campobasso *et al.*, 1998). Mall *et al.* (2001) correlated humerous, ulna and radius length with stature and concluded that the linear regression analysis for quantifying the correlation between the bone length and the stature led to unsatisfactory results with large 95% confidence interval for the coefficients of high standard error of estimation (Mall *et al.*, 2001).

Ross and Konigsberg devised new formulae for estimating stature in the Balkans. (Ross and Konigsberg, 2002). They compare the data obtained from 545 white males from world war II with East European sample of 177 males including the Bosnia and Croatian victims of war.

Bidmos and Asala derived regression equations for estimation for stature from nine calcaneal measurements (Bidmos and Asala, 2005). The sample consisted of 116 complete skeletons from Raymond Dart collection. Hauser *et al.* established the relationship between stature and greatest length of femur and computed correlation coefficients and regression equations to predict stature (Jantz and Jantz, 1999; Hauser *et al.*, 2005). Pelin *et al.* (2005) evaluate the possibility of prediction of living stature from the coccygeal vertebral dimensions in adult male Turkey population. They recommended the use of combined variables of different coccygeal vertebral segments for accurate prediction of stature (Pelin *et al.*, 2005). Rexter *et al.* (2007) revised Fully's technique for estimation of stature and tested the accuracy and applicability of his method and clarified measurement procedures (Raxter *et al.*, 2007).

Jadav and Shah reported that stature estimate can be done by measuring head length, however the study show no significant correlation (H.R Jadav and G.V Shah, 2004).

Radoinova *et al.* shows the significant correlation between the length of femur, tibia and fibula with the stature estimation. The study reported that minimal standard error of estimation in both sexes in Bulgarian is around 1 to 2 cm (D.Radoinova *et al.*, 2002).

Hallikeri *et al.* (2012) developed formulae for estimation of stature by using percutaneous measurements of long bones of leg and forearm In South Indian (Hallikeri, 2012). Before that Sarajilic *et al.* had developed stature estimation formula from the lower limb part from the Bosnia Population (Sarajlić and Cihlarz, 2007). Kishan and Sharman gave linear and multiple regression equation for estimation of stature estimation from the hand and feet dimension in North Indian Rajouts (Krishan and Sharma, 2007). Krishan and Kumar (2007) calculated regression equations for estimation of stature from cephalo-facial dimensions in Koli adolescents of North India. They also suggested that future researchers should categorize their adolescent sample in to various age groups for better reliability and practical utility of stature estimation. Duyar and Pelin hypothesize that ‘estimation of stature are more accurate if different regression formulae are used for specific stature group’ (Duyar and Pelin, 2010). A regression formula is the results of regression analysis which allows researcher to predict the value of stature, in this case, from random variables.

Agnihotri *et al.* did a study in 2011 to estimate stature from the facial dimensions among the people in Indo-Mauritian population (Agnihotri *et al.*, 2011). They were using a regression equation and multiplication factors in their study. Total sample sizes in their study are 199 male individual belonging to the age range from

18 to 45 years old. Six facial dimensions of each subject with their stature and the Bigonal breathe with an ‘r’ value of 0.365.

Ubelaker show that, lengths of humerus, radius, ulna, femur, tibia and fibula could be used in calculating the heights of Finnish children. The results are acceptable in accuracy (Ubelaker, 2006). A study done in Turkey, in 2006 is estimating stature from wrist radiograph using a mathematical method to develop height regression formulas using measurements of second and third metacarpals bone. In the study, they were capable of forming a regression models to calculate a height. Since the calculated height is unique for the certain population examined, their regression formulae cannot be used outside the turkey population (Zeybek *et al.*, 2008).

Due to substantial diurnal variation in stature, one should avoid taking stature measurement at different time in the day. It means, while making standards or references data of stature estimation, careful consideration should be given to the time of the day at which the measurements are be recorded (Krishan, 2007).

2.7 ESTIMATION OF STATURE FROM CALCANEUS AND FOOT DIMENSIONS

Calcaneus developments are unique and had similar growth rate as other skeletal. It reaches peak growing rate around 14-16 years old were the epiphysis plated close at age of 19-20 years old (Passalacqua, 2011). Study performed by Passalacqua (2011) on European American and African American can estimated age of death in subadult from Hamman-Todd collection using calcaneus measurement as variables for estimation. In his study MaxL was one of the significant variables for estimation (Passalacqua, 2011).

Mubarak Bidmos reported that adult stature estimation can be measured by calcaneus measurement on cadaver with the standard error of estimation around 4 to 5 cm. The stature estimation can be calculated from the individual bone measurement or using combination of variables (Bidmos, 2006b).

Another study by Bidmos and Asala in estimating stature from calcaneus measurement of South African blacks, demonstrated variables that have significant correlation in estimating stature. Three of the variables that can be applicable for this study was MaxL, BH and MaxH (Bidmos and Asala, 2005).

Calcaneus measurements were used in estimating gender identification. Study by DiMichele and Spradley proven that MaxL, LaL, Load arm width (LaW) and Posterior circumferences (PC) had significant correlation determine gender among American blacks and American white (DiMichele and Spradley, 2012). Study done in Korean populating using calcaneus measurement reviled that MaxL and Minimum Breadth (MINB) show high accuracy (80.0 to 82.7 %) in determine gender (DiMichele and Spradley, 2012). Determination of stature or gender base on calcaneus measurement, shows lower standard error of estimation if multi-linear regression were performed and improved the accuracy (Holland, 1995b; Murphy, 2002a; DiMichele and Spradley, 2012; Kim *et al.*, 2013; Pablos *et al.*, 2013).

However, no other similar study done on base on calcaneus bone measurement base on plain radiograph and non-similar study in Asian group of population.

2.8 MALAYSIA EXPERIENCES IN HOMICIDE CASE AND MAJOR DISASTER WITH UNIDENTIFIED VICTIM

There is an alarming trend of homicide cases each year. In Malaysia, homicide cases are increasing significantly based on statistic from year 2007 to 2009 (S. Bhupinder *et al.*, 2010). A few of the victims founded were unidentified.

Bhupinders *et al.* reported that most of the homicide cases in Penang from 2007 to 2009 were involved stabbing, mechanical asphyxia, blunt head injuries and shooting (S. Bhupinder *et al.*, 2010). However, cases that involved the missing of body parts of the victims are rising recently and this causing difficulty in identifying the victims especially to determine their heights. In addition, in major disaster cases, identification of victims may be determined by estimating the stature.

Bhupinders *et al.* (2010) also reported that most of the homicide victims are Chinese (37 %) followed by Indian (23 %) and Malays (17%). In forensic sciences, identification of victim is determined from the parts of the human body. The identification is based on the anthropometric study of the length of lower extremity which shows significant correlation in estimation of height (T. Schepers *et al.*, 2007).

Zanlan *et al.* reported that anthropometric technique is commonly used by the anthropometrologists and adopted by medical researcher in estimating the human body size for many years ago. The study shows that stature estimation can be based on the thigh length, lower leg length, trochanter length, foot length and foot height (Zaslan *et al.*, 2003).

CHAPTER THREE

OBJECTIVE

3.0 OBJECTIVE

3.1 GENERAL OBJECTIVE

To estimate the height of individual Malay adult for male and female based on the measurement of calcaneus bone on plain radiograph.

3.2 SPECIFIC OBJECTIVE

3.2.1 To correlate the calcaneus measurements with height and age in male and female adult Malay.

3.2.2 To estimate stature of Malay adult population based on different calcaneus measurements.

3.2.3 To compare standard errors mean of estimation and mean residual between for calcaneus measurements.

3.3 HYPOTHESIS

Ha_1: There is a significant correlation between calcaneus measurements with body height.

Ha_2: Able to determine correlation coefficient for the body estimation based on calcaneus measurement.