GEOMETRIC MORPHOMETRIC ANALYSIS ON THE PELVIC BONE BY RACE, SEX, AND AGE

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GEOMETRIC MORPHOMETRIC ANALYSIS ON THE PELVIC BONE BY RACE, SEX, AND AGE

by

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Thesis submitted in partial fulfilment of the requirements
for the degree of
Master of Science (Forensic Science)

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CERTIFICATE

This is to certify that the dissertation entitled "Geometric Morphometric Analysis On The Pelvic Bone By Race Sex Age" is the bona fide record of research work done by Nur Salwani binti Zainuddin during the period from February 2020 to September 2020 under my supervision. I have read this dissertation and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Master of Science (Forensic Science).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated and duly acknowledge. I also declare that it has not been previously for concurrently submitted as a whole for any other degrees at Universiti Sains Malaysia or other institutions. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research and promotional purposes.

…………………………………..

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LIST OF ABBREVIATIONS

*dta	Data file (Turbo Pascal-PC-File-Stata)
*ply	Polygon File Format or the Stanford Triangle Format (store 3D data)
3D	3 Dimensional
ANOVA	Analysis of variances
CV1	Canonical Variate 1
CV2	Canonical Variate 2
CVA	Canonical Variate Analysis
DFA	Discriminant Function Analysis
et al	et alia and others
GMM	Geometric Morphometric
IDAV	Institute of Data Analysis Visualisation

KAJIAN MORFOMETRIK GEOMATRIK MENGENAI JANTINA,UMUR, DAN BANGSA BERDASARKAN TULANG PELVIK

ABSTRAK

Kajian teknik morfometrik geomatrik merupakansalah satu kaedah yang selalu digunakan oleh ahli antropologi kebelakangan ini dalam menganalisis identiti pemilik specimen biologi seperti tulang. Tulang pelvik memainkan peranan penting dalam kehidupan seharian terutamanya dalam perilaku lokomotor dan juga sebagai pengendong anak semasa tempoh kehamilan bagi memastikan kemandirian spesies. Dengan teknik morfometrik geomatrik pada tulang pelvik., pengesanan identiti seperti umur,jantina dan bangsa dapat dikaji. Dengan menggunakan kajian secara retrospektif ke atas imbasan CT tulang pelvik, 58 sampel tulang telah dipilih secara rawak untuk dikaji. Sampel imej tulang yg diterima akan dibersihkan dan dipotong menggunakan perisian Meshmixer. Selepas itu, perisian IDAV digunakan bagi meletakkan mercu tanda pada tulang pelvik. Menggunakan perisian MorphoJ, analisis statistik dilakukan ke atas sampel.

Terdapat tiga analisis statistik yang digunakan iaitu Procrutes ANOVA, analisis komponen utama (PCA), dan analisa variasi kanonik (CVA). Berdasarkan ketiga analisis statistik ini, penulis mendapati beberapa gugusan yang terdapat dalam graf. Antara gugusan yang ketara dapat dilihat adalah kumpulan umur. Gugusan ini melibatkan kumpulan umur 10 tahun iaitu sampel yg berusia antara 1 ke 10 tahun, 51 ke 60 tahun, dan 61 ke 70 tahun. Hal ini berlaku kerana perubahan sistem anatomi dan lokomotor pada kanak-kanak serta orang berusia mempengaruhi cara perletakan mercu tanda sekaligus menyebabkan gugusan tampak jelas dalam graf. Berbeza dengan kumpulan umur yang lain ,bangsa, mahupun jantina. Setiap kumpulan bertindan antara satu sama lain. Hal ini menyukarkan penulis untuk menganalisis graf.

GEOMETRIC MORPHOMETRIC ANALYSIS ON PELVIC BONE BY RACE, SEX AND AGE

ABSTRACT

Geometric Morphometric technique is one of the wide techniques has been used by anthropologists in the identification of biological specimens such as bones. The pelvic bone has played a significant role in the human system such as locomotor behavior and baby carrier for females during pregnancy period. By analysing the geometric morphometric method on pelvic bone, the identification of bone such as race, sex, and age, may be determined. Using PACS database, 58 bones were selected randomly to assess sex, age, and race. After that these random image were cleaned and cut using Meshmixer software. Using Institute for Data Analysis and Visualization (IDAV), the landmark of the pelvic bone was selected and ready to analyse by MorphoJ software.

There were three statistical analysis that were done which were procrutes ANOVA, principles component analysis (PCA), and canonical variate analysis (CVA). Based on these three statistical analysis, it is found that there is a cluster was shown which is age group of 10 whom from age 1 to 10 years old, 51 to 60 years old and 61 to 70 years old. These cluster were obviously shown compared to other group such as sex and age because of physiology and locomotor changes. There is interference were shown in the other group such as sex, race and other group of age. The interference of group causing the difficulty to analyse the graph.

CHAPTER 1

INTRODUCTION

1.1 Background of study

The primary function of the human pelvis is that the weight of the upper body is shifted to the legs when standing, walking and running. The pelvis is made of two large bones, called the hip bones, or os coxae. These two bones link the pubic symphysis and the sacrum at the sacroiliac joints. The bones form an incredibly stable structure called a pelvic ring, allowing virtually no shift, shifting weight to the legs and helping to protect and retain abdominal organs. While the pelvis has a unique morphology relative to the rest of the human skeleton, it grows as well as the other bones in the entire body, starting with a mesenchymal intrauterine base that turns to cartilage and eventually ossification into the bone.

1.2 Overview of pelvic bone

The pelvic bone is useful for assessing sex, age, and race. Anatomy of the pelvic affects human performance. To move upright in a powerful way with minimal risk of injury, the pelvis must be durable and shape which maximises the arms of the muscle lever and minimises load. The body is supported by a single supporting arm while walking and running, a particular biomechanical challenge of human bipedal.

Since the hip joint is some distance from the midline of the body, the pelvis tends to rotate away from the supporting side during a single leg, and the ability to regulate the body temperature depends on the width and depth of the pelvis which plays a vital role for determining the total body proportion and the surface-to-mass ratio of the body.

On day 28, as the lower limb buds begin to develop, the first sign of in-utero pelvic development takes place. Instead, the shutter, femoral and sciatical nerves rapidly spread into a forming limb bud between days 34 and 36 before large structures form. Nonetheless, it must be remembered that shape shifts continue to occur throughout the pelvis during a person's lifespan. Age, trauma, and illness can be responsible for these changes. Depending on the gender position of birth and aging, each individual's form of the pelvic bone can differ. The identity of the bone may therefore, be established. (Gruss & Schmitt, 2015 ; Warrener, et al., 2011)

1.3 Sex determination

Throughout humans, sexual dimorphism is mostly based on the difference between males and females, while females may give birth. Variations in shape between male and female pelvic, which forensic anthropologists may use to differentiate between the two sexes. The diagnostic techniques used to determine the male or female origin of an unknown bone are usually based on a visual examination of the different parts of the pelvis. These techniques of visual analysis are reliable from 90-95% when employed by an experienced forensic anthropologist. (Bytheway& Ross, 2010)

Nevertheless, it has been shown that postcranial examination can be as precise or reliable as the cranium in sex determination, and it is known that the pelvis is the best absolute predictor of sex. Further work on the postcranial skeleton using 3D techniques is required to help enhance the accuracy of the sexual assessment in forensic and archaeological contexts.

The pelvic work mainly focuses on age transitions, and few studies aim to assess sex metrically. Improving the unique characteristics of sex determinations in the pelvis has the potential to strengthen both contemporary forensic anthropology and bioarchaeological and forensic science (Spradley & Jantz, 2011; Wink, 2014; Berg, 2008)

1.4 Age estimation

Age assessments are a vital component in determining the biological profile of forensic anthropology and adult skeletal remains and can be tested for many gross osteological characteristics reflecting age transition.

According to Bytheway & Ross, (2010), pelvic inlet diameter is growing, the lower portion of the ilium is expanding as is the pubic bone. The angle of larger sciatic notch, pubic width and preauricular sulcus are therefore part of the pelvic bone which makes age estimates most accurate.

On the other hand, Wink (2014), pointed out that, while maturity and senescence the pubic symphysis has regularly observed degenerative changes, making it not only highly accurate as a result of an age assessment, but also common because of the differentiation of changes correlated with age.

1.5 Geometric Morphometric

The pelvis of a woman would be shorter and wider to give birth, whereas the pelvis of a male is generally broader and narrower. Due to the functional differences in the pelvis, some morphological features have developed among the two biological sexes.

These traits are also used to determine an adult's sex as babies do not develop these distinctive features until they have been wholly fused after puberty and bones. The conventional assessment of gender uses a visual analysis of these features to determine the gender of an individual. However, statistics and Figures use mathematical techniques such as geometric morphometry to calculate sex determination. Geometric morphometrics, in particular, is a 3D shape analysis. The approach has been used in biological sciences for many years, but recently was widely used in anthropology. A study using geometric morphometrics varies from age or gender to skeleton components in many aspects. For digitized shape variation data, there are two main methods. Studies found the informative power of geometric morphometrics and how the method can help to further understandings of evolution, shape change, phylogeny, and habitat adaptation.

1.6 Landmarks on Geometric Morphometric

In the geometric morphometric field, landmarks are defined as a specific bone point that can be positioned in any sample and documented in 3D space afterward. Such early landmarks have been chosen by the author based on previous studies, traditional landmarks and other modern landmarks.

New sites were chosen to enhance existing sites and the overall analysis of the design. While collecting data on landmarks, whether collected by means of a digitalised or a camera, it is crucial to decide which type of landmark it is.

According to Perlaza (2014), landmarks can be categorised as Type I, II, or III. Type I landmarks are considered the easiest to locate and consist of a single point on the bone where differences in tissue, such as the suture crossing, are occurring. Type II monuments are known to be maximum curvature points or the most significant muscle attachment, euryon on the cranium being an example of this. Type III features are the most extreme points in the overall structure, often called “posteriormost” points.

Perez, et al.,(2006) have mentioned that a category added to the list in subsequent studies is the establishment of landmarks that are identified as ‘points that correspond to locations specified using a combination of traditional landmarks and geometric information.’ For instance, measuring and using the centre point along a maximum width line as a reference point. Most literature of geometric morphometrics tell which points are used to classify which types of points are most useful, or which points lead to the most error (Marcus, et al., 2000).

1.7 Significance of the study

The study of pelvic bone using geometric morphometric method have been widely used by other countries. However, the literature regarding geometric morphometric on pelvic bone in Malaysia is seldomly founded.

This research can be helpful in estimation and confirmation of the age of living persons that are especially involved in criminal cases and can be useful for the estimation of age of individuals in case of decomposed, commingle and unknown body.

1.8 Research Question

Is it possible to estimate the identity of the pelvic bone with morphometric analysis?

Is the pelvic bone useful to determine the sex and age of an individual?

Is it possible to classify race by pelvic bone?

1.9 Objective

1.9.1 General Objective

To perform geometric morphometrics (GMM) assessments on the lower limb, specifically pelvic bone by age, sex, and race.

1.9.2 Specific Objective

i. To study the possibility to determine sex, age and race based on GMM of the pelvic bone

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of study

Forensic anthropology is one of the disciplines that widely used in homo sapiens study. This discipline consists such as cultural, languages, medical and biologically. One of the disciplines that widely learnt by the scientist in anthropology is forensic anthropology. Forensic anthropology has given a large contribution for human civilisation such as human recognition identification. One of the most ancient techniques widely used in forensic anthropologist is skeletal recognition. In this review, skeletal were determined for sex, race, and age identification.

2.2 Overview of forensic anthropology

Forensic anthropology is defined as physical anthropology applied to the identification of skeletonised human remains in terms of the medicolegal context. Although the current definition of forensic anthropology has increased to include subfields like forensic taphonomy, it remains a primary aim to identify individual human remains. The process of identification starts with the creation of a biological profile or osteobiography.

The procedures for data collection continue with the identification of the remains as human or non-human. After the remains are identified as human, the anthropologist identifies the minimum number of persons and starts collecting information on physical characteristics. The forensic anthropologist gathers data into a biological profile, which is then searched for a list of missing persons. (Holobinko, 2012; Krishan, et al . , 2016).

According to Torimitsu, et al., (2014), forensic anthropology plays a crucial role in the medicolegal investigation of unidentified skeletonised or decomposed human remains. Together with sex, age, and ancestry, stature is a biological characteristic that can be evaluated from the skeleton even many years after death.

Anthropometry is a collection of systemized measuring techniques that quantitatively describe the proportions of the human body and skeleton. Anthropometry is also considered to be a conventional and perhaps the primary method in biological anthropology, but its use in forensic science has a long history. The value of craniometry, somatometry, Throughout human identification, cephalometry and osteometry have been described and the modern term "forensic anthropometry" has been defined (Panjakash, et al., 2019).

Geometric morphometric technique (GMM) is used by forensic anthropologists. The sex, age and race may be defined by placing the marker on each anatomical component or biological specimen, such as bone and feather. This chapter will investigate how a person's demographic profile can be extracted by bones, such as sex, age and race. The history of the morphometric system will also be studied.

2.3 Geometric morphomteric as sex, age, and race detrmination

Geometrical morphometric (GMM) is used for the identification of species, sexually associated dimorphisms, geographically separated identification of new species, colonial reproduction regulation, numerical taxonomy (Tatsuta, et al., 2004). This form, now known as geometric morphometry, was previously called biometrics. Geometric Morphometric Method (GMM) is an anthropologist's widely used method.

Tatsuta, et al.,(2004) also added when a landmark or semi-landmarks are positioned in biological specimens using Cartesian coordinates and the identification of bones is justified by quantifying the statistical process. Metric asset assessments were performed in the years 1950 and 1960. These measurements have been assessed using variance and chi square tests. After 1970, multivariate statistical methods were used to evaluate metric measurements. The name started to be named multivariate morphometry around 1950-1960. Study of morphometry was performed manually before 1970. This is why the process was disturbing. Furthermore, statistical analyzes were often difficult to perform. The approach was not commonly used in empirical research for these reasons.

Traditional morphometry was the method used in these years. Many researchers apply a traditional morphometry approach (Spradley & Jantz, 2016; Yuskel, 2018). GMM has been commonly used over the years because it is a powerful method of statistical and analytical analysis for forms which has become more and more commonly used in anthropological research. The basis of the geometric morphometrics are identifying and quantifying landmarks, defined as "a correspondence point on an object that coincides between and in populations" (Taubadel, et al. 2007). The key advantage of landmark methods over more conventional methods based on interland distances is to retain the complete morphology of the studied specimens and to show consistent graphical results from the resulting shape changes.

According to Krishan, et al . (2016), and Machado, et al . (2018), traditional methods, such as visual methods, used typically for sex recognition, were invented before the modern method was developed. This system can not, however, be as accurate as a modern one. There are currently modern three dimesional sex recognition approaches, which are very easy and functional, and have a high assertiveness index in the different population groups where research has occurred, such as *sexual probabiliste diagnosis* (DSP) and geometric morphometric diagnosis (GMM).

Additionally, Gonzales (2009) has added, by applying geometric morphometric techniques to measure an object's shape, and by using two dimension and three dimension anatomic co-orders to classify the variations between the male and female pelvis. By means of multivariate analysis of landmarks and geometric morphometrics, Gonzales established GMM as a reliable method of measuring pelvic distinctions among men and females.

In addition, Frelat et al.(2012) helps researchers to measure geometry of complex biological shapes, using statistics that take into account the typical shape as well as the variance around it. Geometric morphometrics have been typically applied in this sense to quantify the geometry of complex biological forms in cranial and mandibular morphology. In order to equate this with Figures about the normal shape and the variability around it, applications of post-crane skeletal elements were rare for some anatomical regions, such as morphology of the epiphysis, due to the lack of proper landmarks for the long diaphysis of the bone.

Even accurate in the medicolegal sense is geometric morphometric. Australia was a clear example of this medical-legal background of juvenile cases. The cranial scans were taken from a Picture Archiving and Communication Systems (PACS) for this study with 152 cranial samples from (Noble, et al., 2019). The composition is then determined by standardizing size and reducing location variations by means of a Procrustes superposition.

Noble, et al., (2019) found that, based on the GMM test, males appear to have a higher cranium than females, but the variability range normally varies between the sexes, except for young adults (18 to 19 years old), where almost all males are larger than female. In post-pubertal / adolescent classes (9 to 11, 12 to 14, and 15 to 17 years) nearly half of males are larger than females, while the size of the overlaps between sexes is slightly higher before 9 years of age. Based on this analysis, the age was able to assess cranial landmarks using GMM techniques. This approach was also effective in juvenile situations.

2.3 Geometric morphometric in sex determination

Forensic and bioarchaeologist usually determine sex by examining the quantitative and qualitative features of the human skeleton. In general, pelvis and skulls are the most widely used skeletal elements, but they are many cases absent or fractures. In these circumstances, techniques based on other skeletal elements are required (Manolis, et al., 2009)

Sex determination can be identified by molecular techniques such as DNA analysis, as stated by Safont, et al., (2000). Neverthelss, the determination of sex in ancient bones can be difficult as DNA may not be well preserved in the old bones. long bones common to bones researchers, such as tibia, femur and humerus are long bones commonly used by sex determination researchers (Cavaignac, et al., 2016). However, skull and humerus are the most accurate bones for determining sex (Soni, et al., 2010).

Pelvis followed by a skull is identified as the most accurate component in gendering adult or juvenile skeletal remains that use metris or non metrical approaches. According to Krishan, et al., 2016). Sexing techniques are aimed mainly at the pelvis for demonstrating breeding variations in the bone and the cranium in which the variation I the size and morphology of the sexes is best shown. Including the pelvis and skull, the long bones are skeletal feature most widely studied.

There are also various way to obtain data using 3D digitisers or C devices. The first technique is to collect 3D points, such as the average length of the bone, to measure typical interland distances. The second approach is to record several landmarks in order to carry out a type anlaysis of the feature. This method would record landmarks such as the intercondylar tuber and the maximum anterior part of the proximal tibia's medial condyle. The third procedure uses a mix of foxed points identical to the second method and incorporates evenly spaced points across the surface of the bone.

2.4 Long bone as sexual determination

2.4.1 Tibia have been used as sexual determination

According to Kranioti, et al., (2009) investigated on the tibia for sexual dimorphism. Kranioti stated tibia had been extensively studied and used for the development of sex estimation methods due to its robusticity and its resistance to taphonomic agents. Studies on the tibia on different populations employing different combinations of tibia measurements are presented.

For example, Slaus & Tomicić, (2005) used six variables from the tibia in a Croatian sample providing accuracy of 92%. Lower accuracy rates were achieved by Isçan and Miller-Shaivitz who found that tibia nutrient foramen provided an accuracy of 80% in whites and black individuals from the Terry Collection emphasising the need of population specific standards. Gonzalez, et al., (2009 carried out a metric study on a prehispanic Canarian population obtaining promising results (98% of correct sex classification) using a single variable.

The authors argued that this parameter – tibia breadth – is useful for sexual dimorphism because it maximises muscular development differences between sexes. Similarly, Garcia, (2012) tested tibial circumference at the nutrient foramen parameter on a contemporary Portuguese collection and a medieval sample reaching different levels of correct classification (78% and 90% respectively). Holland, (1986) achieved between 85–100% correct sex determination using five measurements from the proximal tibia on an American collection. Kieser, et al., (1992), also obtained significant results using proximal tibia for sexing Caucasoid and Negroid specimens from the Dart Collection.

Kranioti, et al., (2009) mentioned that the humerus is one of the most robust long bones of the skeleton, which, even in a fragmented state, is likely to be recovered in a forensic case. By investigating humerus bone using Geometric Morphometric method, the sexual dimorphism is seen on the Greek population. Kranioti (2009), found that there is differences between male and female at the distal end. The male configuration is rectangular, while the female configuration is square, probably due to the relatively wider epiphyseal breadth in males. A relatively wider lateral trochlea, accompanied by a relatively smaller capitulum in males with respect to females.

Torimitsu, et al., (2014) reported that the male sacrum was significantly longer than the female sacrum. These results suggest sexual dimorphism of the length of the sacrum and coccyx. Some researchers have reported that sexual dimorphism of stature occurs in every population; males are taller than females because of the later onset of puberty in males. Therefore, in this study the correlation between stature and the length of the sacrum.

Besides tibia, femur were commonly used in sex determination. This hypothesis, which suggested geometric morphometric analysis, revealed sexual dimorphism in the distal femur was confirmed by (Cavaignac, et al., 2016). By analysis traditional and geometric morphometric which using three dimensions (3D) reconstruction of distal femur landmark, Cavaignac confirmed that sex determination was attainable by using geometric morphometric on distal femur.

Zech, et al., (2012) stated, by studying os sacrum by post-mortem CT, the sexual can be determined. Besides long bone like tibia or humerus other bones that were analysed for sex identification was metacarpal bone. By using linear discriminant function equation on metacarpal bone on the Greek population, Manolis found that male metacarpal measurements are significantly larger than those of females. Hence, sex identification may be achieved by analysing the metacarpal bone.

2.5 Forensic anthropolgy in race identification

2.5.1 Evolution of pelvic bone on primate

The pubic symphysis and the auricular surface are two of the most common markers for adult age estimation. The pelvic bone is important for homo sapiens species to support locomotive behaviour. GMM analysis of the acetabulum using newly-defined landmarks and sliding semi-landmarks to evaluate and quantify differences in the shape and size of the hip joint between various extant primate species, and to relate these differences to their respective locomotor repertoires.

By using digital photogrammetric methods to assess the level of variation present in the acetabulum and embed semi-landmark on the pelvic bone and used Proscrutes-based geometric morphometric to gain shape variables for statistical analysis, the locomotor behaviour of hip bone between human and non-human primates such as chimpanzee, pan, pongo, gorilla were analysed. Based on GMM analysis, there is a difference between humans, chimpanzee and gorillas, especially on the acetabular part. This difference is the resulting of locomotor climber behaviour. Surprisingly, although those primates share the same climber behaviour, the acetabulum was different from each other (Millán, et al., 2013; Millan, et al., 2015)

2.5.2 The racial narratives

Some anthropologists have abandoned the idea of racial analysis as quoted by Liebermen and Reynolds “No races exist now or ever did” or “race is a social construct” which suggested that race division was none exist. In 1978, Lieberman and Reynolds conducted an empirical investigation into physical anthropologists’ views on race. They designed their own heuristic that differentiated between “splitters” from elite backgrounds, who believed that races existed, and “lumpers” from marginalised backgrounds, who asserted that races do not exist. Nonetheless, there are many research work has proved that ancestry or race division was not a social construct or political agenda, but racial identification was existed, such as biologist and anthropologist. Based on several anthropologists before, the racial narratives are still in debates.

However, some anthropologists and molecular biologists found that ancestry does exist. Hence, there will differences in molecular context and the bone structure will be different as well. Ancestry is considered one of the more difficult aspects of the biological profile, due in large part to the complicated relationship between skeletal morphology and social constructs.

It should be noted that methods used to estimate ancestry rely on the correlation between skeletal morphology, geographic origin, and an individual’s social race. Race estimation in forensic anthropology generally refers to the classification of an unknown individual’s most likely geographic origin into one or more reference groups using classification statistics and experience-based methods of analysis (Sauer, 1992; Wagner, et al., 2017; Ifekwunigwe, et al., 2017; Dunn, et al., 2020).

2.5.3 Skeletal as race determination

For example, Iscan (1983), stated the femur is the most studied bone of the postcranial skeleton in the assessment of the biological affinity of an individual. Before any measurements were made, the pelvis was articulated with several rubber bands while leaving a small gap between the pubic bones. Iscan also added that pelvis has played a role in ancestry determination.

In 1992, Sauer has stated that skull by studying skull morphology have contributed to study the ancestor identification such as caucasian, negro, mongoloid ancestry. By using geometric morphometric method on the orbital skull and quantify the skull using Canonical variate analysis (CVA), Xing, et al., (2012) found that there is three largest groups of ancestor which are African, Asian, and European. Krüger, et al., (2016) have used long bone such as humerus, femur, tibia and using ANOVA and MANOVA as statistical analysis. The white, coloured and black people were able to be identified. Thus, bones may be used as racial identification.

2.5.4 Pelvis as race determination

Pelvic bone plays a vital role on race identification. Conventional method such as visual technique made race identification was possible. However this method may have error. However, by using recent technology and statistical analysis made race identification much reliable. Discriminant Function Analysis(DFA) and Canonical Variate Analysis(CVA) common statistical method used for race estimation.

For example, by using linear regression analysis on 704 male pubic bone from different racial, Katz & Suchey, (1989) identified the ancestor such as Black, White and Mexican. Aside from that, Katz and Suchey also analysed on how different races were ageing differently were shown on pubic symphyseal patterns. However, the limitation of this analysis because the diet pattern of the respondent was not taken as the variable. Nonetheless, based on this analysis, Katz and Suchey found that it is seen that Blacks and Mexicans with advanced pubic symphyseal patterns tend to have lower ages than Whites.

Using sophisticated software such as FORDISC 2.0, FORDISC 3.1.293, COLIPR 1.5.2 made researchers able to estimate ancestry identification. Using multivariate statistics, particularly discriminant function analysis (DFA) and canonical variates analysis (CVA) the race identification such as African, Eurpean, Afro-Brazillian which are obtained from Forensic Data Bank FDB) are able to be identified. (Urbanová, et al., 2014; Musilová, et al., 2019)

2.6 Forensic anthropology in age dertermination

By using 189 females pubic bones samples were selected. The pubic bone respondent's images whom 40 years and above were taken. This process was repeated, sorting each pelvis using the new definitions. The results included all three phases; the sort was recorded and the pelvis was randomised again. A second seriation was conducted and the results of both analyses were compared. Each pelvis was placed into the same phase assignment except for three individuals, one of which was removed from the analysis due to incomplete pubic symphysis morphology (post-mortem breakage).

According to Suchey-Brooks methods, there is a change that occurred on the pelvic bone especially pubic symphysis, auricular surfaces, and rib ends. Thus, studying the landmark on the pubic bone such as the curvature of foramen obturator ischium the juvenile and adult bones was able to be differentiate (Berg, 2008; Campoa, et al., 2018).Based on Cardini, et al., (2010), the three-dimensional landmark coordinates were analysed using geometric morphometrics. The form of the structure of interest is captured by the Cartesian coordinates of a three-dimensional configuration of anatomical landmarks.

The centroid size of each configuration, a measure of the dispersion of landmarks around their centroid, was computed as the square root of the sum of squared distances of all landmarks from the centroid to study the standard error. Three-dimensional multivariate descriptors of mandibular size and shape, whether age estimation using those data is sex and/or population specific; and validation of the models to estimate their applicability to individuals other than those of the analysis sample. By using linear regression, to predict age using the multivariate descriptors of mandible size and shape, Cardini indicated that mandible were useful for age determination.

2.7 Picture archiving communication system (PACS)

The usage of radiographic imaging in anthropology has been evolved since early 20th century when paleoanthropologist has used x-ray technology to investigate the internal bone structure of the Kapina Neanderthals. The development of radiographic techniques allowed researchers to visualise the internal structure of remains without the requirement for dissection, which importantly is non-destructive to the specimen of interest (whether living or deceased); this was previously unachievable using traditional morphological approaches. Furthermore, studies utilising X-ray technology were less arduous (e.g., time consuming; labour intensive) and thus facilitated research projects that involved a more significant number of specimens than previously possible; this not only generated novel insights but also concurrently increased the quantitative value of the associated research output (Franklin, et al., 2016) .

Franklin also added recent technology widely used Landmarks can be digitally acquired using a microscribe, laser scans, and more recently CT scans of biological structures. Therefore, geometric morphometrics is an essential tool for developing population specific anthropological standards that require constant development and/or refinement over time and space; particularly in relation to the ever increasing mass global movements of people. (Kimmerle, et al., 2008)

Alawi (2016) stated the latest technology widely used in radiography system is Picture Archiving Communication System (PACS) has been adopted as one of the healthcare systems in many countries around the globe. One of the countries which implemented PACS is Kingdom of Saudi Arabia (KSA). The PACS has been implemented and functioning across the KSA's hospitals (85 Radiology PACS/RIS, 10 Cardiac PACS, and 10 Dental PACS) for the last ten years. Today, the PACS has been used at numerous hospitals and the Ministry of Health plans to expand this system into all hospitals of Saudi Arabia. By adopted this system, all radiograph images were kept in one system. Hence, the communication between inter and intra hospital much efficient and safe since not all the radiograph are need to be printed. Besides saving the radiograph printed picture, the physicians, radiologists are able to communicate with each other across the country

As mentioned earlier on Noble's research on juvenile cases, PACS is useful for archiving the radiographic images. The cranial scans were obtained for this study are drawn from a Picture Archiving and Communication Systems (PACS) database maintained by the Department of Health, and which contains patients who presented for clinical cranial evaluation at various Western Australian hospitals between November 2005 and April 2014. Hence, this proves that PACS were able to archive a large number of the image from different healthcare practice. Scientists can interpret and analyse virtually.

2.8 Picture Archiving Communication System in Malaysia

In Malaysia, based on Radiology Information System by Malaysia Ministry of Health in 2006, the Diagnostic Imaging Department will provide diagnostic imaging services as well as certain invasive therapeutic procedures for inpatients, outpatients, and daycare patients in the hospital. These services may also be extended to patients from other clinics and hospitals as per policy of the Ministry of Health. The Department shall provide patient centric and physician centric services such as: provision of efficient, high quality and cost-effective service, ensure maximum consumer satisfaction, provision of continuing professional development to all categories of personnel (MOH,2006).

Archiving media and interpretation media changed from film based to digital imaging, which was considered as a big breakthrough, since 2003 to 2008, where digital image acquisition devices have become more famous than the classic radiology conventional systems. Before picture archiving communication system was exists, the patients were directed from physicians to responsible radiography department. After radiograph images have been taken manually, the image will be interpreted by the radiologist at radiology department. All this process is time consuming and costs more space since all the images will be stored in radiograph image room. By using picture archiving communication system, the physician, radiographer, and radiologist can communicate much easier and less time consuming. Additionally, only small room are required since the image will be stored in digital format (Khaleel, et al., 2018).

2.9 Statistical analysis on Geometric Morphometric

Geometric morphometrics (GM) provides a robust mathematical framework for shape quantification. The application of GMM is beneficial for any research field which includes systematics and evolutionary biology, biostratigraphy, and developmental biology which can aid in identifying shape differences and exploring the causes of intra and inter-specific variation geometric morphometrics analysis.

There are three general styles of morphometrics that are often recognised, distinguished by the nature of data being analysed which are traditional morphometrics, landmark-based geometric morphometric, outline-based geometric morphometric. Traditional morphometrics involves summarising morphology in terms of length measurements, ratios, or angles, that can be investigated either univariate analysis and bivariate analysis. Landmark-based geometric morphometrics involves summarising shape in terms of a landmark configuration, such as Cartesian coordinates, and is inherently multidimensional. Outline-based geometric morphometrics involves summarising the shape of open or closed curves (perimeters), typically without fixed landmarks.

In pelvic analysis, by placed landmarks and sliding semi-landmarks to evaluate and quantify differences in the shape and size of the hip joint between various extant primate species, and to relate these differences to their respective locomotor repertoires. (Webster & Sheets, 2010; Millan, et al., 2015).

There are several methods for superimposing landmark configurations, differing in how and in the degree to which among-configuration differences in location, scale, and size are removed. Partial Procrustes superimposition is the most widely used superimposition method and forms the basis for many subsequent operations in geometric morphometrics. Shape variation among superimposed configurations can be visualised as a scatter plot of landmark coordinates, as vectors of landmark displacement, as a thin-plate spline deformation grid, or through a principal components analysis of landmark coordinates or warp scores (Webster & Sheets, 2010)

There are several statistical analysis that is a part of the GMM techniques such as statistical testing of difference in mean shape between samples using warp scores as variables can be achieved through a standard Hotelling's T2 test, MANOVA, or canonical variates analysis (CVA). Discriminant Function Analyse A nonparametric equivalent to MANOVA or Goodall's F-test can be used in analysis of Procrustes coordinates or Procrustes distance, respectively.

For example, CVA can also be used to determine the confidence with which a priori specimen classification is supported by shape data, and to assign unclassified specimens to pre-defined groups. Along these lines, by using GMM techniques that put landmark or semi-landmark based on Cartesian Coordinates and completes the statistical analysis, the sex, race, and age of pubic bone may be determine.

CHAPTER 3

METHODOLOGY

3.1 Materials and method

This research was conducted by employing several software and application which were utilised in the following order:

a) Picture Archiving Communication System

b) In Vesalius 3.1

c) Meshmixer

c) Institute for Data Analysis and Visualization (IDAV) Landmark

d) Notepad ++

e) MorphoJ

3.2.1 Picture Archiving and Communication Systems (PACS)

The CT Scan image of the lower limb was obtained from previous researcher's data. The code for the research ethic is USM/JEPeM/18050241. The copy of ethical approval is attached in the appendices section. Those who were selected as subjects for this research must have no bone disease or missing limbs. Inclusion criteria include disease that only affected blood circulatory and soft tissue of the lower limb. On the other hand, exclusion criteria include bone disease at bone samples such as osteoporosis, osteosarcoma, bone carcinoma and any bone fractures. All collected data in dicom (*.dcm) file type. These sample images have undergone segmentation of the pelvic bone which may be performed on In Vesalius 3.1 in the next step.

3.2.2 InVesalius 3.1

InVesalius is a free software for the reconstruction of computed tomography and magnetic resonance images. The software is mainly used for rapid prototyping, teaching, forensics, and in the medical field. It is possible to use it on the Microsoft Windows, GNU/Linux and Apple Mac OS X platforms. The software’s main features are the ability to import DICOM or analyse files to export files to the STL, OBJ, and (*.ply) formats, volume rendering, and manual or semiautomatic image segmentation.

InVesalius has been developed since 2001 by Centro de Tecnologica da Informação Renato Archer (CTI), in Brazil. At that time, there was no medical image software in Portuguese that fulfilled the Brazilian hospitals and clinic needs. Therefore, InVesalius came as a proposal of national development with the following goals which are: minimal or null acquisition cost, capability of execution on low-cost personal computers; capability of execution on different operating systems and act as a platform to encourage the use and development of medical images in Brazil (Amorim, et al., 2015).

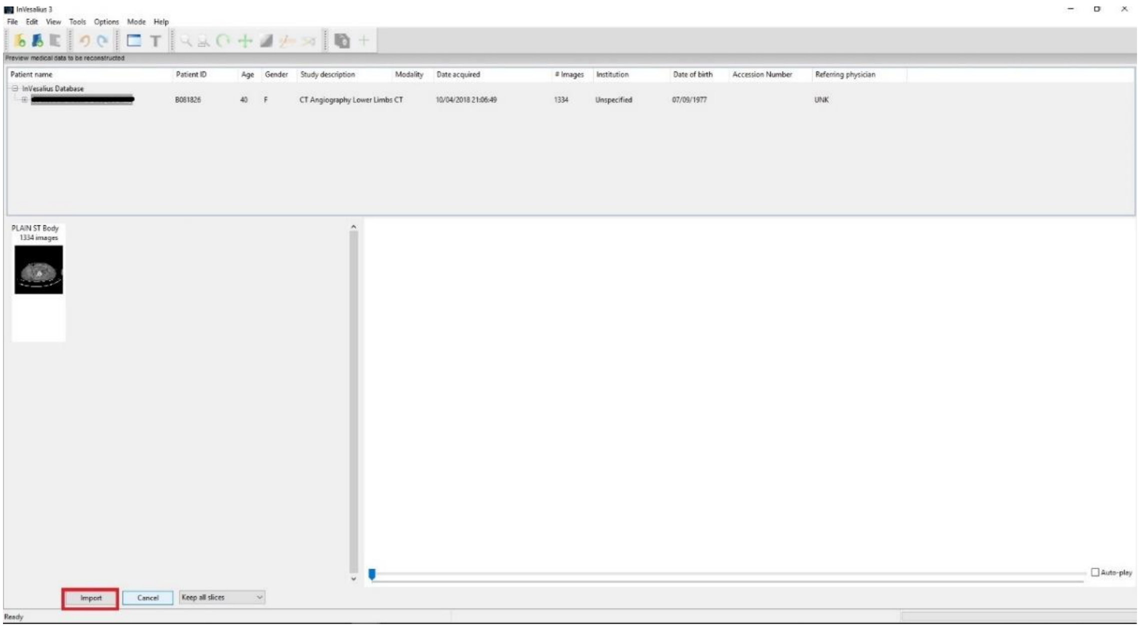

Figure 3.1 The import process of DICOM image

In this research, this InVesalius 3.1 software was downloaded from https://invesalius.github.io/ website.

1. The lower limb image was loaded into InVesalius software by clicking “Import DICOM Images” as shown in Figure 3.1

2. After the lower limb images have been loaded to the window, in the manual threshold column, “bone” was clicked as shown in Figure 3.2. The threshold levels are for enhancing bone density. It can be changed by threshold and manual editing. Each 2D window labeled as axial, sagittal, and coronal slice. Scrolling throughout the widow transversed through the slice of lower limb.

3. After that, by clicked “create surface” the 2D images from axial, coronal, sagittal were merge and convert to 3D images. The 3D images were exported (*.ply) format as shown on Figure 3.3.

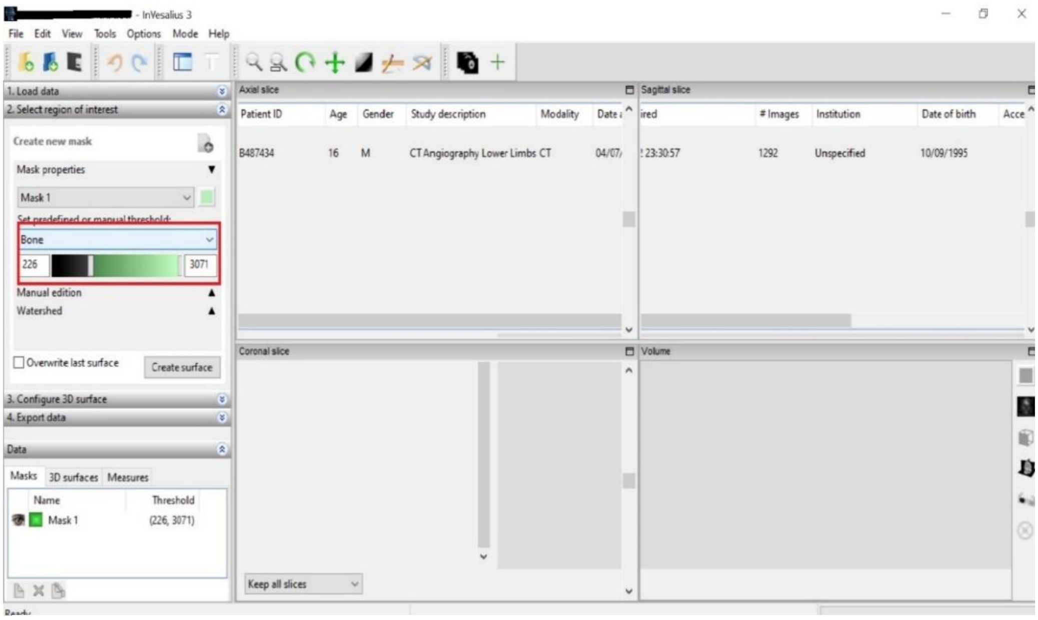

Figure 3.2 By click "create surface" the 3D images will shown