INVESTIGATING ARCHERY STANCE PERFORMANCE BASED ON GEOMETRIC MORPHOMETRICS

by

ERLIZA BINTI ERWIN

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LIST OF ABBREVIATIONS

2D	: Two-dimensional
3D	: Three-dimensional
BEST	: Biomechanically Efficient Shooting Technique
cm	: Centimetre
CT	: Computerised Tomography
df	: Degree of Freedom
GMM	: Geometric Morphometric
GPA	: General Procrustes Analysis
LM	: Landmark
MRI	: Magnetic Resonance Imaging
MS	: Means Square
P	: Parametric
PC	: Principal Component
PCA	: Principal Component Analysis
SS	: Sums of Squares

LIST OF SYMBOLS

%	: Percentage
<	: Less than

ABSTRAK

Morphometrik Geometri (GMM) adalah satu kaedah untuk mengukur sesuatu saiz dan bentuk organisma dengan penggunaan statistik multivariat. Dalam projek ini, cara berdiri para peserta memanah telah diuji dengan analisis morphometrik geometri berdasarkan mercu tanda. Matlamat kajian ini adalah untuk menghubungkaitkan faktor-faktor demografi cara berdiri para peserta memanah dalam kaitan dengan skor. Faktor-faktor yang telah diterokai dalam kajian ini ialah umur, ketinggian, berat, kekuatan tangan dan juga kekuatan kaki dan belakang. Dua kamera telah digunakan untuk merakam video 20 cara berdiri para peserta memanah dan mengambil gambar papan sasaran secara berasingan. Petikan skrin imej pegun cara berdiri para peserta memanah telah dianalisa menggunakan tiga perisian yang sedia ada: tpsUtil, tpsDig2 dan MorphoJ. Keputusan projek menunjukkan bahawa pentaksiran GMM ke atas cara berdiri para peserta memanah berdasarkan kekuatan tangan dan juga kekuatan kaki dan belakang adalah penunjuk yang lebih tepat berbanding faktor skor, umur, ketinggian dan berat. Walaubagaimanapun, tahap signifikan tersebut agak rendah dengan hanya 33.1% untuk kekuatan tangan dan 23.1% untuk kekuatan kaki dan belakang. Keputusan daripada analisa komponen utama mencadangkan jumlah varian lima paksi: PC1, PC2, PC3, PC4 dan PC4 meringkaskan 84.7% daripada perubahan bentuk yang diperhatikan. Sehubungan dengan itu, dapat dirumuskan bahawa GMM boleh digunakan dalam kajian sukan memanah untuk memberi kefahaman yang lebih baik dan maklumat tentang sukan memanah. Ia adalah disyorkan kepada cendekiawan-cendekiawan dan penyelidik-penyelidik untuk menjalankan satu kajian sains sukan dengan menggunakan morphometrik geometri (GMM) sebagai salah satu kaedah analisis

ABSTRACT

Geometric morphometrics (GMM) is a method to quantify the size and shape of organisms with the application of multivariate statistics. In this project, the participants' archery stance was examined by landmark-based GMM analysis. The goal of this study was to correlate demographic factors of participants' archery stance in related to score. The factors that had been explored in the study was age, height, weight, hand grip strength as well as back and leg strength. Two cameras were utilised to record video of 20 participants' archery stance and take picture of the target board, separately. Still screenshots images of participants' archery stance analysed using three available softwares: tpsUtil, tpsDig2 and MorphoJ. The result of this project suggests that GMM assessment of archery stance by hand grip strength as well as back and leg strength are more reliable indicator compared to score, age, height and weight. However, the level of significance is not really high at only 33.1% for hand grip strength and 23.1% for back and leg strength. The results from Principle Component Analysis suggest that the total variance of five axes: PC1, PC2, PC3, PC4 and PC5 summarises 84.7% of the observed shape variation. Therefore, it can be concluded that GMM can be utilised in archery studies as to provide better understanding and information on archery. It is recommended for other scholars or researchers to conduct a study of sport science by employing GMM as their method of analysis.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The Malaysian archery squad has failed to bring back any medals from 2016 Olympic Games which were held in Brazil. The National Archery Association of Malaysia (NAAM) urge the team to rise and bring back glories in upcoming tournaments, that are Sea Games 2017 and 2020 Olympic Games in Tokyo. Therefore, research on archery relevant to the athlete's performance is crucial to increase the performance of the archers.

Archery is a sport which pushes arrows with a bow to the aim or board during shooting (Lee, 2009). Archery techniques vary depending on individuals. The steps of archery according to Edelmann-Nusser *et al.* (2006), archery involves the action of drawing the bow, pulling the arrow to the clicker, setting in this stance and aiming. The archer then releases the shot after pulling the arrow at the end of the aiming phase, which also known as a final pull. Archery shooting techniques can also be described in five phases, which are: bow hold, drawing, full draw, aiming, release and follow-through (Nishizono *et al.*, 2008). These phases are claimed to be a stable sequence of movements and are ideal for research to be done for each phase. World Federal Archery states that the recurve archery techniques comprise 10 steps that are stance, setup, hooking, grip, drawing the bow, anchor, full draw, extending, release and follow through (FITA, 2017). The sequence of the technique is relatively the same, despite the variations ((Stuart and Atha, 1990) in (Lau, 2016)). Some variations can be noticed in the positioning, and different points are emphasized in different methods. These movements can be compared and assessed using a specific system such as a motion analysis system as they are reproducible. Highly-skilled archers are consistent in their sequence of movements in each shot ((Stuart and Atha, 1990) in (Lau, 2016)).

A well-balanced and highly reproducible release during the shooting are the most fundamental parameter in order to achieve a good record in an archery competition (Nishizono *et al.*, 2008). Having a good stance and posture provides better stability in archery (Zulkifli *et al.*, 2014). Stance defines as standing posture of the archer. Strength in the legs is required, and the correct stance can help in maintaining the stability of the archer as well as his body balance while standing for an extended period. A good stance can aid in sustaining stability for a longer time, and hence aiming better at the target board. Therefore, the shots produced by the archer become more consistent and less depressing when the body is stable. The different stages achieved by archers suggest different forms of stance and different weight distribution, depending on the body posture, height and bone structure (Zulkifli *et al.*, 2014).

According to Bookstein (1997), geometric morphometrics (GMM) are termed as the union of geometry and biology. The aim of this method is to quantify the size and shape of organisms with the application of multivariate statistics. These methods are commonly utilised in studies of growth and evolution (Klingenberg, 1996) as well as in studies of the genetic basis of morphological variation (Klingenberg *et al.*, 2001; Weber *et al.*, 1999). Landmark-based geometric morphometric is the most predominant approach in GMM, that is, a set of corresponding points that can be precisely placed on each of the specimens under study (Klingenberg, 2002). Landmarks can be at a suture point where different skull bones, at the intersection of the veins on insect wings, or at the tip of a protrusion such as the angular or coronoid process of a mammalian mandible. These data are the coordinates of these landmarks, which can either be obtained in two dimensions from digital images or located in three dimensions with specialized devices (Dean, 1996) or from computed tomography (Spoor *et al.*, 2000) The variation in the landmark coordinates can be utilised as input for the standard methods of multivariate statistics (Klingenberg, 2002). Bookstein (1997) classified three classes of biological landmarks, which are: discrete juxtapositions of structures or tissues (Type I), maxima of curvature (Type II), or extrema (Type III). This classification concentrates based on the amount of information required to identify or relocate the landmark. The difference between each type of landmark can be explained as follows:

1. Type I landmarks include a junction at which three structures meet.
2. Type II landmarks comprise tips of extrusions and valleys of invaginations. It may also refer to a bulge or other radial phenomenon at some distance from the geometrical boundary under study.
3. Type III landmarks consist of end-points of diameters, centroids, intersections of interlandmark segments, points farthest from such segments, constructions involving perpendiculars or evenly spaced radial intercepts.

The result would not only be presented in tabular presentation but also presented in a graphical form so that they can be explained easily in relation to the geometric and anatomical structure of the part under study. Since geometric morphometrics have not been used widely in studies of sports science specifically archery studies, this study would provide better understanding and information on archery.

1.2 Objectives of study

General objective:

To correlate participants' archery stance and their shooting performance in recurve archery.

Specific objective:

To correlate the demographic factors of participants' archery stance in related to score.

1.3 Hypothesis

H_o: There is no correlation between demographic factors of participants' archery stance and score.

H_a: There is a correlation between demographic factors of participants' archery stance and score.

1.4 Significance of study

This study is emphasised on describing the archery stance based on the participants' age, height, weight, hand grip strength as well as back and leg strength. The findings will propose correct and good stance to be practiced in archery. Furthermore, this study will help to fix the archer's stance, and thus have better accuracy in shooting arrow. This study also helps to promote archery as an excellent sport.

CHAPTER 2

LITERATURE REVIEW

2.1 Archery

Archery is a relatively static sport that required strength and endurance of the upper body, specifically the forearm and shoulder girdle (Mann and Littke, 1989). In the past, archery had been utilised for hunting and combat. Now, it has turned into a competitive sport and recreational activity.

A number of archery disciplines are recognised by World Archery, which are target archery, para archery, field archery, 3D archery, flight and clout archery as well as ski and run archery (Federation, 2014). However, target archery is the most popular and recognisable modern archery. There are two types of bow utilised in international target archery: recurve and compound. Recurve archery competes in the Olympic Games while compound archery is featured at the World Games. This kind of discipline takes place both outdoors and indoors, over a distance of up to 90 metres and utilising the traditional five-colour, 10-ring target (Federation, 2014).

The difference between recurve and compound target archery is based on the distance to the target and the target used. In outdoor target archery, recurve athletes shoot at targets board 70 metres away, while compound athletes shoot 50 metres away from the target board. Target archers shoot at a traditional yellow, red, blue, black and white target that scores 10 for the inner ring and one for the outer ring. The recurve target is 122 cm in diameter with a 10 ring 12.2 cm in diameter each. The compound target is 80 cm in diameter with a 10 ring 8 cm in diameter each. Compound targets only include the yellow, red and blue rings in international competition (see Figure 2.1). Therefore, the size of target mat needed for each target face can be reduced, in order that each athlete has their own target to shoot at. In indoor, both recurve and compound athletes shoot at 18 metres away from targets set. There is a smaller 10 ring, measuring 2 cm in diameter, for compound athletes contrasted with the 4 cm diameter recurve 10 ring. The targets will only include the yellow, red and blue rings and are arranged in vertical groups of three in international competition (see Figure 2.1). Athletes shoot a maximum of one arrow at each target face at any one time (Federation, 2014).

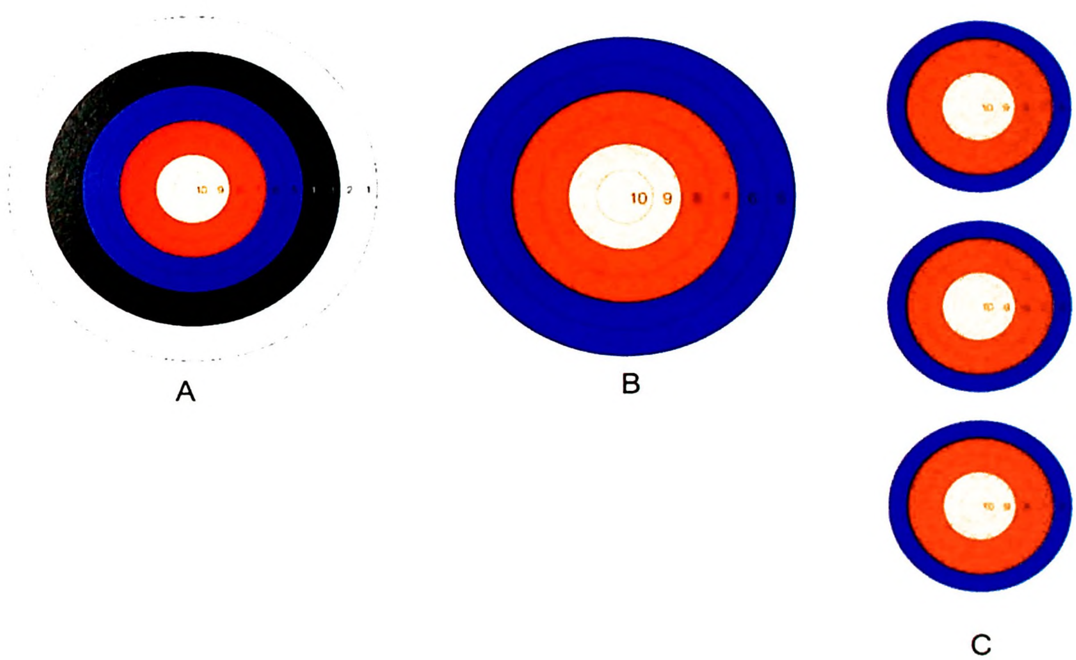

Figure 2. 1 Targets set for recurve target archery (A) and compound target archery (B). Both are used at outdoor. Targets set for both recurve and compound archery (C) at indoor are arranged in vertical groups of three.

Outdoor and indoor target archery comprises individual, team and mixed team competitions at international events (Federation, 2014). Athletes shoot a ranking round that consists of 72 arrows outdoors or 60 arrows indoors, cumulatively scored, to ascertain seedings in their division. The divisions are bowstyle and gender. The athlete in each division who completes with the most points is given the top seed, the athletes with the least the lowest seed. Teams comprise three athletes of the same division, while mixed teams comprise two athletes of the same bowstyle, one of each gender. Both teams and mixed teams usually the top scoring three athletes in qualification, yet team managers may select to substitute athletes. They are ranked for their elimination matches using the total of the individual ranking round scores of their athletes.

Performance in sports is an outcome of physical, physiological, and psychological training, even if other aspects, such as equipment and environment, may affect the performance (Lee, 2009). Training of a sport commonly starts with physical or biomechanical factors, which after that covers physiological training. Physical or biomechanical training involves basic posture, body movements, and motions. The biomechanics principle in archery state that the forces acting on the bones should be maximised while the force acting on the muscles should be minimised so that the injury impact to the archer can be lessened (Zulkifli *et al.*, 2014). The force applied must be more on the bones than on the muscles since the bones do not get worn-out while muscles most indeed become weary.

The application of biomechanics in archery has been very important as it helps in the control of the movement of muscles and in reducing fatigue effects that may probably cause major injuries in the long term. However, there is limited research that had been done on it. A study in Malaysia by Zulkifli *et al.* (2014) showed that biomechanic parameters such as muscle activity, heartbeat, balance and body posture as well as draw force line can influence the archer's performance. Wrong drawing technique can cause muscle fatigue as muscle activity increases. Weight balance must be stabilised to obtain a good result.

Lau (2016) had done a research to compare the effects of two different archery methods on their shooting performances. The methods are participants' method and Biomechanically Efficient Shooting Technique or BEST method. The BEST method has resulted a shooting form approach that maximises the body's strengths and minimises the shot variables (USA Archery, 20016). This method consists of 4 phases and several components. The phases include foundation of shot, shot set-up, execution of shot and recovery. Lau's study has applied Qualysis 3D motion analysis method. It was proven that BEST method proposed by Kisik Lee, South Korean's coach can improve the shooting performance of the participant (Lau, 2016).

A study by Edelmann-Nusser *et al.* (2006) suggested that regular, smooth and steady final pull are crucial to getting a higher score in archery. This study employed a modified NOPTEL system that was fixed to the bow instead of low stabiliser as well as clicker with strain gauges replacing the archers' clickers. The former was utilised to examine the motion of the bow and the latter was utilised to measure alterations in draw-length. Both are simple devices and often utilised in the training of German Junior National Team.

Martin and Heise (1992) had done a study to evaluate the effects of skill level and fatigue on bow grip force distribution. This study was conducted as archery instructors suggested that changes in force distribution between hand and bow grip could affect the archer's performance. However, this study proved that there was no correlation between grip force distribution, arrow position and performance. The association between vertical as well as horizontal force distribution and arrow position was generally poor.

A study by Humaid (2014) in Indonesia showed that there was a direct influence of arm muscle strength and pull length to archery technique. This study also proved that arm muscle strength, pull length and archery technique can give positive effect to archery performance. Therefore, Humaid proposed the coaches to improve archery achievement pertaining to body anthropometry and development of physical components.

2.2 Geometric morphometrics

Morphometrics is the quantitative study of biological shape, shape variation, and covariation of shape by means of other biotic or abiotic variables or factors (Webster and Sheets, 2010). This quantification proposes more rigor into the description of and comparison between morphologies. Therefore, morphometric techniques aid any research field depending upon comparative morphology which comprises systematics and evolutionary biology, biostratigraphy and developmental biology.

Geometric morphometric is an alternative method to the study of shape that denoted a radical shift in the way the shapes of anatomical structures were quantified and analysed (Adams *et al.*, 2013). This shift occurs since much of the 20th century morphometric analyses encountered certain shortcomings limited the biological interpretations that are possible with these methods. For instance, the generation of graphical representations of shape and shape changes is rarely possible as the geometric relationships among variables are usually not preserved in the measurements taken (Strauss and Bookstein, 1982). Geometric morphometric acquires and retains the geometry of the morphological structures of interest throughout the analyses (Adams *et al.*, 2013). This approach commonly utilizes primarily several types of data to quantify shape, that are landmark coordinates, outline curves, and surfaces. Owing to this paradigm shift, landmark-based geometric morphometrics (GMM) offers a powerful technique for the study of shape variation and the identification of its causes. Furthermore, these methods are progressively utilised to quantify anatomical shapes in an extensive range of scientific disciplines.

According to Webster and Sheets (2010), there are three general kinds of morphometrics that are classified by the nature of data being analysed. The classification can be described as follows:

1. *Traditional morphometrics* includes summarizing morphology in terms of length measurements, ratios, or angles, that can be studied individually (univariate analyses) or several at a time (bivariate and multivariate analyses).
2. *Landmark-based geometric morphometrics* includes summarizing shape in terms of a landmark configuration and is integrally multidimensional.
3. *Outline-based geometric morphometrics* encompasses summarizing the shape of open or closed curves (perimeters), commonly without field landmarks (Webster and Sheets, 2010).

Geometric morphometric data comprises 2D or 3D Cartesian landmark coordinates that relative to some randomly chosen origin and axes (Webster and Sheets, 2010). Landmarks are points of correspondence on each sample that correspond between and within populations or, equally, biologically homologous anatomical loci identifiable on all specimens in the study (Bookstein, 1997; Dryden and Mardia, 1998). Several factors must be considered when determining which and how many landmarks to incorporate in a study (Webster and Sheets, 2010). Firstly, by definition, each landmark must be a homologous anatomical locus recognizable on each sample in the study. Next, landmark configurations must be chosen to provide a sufficient summary of morphology. Landmarks must be steadily digitisable, for instance, they are constantly replicable with a high level of accuracy. Landmarks also should be coplanar in 2D data. Lastly, landmarks must have preserved topological positions comparative to other landmarks.

Two-dimensional landmark coordinates can be obtained from a digital image of a specimen utilising free software such as tpsDig, ImageJ, or ScionImage. Extracting 3D landmark coordinates will be varied in terms of the technique and cost depending on the size of the specimen. Small specimens utilised Reflex measurement microscopes, while large specimens may utilise 3D scanners, MicroScribe digitisers, and MRI or CT scans. The quality of the specimen and/or photograph is important and easily overlooked issue as these will decide the quality of the final data. The quality of the specimen and/or photograph must be as high as possible prior to digitising the landmarks. Depending on the study organism, this may involve specimen cleaning such as removal of rock matrix, whitening or sometimes preceded by blackening, careful mounting, illumination, and image shooting. Image processing software such as Adobe Photoshop can aid in improving a digital image, but will be of partial use if the image is originally out-of-focus or poorly illuminated (Webster and Sheets, 2010).

A generalized Procrustes analysis is utilised to superimpose the configurations of landmarks in all samples to a common coordinate system as well as to create a set of shape variables (Adams *et al.*, 2013). This least-squares process translates all specimens to the origin, scales them to unit centroid size and rotates them to minimise the total sums-of-squares deviations of the landmark coordinates from all specimens to the average configuration. After superimposition, the aligned Procrustes shape coordinates explains the location of each specimen in a curved space related to Kendall's shape space (Rohlf, 1999; Slice, 2001). These are normally projected orthogonally into a linear tangent space generating Kendall's tangent space coordinates (Dryden and Mardia, 1998) on which multivariate analyses of shape variation are then performed.

Multivariate statistical methods are performed to test biological hypotheses (Adams *et al.*, 2013). For example, shape differences among groups can be examined utilising Hotelling's T^2 or multivariate analysis of variance (MANOVA), while patterns of covariation between shape and other continuous variables can be identified utilizing multivariate regression or partial least squares (Rohlf and Corti, 2000). Finally, graphical methods are utilised to visualize patterns of shape variation and help descriptions of shape changes (Adams *et al.*, 2013). Here, ordination methods such as principal components analysis (PCA) produce scatterplots signifying the dispersion of shapes in tangent space, while thin-plate spline transformation grids can offer a visual description of the shape differences between objects.

2.3 Software

2.3.1 tpsUtil

The first software to apply on data collected is tpsUtil. This software is a combination of many specialized utility programs that needed when carrying out morphometric studies. The operations include such as change file formats, delete or reorder landmarks, delete or reorder specimens, split or combine files, and change file formats. A normal use of tpsUtil is to build the initial .tps file that is utilised as input to the tpsDig2 software (Rohlf, 2015a).

The programs use the .tps file format designed for bearing the 2D and 3D coordinates of landmark points as well as coordinates of points along curves and entire outlines. The landmark coordinates can also be saved as matrices utilising the .nts (NTSYSpc) file format. These are all plain ASCII text files than can be explored and modified using other software such as the Windows Notepad.

2.3.2 tpsDig2

This software is employed to digitise the coordinates of landmarks for a variety of 2D image formats (Rohlf, 2015a). The intended use of the software is to begin with a .tps file created automatically in the tpsUtil program that contains lines with "LM=0" and "IMAGE=xxx" (where "xxx" is the name of an image file) for all the specimens in a study. After loading the file, one can then go through the images by pressing the red left and right arrow buttons. TpsDig2 is an update of TpsDig. The update was required for compatibility with high-resolution image files that are currently used. The program can also be employed to measure distances, angles, and areas.

2.3.3 MorphoJ

The MorphoJ software is created based on geometric morphometric approach and intends to offer a flexible and accessible program for a wide range of morphometric analyses for two- or three-dimensional landmark data. It aims to provide a single, integrated environment for geometric morphometrics so that one can focus on the biological and statistical aspects of the analyses. It also executes the standard range of multivariate techniques that are broadly employed in geometric morphometrics as well as several more specialized or newer methods (Klingenberg, 2011).

Raw landmark data from tab- or comma-delimited text files or from several of the customary file formats utilised in other morphometric software: the TPS series, NTSYSpc (Rohlf, 2015a) and Morphologika (O'Higgins and Jones, 1998) can be imported by MorphoJ. Data as tab-delimited text files can be exported by MorphoJ, which can simply be imported into various spreadsheet or statistics programs (Klingenberg, 2011). Furthermore, MorphoJ can import additional information in the form of categorical data as "classifiers" and continuous variables as "covariates". Thus, making it available for morphometric analyses.

According to Dryden and Mardia (1998), the first step in a morphometric analysis after importing landmark data in MorphoJ is to extract shape information from the data with a Procrustes superimposition. This procedure separates size and shape as well as projecting shape coordinates onto the Euclidean space tangent to the Procrustes shape space, which yields a new set of shape variables that can be utilised in further analyses (Viscosi and Cardini, 2011). The projection is conducted since standard statistical methods such as regression, analysis of variance and many others usually need data to be in a flat Euclidean space. Information on the size of the landmark configuration is maintained in the dataset and accessible for following analyses (Dryden and Mardia, 1998).

MorphoJ provides several techniques that can be utilised to study the aspect of covariation of shape with other types of variables (Klingenberg, 2011). Multivariate regression analysis can be employed for evaluating allometry or other associations between variables, such as shape changes over time, which can be analysed by regressing shape on size or on time (Drake and Klingenberg, 2008; Monteiro, 1999). Partial least-squares analysis is another technique to study the relationships between sets of variables and can be utilised in aspects such as ecomorphology (Adams and Rohlf, 2000) or morphological integration (Klingenberg *et al.*, 2001; Klingenberg and Zaklan, 2000).

Another method is PCA. It aims to study the key features of shape variation in a sample and as an ordination analysis for examining the arrangement of specimens in morphospace (Klingenberg, 2011). It also can be utilised to cut a large set of variables to a few dimensions that embody most of the variation in the data (Mitteroecker and Gunz, 2009). It is computed by an eigendecomposition of the sample covariance matrix and is a rigid rotation of the data retaining the Procrustes distances among the specimens. Principal component scores are the projections of the shapes onto the low-dimensional space spanned by the eigenvectors that comprise the weightings for the linear combinations of the original variables and can be viewed as actual shape deformations.

It is possible to calculate measurement error relative to the effects of biological interest if the user has digitised specimens repeatedly by using Procrustes ANOVA (Klingenberg *et al.*, 2002). It is mostly significant if a study is concentrating on subtle effects, such as variation within populations or left-right (Klingenberg, 2011). The Procrustes ANOVA also was devised for studies of asymmetry in bilateral symmetric structures (Klingenberg *et al.*, 2002)

MorphoJ offers diverse types of graphical outputs, including scatter plots and other standard types of graphs to visualise statistical results (Figure 2.2). Furthermore, it offers numerous types of graphs for visualizing shape changes associated with the statistical results, including transformation grids (Figure 2.3) or warped outline drawings (Figure 2.4) of the structure under the study of two-dimensional data (Klingenberg, 2011). “Lollipop” graph (Figure 2.5) is also provided in MorphoJ to show the relative differences between two specimens utilising displacement vectors. Displacement vectors are arrows drawn between a landmark in a beginning shape and the same landmark in a target shape (Viscosi and Cardini, 2011).

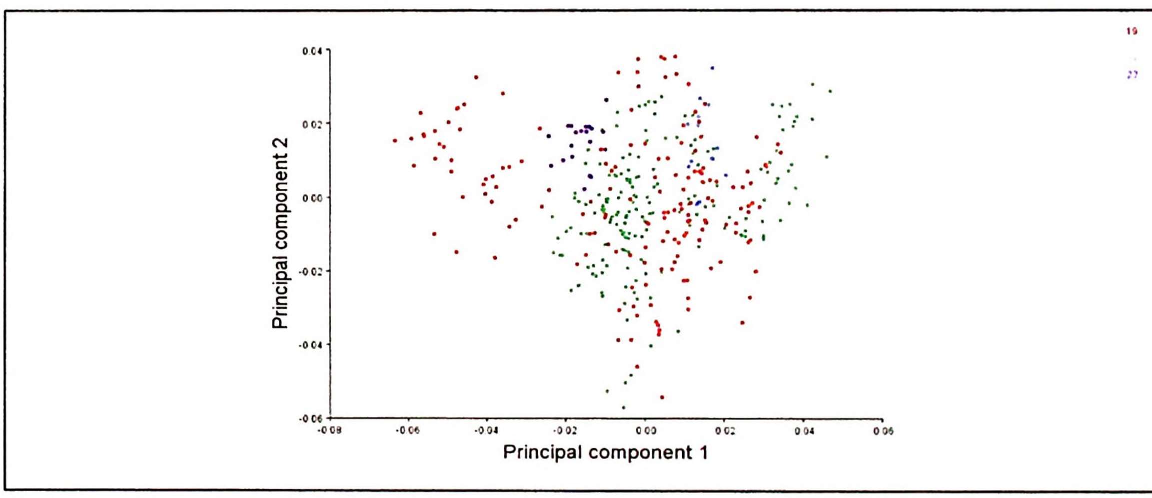

Figure 2. 2 A scatter plot of principal component scores

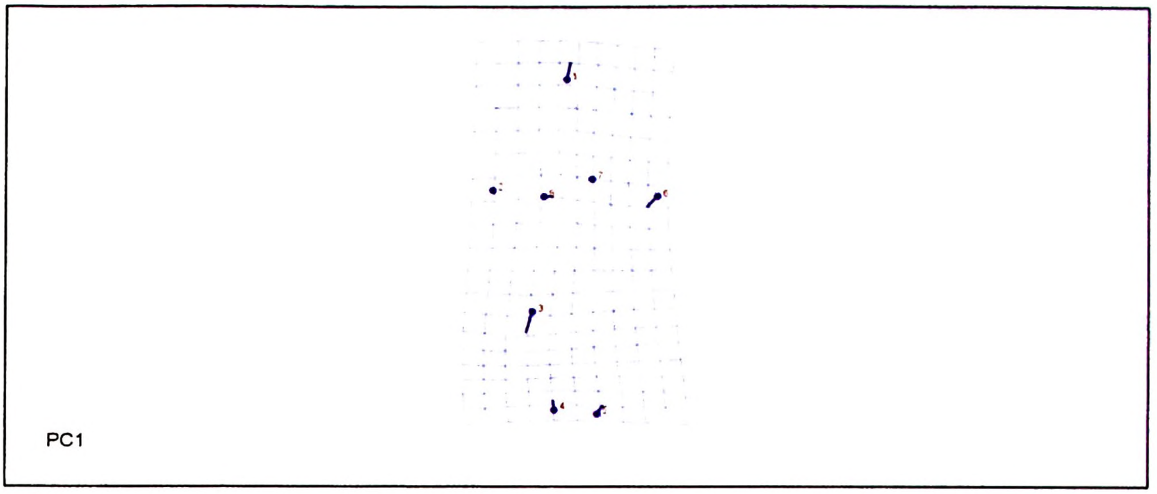

Figure 2. 3 A transformation grid for visualizing a shape change

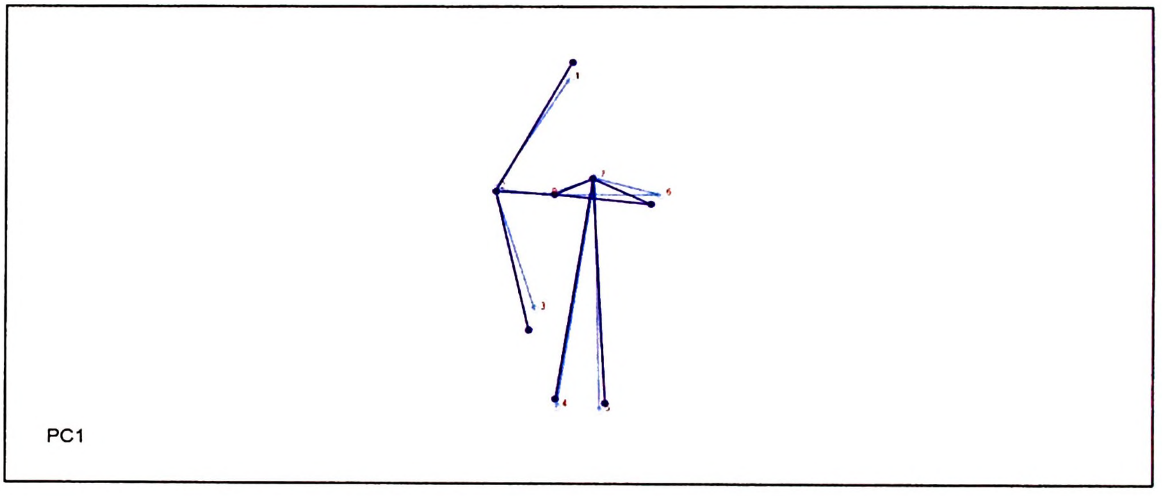

Figure 2. 4 Warped outline drawing representing the shape change

Figure 2. 5 "Lollipop" graph that shows shifts of landmarks positions by lines or arrows

2.4 Past Studies on GMM

Insect wings commonly become the subject of geometric morphometric analysis in the past as they are specifically attractive because they can be treated with biological realism in only two dimensions (Sadeghi *et al.*, 2009). Klingenberg and Zaklan (2000) explained the integration in the wing of *Drosophila melanogaster* in the study. They focused on the hypothesis that the anterior and posterior wing compartments are separate developmental units that differ independently. The hypothesis was evaluated by the framework of landmark-based geometric morphometrics and partial least-square method. The results indicate that the anterior and posterior compartments are not distinct units of variation, but that the covariation between compartments is adequate to account for nearly all the variation throughout the entire wing.

Geometric morphometric on the Old-World screwworm (OWS) fly, *Chrysomya bezziana* (Diptera: Calliphoridae) had been conducted by Hall *et al.* (2014). The result of the study showed a constant and statistically significant difference exists between landmark configurations originated from wings of pinned specimens and those removed from the body and mounted on slides. It also illustrated a highly statistical significant sexual dimorphism in wing morphometry and difference in wing morphometry between populations of the OWS fly from some regions in Africa and Asia. Therefore, this study proved that wing morphometry can aid in the identification of the geographical origin and complement molecular diagnostics.

The paper by Nuñez and Liria (2016) described the study of geometric morphometrics on cephalopharyngeal skeletons from *Chrysomya albiceps*, *C. megacephala* and *Lucilia cuprina.* These blowflies (Diptera: Calliphoridae) are significant in medical and forensic since some species are responsible for myiasis and immature stages of several species feed on corpses and show a preference for certain stages of decomposition. Thus, the correct taxonomic determination is an important characteristic for a medical or forensic investigation. The study was conducted to analyse the variations on cephalopharyngeal morphometrics and to assist the identification of forensic immature flies. It was found that there were differences in the cepahalopharyngeal shape of three blowfly species that could be beneficial for taxonomic identification.

Sadeghi *et al.* (2009) studied the *Chrysomya splendens* to discriminate populations within the species and to observe whether this has implications at a taxonomic level. This study used landmark-based geometric morphometrics method to quantify and analyse wing morphological features in ten European and Anatolian *C. splendens* populations. The result showed that overall wing shape was significantly different between populations, but the results were only partially compatible with taxonomic studies based on wing spot size. All populations showed difference in wing shape regardless of wing spot size.

Apart from the studies of flies, geometric morphometrics also had been incorporated in the studies of human skeletal biology, in both physical and forensic anthropology. Franklin *et al.* (2007) investigated a study on mandible to discriminate immature individuals by sex. In the study, the three-dimensional data were analysed using the shape analysis software *morphologika*. The result showed that the subadult mandible was not dimorphic and the sex determination from the subadult mandible would probably viable from puberty.

CHAPTER 3

METHODOLOGY

This project was conducted by employing few protocols and software which were utilised in the following order:

a) Recruitment of the participants
b) Measuring hand grip strength and back and leg strength
c) Video recording and image capturing
d) Image Archiving
e) Adobe Photoshop (Adobe, 2012)
f) tpsUtil ver. 1.72 (Rohlf, 2015b)
g) tpsDig2 ver. 2.29 (Rohlf, 2005)
h) Notepad++ (Ho, 2011)
i) MorphoJ (Klingenberg, 2011)

3.1 Recruitment of participants

Participants involve in this study are novice archers, which mean that they are not professional nor representing university or state for major competition. A total of 20 participants from Health Campus, Universiti Sains Malaysia were participated in this study. The participants were required to join the introduction session which was held three weeks prior to data collection. In this session, all the participants were briefed regarding to this research and went through familiarisation session. The familiarisation session involved the learning of archery steps and training to have correct stance. They must pass all the requirements to master the basic skills in archery by the coach.

Demographics of the participants such as sex, age, archery experience, and education background are obtained. The demographic form also included the record of weight, height, hand grip and back and leg strength test. The participants' demographic profile as well as their scores are shown in Appendix 2. Multiple regression analysis was performed based on the demographic data where dependant variable is the archery score and independent variables are weight, height, hand grip strength and back and leg strength.

3.2 Measuring hand grip strength and back and leg strength

The purpose of hand grip strength test is to measure the maximum isometric strength of the hand and forearm muscles of the participants. The procedure began as the participants held the dynamometer in their dominant hand, with the arm positioned at a right angle while the elbow placed by the side of the body. The handle of the dynamometer was adjusted if necessary. The base should be rested on the heel of the palm, while the handle should be rested on the middle of four fingers. When ready, the participants squeezed the dynamometer with maximum isometric effort and maintained for about 5 seconds. Any body movement was not allowed. A total of three trials had been done and the highest reading were taken. The participants were encouraged to give maximum effort during the test.

Back and leg strength test is performed to measure participants' back and leg strength, specifically the contraction of isometric muscle when force is applied to a static object. In the procedure, the dial was reset to zero before the start. Participants stood upright on the base of the dynamometer with feet and shoulder wide apart. Arms were hanged straight down to hold the centre of the bar with both hands. The chain was adjusted so that the knees were bent at approximately 110 degrees. In this position, their back should be bent slightly forward at the hips, their head should be held upright, and they should look straight ahead. Without bending their back, the participants had to pull as hard as possible on the chain and try to straighten their legs and arms. The participants were required to pull against the weight steadily without jerky movements and kept the feet flat on the base of the dynamometer. Three trials had been done and the highest reading were taken. The participants were encouraged to give their maximum effort during the test.

3.3 Video recording and image capturing

The archery performance was conducted from 29th of November 2016 to 3rd of December 2016 at Sport Science Laboratory, Exercise and Sport Science, School of Health Sciences, Universiti Sains Malaysia by Sport Science students who were also conducting their data collection. Volunteers were assigned to record video of the participants making their shot and capture image of the scoreboard. The setup in Sport Science Laboratory is as follow: