CORRELATES OF NON-CLINICAL FACIAL ASYMMETRY AND FACIAL SEXUAL DIMORPHISM IN A SUB-SAHARAN AFRICAN POPULATION

By

Anas Ibrahim Yahaya

(MBBS, M.Sc., Anatomy)

A thesis submitted in part fulfilment for the award of the Degree of Doctor of Philosophy (PhD) of Biological Anthropology

University College London

(UCL)

JUNE 2015

CERTIFICATION

I, Anas Ibrahim Yahaya confirm that the work here presented in this thesis is my own original research, and where information is derived from other work, I confirm that this has been referenced in the thesis.

DEDICATION

This thesis is dedicated to my beloved wife Mami (Khadijah) who I always hold with high esteem, and to my lovely children: Sumayya, Hisham, Fatima and Abdul-Azeez, who spent sleepless nights to pray for my success and were always in my support in the moments when there was no one to answer my queries. Words could not express how grateful I am, in fact I am fully indebted to you all.

I dedicate this thesis to my late daughter, Fatima (senior) who died 8 weeks after birth from Patau's Syndrome (Trisomy 13) during the course of my M.Sc., educational struggles.

I also dedicate this thesis to my dear mother Hajiya Fatima Aliyu whose endless prayers and blessings on me put me through success, to my father Alhaji Ibrahim Yahaya who was the source of my education and good moral up-bringing and to my brothers who have always been prayerful.

I also dedicate this to the participants from the two villages in Zaria (GARU and DAN-BAMI), Kaduna State, and to those participants of the three Nigerian institutions: Bayero University, North-West University and Aminu Kano College of Islamic and Legal Studies all in Kano, many thanks to all.

ACKNOWLEDGEMENTS

I would like to express my sincere and special appreciation and gratitude to my major supervisor Dr Christophe Soligo, for his excellent and tireless guidance, advice, support, caring and patience for almost four years, you have indeed been a great mentor for me. Your words of encouragements in my research years and seeing me to grow as a researcher in the field of Biological anthropology are priceless. I would also like to thank Professor Ruth Mace, who despite her tight schedules was able to read and contribute to the thesis as a second supervisor, your contributions in making the study a success were fully appreciated. I would never forget Dr Matt Skinner who in his presence at Aiello lab, always gave words of encouragement, advice and support, thank you very much for that. Many thanks to Dr Lucio Vinicius whose door was always open for me to tap his vast statistics knowledge, you are indeed great in statistics and your support and guidance in the analyses of my data were huge and fully acknowledged. I will never forget Anthropology department and its staff especially the head of department, Professor Susanne Kuechler by making all necessary instruments available and financial support for the data collection trip, your leadership is mentoring, I all thank you. Big thanks to the University College London and its management team for giving me an opportunity to come and study in your one of the best Universities not only in the United Kingdom but also in the world. Thanks to my PhD colleagues in the lab, Anna Barros (PhD), Katharine Balolia (PhD), Kathleen, Gemma and Josephine.

I must specially thank my able vice chancellor of Bayero University Kano, Professor Abubakar Adamu Rasheed who administratively approved my sponsorship and fellowship without any hesitation. You are a father, and a mentor, your assistance is highly appreciated. Thanks to the then Dean, now the provost of the College of Health Sciences Professor Abdul-Razaq Habib and other staff of Bayero University management as well as the TETFUND scholarship committee and staff for their support.

I must knowledge the approval to conduct the study from the vice chancellor of the North-West University and great role played by my friend the student affairs secretary of the University, Mallam Nasiru Maikano Abdullahi. In a similar note, the approval by the principal of the Aminu Kano College of Islamic and Legal Studies Dr Garba Shehu and the supportive role of his student affairs secretary, Mallam Faruk and his assistant Mallam Aminu, are well appreciated.

I would like to also acknowledge and appreciate the immense support given by my father-in-law Professor Abdu Yahaya and his wife: my mother-in-law Hajiya Amina all of which showed concern and support in my career. I also acknowledge the greater role played by my close friends during my study, specifically, Drs Muhammad Sagir Saleh, Abdullahi Abdu Baffa, Magaji Garba Taura, Idris Sulaiman, Abdussalam Abubakar Salisu, Isyaku Ibrahim Indabawa. To my colleagues in my department (of Anatomy: Bayero University Kano) who assisted me in seeing the data collection to success, I say bravo and many thanks, these are: Mallam Lawan Adamu, Mallam Idris Abdu Tela, Mallam Saadu Datti, Dr Abdullahi Asuku Yusuf, and Dr Musa Habib Modibbo. Those who made my stay in England so comfortable and lively are not forgotten especially: Drs Ali Abdullahi Farar-Hula Bichi, Nasiruddeen Dan-Baba Bauchi and Mallam Salisu

Abubakar Mai-Wada including my Ghanian friend Mallam Sulaiman and his family.

Many thanks to my brothers and sisters, my cousins, my other friends and relatives as well as neighbours who assisted in one way or another.

Finally, special thanks to almighty Allah for letting me through all the difficulties encountered and made me what I am today, I have experienced Your guidance day by day and without You I will be become nothing!

ABSTRACT

A substantial body of literature has reported on correlates of facial symmetry and facial masculinity/femininity including the role these two traits play in human mate choice. However, major gaps persist, with nearly all data originating from Western industrialised populations, and results remaining largely equivocal when compared across studies. This thesis has two parts: the 1st part sets out to explore if human variation in measures of socioeconomic and health status is reflected in variation in facial asymmetry as a measure of developmental stability, or reflected in variation in facial masculinity/femininity as a measure of facial sexual dimorphism. The faces of 426 participants (215 males, 211 females) from the Hausa ethnic group of northern Nigeria were scanned using a 3D surface laser scanner. This population could potentially provide greater variation in developmental and other environmental factors than studies based on Western industrialised populations. Facial asymmetry and masculinity data were generated from the resulting virtual 3D models, individual biometric data were recorded, and socioeconomic and past medical history data were acquired through questionnaires. For the 2nd part of the thesis, 179 raters (98 males, 81 females) were recruited in order to determine their perceptions and judgements of standardised facial images with different levels of asymmetry and masculinity/femininity using questionnaires.

Data were analysed using bivariate and multivariate methods. Significant correlates of whole face asymmetry included age, body height, whole face surface area (WFSA), education and diastolic blood pressure (BP). Significant correlates of asymmetry in the eye region alone included weight, sex, body mass

index (BMI), and diastolic BP. Significant correlates of facial masculinity/femininity included body height, number of siblings, income, and total disease loads (TOTDX) in females, and WFSA, occupation and TOTDX in males. In the 2nd part of the study, individuals with higher facial symmetry and facial femininity were perceived as more attractive, more suitable as marriage partners and more caring, whereas less symmetrical and more masculine individuals were perceived as more aggressive.

Although the amount of variation explained by statistically significant correlates was routinely low, the results of this study are consistent with an evolutionary psychological perspective on the link between physical attractiveness, health and environment. The study can also conclusively assert that facial symmetry or masculinity preferences were not just dependent on single, but rather on multiple facial features; thus the study supports that physical attractiveness is not just an arbitrary social construct, but at least in part a cue to general health and related to environmental context.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

Chapter 1 : GENERAL INTRODUCTION

1.1 Face as a biological source of information

Although facial morphology in humans is, arguably, one of the most important aspects of our morphology, as it provides the medium for visual communication, recognition, identity, and mood of an individual (Mitra and Savvides, 2006, Mitra *et al.*, 2007), there has not been much recent research on the facial morphology of sub-Saharan populations. Specifically, the face is also thought to be particularly important in mate selection (Grammer and Thornhill, 1994, Peters *et al.*, 2007, Currie and Little, 2009), through the evaluation of a potential mate's general state of health and through the assessment of sex-specific variation in morphology, both of which may correlate with fertility (Grammer *et al.*, 2003, Rhodes, 2006, Koscinski, 2007, Soler *et al.*, 2014). However, specific influence of facial attractiveness on individual fitness has remained difficult to demonstrate with even recent studies both showing (Hill and Hurtado, 1996, Jokela, 2009, Pfluger *et al.*, 2012) and failing to establish (Pawlowski *et al.*, 2008, Silva *et al.*, 2012) a link between facial attractiveness and fertility.

1.2 Facial asymmetry

Although the anatomical structures of most animals indicate an overall bilateral symmetry, minor variations in terms of size or position of internal organs between the two sides of the mid-sagittal plane are present. These variations are called asymmetries, which can be non-clinical or clinical [see (Palmer, 1993)] and can occur everywhere in the body of an individual including the face.

Based on the actual definition in the Stedman's Medical Dictionary, asymmetry is "any deviation from normal or difference in size or relationship between two sides of the body"

Facial asymmetry (WFACE) is therefore here defined as: the variation between sides in terms of size and shape or where one side is larger than the other [see (Smith, 2010)]. However, the degree of left-right differences can vary considerably between healthy individuals (Farkas and Cheung, 1981, Sackheim, 1985, Peck *et al.*, 1991), or between sexes (Ercan *et al.*, 2008, Smith, 2010).

Hundreds of years back, bilateral facial symmetry was regarded as the normal structural characteristic as depicted by the paintings of Leonardo da Vinci and Albrecht Dürer and these authors are therefore regarded as the originators of the classical concept of facial symmetry [reviewed in (Naini and Gill, 2006) and (Smith, 2011)]. But many centuries after the depiction of facial symmetry, mild to moderate craniofacial asymmetries were then revealed amongst the sculptors' creations of early Greek statuary by artist Hasse in 1887 [see (Brionne *et al.*, 2013)]. Since then, many scientists in the field of anatomy, anthropology, biology, psychology, medicine, and other related fields, have indicated great interest to investigate asymmetry of body form, function, and proportions in both animals and humans.

WFACE, like any other asymmetry may result from genetic or environmental perturbations during developmental processes. The clinical type of WFACE, which is of clinical relevance, results from genetic insults (e.g. mutations) such as observed in individuals born with gross birth defects (Rasmuson, 1960) or minor anomalies (Hoyme, 1993).

The non-clinical type of WFACE, which is the subject of the present study, exists in all faces, and so far, perfect symmetry has not been revealed in human faces [e.g., (Ferrario *et al.*, 1994, Ercan *et al.*, 2008, Primozic *et al.*, 2012, Pound *et al.*, 2014)], including those with the most beautiful faces (Peck *et al.*, 1991, Zaidel and Cohen, 2005, Zaidel and Hessamian, 2010). Such mild WFACE is normal (Anubhav and Brijesh, 2014), and people are not aware of its existence, as it does not present unpleasantly (Ferrario *et al.*, 1995, Ferrario *et al.*, 2001). It has been suggested to remain stable during an individual's lifetime, without any tendency to increase or decrease with growth in the pre-pubertal period [e.g., (Ferrario *et al.*, 2001, Primozic *et al.*, 2012)]. In some studies, the right side is shown to be larger than the left (Burke, 1971, Peck *et al.*, 1991, Ferrario *et al.*, 1993a, Farkas and Cheung, 1981), but the opposite is shown in others (Burke, 1971, Previc, 1991, Ercan *et al.*, 2008). Studies have shown that the lower part of the face is commonly more asymmetric than the upper (Cheong, 2011, Primozic *et al.*, 2012).

In the literature, three types of asymmetry have been defined: Fluctuating asymmetry (FA), Directional asymmetry (DA), and Antisymmetry (AS) [see (Valen, 1962)]. WFACE mostly represents FA, and an increased level of FA is thought to indicate exposure to various environmental stresses during ontogeny (Parsons, 1990, Parsons, 1992, Palmer, 1996b). Consequently, FA is considered to be an index of developmental stability (Palmer and Strobeck, 1992, Wilson and Manning, 1996a, Palmer and Strobeck, 1997, Palmer and Strobeck, 2003), i.e., of the ability of an organism to resist environmental stressors (Thornhill and Moller, 1997, Moller and Swaddle, 1997b, Gangestad and Thornhill, 2003b).

These environmental stressors include diseases or their symptoms [e.g., (Shackelford and Larsen, 1997b, Gangestad and Thornhill, 1997, Wynforth, 1998, Thornhill and Gangestad, 2006)], or health risks [e.g., (Tomkinson and Olds, 2000, Milne *et al.*, 2003)] and many others.

While some studies found an association between asymmetry and diseases, recent studies have failed to do [e.g., (Hume and Montgomerie, 2001, Rhodes *et al.*, 2001b, Honekopp *et al.*, 2004, Pound *et al.*, 2014)]. However, there is little evidence of diseases and other health risks having any impact on non-clinical facial asymmetry levels among Western industrialised populations, it is still not clear whether this is the case in socioeconomically and educationally more challenged societies (e.g., sub-Saharan Africans).

In this part of the study, the hypotheses are that (1) *People with serious postnatal medical history and/or whose mothers were affected by serious medical conditions while carrying their pregnancy will have higher levels of facial asymmetry than those without such history*. (2) *Higher levels of facial asymmetry are expected in people of lower socioeconomic status.*

As a consequence of facial asymmetry, individuals with more symmetrical faces are expected to be rated the most attractive and most preferred as potential mates (Grammer and Thornhill, 1994, Rhodes, 1998, Perrett *et al.*, 1999, Mealey *et al.*, 1999, Penton Voak *et al.*, 2001). In the context of human mate choice, facial attractiveness therefore remains one of the sexually selective pressures. The first person to demonstrate preference for facial symmetry with regards to mate choice was Francis Galton (an English scientist) who demonstrated that several superimposed face photos look more attractive than a single one from the composites (Galton, 1879).

Over a century later, a study confirmed Galton's finding, indicating that the more faces used in the composite, the higher the rating scores of the attractiveness, because the composites tend to be more symmetrical than the single ones, primarily due to the elimination of the fluctuating asymmetry (Langlois and Roggman, 1990).

However, since facial symmetry does not exist [see reviews in (Bishara *et al.*, 1994)], most of the studies on the relationship between facial attractiveness and facial symmetry were conducted using composites of photographs [e.g.,(Grammer and Thornhill, 1994, Rikowski and Grammer, 1999, Hume and Montgomerie, 2001, Perrett *et al.*, 1999, Penton Voak *et al.*, 2001, Currie and Little, 2009)] to make faces look average and symmetric. Such studies that created left-left, or right-right composites from face photos reflected along their midline have indicated preference for the naturally asymmetrical ones rather than their symmetric composites (Langlois *et al.*, 1994, Swaddle and Cuthill, 1995, Kowner, 1996). However, this technique poses problem as raters in those studies might have preferred asymmetric facial images (which look more natural) to symmetric images possibly because abnormal facial features were introduced in the created images making them look unnatural as demonstrated by Perrett et al., (Perrett *et al.*, 1999). Similarly, there is a problem of presenting images with different skin textures when asymmetric original face photos are compared to symmetric face photos which may result in asymmetric faces being preferred as seen in the study of Swaddle and Cuthill (Swaddle and Cuthill, 1995). Moreover, some studies that only examined attractiveness in relation to asymmetry of some aspect of facial traits [e.g., asymmetry of nose and jaw: (Grammer and Thornhill, 1994, Shackelford and Larsen, 1999)] may miss certain important facial traits which may show significant asymmetry, and this might raise questions about the validity of such results.

The present study used 3D full facial models and therefore the problem of introducing abnormal facial features by creating left-left or right-right images is avoided. The study also used 3D facial models instead of photos to do away with presenting different skin colour and texture. Therefore, other working hypotheses in this part of the present study are that: *(1) Men and women will prefer individuals with lower facial asymmetry as more attractive, more likely as marital partners, and more caring than individuals with higher facial asymmetry (2) Facial asymmetry is not expected to have an effect on perceived aggressiveness in this study.*

1.3 Facial sexual dimorphism

In the context of human identification, individuals' ability to differentiate between faces, has led some researchers to hypothesize that when humans physically observe faces of their fellows, they have an inherent ability to recognize and differentiate which one is male and which one is female (Pascalis *et al.*, 2002). This means that there are actually structural physical differences between sexes making them identifiable, and therefore this observed phenotypic difference between males and females of the same species, is termed sexual dimorphism (Anubhav and Brijesh, 2014). Sexual dimorphism arises as a consequence of sexual maturation, leading to the full appearance of the secondary sexual characteristics, which develop at puberty due to the influence of sex hormones, that is oestrogen in women (Law Smith *et al.*, 2006) , and testosterone in men (Koehler *et al.*, 2004a) which serves as a major determinant of extra-genital sexual dimorphism (Bardin and Catterral, 1981). And the magnitude at which these sexually dimorphic facial features are expressed in an individual is an important evolutionary signal of the genetic and or phenotypic quality of that individual (Perrett *et al.*, 1998) which also indicates his or her ability to produce offspring that are healthy and attractive.

In men, testosterone is linked to the appearance of the masculine facial features (Penton-Voak and Chen, 2004) such as broader jaw, prominent ridges of the eye brow, prominent cheekbones, protruded chin and other features (Koehler *et al.*, 2004b, Rhodes, 2006, Lefevre *et al.*, 2013), although it is an immune system depressor [(Duffy *et al.*, 2000, Messingham *et al.*, 2001, Alonso-Alvarez *et al.*, 2007) reviewed in (Muehlenbein and Bribiescas, 2005)]. And from the ***immunocompetence handicap hypothesis*** (Folstad and Karter, 1992), only healthy males are expected to fully express masculinity traits without immune-compromising function. However, masculinity traits are honest cues to dominance in both male (Muller and Mazur, 1997, Swaddle and Reierson, 2002, Neave and Shields, 2008) and female (Quist *et al.*, 2011). On the other hand, higher oestrogen levels in females, inhibit the growth of their facial features to the level of that of their opposite sex (Thornhill and Gangestad, 1993, Thornhill and Moller, 1997) resulting in their femininity look (Law Smith *et al.*, 2006) with many baby-like traits such as large eyes, short nose, small chin, thick lips, narrow jaw, thin eyebrows, and wide-set eyes., but with some adult traits, particularly pronounced cheekbones and narrow cheeks [reviewed in (Koscinski, 2007)] cueing their status and health (Moore *et al.*, 2011).

Facial masculinity in males and facial femininity in females, are other important determinants of facial attractiveness apart from facial symmetry. However, literature regarding masculinity-femininity rating is largely drawn from the ***WEIRD*** [***western, educated, industrialized, rich and democratic***: (Henrich *et al.*, 2010)] population with only a few authors that tested masculinity or femininity preferences in less developed societies [e.g., (Scott *et al.*, 2008, Penton–Voak and Scott, 2010)].

Indeed, facial masculinity is plausibly costly and an honest signal of male quality (Scott *et al.*, 2013), therefore, male with more masculine faces are expected to be more attractive and more preferred. Specifically, women showed preferences for men with higher facial masculinity (Penton Voak *et al.*, 2001, Fink and Penton-Voak, 2002b, Little and Hancock, 2002, Rhodes, 2006, Rhodes and Simmons, 2007) in less developed societies where there is high income in-equality (Brooks *et al.*, 2011) and high prevalence of pathogens, couple with lack of access to, or poor health care, which are threats to the survival of offspring (Thornhill and Gangestad, 1996, Perrett *et al.*, 1998, Fink and Penton-Voak, 2002b, Gangestad and Scheyd, 2005, Glassenberg *et al.*, 2010, DeBruine *et al.*, 2010) as proposed by the ***investment trade-off hypothesis***. Therefore women who showed preferences for men with more masculine faces, have *traded-off paternal investment (in time and earnings) against honest signal of heritable health* and thus may have an indirect advantage of having healthy offspring that will be independent of societal health care provision. In developed societies, women preferred men with more feminine faces [e.g.,(Perrett *et al.*, 1998, Boothroyd *et al.*, 2007, Rennels *et al.*, 2008)] specifically because of excellent health care system taking care of the other aspect of mate choice benefits, for example, highly masculine man, healthy offspring. Thus women in such societies have *traded-off heritable health benefits against paternal investment (in time and earnings)* by their preferences for men with feminine faces.

The preferences for masculinity or femininity in both sexes are inconsistent whether in developed or less developed societies.

In her meta-analytical review, Rhodes has shown the absence of clear evidence to indicate that masculinity is always more preferred by women (Rhodes, 2006), similar to the reports of other studies (Koehler *et al.*, 2004b, Thornhill and Gangestad, 2006, Scott *et al.*, 2010) even among populations exposed to higher level of disease load (Stephen *et al.*, 2012). That means some women may prefer men with more feminine rather than more masculine faces as demonstrated by some studies [e.g., (Perrett *et al.*, 1998, Carles *et al.*, 2012)]. And if women would prefer men with more feminine faces and men would also prefer women with more feminine faces, it is thus arguably that femininity is more appealing to both sexes than masculinity in any society. Many recent studies have indicated men's preferences for more feminine women [e.g., (Little *et al.*, 2008b, Little *et al.*, 2011c, Claes *et al.*, 2012, Little *et al.*, 2013, O'Connor *et al.*, 2013, Marcinkowska *et al.*, 2014)] especially those with higher testosterone levels (Welling *et al.*, 2008).

However, despite the growing interest and the large body of literature on the preference of men for women with more feminine faces, and the preference of women for men with more masculine faces, such a pattern of preferences among the sub-Saharan African population is still not clear. The present study therefore aims at testing the following hypothesis: *(1) Men will show preference for women with more feminine faces, and women will show preference for men with more masculine faces, with the effect emphasised in individuals from lower socioeconomic backgrounds. (2) Men and women from lower socioeconomic* *backgrounds are expected to show higher levels of sexual dimorphism, reflecting increased selective pressure for access to resources.*

1.4 Why this study is important?

Socioeconomically, Nigerians are among the poorest people in the world (Etim and Edet, 2009), and Nigeria experiences an increased morbidity and mortality as a result of some endemics (e.g., malaria, typhoid fever) and immunizable diseases (e.g., measles, poliomyelitis, and tuberculosis). In 2009, a Nigeria Federal Ministry of Health report indicated that Malaria alone is estimated to cause 300,000 deaths each year, 60% of outpatient visits and 30% of hospitalizations (FMOH., 2009). Pulmonary tuberculosis, which is another health menace in Nigeria, had an annual population incidence of 311/100,000 and a mortality rate of 81/100,000 in 2006 (WHO, 2008).

While Nigeria presents a challenging environment in which to conduct such a study, it also provides substantial variation in socioeconomic background and access to medical care, which should increase phenotypic variability and, hence, facilitate the testing of hypotheses based on phenotypic data.

I presume that the present study will provide an established normative sub-Saharan African population database concerning facial asymmetry and facial sexual dimorphism, adding to the pool of the literature based on populations from Western industrialised countries, which might act as a reference. And since subtle asymmetries exist in all individuals, normative data specific for a particular population is important before asymmetries are used as indicators of an individual's phenotypic quality: the ability to resist environmental and genetic stressors during development. Additionally, the possible causes of the increased levels of facial asymmetry and facial sexual dimorphism particularly in such a challenging environment where this study was conducted will be revealed.

As a consequence, an insight to which of the studied facial features (facial asymmetry versus symmetry, masculinity versus femininity) is more susceptible to sexual selection pressure with regard to mate selection in sub-Saharan Africans will be showcased. Moreover, more light on the perception of sub-Saharan Africans to the placement of trust based on facial features (asymmetric, symmetric, highly masculine or highly feminine individuals) will be shed. The study will reveal the typical facial characteristics of the studied population whether it is different or similar to those in the socioeconomically and educationally well-developed societies. And since health measures (e.g., blood pressure, weight, height and body mass index) were part of the biometrics collected, the analyses of the study will indicate how physically fit the studied population are in their challenging environment. The results of the study will also provide information to policy makers towards an understanding of the relationship between socio-economic context and wellbeing of their population.

1.5 General Objective

The major objective of the study is to identify correlates of facial asymmetry and facial sexual dimorphism, and to assess the community perception of facial asymmetry and facial sexual dimorphism (through facial attractiveness rating) amongst the Hausa ethnic group in Nigeria; and to use modern 3D methods of quantification and analyses of facial asymmetry and sexual dimorphism through surface laser scanning.

Chapter 2 : SOFT TISSUE FACIAL ANATOMY

2.1 Macroscopic Anatomy of the face

2.1.1 Brief Anatomy

The facial muscles (also called muscles of facial expressions) are in the subcutaneous tissue of the anterior and posterior scalp, face, and neck. They move the skin and then change facial expressions to convey mood. Most facial muscles attach to the bones of the face (which include the zygomatic, maxillae, nasal, vomer, palatine and the lacrimal as well as the mandible), or those of the skull or fascia and produce their effects by the pulling of skin. A subcutaneous muscle (paniculus carnosus) sheet forms during embryological development, spreading over the neck and face, carrying branches of the facial nerve, which supply all the muscles formed from the 2nd branchial arch (Drake *et al.*, 2010). This muscle sheet differentiates into muscles that surround the facial orifices (mouth, eyes, and nose) serving as sphincters or dilator mechanisms that also produce facial expressions. These muscles include those around the eyes (orbicularis oculi), in the middle of the upper face (corrugator, supercilii and procerus), around the nose (depressor septi, levator labii superioris alaque nasi), around the upper lip (levator labii superioris), around the angle of the mouth (depressor anguli oris), around the lower lip (depressor labii inferioris), around the mouth orifice (orbicularis oris) and those by the side of the face such as zygomaticus major and minor, and the buccinators (Sinnatamby, 2011). The orifices of orbit, nose and mouth are guarded by eyelids, nostrils and lips, respectively, and there is a sphincter and an opposing dilator arrangement specific to each, in which their purpose is to control these orifices (Sinnatamby, 2011).

2.1.2 Blood supply to the face

The face is richly supplied mainly by the facial artery, which is a branch of the external carotid artery. The facial artery originates from the external carotid artery close to the lingual artery and anastomoses with the orbital vessels and transverse facial branch of the superficial temporal artery. The venous drainage of the face is through the facial vein, which accompanies the artery. The vein communicates with the orbital veins and the cavernous sinus within the cranium. It communicates also with the anterior branch of the retromandibular vein to form the common facial vein that finally drains into the internal jugular vein (Dean and Pegington, 2002).

2.1.3 Lymphatic drainage of the face

The lymphatic vessels drain three parts of the face: (a) The upper part of the face, including the greater part of the forehead, lateral halves of the eyelids, conjunctiva, lateral part of the cheek and the parotid area drains into the pre-auricular parotid nodes. (b) The middle part of the face, including a strip over the median part of the forehead, the external nose, the upper lip, the lateral part of the lower lip, the medial halves of the eyelids, the medial part of the cheek, and the greater part of the lower jaw, drains into the submandibular nodes. (c) The lower part of the face, including the central part of the lower lip and the chin, drain into the sub-mental nodes (Garg, 2006. Editor).

2.1.4 Nerve supply to the face

Nerve supply to the face includes both the cutaneous (sensory) and the motor nerves. The main sensory nerve supplying the face is the Trigeminal nerve (the 5^{th} cranial nerve) through three branches: the supra-orbital (a branch of the ophthalmic division of the trigeminal), supplies the skin of the forehead, the eyelids and the eyeballs; the infra-orbital (a branch of the maxillary division of the trigeminal), supplies the skin of the cheek, its mucosal lining, the outer surface of the gums, the side of the nose, the nasal cavity, and the paranasal air sinuses; the mental (a branch of the mandibular division of the trigeminal), supplies the skin of the chin, the mucous membrane of the lower lip, and the outer surface of the gums. The motor nerve to the face is the facial (which is the 7^{th} cranial) nerve that emerges from the styloid foramen and finds its way into the parotid gland where it divides into five terminal branches. The five branches include temporal, zygomatic, buccal, marginal mandibular and cervical branches. They break up to supply the muscles of facial expression (Moffat, 1993).

2.2 Developmental Anatomy of the face

2.2.1 Brief craniofacial development

The human face starts to develop from the 4^{th} week of intrauterine life by the development and fusion of five processes. These processes are: the frontonasal process over the forebrain, the two maxillary processes and the two mandibular processes. The maxillary and the mandibular processes are derived from the mandibular (first pharyngeal) arch, with the mandibular processes giving rise to the maxillary processes.

Together, the 5 processes bound the primitive mouth (**Figure 2.1**), which is separated from the gastrointestinal tract by the buccopharyngeal membrane (Scheuer and Black, 2000).

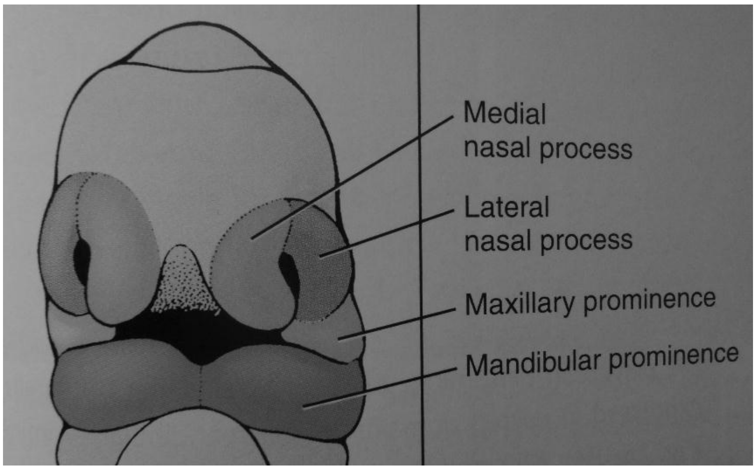


Figure 2:1: 6th week embryo

Taken from Schoenwolf et al., 2009]

The two mandibular processes are separated by a mid-ventral fissure that is filled in during the 4th-5th week by proliferation of mesenchyme, thus forming the lower lip primordium. The buccopharyngeal membrane ruptures in the 5th week to form an embryonic mouth which at this moment appears very wide and slit-like (**Figure2.2**), but decreases to its final length in the 2nd month by the fusion of the lateral portions of the maxillary and mandibular swellings that form the cheeks (Schoenwolf *et al.*, 2009).

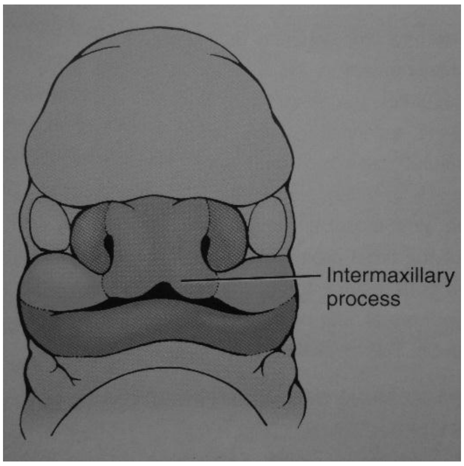


Figure 2:2: 7th week embryo

[Taken from Schoenwolf et al., 2009]

2.2.2 Nose and nasal cavity

The nasal bridge (from the frontonasal process), the alae (from the two lateral nasal processes), the crest and the tip (from the two merged medial nasal processes) all form the soft part of the nose (the external nose). Hence, the nose develops from five facial processes (Sadler, 2006). This development begins in the 5th week from two ectodermal thickenings, called the nasal placodes on either side of the frontonasal process. During the 6th week, the centre of each ectodermal nasal placode invaginates to form an oval nasal pit, thereby dividing the frontonasal processes into two lateral and two midline medial nasal processes (Scheuer and Black, 2000, Schoenwolf *et al.*, 2009) as in **Figures 2.1 & 2.2**.

During the 5th week, the maxillary processes (left and right) enlarge and grow ventromedially towards the midline. The maxillary process of each side joins with the lateral nasal process of the same side to form the sides of the nose and the cheek (Scheuer and Black, 2000).

The growth of these processes forms an ectodermal groove (between the lateral nasal process and the maxillary process), which is called the nasolacrimal groove (**Figure 2.2**). At the 7th week, the ectoderm at the floor of this groove invaginates into the underlying mesenchyme to form a tube called the nasolacrimal duct and lacrimal sac. The caudal end of this duct proliferates to connect with the caudal part of the lateral nasal wall, while its cranial extremity later connects with the developing conjunctival sac (Schoenwolf *et al.*, 2009).

During the ossification process of the maxilla the nasolacrimal duct is invested by bone. The duct functions to drain excess tears from the conjunctiva of the eye into the nasal cavity after birth. The so formed medial nasal processes migrate ventromedially, fusing with each other in the midline to form the primordium of the nasal septum and nasal bridge during the 6th week. At the end of the 7th week, the lower ends of the medial nasal processes grow inferolaterally to form the intermaxillary process, which fuses with the tips of the maxillary process forming the primary palate and the philtrum (**Figure 2.3**).

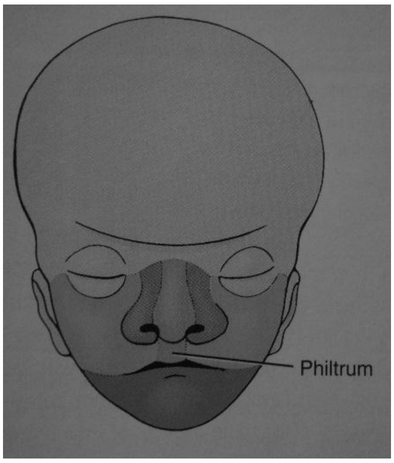


Figure 2:3: 10^{th} week embryo
[Taken from Schoenwolf et al., 2009]

By the end of the 6^{th} week, the nasal passages are formed by the merging of the medial nasal processes, deepening, and the fusion of the dorsal region of the nasal pits, resulting in a single large ectodermal nasal sac lying posterosuperior to the intermaxillary process. Between the 6th and 7^{th} week, the nasal fin (a thickened plate-like fin of ectoderm) forms in the floor and posterior wall of the nasal sac and separates the nasal sac from the oral cavity. The nasal fin is later reduced to a thin membrane, called the oronasal membrane, which degenerates by the end of the 7th week to form an opening called the primitive choana. At this period, the posterior extension of the intermaxillary process (now the primary palate), forms the floor of the nasal cavity (Schoenwolf *et al.*, 2009).

The nasal septum forms due to proliferation of both the ectoderm and mesoderm of the frontonasal prominence as well as the medial nasal processes. This septum grows down from the roof of the nasal cavity to fuse with the upper surface of the primary and secondary palates along the midline (**Figure 2.4**). The septum thus divides the nasal cavity into two nasal passages opening into the pharynx just at the back of the secondary palate through an opening called the definitive choana (Scheuer and Black, 2000).

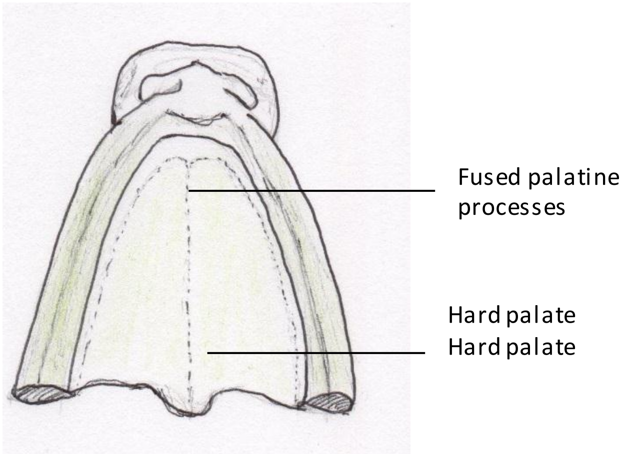


Figure 2:4: 10th week embryo (seen from below the roof of the mouth)

[Re-drawn from Scheuer and Black 2000]

The neural crest cells derived from the midbrain and forebrain give rise to the mesenchyme in the frontonasal prominence whereas those from midbrain and hindbrain contribute to the mesenchyme of the maxillary and mandibular prominences. The failure of some of these facial prominences to either grow or fuse correctly results in the relatively common congenital facial anomalies (facial clefts) that include the cleft lip and palate (Schoenwolf *et al.*, 2009).

2.2.3 The development of the lips and the jaws

The lower lip and the lower jaw are formed from the mandibular processes (from the 1st branchial arch) of the left and right of the developing face, which fuse in the midline forming the lower boundary of the stomodeum *(the primitive mouth)*. The chin projects forward from the midline of the fused mandibular processes.

The triangular elevation, which projects from the cranial aspect of the dorsal region of each mandibular process, is the maxillary process (also from the first branchial arch), which grows ventromedially to fuse with the lateral nasal process of its side. Each of the maxillary processes then passes below the nasal sac to fuse with the medial nasal processes (from the frontonasal process) to form the upper lip and the upper jaw. The upper lip and the upper jaw (now forming the upper boundary of the stomodeum) are therefore derived from both the maxillary and the frontonasal processes. The mesodermal portion of the middle part of the upper lip (the philtrum) and the upper jaw are from the frontonasal process, while the mesodermal component of the lateral part of the upper lip and the upper jaw are from the maxillary process. The ectoderm of the maxillary process overgrows the midline frontonasal mesoderm so that the skin of the entire upper lip is supplied by the maxillary nerve (Singh and Pal, 2006).

2.2.4 Cheeks

The formation of the upper and lower lips makes the stomodeum (now the mouth) very wide, which is bounded by the maxillary process in its lateral part and the mandibular process below. These two processes fuse progressively with each other to form the cheeks. The maxillary process fuses with the lateral nasal process not only in the lip region but also extends to the medial angle of the eye. This is marked by a groove known as the nasolacrimal sulcus lined by a strip of ectoderm that later gives rise to the nasolacrimal duct (Singh and Pal, 2006).

2.2.5 Eyes

The development of the eyes begins early in the 4th week from two (right-left) lateral grooves on the neuroectoderm (ectoderm populated by the migrated neural crest cells) of the forebrain neural groove. These are the optic sulci. The optic sulci evaginate to form the optic vesicles, which continue to grow until they reach the surface ectoderm where the tip of each vesicle invaginates, transforming from a vesicle to a goblet-shaped optic cup attached to the forebrain by a narrow and hollow optic stalk. The surface ectoderm overlying the optic cup then thickens to form a lens placode, which invaginates and pinches off, becoming a hollow lens vesicle. The cells in the posterior part of the lens vesicle form long, slender, anteroposteriorly oriented primary lens fibres. However, the secondary lens fibers form most of the mature lens and these fibers originate from the cells in the anterior part of the vesicle, which develop into a simple epithelium on the face of the lens (Schoenwolf *et al.*, 2009).

Now that the optic cup has two walls, the inner wall (the former optic disc) forms the neural retina, which fully differentiates between the 6th week and 8th month, while the outer wall of the cup forms the thin, melanin-containing pigmented epithelium.

In the neural retina (inner wall of the cup), six neuronal cells and one glial cell are formed: the rods and cone photoreceptors are the outermost regarded as the outer nuclear layer; the middle layer contains ganglions; and the innermost layer contains the amacrine, horizontal, and bipolar cells termed as the inner nuclear layer. The axons from these cells convert the optic stalk to the optic nerve, which then passes to the brain as the 2nd cranial nerve.

The sheath of mesenchyme derived from the neural crest cells and cranial mesoderm encloses the developing optic vesicle. Two coverings are formed over the optic cup from the differentiation of the sheath presenting as: the outer fibrous sclera and the thin inner vascular choroid. Again, the mesenchyme lying over the developing lens divides into two layers enclosing a space known as the anterior chamber. The anterior chamber therefore has two walls: the inner wall covering the lens now called the pupillary membrane and the outer wall deep to the surface ectoderm forming the cornea. The deep part of the pupillary membrane undergoes vacuolization, creating a new space called the posterior chamber, between the lens and the thin remnant of the pupillary membrane. This membrane later breaks down completely to form the pupil. The rim of the optic cup differentiates to form the iris and ciliary body. The extrinsic ocular muscles are formed from the mesoderm adjacent to the optic cup, which differentiates between the 5th and 6th weeks. The connective tissue components of the extrinsic ocular muscles are derived from neural crest cells. The surface ectoderm folds to give rise to the eyelids which are fused together in the 8th week to about the 5th month (Schoenwolf *et al.*, 2009).

2.2.6 Eyelids

Formation of the eyelids begins in the 6th week with small folds of surface ectoderm projecting together with a core of mesenchyme above and below the developing cornea. The upper eyelid therefore originates from the frontonasal process and the lower one from the maxillary process. The eyelid primordia grow rapidly to meet and fuse with each other in the 8th week enclosing a space between them known as the conjunctival sac. During the 5th and 7th months, the eyelids separate again and, therefore, the conjunctival sac communicates freely with the amniotic fluid. The mesoderm enclosed by the folds of ectoderm that gave rise to the eyelids gives rise to the eyelid muscles (orbicularis and levator). During the development of the eyelids, the deep ectodermal layer of the upper ectodermal fold invaginates at the superolateral angles of the conjunctival sacs to form the lacrimal glands, which mature at about 6 weeks after birth. The lubrication of the cornea and the conjunctival sac is done by the tear fluid produced by these lacrimal glands and any extra tear fluid passes to the nasal cavity through the nasolacrimal duct (Schoenwolf *et al.*, 2009).

2.2.7 Ossification of the facial bones

The superficial bones of the face mostly ossify in membrane from migrating cells that are derived from the neural crest cells. The ossification of these facial bones results from a complex interaction between the overlying facial epithelium and the underlying mesenchyme. The primary ossification centres can be seen in various parts of the bones. For example, early ossification centres for the maxillae and zygomatic bones are seen on the sidewall of the nasal capsule, and for the vomer and the palatine plates in the posterior region of the nasal cavity.

Concerning the ossification of the nasal and lacrimal bones, these ossify later than the rest during the foetal period. The growth of the face is primarily linked to the growth and development of the dentition and muscles of mastication, unlike the growth of the rest of the skull that is related to the rapid pattern of the neural growth. However, since the development of the skull vault precedes that of the facial skeleton, infants and young children have substantially larger head to face proportions than adolescents and adults. The calvaria to face ratio is about 8:1 at birth, 4:1 at 5 years and 2.5:1 in adult life (Scheuer and Black, 2000).

2.2.8 Anomalies affecting the face and its associated structures

Several congenital anomalies can occur on the face or its associated structures, for example cleft lip, cleft palate and the facial cleft, which may be unilateral or bilateral due to a complete or partial failure of fusion between any of the five swellings forming the face (Sadler, 2006). Cleft lip (**figure 2.5A**) is found to be much more common in males than in females and results from failure of the maxillary processes to fuse with the intermaxillary process.

Cleft palate (**figures 2.5B, C, D, & E**) on the other hand, is more common in females and results from the failure of the two palatine shelves to fuse with each other along the midline. The palatine shelves fail to fuse because of failure to adequately grow from failure of neural crest cells migration, proliferation, or due to excessive apoptosis, or fail to elevate at the right time (Schoenwolf *et al.*, 2009). Cleft palates can also develop from the inability of the mandibular primordium to grow (mandibular dysplasias) so as to lower the tongue for the palatal shelves to elevate or the developing tongue may fail to drop from between the shelves because of micrognathia (Moor and Persaud, 2005).

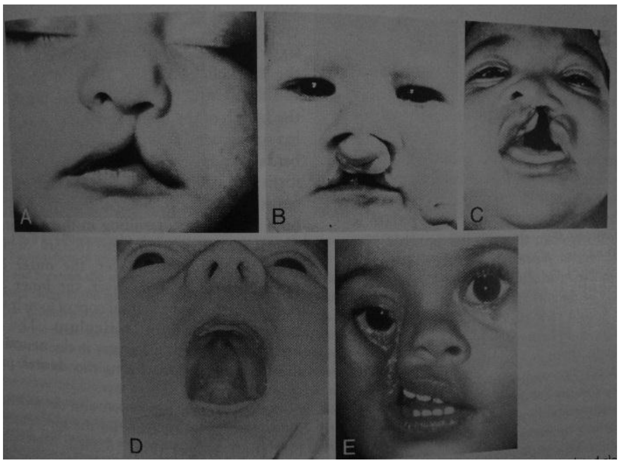


Figure 2:5: Facial clefts

[Taken from Sadler 2006]

Cleft lip (Hare lip) results from the underdevelopment of the mesenchyme of the maxillary and medial nasal processes thereby causing inadequate contact between the two processes. Several factors are believed to be associated with the mesenchymal underdevelopment within the maxillary and medial nasal processes. These include: inadequate proliferation or migration of neural crest cell ectomesenchyme, and excessive apoptosis (Schoenwolf *et al.*, 2009).

There are many facial abnormalities that occur due to defects of the forebrain and these are seen in babies who were born holoprosencephalic. These babies have flat noses, closely spaced eyes (ocular hypotelorism), deficient philtrum or cleft lips, high arched or cleft palates, and small skulls (microcephaly). Severe facial defects develop as a result of the failure of the medial nasal processes to form (from the nasal placodes of the frontonasal process) leading to absence of the intermaxillary process, the nasal bones, nasal septum, and ethmoid. The babies with these defects may have a single nostril (cebocephaly) or single eye (cyclopia) if the defects are severe. Premature closure of the skull sutures (sinostosis) may result in a triangular skull also called trigonocephaly (Schoenwolf *et al.*, 2009).

Abnormalities of the eye can arise at any stage of eye morphogenesis and differentiation and are mainly part of genetic syndromes. Because of the close relationship between eye and brain development, malformations of the eye often suggest the presence of underlying abnormalities of the brain.

Anomalies of the eyelids can be associated with congenital malformations like Down's syndrome presenting with folds of skin covering the medial angle of the eye (epicanthal folds), but this is normally present in several ethnic groups. In addition, failure of the palpebral fissure (fissure that separates upper and lower eyelids) to develop properly, may result in fusion of the eyelids. The fusion can be complete as in cryptophthalmos or incomplete as in blepharophimosis. Eyelids may droop (ptosis) or may curve downward and laterally from the inner canthus (epicanthus inversus) (Schoenwolf *et al.*, 2009).

Chapter 3 : ASYMMETRY

3.1 Introduction

The biological (rather than dictionary) definition of asymmetry is: when one of a bilaterally symmetrical trait or a character on one side of the body in a bilaterally symmetrical organism is larger on one side than the other (Valen, 1962, Palmer, 1993, Palmer, 1994, Palmer, 1996a, Moller and Swaddle, 1997a). And since bilaterally represented traits (e.g. ears, eyes, etc.) are coded for by the same genes, their target phenotype is presumed to be identical (Polak and Trivers, 1994). Similarly, genetic and environmental influence on the ontogeny of an organism is assumed to be the same on both sides (left or right) of the body, which means that perfect symmetry of paired traits is expected under normal circumstances (Mather, 1953, Valen, 1962, Palmer, 1996b). Asymmetry can therefore be said to result simply due to unequal effects of genes, environment or both on the body (Parsons, 1992), which is generally mild (Farkas and Cheung, 1981, Burke and Healy, 1993), because it occurs in normal growth and development.

In the early 1960s, Van Valen, one of the most frequently quoted authors in the field of biological variation studies, shed more light on the development and classifications of asymmetry in general (Valen, 1962). Three basic types of asymmetries are known in the literature [e.g., (Valen, 1962, Moller and Swaddle, 1997a, Palmer and Strobeck, 2003, Palmer, 2012)]: ***Fluctuating Asymmetry (FA***), ***Directional Asymmetry (DA)*** and ***Anti-symmetry (AS)***. A combination of all three types of asymmetry can be present in the same character especially the combination of DA and FA, which has always led to confusion (Van Valen, 1962).

In fact, antisymmetry and directional asymmetry are often regarded as a nuisance if they co-exist with FA in the same character, because they confound measurement of fluctuating asymmetry (Palmer and Strobeck, 1986). Similar to any other part of the body, FA & DA are found to co-exist in the face [e.g., (Hershkovitz *et al.*, 1992, Simmons *et al.*, 2004, DeLeon, 2007, Özener and Fink, 2010)].

In general, asymmetries result from genetic, developmental, or environmental insults [e.g., (Parsons, 1992, Moller and Swaddle, 1997a, Thornhill and Moller, 1997, Palmer, 2004b, Palmer, 2005)]. Therefore, individuals are thought to minimally experience an inability to counter the negative effects of genetic or environmental influence during development (Leung and Forbes, 1996, Palmer and Strobeck, 2003).

Mild asymmetry occurs everywhere in the body including in both hard and soft tissue facial structures, but the degree varies considerably between healthy individuals [(Farkas and Cheung, 1981, Peck *et al.*, 1991), reviewed in (Sackeim, 1985)]. Studies of facial asymmetry have reported very different average and/or extreme values (right minus left measurements) in healthy subjects. In some, facial asymmetry value was found to be less than 2mm (Farkas and Cheung, 1981) and in others, was between 4% to 12% if measurements were from facial landmarks to centre points (Ferrario *et al.*, 2001). Similarly, Shaner and colleagues reported that for measurements taken from the upper and middle regions of the face, the average limit of the soft tissue asymmetry was not more than 5 mm in males and 6 mm in females; and measurements involving the lower face had much higher asymmetry of 6 mm or more (Shaner *et al.*, 2000).

The area with lowest asymmetry value has been suggested to be the eye region (less than 2%), followed by the nose (7%) and mouth (about 12%) in the normal population (Farkas, 1994). And with regards to average trait size, asymmetry ranges between 1–5% of the trait size (Palmer, 1996b, Palmer, 2005).

3.2 Classification of asymmetry

3.2.1 Directional asymmetry

Directional asymmetry (DA) is when one of a bilateral character (e.g., ears, or eyes) is consistently larger on one side in a population [e.g., (Van Valen, 1962, Palmer, 2012)]. A typical example of DA is the mammalian heart, which is always larger on the left, and also the liver, which is always larger on the right (**see Figure 3.1**). Testicular DA is also reported, with the left one larger than the right in most animals (Yu, 1998, Moller, 1994, Liu *et al.*, 2011). And since DA has some genetic component, those heritable DAs appear before birth though thus might change thereafter (Kharlamova *et al.*, 2010) especially external DA such as found in the skeletal systems. On the other hand, DA might result from handedness [e.g., (Schell *et al.*, 1985, Van Dongen *et al.*, 2009, Shaw and Stock, 2009)], or differential biomechanical loading during bone growth (Auerbach and Ruff, 2006, Özener, 2010). This type of DA is typically observed in hominoid limbs, where it is greater in the upper than in the lower limb (Sarringhaus *et al.*, 2005, Auerbach and Ruff, 2006, Kujanova *et al.*, 2008), more on the right limb than on the left limb [e.g., (Sarringhaus *et al.*, 2005, Auerbach and Ruff, 2006)]. The DA of the upper extremities however, increases with age (Blackbum, 2011), years of heavy working conditions (Özener, 2010), and locomotion (Marchi and Shaw, 2011).

While some DAs are subtle (Leamy, 1999, Auerbach and Ruff, 2006), others are conspicuous such as those observed in big flounders, birds and mice (Palmer, 2004a, Palmer, 2009b). Like any other part of the body, DA is also found in the face (Özener and Fink, 2010).

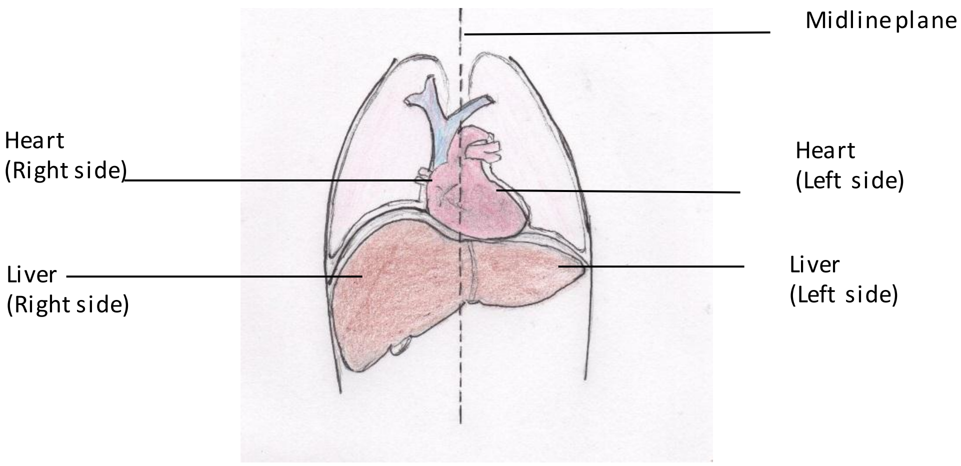
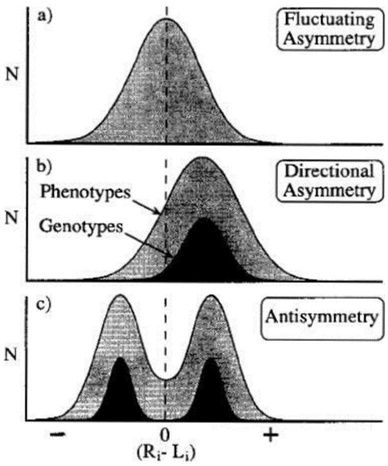


Figure 3:1: Human Heart (L>R) & human Liver (R>L) Directional asymmetry (DA)

When the variation of individual DA of the studied population is plotted (i.e. left side value minus right side value of a character), it has a unimodal distribution with a mean that is significantly greater or less than zero ($\mu \neq 0$) (Graham *et al.*, 1993b, Graham *et al.*, 1998, Palmer and Strobeck, 2003, Palmer, 2012) as shown in **Figure 3.2**. Generally, DA occurs in normal development and is very common in both animals [e.g., (Carter *et al.*, 2009, Breno *et al.*, 2013, Benítez *et al.*, 2014)] and humans [e.g., (Auerbach and Ruff, 2006, Özener, 2010, Barros and Soligo, 2013)].

Frequency



Variation between right and left sides

Figure 3:2: Three 'pure' forms of bilateral asymmetry:
a) Fluctuating asymmetry
b) Directional asymmetry c) Antisymmetry
[Taken from Palmer and Strobeck 1992]

The direction of the difference between sides in traits that exhibit DA, is generally accepted to be genetically determined (Helmkamp and Falk, 1990, Kimmerle and Jantz, 2005, Leamy, 1999, Loehr *et al.*, 2012), and “probably normally adaptive” (Valen, 1962, Graham *et al.*, 1993b).

3.2.2 Anti-symmetry

Antisymmetry (AS) is a condition in which half of the individuals in a population have greater development of a character on the right (dextral) side and the other half have greater development on the left (sinistral) side (Van Valen, 1962, Dongen, 2006, Palmer, 2009b), without any prediction for which side will dominate the other in the population (Graham *et al.*, 1993c, Palmer, 2004a).

In this case, if the variation of individual AS is plotted (i.e., left side value minus right side value of a character), the distribution of this variation is bimodal or platykurtotic (flat curve, instead of Gaussian curve), but with a mean of zero (μ = 0) (Palmer and Strobeck, 2003, Palmer, 2004a, Palmer, 2005) as in **Figure 3.2**. Similar to DA, AS also reflects normal development in most of the cases (Palmer and Strobeck, 1992, Palmer, 1994, Palmer *et al.*, 1994) but no study has reported AS an indicator of developmental instability. As Palmer *et al*., (1994) suggest, AS and DA have unknown genetic components. Although, the asymmetrical state in traits that display AS is presumed to be under genetic control (due to developmental trade-off between the two sides), the direction of the left–right difference is generally not heritable (Palmer and Strobeck, 1986, Palmer, 2005).

A typical example of anti-symmetry is seen in male fiddler crabs (***Uca*** spp.), with a claw size that is either larger on the left or right (**figure 3.3**). This type of asymmetry is common in both animals and plants (Moller and Swaddle, 1997b).

Figure 3:3: Antisymmetry [dextral (upper) and sinistral (lower)]: Male Fiddler crabs with equally common antisymmetry [Taken from Palmer, 2012]

Antisymmetry is classified into two categories (Palmer and Strobeck, 1986): Antisymmetry I, also called polymorphic directional asymmetry, results by mixing of two genotypes (thus heritable), with each having directional asymmetry in opposite directions (Van Valen, 1962, Palmer, 2009b, Palmer, 2012). Male Fidler crabs (Palmer, 2012) and male genitalia of *Scythris antisymmetrica*, Nupponen, sp. n., (Nupponen, 2009) are typical examples of Antisymmetry 1. Similarly, the palp in male Arachnida (theridiid, pholcid spiders) and the side of elongated legs in Acari (feather mites), all have equal frequency of left or right asymmetry (Palmer, 2009a).

In ***antisymmetry II***, a character or a trait on one side of the body is consistently larger than its partner on the other side, similar to but different from directional asymmetry, because this antisymmetry II, is as a result of non-genetic developmental noise as against heritable directional asymmetry [e.g., (Palmer and Strobeck, 1986)]. However, Graham et al. (1993) referred to *antisymmetry II* as fluctuating antisymmetry that is not inherited like antisymmetry I and gave as a typical example the lobsters' large crusher claw and smaller cutter claw, which largely results from an adaptation process that stems neither from exogenous nor from endogenous stress (Graham *et al.*, 1993b). Structural antisymmetry can be translated to physiologic or behavioural antisymmetry. This link between morphology and behaviour was predicted (Takeuchi *et al.*, 2010) and may be due to the favoured use of one eye or lopsided behavioural control by neuronal circuits (Tobo *et al.*, 2012) in accordance with the morphological difference. Typical examples of such translation of structural to behavioural asymmetry is seen in some fishes with leftward or rightward bias in their predatory behaviour in their use of limbs, mouths or sensory organs (Hata *et al.*, 2011, Yasugi and Hori, 2012). However, antisymmetry of the face has not yet been reported.

3.2.3 Fluctuating asymmetry

Fluctuating asymmetry (FA) refers to minor but random deviation from perfect symmetry of paired structures such as the ears and eyes of a bilaterally symmetrical organism [e.g., (Valen, 1962, Palmer and Strobeck, 1986, Palmer, 1994, Watson and Thornhill, 1994, Palmer, 2004b)]. In other words, it is a situation where a character (such as ear) on one side (e.g., right side) is larger than the one on the other side without consistent bias to a given side.

In bilaterally symmetrical traits (such as eyes, ears), the corresponding sides are encoded by the same genes, and FA arises from environmental stressors or stressors from a hostile genetic environment within the genome that lower developmental stability.

In a measurement of asymmetry such as FA, the variation of individual FA (left side value minus the right side value of a trait) when plotted, has a unimodal distribution with a mean of zero ($\mu = 0$) across many traits within an individual or across one trait within a population (Valen, 1962, Palmer, 1993, Palmer and Strobeck, 2003) as shown in **Figure 3.4**. The degree of the deviation is assumed to reflect failure of the affected organism to maintain developmental stability: the inability of the organism to resist the genetic or environmental stressors (Leamy and Allendorf, 1989, Moller and Swaddle, 1997b, Thornhill and Moller, 1997, Polak, 2003, Polak, 2008). Palmer and Strobeck (1992) argued that FA represents only variation that has an environmental origin and is therefore arguably not heritable [e.g.,(Leamy and Klingenberg, 2005, Sengupta and Karmakar, 2007)].

FA can be found in several parts of the body, for example, the crania (Hershkovitz *et al.*, 1992, DeLeon, 2007), the face [e.g., (Erkan *et al.*, 2008, Özener and Fink, 2010, Cheong, 2011)], and upper extremities (Özener, 2010).

It exists in animals other than humans (e.g.(Van Nuffel *et al.*, 2007, Palmer, 2009b) and also in humans (e.g.(Van Dongen *et al.*, 2009); in children (e.g.(Wilson and Manning, 1996b), and in adults (e.g.(Gray and Marlowe, 2002); in males (e.g.(Özener, 2010), and in females (e.g.(Özener and Fink, 2010); in the skeleton (e.g.(Hallgrimsson, 1998) and in soft tissues (e.g.,(Ozener and Özener, 2010c).

The quantification of FA in one population or another is done in a variety of ways but the commonest way is by calculating the variance of individual asymmetry, that is: variance (d^2) is $D_i = L_i – R_i$, where L_i is the value of a character on the left side of an individual and R_i is the value of the same character on the right side of the same individual (Palmer and Strobeck, 1986, Palmer, 1994). The major source of concern in the study of FA is either over or under-estimating it particularly in a trait that exhibits both DA and FA and measurement error (ME) (see (Palmer and Strobeck, 1986).

Although there are several correction methods to extract the FA component from a DA trait (Palmer and Strobeck, 1986, Palmer and Strobeck, 1992, Palmer, 1994), residual variance is reported to be much better because FA is overestimated in the other correction approaches (Graham *et al.*, 1998). Measurement error (ME) is suggested to account for 25-100 % of the apparent variation between trait sides (Palmer and Strobeck, 2003) and it is therefore suggested to always estimate ME by measuring repeatedly at intervals (Moller and Swaddle, 1997b) without knowledge of earlier measurements or the identity of the individuals. A trait measure is said to be reliable if it is repeatable and important quantitative genetic parameters like heritability can be underestimated if traits are less repeatable (Whitlock, 1998).

Given that the amount of FA in an individual signals the amount of stress encountered by that individual during growth and development (greater stress, greater asymmetry), FA therefore serves as an index of developmental instability (Palmer and Strobeck, 1986, Palmer and Strobeck, 1992, Thornhill and Moller, 1997, Palmer and Strobeck, 2003, Dongen, 2006). Therefore, individuals that are able to be more resistant to environmental stresses express lower levels of FA, and are assumed to be of higher phenotypic and genetic quality [reviewed in (Moller and Swaddle, 1997b)].

For decades, evolutionary biologists have been using FA as a tool in evaluating the condition of individuals in natural populations (Graham, 1992, Zakharov, 1992) precisely for the assessment of developmental stability (Moller and Swaddle, 1997b). Although FA is considered as an indicator of individual quality and developmental stability [e.g., (Valen, 1962, Palmer and Strobeck, 1986, Parsons, 1990, Graham *et al.*, 1993b, Graham *et al.*, 1993d, Moller, 1997, Thornhill and Moller, 1997, Palmer and Strobeck, 2003) but see meta-analysis in (Van Dongen and Gangestad, 2011)] its use as a general indicator of environmental stress still remains controversial (Lens *et al.*, 2002, DItchkoff *et al.*, 2001, McCoy and Harris, 2003).

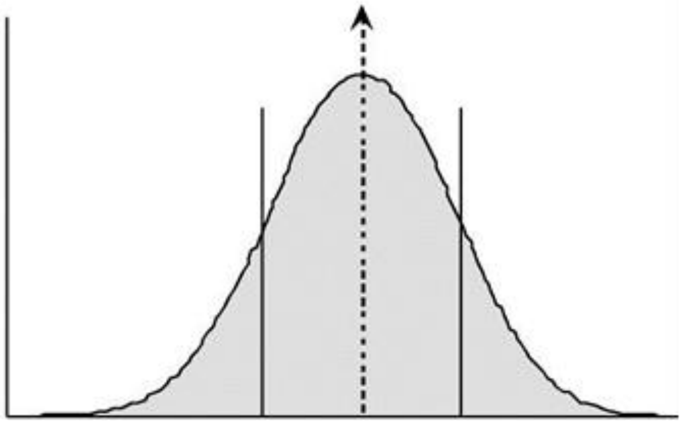
However, FA has been shown to correlate negatively with growth (Duyar and Özener, 2005), fecundity (Polak, 2003), longevity, and parasite resistance

(Moller, 1997) and survival (Parsons, 1990, Parsons, 1992). In fact, high levels of fluctuating asymmetry in individuals in a population are considered to be a sign of a population under stress (Graham *et al.*, 1993d, Polak, 2003).

FA is therefore important since it reflects a general health record of an individual in its environment given its genotype as well as its use to compare populations or individuals within populations, as asymmetry differs considerably across individual organisms [see (Thornhill and Moller, 1997) for review]. Moreover, environmental and genetic stresses experienced by populations are better assessed by quantifying FA than by conventional indices like mortality rate, growth rate, fecundity or population density [e.g.,(Zakharov, 1992, Graham *et al.*, 1993d, Graham *et al.*, 1993a, Clark, 1995).

The lack of proper understanding of the underlying genetic influence on FA (Lens *et al.*, 2002, Leamy and Klingenberg, 2005) and difficulties with measuring FA accurately, have yielded several conflicting results in the study of FA (Whitlock, 1996, Dongen, 2006). While others consider FA as a measure of quality or fitness, others cautioned that it should not be universally assumed to reflect fitness (Leung and Forbes, 1996, Lens *et al.*, 2002, Leamy and Klingenberg, 2005). With regard to the heritability of FA, controversy also remains, with little evidence of its heritability (Loehr *et al.*, 2012) or even none [e.g.,(Leamy and Klingenberg, 2005, Sengupta and Karmakar, 2007)].

Frequency



Variation between right and left sides of the body (Ri-Li)

Figure 3:4: Signed asymmetry: Fluctuating Asymmetry (mean = 0) [Taken from Palmer and Strobeck 2003]

3.3 The ontogeny of asymmetry

The ontogeny of asymmetry, especially of the postcranial region, appears from the beginning of the second trimester of intra-uterine life, before any environmental or functional influence on the developing organism (Schultz, 1923, Schultz, 1926). However, genetics and environment are the two major conditions playing a significant role in the development of asymmetry [e.g., (Lundstrom, 1961, Melnik, 1992, Farkas *et al.*, 2007, Özener and Fink, 2010, Loehr *et al.*, 2012)].

Several theories (hypotheses) have been formulated about the ontogenesis of asymmetry and how other developmental mechanisms curtail its development to the barest minimum (Swaddle and Witter, 1997, James and Ross, 2003).

The influence of internal or external environment on the asymmetrical growth and development of an individual is well documented [e.g., (Gray and Marlowe, 2002, Hallgrimsson, 1993, Milne *et al.*, 2003, Özener, 2010, Özener and Fink, 2010, Hope *et al.*, 2013)]. A typical example of external environment influencing asymmetrical growth and development is seen in sessile plants blown by windy currents, or part of a plant that is more exposed to sunlight thus having a greater growth than the other parts, resulting in asymmetry. In the case of internal environmental influences on growth, an individual may prefer to use one limb over the other (handedness bias) resulting in asymmetry in the most commonly used limb (Hallgrimsson, 1998, Hallgrimsson, 1999), specifically antisymmetry (Valen, 1962, Palmer and Strobeck, 2003). The hypothesis supporting the development of asymmetry due to these factors is the "*directional external cue hypothesis*", which predicts that time series measured within individuals should persistently vary at rates and in directions that depend on the strength and direction of signal or stimulus bias within individuals (Hallgrimsson, 1998, Hallgrimsson, 1999).

The structures of individual plants or animals grow by deposition of structural subunits (cells) and the size of the structure will therefore depend on the combined sizes of these deposited subunits which may differ from one structure on one side to another on the other side (in a bilateral trait). This cumulative result of differences in sizes between the corresponding subunits is said to be determined by chance just like the probability of getting a head or a tail when tossing a coin. This is another theory by which asymmetry may develop which Hallgrimssom (1998, 1999) coined the "*Coin- toss hypothesis*".

Its prediction is that relative levels of asymmetry in an individual vary early on, but then decrease throughout most of the period of development. In a bilaterally represented structures, random differences in the initial rates of cell division may differ between sides, affecting the rates of growth of either structure. Additionally, small variation (asymmetry) during the initial growth conditions of a structure can become bigger (magnified) during future structural growth resulting in a larger final asymmetry; this is called the "*Magnification of asymmetry hypothesis*" (Emlen *et al.*, 1993). In another hypothesis, perfect symmetry is not targeted by the developmental program, but the program only aims for a range of the difference between right and left (R-L) values about perfect symmetry. However, if the range is beyond what is targeted, the variation in R-L values (the asymmetry) within a population will increase as development progresses. This is the "*Accumulation of accidents hypothesis*" (Hallgrimsson, 1998, Hallgrimsson, 1999).

Since genetic or environmental factors have influence on growth and development, asymmetry may arise due to the influence of these factors on the early phase of ontogenic process of an individual, with the sign and magnitude of the asymmetry persisting over time (Chippendale and Palmer, 1993). This gave rise to the "*persistence of asymmetry hypothesis*". Moreover, during growth, one side (in a bilateral structure) may grow bigger than the one on the other side and because big random variation between two bilateral structures is not the norm, feedback mechanisms therefore correct this. The feedback may be negative inhibiting or slowing growth on the larger side until the lagging structure on the other side catches up; or the feedback may be positive, stimulating more growth on the lagging side until it catches up with the larger side (Emlen *et al.*, 1993). This is the "*compensatory growth hypothesis*".

Compensatory mechanisms, as the normal physiological processes of living organisms, play a significant role in opposing developmental noise (Palmer and Strobeck, 1986, Palmer and Strobeck, 1992, Palmer and Strobeck, 2003). The level of asymmetry in each individual therefore is the residual result of the developmental noise minus the correction (from the compensatory mechanism that tries to correct any imbalance from the developmental noise), this is the "*residual asymmetry hypothesis*" (James and Ross, 2003).

3.4 Developmental instability (DI) and canalisation

Developmental instability showcases failure of an organism to buffer both genetic and environmental disturbances [e.g., (Moller and Swaddle, 1997b, Thornhill and Moller, 1997, Polak, 2003, Polak, 2008) but see review in (Moller, 1997)] and therefore an inability to produce a consistent phenotype under a given condition (Zakharov, 1989). The buffering capacity in heterogeneous populations differs because of some genetic variation, although this does not, however, increase the level of developmental instability provided all the different genotypes have the same developmental trajectories (Mather, 1953).

In the absence of perturbation, the key assumption in the studies of developmental instability is that all individuals in a population have the same developmental pattern and thus all will be developmentally stable. And in the presence of perturbation, if an individual is able to buffer the developmental perturbation, then the development in that individual is canalized. Therefore, canalization refers to the buffering capacity of an organism in the face of genetic or environmental noise (Meiklejohn and Hartl, 2002).

In that case, the combined effects of DI and canalization result in developmental stability (Debat *et al.*, 2000) which reflects the ability of a genotype to undergo stable phenotypic development under given environmental conditions (Thornhill and Moller, 1997). However, deviations from developmental stability yield DI, which refers to the inability of an individual, to buffer its ontogeny against random noise (Nijhout and David, 2003, Klingenberg, 2003, Dongen, 2006, Pertoldi *et al.*, 2006). The study of DI has since been the focus of attention in evolutionary biology with a huge literature for several decades, and has become an important tool in the field of physical anthropology, medical sciences, and other related fields. It is considered as the breakdown in developmental stability and is most often measured as fluctuating asymmetry (Palmer and Strobeck, 1992, Palmer and Strobeck, 1997, Palmer and Strobeck, 2003), which is taken to be the best measure of phenotypic quality (Thornhill and Moller, 1997) that is relatively easy to measure (Palmer and Strobeck, 1986). To make a valid estimate of DI using FA, it is suggested that a population should be homogeneous, that is, all members of the population should follow the same underlying developmental trajectory (Graham *et al.*, 1998).

In line with the previous statement, most individuals can therefore be said to have subtle DI since it was demonstrated that subtle asymmetry in the form of fluctuating asymmetry (FA) occurs in most individuals (Thornhill and Moller, 1997).

The study of FA and DI is very important as both FA and DI have been suggested to play a key role in the evolution of mate choice and sexual selection (Thornhill and Gangestad, 1994).

The term canalization was coined by Waddington (Waddington, 1942) and is defined as the reduced sensitivity of a phenotype to changes in the underlying genetic and environmental factors that determine its expression (Meiklejohn and Hartl, 2002, De Visser *et al.*, 2003).

However, several words such as autonomous development, auto-regulation, homeostasis, homeorhesis, buffering and epigenetic stability are all synonymous with canalization [reviewed in (Thomas, 2005)].

In the literature, two types of canalization are reported: Firstly, genetic canalization, which refers to the genotype insensitivity against both genetic (heritable) and epigenetic disorders (Sollars *et al.*, 2003); and therefore, highly canalized genotypes are said to be much more insensitive to mutational or environmental changes than the less canalized ones (Wagner *et al.*, 1997, Gibson and Wagner, 2000). Secondly, environmental canalization which refers to any kind of insensitivity of a phenotype to micro-environmental perturbations (Wagner *et al.*, 1997) or against non-heritable perturbations (Waddington, 1942, Roff, 1997, De Visser *et al.*, 2003) such as external environmental factors (e.g., temperature) or internal environmental factors (e.g., developmental noise). Thus, one phenotype is said to be more canalized than another, if it is less sensitive (more resilient or robust) to genetic and/or environmental changes affecting the genotype that determines it.

3.5 Causes of Asymmetry

Several causes for both non-clinical and major clinical asymmetries have been demonstrated, and while non-clinical asymmetries do not require clinical intervention, clinical asymmetries mostly require clinical interventions [see (Cheong, 2011)].

For non-clinical asymmetries, a wide range of environmental factors has been suggested. For fluctuating asymmetry (FA), poor health [e.g., (Flinn *et al.*, 1999, Wynforth, 1998, Shackelford and Larsen, 1997b)] from parasites and other microbial infections [e.g., (Moller, 1992, Moller, 1996)], symptoms of diseases [e.g., (Shackelford and Larsen, 1997b, Gangestad and Thornhill, 1997, Wynforth, 1998, Thornhill and Gangestad, 2006)], maternal health [e.g., (Livshits *et al.*, 1988)], health risks [e.g., (Tomkinson and Olds, 2000, Milne *et al.*, 2003)], pollutants and other adverse physical conditions [see (Parsons, 1990, Parsons, 1992)], extreme temperatures [e.g., (Gest *et al.*, 1986)], poor living conditions [e.g., (Özener and Fink, 2010)], lack of shelter (Parsons, 1992, Moller and Swaddle, 1997c), poor or inadequate nutrition (Hoover and Matsumura, 2008), genetic stressors such as inbreeding (Markow and Martin, 1993), deleterious recessives (Parsons, 1990), and homozygosity (Mitton and Grant, 1984) have all been suggested to affect FA levels. For directional asymmetry (DA), heritability is considered one of the causes (Stewart and Albertson, 2010, Loehr *et al.*, 2012, Breno *et al.*, 2013), such as the DA seen in the internal organs: heart, liver, and lungs, but non-heritable DA is suggested to be due to biomechanical loading (Kontulainen, 2003, Kharlamova *et al.*, 2010), prolonged repetitive strenuous exercise or heavy working conditions [e.g., (Kontulainen, 2003, Özener, 2010)].

For clinical asymmetries, several diseases or conditions are demonstrated to be the causes and these include: birth defects such as cleft lip and cleft palate (Ras *et al.*, 1994, Laspos *et al.*, 1997, Feragen *et al.*, 1999, Ferrario *et al.*, 2003, Stauber *et al.*, 2008, Tziavaras *et al.*, 2009, Meyer-Marcotty *et al.*, 2011a), dysmorphic syndromes (Winter, 1996), Bell's palsy (Kannikeswaran *et al.*, 2006), maxillary sinus hypoplasia (Price and Friedman, 2007), sinus infections (Farkas and Cheung, 1981) hemifacial microsomia (Bishara *et al.*, 1994, Cheong, 2011), dental arch asymmetry (DeLeon, 2007), and partial epilepsy (Tinuper *et al.*, 1992), osteochondroma of the mandibular condyle, genetic diseases (e.g. neurofibromatosis), intra-uterine pressure on the head of the foetus in the birth canal during delivery (Boder and Boder, 1953), trauma [e.g., (Li *et al.*, 2004, Stellwagen *et al.*, 2008)], and others [in (Siebert *et al.*, 1996, Inui *et al.*, 1999, Arslan *et al.*, 2002, Cheong, 2011)]. The asymmetry due to those causes mostly requires clinical intervention [e.g., (Williams *et al.*, 2001, Singh *et al.*, 2007, Uzel and Alparslan, 2011, Shi *et al.*, 2013, Toro-Ibacache *et al.*, 2014)] because it exists as nuisance to the individual (Cheong, 2011)***.***

3.6 Developmental stability and Fluctuating Asymmetry

The influence of developmental stressors on human structures is shown to disrupt developmental stability and therefore cause developmental instability most often measured as fluctuating asymmetry (FA). (Wynforth, 1998, Flinn *et al.*, 1999, Little *et al.*, 2002, DeLeon, 2007). Therefore FA, which is relatively easy to measure, is a form of developmental instability that is commonly used as the best measure of phenotypic quality, which is the ability of an individual's high performance in biological fitness for example resistance to diseases, growth, reproduction, mating and survival [reviewed in (Thornhill and Moller, 1997)].

Since FA is a measure of developmental stability and considered to be the best measure of the quality of an individual's phenotype, it is therefore very important in evolutionary biology and other related fields [e.g., reviewed in (Dongen, 2006)]. Factors that affect developmental stability also affect FA levels and the literature is full of factors suggested to affect developmental stability. These factors are mainly categorized into two: genetic [e.g., (Parsons, 1990) but see (Moller and Swaddle, 1997a)] and environmental. The environmental factors range from, nutritional status (Little *et al.*, 2002), and biomechanical stress (Özener, 2010), to pollutants and extreme temperature (Parsons, 1990, Parsons, 1992).

Physiological processes for example body metabolism, are also suggested to be associated with developmental stability, specifically low metabolism (Manning *et al.*, 1997), because all the energy in individuals with high metabolism is used to maintain body processes, whereas free energy is available in individuals with low metabolism that is utilized in maintaining symmetric development [see review in (Thornhill and Moller, 1997)]. Therefore, individuals with high metabolism are expected to have higher FA with reduced developmental stability.

It is generally accepted that developmentally stable individuals have a well-developed, symmetrical body, which is an indication of resistance to the challenges of developmental stress (Moller and Swaddle, 1997b) and therefore a certificate of health [see (Thornhill and Moller, 1997) for review].

3.7 Developmental Stability (DS) and Directional Asymmetry (DA)

In the studies of asymmetries, FA is the only asymmetry that is inarguably accepted as a measure of DI, whereas DA is arguably considered an estimator of

DI (Palmer and Strobeck, 1992) because of its unknown genetic component of the asymmetric variance, and the traits that exhibit DA are presumed to be unrelated to developmental stability (Palmer, 1994). However, Graham et al., 1998 have argued that DA traits may indicate developmental instability if asymmetry (Graham *et al.*, 1998), as measured by Di=Li-Ri, changes with time or size (Graham *et al.*, 1998) and can therefore be used as an index of DI (Graham *et al.*, 1993b, Moller, 1994, Leamy, 1999, Ruff, 2000).

This is particularly true in as much as DA might result from environmental stressors such as handedness [e.g., (Schell *et al.*, 1985, Van Dongen *et al.*, 2009, Shaw and Stock, 2009)], differential biomechanical loading during bone growth (Auerbach and Ruff, 2006, Özener, 2010), years of heavy working conditions (Özener, 2010) and locomotion (Marchi and Shaw, 2011).

In fact many authors have suggested that all three types of asymmetries (FA, DA and AS) should be taken as dynamically interrelated rather than as separate entities and may therefore be useful tools for measuring DI under particular environmental conditions (McKenzie and Clark, 1988, Graham *et al.*, 1993a, Moller and Swaddle, 1997a, Leamy *et al.*, 1999).

3.8 Correlates of Asymmetry

Relationship of asymmetry with some elements of attractiveness has been suggested by several studies [for reviews, see (Grammer *et al.*, 2003, Rhodes, 2006, Little *et al.*, 2011a) as shown in a study by Gangestad and colleagues showing that fluctuating asymmetry (FA) correlated negatively with facial attractiveness (Gangestad *et al.*, 1994). This indicates that the higher the FA, the lower the facial attractiveness. And if FA provides reliable information on the developmental instability of an individual, then symmetry, especially facial, could be regarded as a health certification of a potential mate (Baudouin and Tiberghien, 2004). Symmetry, as opposed to asymmetry, is positively related to facial attractiveness (Penton Voak *et al.*, 2001) as seen in women with symmetrical faces that are rated as more attractive (Baudouin and Tiberghien, 2004) and have more sexual orgasm if their sexual partners possess more symmetrical faces (Thornhill *et al.*, 1995).

It implies that facially attractive individuals display genetic quality through developmental stability (Thornhill and Gangestad, 1993, Hume and Montgomerie, 2001). Moreover, in our daily interactions, there is no doubt that individuals termed as attractive by all standards, accrue numerous benefits, ranging from being treated more positively (Langlois *et al.*, 2000) as in paying lower bail (Downs and Lyons, 1991), having higher reproductive success [e.g., (Thornhill *et al.*, 1995, Prokop and Fedor, 2011, Pfluger *et al.*, 2012)], longevity (Henderson and Anglin, 2003), having more dates (Riggio and Woll, 1984), and getting quickly employed (Marlowe *et al.*, 1996, Chiu and Babcock, 2002). In fact, it was demonstrated that attractive individuals are gazed at for longer even by infants, receive lesser punishment in schools, better and easier court convictions, get higher grades in university and colleges, and above all, they are more frequent allies for friendships [see review in (Grammer *et al.*, 2003) than individuals with less attractive faces.

It is important to be aware, though, that not all quantifiable asymmetry can be perceived by the human eye, and to note that perception of asymmetries can vary between individuals (McAvinchey *et al.*, 2014), which may go some way towards explaining discrepancies between results from studies that have sought to correlate measures of asymmetry with perception of beauty or attractiveness. Nevertheless, there is evidence that perception of facial asymmetry may reflect specialised face-specific cognitive mechanisms, with individual sensitivity to geometric variation that results in facial asymmetry having been shown to exceed sensitivity to other types of geometric variation, or to variation in the symmetry of non-facial shapes (Anderson and Gleddie, 2013).

A specialised cognitive mechanism may imply a role for natural selection and evolutionary significance for the perception of facial asymmetry; but recent failures to demonstrate a general link between asymmetry and fertility (Pfluger *et al.*, 2012) and between asymmetry and childhood health in a British cohort (Pound *et al.*, 2014) may imply that detection of asymmetry serves to identify individuals that have suffered significant developmental disturbance and pathology rather than to distinguish low-level differences in developmental stability and individual fitness (Pound *et al.*, 2014). Although the existence of a relationship between facial symmetry and perceived attractiveness in the absence of a corresponding relationship between symmetry and fertility (Pfluger *et al.*, 2012) remains intriguing and may, alternatively, hint at problems with quantifying fertility.

3.9 Quantification of facial asymmetry

3.9.1 Direct anthropometry of facial morphology

Direct anthropometry has been the first method for the quantitative assessment of the human face, the major source of many published normative population data (Farkas, 1994, Zankl *et al.*, 2002) and the foundation stone for the validity of other measurement techniques (Aung *et al.*, 1995). Although it is still considered the gold standard for facial measurements because it is a simple, cheap, non-invasive technique that uses commonly available instruments (Farkas, 1994, Zankl *et al.*, 2002), it is mainly used currently for comparative methodological studies [e.g.,(Farkas, 2002, Weinberg *et al.*, 2006, Ghoddousi *et al.*, 2007, Noyan *et al.*, 2011, Joe *et al.*, 2012, Kramer *et al.*, 2012)] in order to validate or invalidate the technique over others.

The technique employs the use of metallic instruments such as Vernier, Sliding or Spreading Callipers, or the use of plastic materials such as rulers or measuring tapes. Unfortunately, the technique has a lot of problems: such as training the participants and the researcher, and it is time consuming, boring, not suitable for infants and children, does not provide digital coordinate record of the participants for later use in order to extract new facial measurements, cannot be used to determine certain facial features (e.g., surface area, volumes, and shape quantification), or limitations on re-measuring in cases where there are missing values since the subject is released. Also, it is very easy for errors to be introduced by the measuring tools and by the measurer (Farkas, 1996) and one fundamental source of concern with direct anthropometry is the likelihood of injuring the participants from the use of the metallic instruments, because they have pointed tips and sharp edges. The accuracy and reliability of this technique is therefore questioned since the measuring instruments may press against the participants when measuring soft tissues especially in the face, which might alter the dimensions being measured.

Ferrario et al. (1998) introduced an extended direct anthropometric approach by digitalizing the landmarks on the human face using a non-contact digitalizing device. The device acquires the 3D coordinates of the facial landmarks already placed on the subjects, thus recording the coordinates without skin contact and therefore avoiding skin indentation introduced by the direct anthropometry.

3.9.2 Indirect facial anthropometry using two-dimensional (2D) images

In this approach, human facial variations are assessed using recorded 2D images such as photos or radiographs. Given the problems of direct anthropometry, researchers shifted towards indirect anthropometry using 2D images [e.g., (Langlois and Roggman, 1990, Ferrario *et al.*, 1993a, Rhodes, 1998, Rhodes *et al.*, 2005, Rennels *et al.*, 2008, Lee *et al.*, 2010, Hooder and Souza, 2012)]. The main advantages of this method over the direct method are that the technique is faster, and records remain available in case where there are missing values. However, major problems of this approach are, firstly, that this technique can only capture horizontal and vertical facial dimensions with loss of facial depth, therefore presenting 3D subjects in the form of 2D images (Da Silveira *et al.*, 2003); secondly, the problem of various types of image distortions from different degree of resolutions by different photographic techniques. Moreover, there is still the difficulty of accurately placing landmarks to their exact locations in 2D studies; and facial landmarks are subject to rotation, position and magnification errors (Houston, 1983).

3.9.3 Indirect facial anthropometry using three-dimensional (3D) Stereo photogrammetry

Based on the lack of reliability, accuracy, and other limitations associated with the direct and indirect 2D techniques, the best option, is to use 3D measurement techniques, which have been used by several studies [e.g., (Burke, 1971, Burke and Healy, 1993, Ras *et al.*, 1995, Heike *et al.*, 2010, Verhoeven *et al.*, 2013, Ladeira *et al.*, 2013)].

Such 3D measurement techniques include stereophotogrammetry, which is an old method of assessing facial form, specifically to determine the geometry of objects from photo images. In this technique, two cameras stationed as a stereo-pair, are used to capture the 3D distance to features on the facial surface by means of triangulation. To decrease the introduction of errors from the subject movement, several views of images are simultaneously recorded and the images are later processed to calculate facial surface coordinates (Ferrario *et al.*, 2003). Stereophotogrammetry is non-invasive, accurate (therefore reliable), and very fast (data capture < 1 second) and therefore suitable for infants and children facial studies (Heike *et al.*, 2010) and many subjects can be captured within a short period.

3.9.4 Indirect facial anthropometry using three-dimensional (3D) CT-scans

Three-dimensional CT scans to determine facial variations have also been used [e.g., (Moro, 2009, Hwang *et al.*, 2012)]. Although this technique has the advantage of visualizing and assessing internal morphology for other body morphometric studies, its use is very limited for two reasons: firstly, it is a very expensive investigation, secondly, it uses a high dose of radiation and is thus unjustifiable for use on healthy subjects for research purposes (Tziavaras *et al.*, 2009). Hence, almost all the studies reporting facial morphology data using this technique were of patients with normal craniofacial morphology but with sufficient medical and diagnostic evidence to undergo CT investigation, such as patients with meningitis and mild hydrocephalus (Tziavaras *et al.*, 2009), because these conditions do not present with abnormalities in craniofacial growth and morphology (Yusof, 2007).

3.9.5 Indirect facial anthropometry using three-dimensional (3D) Laser surface scanning

Laser scanners illuminate the scanning face of the subject with eye safe laser light rays, and the in-built cameras capture the reflected light from the reflecting targets placed all over the face of the subject and the image is obtained on the computer screen by triangulation geometry. The resolution of laser scanners is far better than that of the Stereo photogrammetry, thereby making the 3D laser scanning method better. The resolution of the images acquired from Stereo photogrammetry, for example 3dMD (Atlanta, GA) cameras, is between 0.6-1.0 mm (Ayoub *et al.*, 2003), which is lower than that of laser scanning.

Three-dimensional anthropometry using 3D laser surface scanning has received immense acceptability in the recent time [e.g., (Hennessy *et al.*, 2005, Dong *et al.*, 2009, Meyer-Marcotty *et al.*, 2011b, Djordjevic *et al.*, 2011b, Kusnoto and Evans, 2002, Primozic *et al.*, 2012, Pound *et al.*, 2014)] because it is also non-invasive, accurate, provides high image resolution, is reliable, portable, and can adequately capture 3D morphological variations.

3.9.6 Indirect facial anthropometry using Landmarks

Landmark-based methods for quantifying facial asymmetry have been criticised for introducing a degree of bias (Houston, 1983, Toma *et al.*, 2009), especially when based on estimates of a facial midline. A facial midline cannot be determined accurately, because the midline landmarks (glabella, nasion, pronasale, subnasale, labrum superior, stomium, labrum inferior, sublabius, pogonium, and mentum) do not lie exactly on the midline (Haraguchi *et al.*, 2008). Therefore, landmark-independent techniques are recommended for the quantification of facial asymmetry (Meyer-Marcotty and Stellzig-Eisenhauer,

2009) and have been embraced by some recent studies (e.g., (Meyer-Marcotty *et al.*, 2010, Djordjevic *et al.*, 2011a, Primozic *et al.*, 2011, Primozic *et al.*, 2012). The present study therefore adopts the use of a 3D laser scanning, landmark-independent method. The major limitation of this method is that differentiating between the three forms of asymmetry in the face is difficult.

However, the present study is only interested in the evolutionary and more specifically sexual selection dimension of asymmetry; and since to the observer, asymmetry is asymmetry, irrespective of its exact developmental origins, it is relevant to establish both correlates and consequences of overall asymmetry, not just of individual elements of asymmetry.

Chapter 4 : SEXUAL DIMORPHISM

4.1 Evolutionary significance of sexual dimorphism

Sexual differences in body size and morphology are marked in all animal taxa and the evolution of these differences was explained in terms of sexual selection theory, in which Darwin proposed that the evolution of sexual dimorphism is a consequence of sexual selection for characters that offer benefit in either contest competition (male-male fight) for mates or mate choice, such as female choice for ornamented male as in Peacock tail (Darwin, 1871). However, sexual dimorphism does not solely evolve from sexual selection pressure but may also evolve from food competition, or from intrinsic differences between the reproductive roles of males and females (Selander, 1972). Additionally, sexual dimorphism can also evolve due to the action of certain ecological forces such as competition between male and female for the limited available resources for example food (Slatkin, 1984, Shine, 1989).

The study of sexual dimorphisms is very important as they have some important functions in reproductive behaviour and mate choice and are subject to powerful sexual selection pressures (Anderson, 1994). These sexual selective pressures that differ between the sexes fashion sexually dimorphic phenotypes and indicate the divergence of the reproductive fitness interests of males and females (Chippindale *et al.*, 2001).

Many of the sexual dimorphisms are said to be under the control of steroid sex hormones (Ketterson *et al.*, 2005, Mank *et al.*, 2007), which then control the genes underlying sex-specific phenotypes (Reinuis *et al.*, 2008).

As a result of sexual dimorphism, highly ornamental males across many species of organisms are known to have a high quality immune system and reduced parasitism (Moller *et al.*, 1999, Thornhill and Gangestad, 2006) as well as an increased adult survival (Jennions *et al.*, 2001), though this pattern is not universal across the studied species. In humans, facial sexual dimorphism in adolescent males has been correlated positively with rated and actual health history (Rhodes *et al.*, 2003). Additionally, sexual dimorphism also has shown positive correlation with developmental stability which is considered to be an indicator of developmental health (Gangestad and Thornhill, 2003a), and in females it has been proposed that femininity (facial and bodily estrogenization) signals individual quality and, specifically, fertility (Thornhill and Gangestad, 1993).

4.2 Sexual dimorphism of facial development

Sexual dimorphism with regards to body proportions has not been demonstrated in human developmental process, but the general size is slightly greater in males than in females during the last two months of prenatal life (Schultz, 1923). However, little difference exists in the skull and face between males and females after birth until they reach puberty. The skull of the adult male is a little heavier and larger, the walls of the flat bones are thicker and muscular ridges are more pronounced. The glabella, supercilliary arches, and mastoid processes are all more prominent (Schoenwolf *et al.*, 2009). The upper orbital margins are thicker, the orbit is squarer, the forehead less vertical, and frontal and parietal tuberosities are more pronounced. The face is more elongated, facial bones are not smooth, mandible, maxillae and the contained teeth are larger. Muscle markings are larger and heavier on the nuchal crest, temporal bone and crest, and on the zygomatic roots (Schoenwolf *et al.*, 2009).

Fewer childhood characteristics are retained in adult males than are retained in females. Females undergo puberty 2 years earlier than males on average with the males having an additional two years of somatic growth. The expression of sexual differences in the skull is believed to be influenced by several factors, including, genes, diseases and nutrition (Schoenwolf *et al.*, 2009).

4.3 Quantification of facial sexual dimorphism (here referred to as FSD)

A large volume of literature is currently available concerning the quantification of FSD in different populations, but most of these studies have used two-dimensional (2D) assessments using facial photos (Penton Voak *et al.*, 2001, Koehler *et al.*, 2004b, Lefevre *et al.*, 2012, Ozener, 2012, Kramer *et al.*, 2012, Hill *et al.*, 2013) or radiographs (Bulygina *et al.*, 2006). In the last few decades, other studies used direct anthropometry to study growth and development of the face and to establish normal 3D facial soft tissue values for different populations (farkas and Munro, 1987, Farkas *et al.*, 1995, Farkas *et al.*, 2003).

Similar to the quantification of facial asymmetry, FSD can also be quantified by direct measurements from a set of standard landmarks using an angle meter, a measuring tape, or sliding and spreading callipers [e.g., (Farkas, 1994, Aung *et al.*, 1995, Weinberg *et al.*, 2006, Kramer *et al.*, 2012)]. These instruments are used to measure both paired (e.g., eyes, ears, and nostrils) and un-paired facial distances (e.g., facial height and nasal height). However, others have used an easy, quick and reliable indirect technique (Aung *et al.*, 1995) such as facial photographs, 3D CT-scans (Franklin *et al.*, 2012) or 3D facial scans from laser scanning technique (Kramer *et al.*, 2012) including recent univariate and multivariate methods (Green and Curnoe, 2009, Bigoni *et al.,* Franklin *et al.*, 2012, Hill *et al.*, 2013). In the quantification of FSD, there is no limit for the set of facial dimensions to be used as some authors used few [e.g., (Penton Voak *et al.*, 2001, Gangestad and Thornhill, 2003a)], or even a single ratio such as facial width-to-height ratio (FWHR) measured as the ratio of upper facial height (upper lip to brow) to bizygomatic width. Sexual dimorphism in FWHR has received a lot of attention in recent years, but results have not been consistent.

An analysis of southern African skulls from 30 men and 30 women suggested that men have larger FWHR than women (Weston *et al.*, 2007), which means a wider face that cannot be attributed to dimorphism in size. Similarly, FWHR was shown to be significantly larger in males from a sample of 88 undergraduate students (37 men, 51 women) of mixed ethnic origins (Carre and McCormick 2008). In contrast, FWHR was not significantly dimorphic even with a larger sample of 192 and 123 students (Haselhuhn and Wong, 2011), similar to the result obtained from a Turkish sample of 470 university students (Ozener, 2012). Additionally, FWHR was not found to be sexually dimorphic in samples of white Europeans ranging from 155 to 415 (Kramer *et al.*, 2012), nor in a further four large adult samples, ranging from 145 to 306 individuals and including both Caucasian and African populations (Lefevre *et al.*, 2012). In summary, studies of dimorphism in FWHR are not conclusive, but the majority of studies using large samples have not been able to confirm a consistent presence of sexual dimorphism in this trait (Weston *et al.*, 2007, Carre and McCormick 2008, Haselhuhn and Wong, 2011, Kramer *et al.*, 2012, Ozener, 2012). Other facial traits analysed by Lefevre et al. (2012) included lower face-face height, cheekbone prominence, and face width-lower face height, which were found to be sexually dimorphic.

In addition to standard linear measurements, recent advances in morphometric research have also resulted in quantification of facial shape, of sexual dimorphism and of sex-specific morphology based on landmark data and geometric morphometric methods of analysis [e.g., (Fink *et al.*, 2005, Pfluger *et al.*, 2012)].

In the present study, facial dimensions are used to quantify FSD, including masculinity-femininity scores derived from facial dimension subjected to the principal component analysis (PCA) and discriminant function analysis (DFA).

Chapter 5 : GENERAL MATERIALS AND METHODS

5.1. Participants and participants' information

5.1.1 Study area

Nigeria is in West African, sharing borders with 4 countries: Niger (north), Chad and Cameroon (east), Benin (west), the Atlantic Ocean lies to the south (SWP, 2000) (**Figure 5.1**). It lies between 4°16' and 13°53' northern latitude and 2°40' and 14°41' eastern longitude. It has a tropical climate with 2 seasons. The dry season (October to March) is associated with the cold, dry and dusty Harmattan wind, which normally blows from the north. The wet season (April to September) is associated with rainfall that ranges from 265cm in the south to less than 60cm in the north with maximum temperature oscillating between 25° and 40°C. The vegetation is Sahel grassland in the north and mangrove swamp forest in the Niger Delta (NPC, Macro; 2009). Nigeria has a mostly rural human population of 140.4 million (NPC, 2006a) with three major ethnic groups: Hausa, Igbo, and Yoruba (NPC and ORCM, 2004).

Nigeria is a very rich country based on its crude oil production capacity of 2.5 million barrels per day, which ranks it as Africa's largest producer of oil and the sixth largest oil producing country in the world (NNPC, 2013). Unfortunately, however, the country has one of the highest neonatal death rates (Zupan and Aahman, 2005) and maternal mortality ratios in the world (Hogan *et al.*, 2010). The country has a young population structure as a result of its fertility and mortality patterns.

Poverty in the country is deeply engrained with 54.1% of the population living in severe poverty on under 1.25 USD per day (OPHI, 2013).

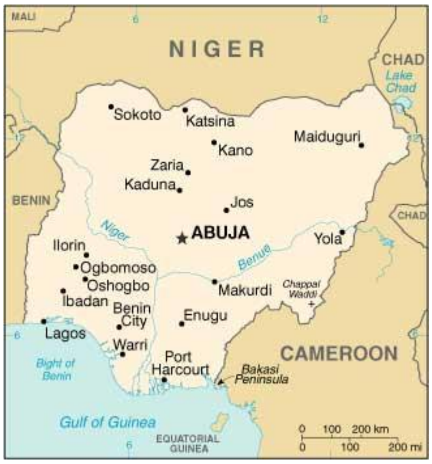


Figure 5:1: Nigerian Map and cities

5.1.2 Study participants

The Hausa ethnic group is mostly found in the northern states of Nigeria and has a population of about 75 million (Christian, 2006). They were established between (the end of) the 9th and (the beginning of) the 13th century with their kingdoms situated between the River Niger and the Chad Basin where ethnologists considered their origin to have been (Simon and Vassar, 1992). They speak Hausa language (of mixed origin), a Chadic group of Hamitic (or Afro-Asiatic) family of languages and the language is spoken by millions of people in the North and West Africa and are known to be hardworking people, skilful in smithcraft, weaving, dyeing and leatherwork (Gwandu, 1977). The major staple foods include millet seed, Guinea corn, Maize and Rice and soup made from green leaves.

The absence of any population genetic studies on the Hausa population of northern Nigeria has caused many conflicting theories about their origin, but the most popular story is that of a man who migrated from Middle-East (Sutton, 1979, Lange, 1987, Mary, 1997, Sarah, 2009): Bayajidda, son of king Abdallah (Hallam, 1966, Pellow, 1996) of Baghdad fled (after a conflict with his father) to Kanem – Borno, in the Chad basin and was fully received by the Mai (or Maina) of Borno and got married to the Mai's daughter (Magira) but later fled Borno (with his wife) because the Mai (his father-in-law) wanted to kill him. He proceeded westward of Borno with his wife to Biram-ta-Gabas (Sarah, 2009) where she bore him a son called Biral (Mary, 1997) or Burkimu (Hallam, 1966). He left the wife there and reached Gaya town (a local government in the present-day Kano State) where he met some blacksmiths who made him a knife and then continued his journey further west, to a town called Daura (a local government in the present-day Katsina State) whose occupants were only allowed by a sacred snake called Sarki to fetch water on Fridays (Hallam, 1966) from the only well in the town. The very night of his arrival in an old woman's house (who offered him a place to sleep), whose name was Ayana (Hallam, 1966), Bayajidda asked her for some water to use, and since she had none, she informed him about the well and the snake. Bayajidda proceeded to the well and emerged the hero by using his knife to kill the snake (Sutton, 1979, Lange, 1987, Mary, 1997, Sarah, 2009). The following morning, the queen of the town, Magajiya Daurama (whose origin was claimed to be Palestine) from whom the town 'Daura' got its name, married him in gratitude for rescuing the people from the tyranny of the snake (Mary, 1997) and also gave him a Gwari concubine who bore him a son called 'Mun karbi gari' or 'Karbagari': meaning that, 'we have snatched the town', that means the concubine children will in future rule the town since the queen had no child as at then.

Mun karbi gari had seven sons who became the progenitors of the Banza Bakwai (seven illegitimate Hausa kingdoms): Zamfara, Kebbi, Nupe, Gwari, Yauri, Yoruba and Kororofa or Kwararrafa (Mary, 1997, Sarah, 2009), so called illegitimate (Banza) because they originated from out of wedlock (from concubine). However, upon seeing that the concubine had a son, the queen also decided to get pregnant for Bayajidda (out of jealousy) and thus had a son whose name 'Ba mu garinmu' or 'Bawo': meaning that, 'give us our town'. Bawo in turn had six sons (Hallam, 1966), and together with Bayajidda's first son Burkimu from his first wife whom he left at Biram-ta-Gabas, the seven legitimate sons were then the originators of the Hausa Bakwai (seven legitimate Hausa kingdoms): Daura, Katsina, Zazzau (Zaria), Kano, Rano, Gobir and Biram (Lange, 1987, Sarah, 2009). Therefore Bayajidda fathered three sons from three wives: the Borno princess, Daurama and the concubine which is typical representation of Hausa polygamous marriage (Mary, 1997).

The Hausa ethnic group was chosen for the purpose of this study because they constitute the largest population in Nigeria (NPC, 2006b). In addition, the majority of the young people in the country are Hausas, providing more access to participants between the ages of 18-25 years as required for this study. The Nigeria national population data (2006) show that about one-third of these youth in the northern part of the country are either uneducated or unemployed (NPC, 2006b) making this ethnic group more favorable to test the effect of socioeconomic status. Moreover, the majority of the Nigerian people living in severe poverty are found in the north of the country (OPHI, 2013).

In addition, maternal mortality and neonatal deaths are highest amongst this ethnic group (Wall, 1998) and since maternal and neonatal deaths are amongst the indices used to measure population health, this suggests an appropriate background against which to explore the influence of medical history on facial asymmetry. The highest temperatures and lowest rainfall are usually recorded in the north (NPC, Macro; 2009) and malaria and typhoid are endemic in the area. All of this emphasizes that northern Nigeria is a particularly challenging environment, and one that is particularly suitable for assessing the influence of environmental variables in the broadest sense on facial asymmetry and for testing hypotheses of the causes and consequences of facial morphology in general.

5.2 Study design

This is a prospective cross-sectional study with subjects fully informed about the procedure of the scanning, and the questionnaire protocols. Informed consent was obtained from all those who participated in the study and all were of Hausa ethnic background.

5.2.1 Ethical approval and consent

Ethical approval was granted by the ethics committee at University College London (UCL Ethics Project ID Number 3080/001) and the Federal Ministry of Health in Nigeria [Health Research Ethics Committee (HREC) assigned number: NHREC/01/01/2007]. Copies of the Participant Information Sheet and Consent Form are included in **Appendix 1**.

5.2.2 Recruitment of participants for scanning

In order to test the effect of socio-economic status on facial asymmetry and dimorphism, two sets of participants were recruited. The 1st group of participants were from low socio-economic status (SES) selected from two villages at random from Kaduna State (one of the Northern Nigerian States where Hausa are found in large numbers). The two villages, Garu and Dan-bami were areas where living conditions are poor, with people living densely populated in a few settlements with un-tarred muddy and narrow roads. Most of the families in these areas live as an extended family where multiple families share a single house and many people share a room. These houses were mostly built in thatches and muds and are surrounded by bush land. The youths in these two villages are mostly un-employed but engage in petty trading, manual labor, farming or animal rearing. Health facilities and social amenities are scarce, electricity is on and off, and drinking water is sourced from stagnant ponds or open wells. Most mothers in these villages are full-time house wives mainly left on their own to feed themselves by in-house paid work (e.g., grain grinding, grain pounding, hand-washings and charcoal pressing etc.).

The 2nd set of participants was students from two institutions: Bayero University Kano and Aminu Kano School of Legal and Islamic Studies. These two schools are in the city of Kano State (the 2nd largest city in Nigeria) where the Hausa population constituted the majority. Most of these students were from well-educated families and some had parents who were civil servants or business-men with a higher than average income. These set of participants live within the city of Kano with electricity, pure and wholesome drinking water, tarred roads and other social amenities.

In addition, their family members live in houses built in blocks or bricks with multiple rooms that are well ventilated and with mosquito nets. Their parents may own vehicles such as cars, trucks, bikes and other machines. Furthermore, some of the participants' parents own many houses for rent, lands for farming and several plots of lands for building houses or to be kept as assets.

The participants were ranked according to their wealth, using criteria used in assessing wealth in the area. The Medical history of both the participants and their mothers was collected using questionnaires. The subjects were selected using a random sampling technique. Participants were selected from young adults between the ages of 18 and 25 in order to minimise variation introduced by on-going ontogenetic development (in younger individuals) or aging (in older individuals). Individuals found to have a significant amount of hair on their faces, surgical facial scars, traditional facial identification marks, facial keloids, or any disproportionate facial size or expression due to disease or infirmity (including cleft lip or palate, brachycephaly, dolichocephaly, plagicephaly, hemifacial microsomia, dysmorphic syndromes, facial trauma, past facial surgery or obvious facial swelling from any) were excluded from the study. Furthermore, only individuals with sound dentition were included, in order to minimise variation introduced by functional asymmetries resulting from dental pathologies. All data were then recorded anonymously.

5.2.3 Demographic questionnaire

A demographic questionnaire was used in this study, which has long been one of the major research tools in social sciences, arts and humanities and other fields.

The questionnaire consists of 4 sections: *section 1* contains the demographic /personal data about age (in years), sex, religion, tribe, birth order, number of siblings, and marital status. *Section 2* of the questionnaire has questions about the socioeconomic levels of the participants or their parents and the socioeconomic levels indicators used are: levels of education (for the participant, mother and father), occupation (of the father, if the participant is dependent, or of the participant if the participant is independent), assets ownership of the participant or the father (including land, house, house built, livestock and vehicles acquisition) and total income per month. *Section 3* of the questionnaire tries to explore the past medical history of the participant and his/her mother while she was carrying the participant in her womb or at the time of breast-feeding the participant. Most of the diseases included are endemic and were deliberately placed in the questionnaire to explore maternal medical history, and the diseases are: malaria, typhoid fever, tuberculosis, leprosy, sickle cell disease, diabetic mellitus, hypertension, peptic ulcer disease, HIV and AIDS. For the participants, malnutrition, measles, sickle cell disease, meningitis, severe malaria, severe typhoid, tuberculosis, poliomyelitis, diphtheria, and hepatitis were asked to explore diseases that affected the participant while growing as a child. *Section 4* of the questionnaire is about the basic somato-metric data that includes: weight, height and blood pressure. A copy of the demographic questionnaire is in **Appendix 2**.

Four hundred and twenty-six participants filled in 426 questionnaires with their age ranging from 18-25 years (mean age: 21.19 ± 2.31 years), weight (range, 30.3-117 kg, mean, 55.89 ±9.81 kg), height (range, 1.42-1.92 m, mean, 1.63±0.09 m), body mass index (range, 14.0-44.6 kg/m2, mean, 21.12±3.07

kg/m2), systolic blood pressure (range, 80-158 mmHg, mean, 112±14 mmHg), diastolic blood pressure (range, 36-136 mmHg, mean, 71±13 mmHg), number of siblings in a family (range, 1-45 children, mean, 10±6 children), marital status (178 married, 248 unmarried), participant levels of education (316 educated, 110 uneducated), occupation (221 students, 205 non-students), income per month (range, 0-700000 Naira, mean, 77755.97±106193.77 Naira) (**Table 5.1**).

Table 5:1: Descriptive statistics of the participants' biometric and income data. BMI: Body Mass Index; SYSTBP: Systolic Blood Pressure; DIASTBP: Diastolic Blood Pressure.

	N	Minimum	Maximum	Mean	Std. Deviation
AGE in years	426	18.0	25.0	21.2	2.3
Weight (Kg)	426	30.3	117.0	55.9	9.8
HEIGHT (M)	426	1.42	1.92	1.62	.09
BMI (Kg/m^2)	426	14.0	44.6	21.1	3.1
SYSTBP (mmHg)	426	80	158	112	14
DIASTBP (mmHg)	426	36	136	71	13
Birth Order	426	1	27	4	3
Number of siblings	426	1	45	9	5
Income in Naira	426	.0	700000	77755.97	106193.77

5.2.4 EXAscan 3D Laser Surface Scanner

The instrument used for quantifying facial morphology in the present study was an Exascan 3D Laser surface scanner from Creaform (www.handyscan3d.com) (**Figure 5.2**) which can adequately capture 3D facial morphological variations, it is non-invasive, requires no body contact and introduces no distortion of the tissue surface being scanned. This instrument generates 3D digital facial morphology which can interactively be viewed and manipulated for objective or subjective analysis. It uses a class II laser, which is considered eye and skin safe (but can cause eye damage through extended direct exposure). Through the proprietory software, VXScan Vs.4, the scanning process generates .stl files, which can easily be imported into inspection software and processed.

The ExaScan is a handheld, self-positioning scanner that offers increased resolution (0.05mm) and accuracy (up to 40µm). The self-positioning feature is based on the triangulation of reflective targets that are placed on the subject being scanned. The detailed Exascan scanner properties are listed in **Appendix 3**.

Figure 5:2: ExaScan 3D Laser Surface Scanner

5.3 Scanning process and scan preparation

5.3.1 Scanning protocol

The scanner was calibrated to correct any optical or electronic distortions and the sensor configured for dark skin. Prior to scanning, positioning targets were placed on the face of the participant, from the hair line down to the chin, and along each side of the face including the ears. Test scans were conducted with the participant lying supine with or without the use of a dough-nut shaped head rest and with the subject sitting down still.

The results were better with the subjects sitting rather than lying down, so this position was chosen for all further scans. Scanning was done with each participant seated in an upright position, asked to sit still on a chair with the head facing up (neck extended) at a slight angle of about 45 degree relative to the floor, as this position was found to be the most comfortable to scan in while the researcher was standing, avoiding the need to bend down a lot if the participants were to be looking straight ahead. Participants were instructed to keep their eyes closed to avoid discomfort from the laser beams. During the scanning process, the 3D digital scan is generated on the computer screen in real time, allowing the researcher to continue scanning until a satisfactory scan has been created (**Figure 5.3**). Good quality 3D facial scans were obtained with the subject maintaining a natural pose with neutral facial expression (see (Peter *et al.*, 2004). In a situation where the position or pose of the subject distorted the face, or if the facial expression was not neutral, the scans were discarded as the inclusion of non-neutral facial expressions would have affected morphological comparisons between subjects (see (Peter *et al.*, 2004).

Figure 5:3: Facial scan before cleaning

5.3.2 Cleaning of scans

Contrary to many other scanners, the ExaScan directly generates triangulated surfaces. These were exported as *.stl* files into Geomagic Studio 2012 software for cleaning. Each of the face scan was first cleaned using *Mesh Doctor,* which automatically repairs imperfections in a polygon mesh. The resulting scan was further cleaned using the *Lasso Selection* tool whereby further unwanted polygon mesh elements were selected and deleted. At this stage the scans still have many small holes (defects) or artefacts left-over from the scanning process and these holes were filled using the *'Fill Single'* option. The image was then saved as a *.wrap file* which serves as the original scan for further analysis.

5.3.3 Trimming of scans

Trimming of the original cleaned scans for analysis was performed under the *Trim* options in Geomagic Studio 2012. The 3D Cartesian coordinate system has three axes: the *x*- axis of the coordinate system denoted top-bottom, the *y- axis* right-left*, and the* z- axis *front-back* reflecting the dimensions of the scans. The trimming process took place in three stages:

Trimming the upper facial boundary: In the *Define* option, the *Three Points* option was selected from the drop down menu. The first point was placed on the highest point of one pinna while the second point was placed at the highest point on the other pinna. To place the points on the left pinna, the scan was rotated so that the face faced to the right hand side in anatomical position, and to the left hand side when placing the point on the right pinna. The third point was placed at the highest forehead limit (at the junction between the hairline and the forehead) in the midline. The three lines were aligned together to form a plane by clicking the *Align* option. The *Position* field option was adjusted to shift the Plane inferiorly towards the eyes for a distance of 5 mm to avoid hair inclusion to the scan selection. In the *Operation* box, the *Intersect Plane* option selects the scan data above the *trim* plane, and the *Delete Selection* option deletes the selection. *OK* (without creating any boundary on the sectioned polygon) confirms the trimming operation. Trimming the upper facial boundary deletes any scanned portion of the scalp.

Trimming the lower facial boundary: Using the *Three Points* option, the first and second points were placed on either side at the gonion (mandibular angle) by rotating the scan.

The third point was placed just below the chin at the midline with the scan rotated to face forward in anatomical position. The points were aligned and the resulting plane was shifted 5 mm up towards the lower lip. The selection was then sectioned using the *Operations* menu as described above. Trimming the lower facial boundary deletes any mouth floor that was scanned during the scanning process.

Trimming the posterior facial boundary: Using the *Three Points* option, the first point was placed at the junction of attachment of the helix with the lateral facial wall. The second point was placed at the junction of the ear lobe with the lateral facial wall. The third point was placed on the other ear at the tragus. The points were aligned and the position of the resulting plane was adjusted through rotation, using the *Rot X* and *Rot Y* fields on either side of the face to lie exactly anterior to the helix, the tragus and the ear lobe. The XY *plane* was then shifted forward and parallel to those structures on either side over a distance of 5 mm and trimming the posterior boundary of the face deletes the ears and few millimetres of the area anterior to the ears.

The trimmed scan was saved then mirrored using the *Tools-Mirror* option. The original scan was then deleted, leaving only the mirrored which was saved under the same name as the original trimmed scan but with 'M' to identify it as the mirrored model.

5.3.4 Model alignment

In order to quantify facial asymmetry, original and mirrored scans (cleaned and trimmed) were produced in Geomagic Studio 2012, **(Figure 5.4)** and were aligned.The first step in the alignment procedure, involved registration of the original and the mirrored scans by using the *Manual Registration* option, where 3 corresponding points are identified on the original and the mirrored scans and registration is performed on the basis of the initial alignment of those points. Following this, the alignment was further refined using the *Global Registration* option, setting *Sample Size* to 25000 with the maximum number of iterations set at 100. In practice, convergence was usually reached after 10 to 15 iterations. Finally, *Global Registration* was repeated using the maximum possible *Sample Size* of 50000. The aligned models were then re-trimmed together using the *Three Points* option and protocol outlined previously for single scan in order to equalize the extent of both scans and avoid non-corresponding scan elements affecting asymmetry values. This final aligned model **(see Figures 5.5 & 5.6)** was always saved as a separate model for re-use in later analyses, e.g., for selection of localized facial features such as eyes***.***

Figure 5:4: Original and Mirrored facial scans before alignment

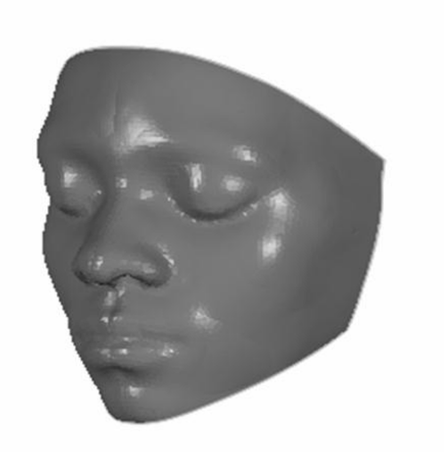


Figure 5:5: Combined (original and mirrored) facial scans (after alignment)

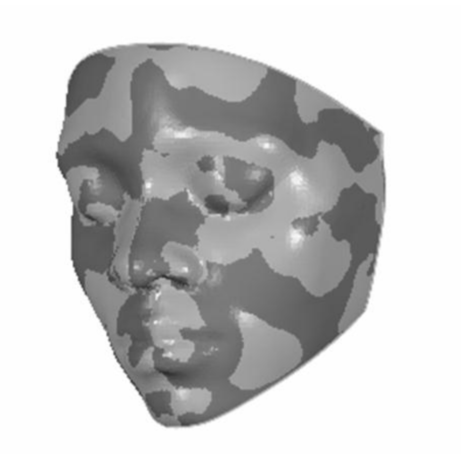


Figure 5:6: Deviation analysis between original and mirrored facial models

5.3.5 Selection of the eye region

For the quantification of asymmetry around the eye region, the already prepared 3D facial model was used. The eye region was selected by using three standard landmarks: the two outer corners of the eyes and any of the inner eye corner. A horizontal plane was then placed at those 3 landmarks and then moved upward to lie 5mm above and parallel to the two eyebrows. The area above this plane is then deleted and the same horizontal plane was moved down to lie 5mm below and parallel to the edge of the closed upper eyelid (since scanning was conducted with eyes closed). Any portion of the face below the plane was deleted.

A Coronal (vertical) plane was placed on the outer corners of the two eyes, moved 5 mm behind the corners and any portion behind the plane was then deleted. This portion of a 3D facial model which looks more or less rectangular, is then used to quantify asymmetry around the eyes (**Figure 5.7**).

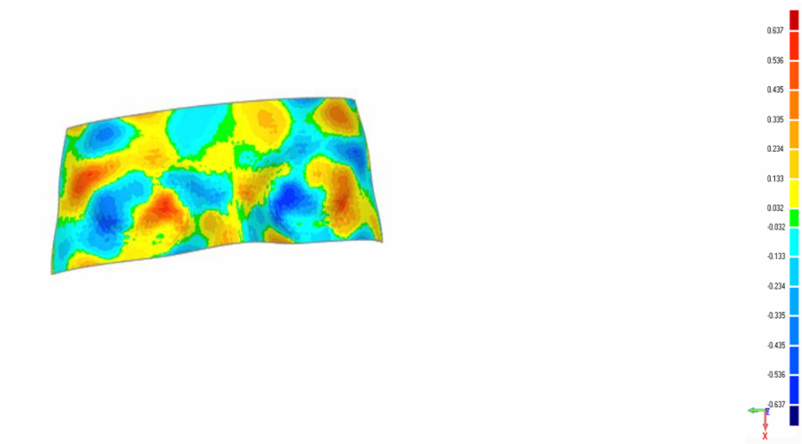


Figure 5:7: Color deviation map between the eye region of original and mirrored models

5.3.6 Measures of asymmetry

Facial asymmetry was quantified as the standard deviation of the shortest distance between each individual 3D point on the reference scan and the surface of the aligned mirrored scan in each of the 3D facial models. The resulting quantitative values for individual asymmetry either for the overall (whole face) asymmetry or asymmetry around the eyes, form the basic data for all subsequent analyses.

The resulting asymmetry values were analysed using *R-statistic software version 3.1.2 (R Core Team., 2014)*.

The present study has the advantage over other studies of using 3D scans instead of 2D photographs, which largely report 3D facial asymmetry on 2D images with a high risk of missing potentially significant dimensions on either side of the face and where even slight differences in the angle at which the camera is faced will introduce spurious asymmetry values. By measuring the overall facial asymmetry (rather than using some selected facial dimensions: landmarks method) to acquire facial asymmetry in the present study, gives it an additional advantage over others, because the method takes into account all possible variations within and between sides. However, the disadvantage of this method is that it does not distinguish between the three types of asymmetry (fluctuating, directional and antisymmetry).

5.3.7 Measurement error

Measurement error has been found to have a significant impact on the studies of asymmetry especially fluctuating asymmetry (FA), and because Measurement error (ME) and FA share the same properties, an increase in either ME or FA results in increased variance (Palmer and Strobeck, 2003).

This can be particularly problematic since FA is often very small and of a magnitude similar to ME (Palmer and Strobeck, 2003).

In order to quantify repeatability, 10 repeat scans of two participants each and taken at different times, were cleaned, mirrored and aligned. The standard deviations of the aligned original and mirrored scans were determined and the mean standard deviations were calculated. Average deviation from the mean for each participant's ten scans was then calculated. Repeatability error was calculated as the proportion of the average deviation of repeats from the mean relative to the average asymmetry value. The resulting error values were 0.070 and 0.028 (or 7.0% and 2.8%) respectively for the two participants (**Table 5.2**) indicating relatively good repeatability of the scanning procedure. When compared to the average deviation from the mean of a preliminary sample of 100 individuals (mean asymmetry: 0.314mm; average deviation from the mean: 0.042mm), the averaged absolute error values (0.020; see **Table 5.2**) amount to about half the average population variation. These values confirm the substantial influence that even very small measurement error can have on studies of FA, but suggest that the protocol for scanning and 3D model preparation is appropriate and the values were 0.03 and 0.01 which means that the procedure of scanning was repeatable with only 1-3% error.

Table 5:2: Within subject repeatability of asymmetry value.

	Participant 1		Participant 2	
Repeat Scan	Asymmetry (StdDev in mm)	Unsigned deviation from mean (mm)	Asymmetry (StdDev in mm)	Unsigned deviation from mean (mm)
1	0.449	0.0222	0.370	0.0015
2	0.466	0.0392	0.345	0.0235
3	0.485	0.0582	0.378	0.0095
4	0.429	0.0022	0.368	0.0005
5	0.454	0.0272	0.385	0.0165
6	0.425	0.0018	0.367	0.0015
7	0.388	0.0388	0.376	0.0075
8	0.353	0.0738	0.346	0.0225
9	0.391	0.0358	0.364	0.0045
10	0.428	0.0012	0.386	0.0175
Mean	0.427	0.0300	0.369	0.0105
Average error		**0.070 (7 %)**		**0.028 (2.8 %)**

In an additional analysis, 30 random combinations of the 10 (repeated) separate scans were generated for each of the two participants in the repeatability study and the resulting paired scans aligned and analysed following the protocol outlined previously. The average standard deviation of each of the 30 combined models from the first and second participants were recorded as 0.2678 mm and 0.270 mm respectively. Comparing these values to the average asymmetry value for each participant suggests average errors of more than 50%, [(0.2678)/ (0.427) = 62.7% in the case of participant 1 and 73% (0.270)/(0.369) in the case of participant 2]. These values are in stark contrast with the values of the previous repeatability test.

Since all scanning and model preparation protocols were identical, the additional error is most likely introduced through differences in overall facial expression between different scans of the same individual. An inspection of colour deviation maps identifies the eye region as the most frequent source of the differences between scans of the same individual, suggesting that difference in how tightly participants close their eyes or how they react to the brightness of the laser beam vary between different scans. Since this does not, however, affect the overall facial asymmetry values, as demonstrated by the initial analysis of repeatability, it is not considered to pose a problem for this study.

5.4 Method of quantifying sexual dimorphism

5.4.1 Linear measurements using landmarks

Facial sexual dimorphism was quantified by using 22 standard landmarks (**Figures 5.8 & 5.9; table 5.3**) on various locations of the face using the Geomagic studio software 12. Raw landmark coordinates were exported into Excel and saved as .csv file (comma delimited) for each individual. From these landmark coordinates of each individual, 150 (left and right) measurements were acquired but reduced to 75 paired metrics by taking the average of the left and right metrics [(L+R)/2]. Additionally, there were 32 unpaired metrics thereby giving a total of 107 metrics. The metrics of each facial scan for each individual were acquired from a personally designed template using the coordinates of a single scan. The required measurements from any two landmarks were acquired by using the Pythagoras formula:

SQRT ((X1-X2)^^{2}+(Y1-Y2)^^{2}+(Z1-Z2)^^{2})

Each individual measurement so acquired from the template, was saved as .xls file, which the entire 107 measurements (75 paired & 32 unpaired for each individual scan) were copied and pasted into the main Excel file in ascending order of the questionnaire number. The facial metrics (**Table 5.3**) were divided (for easy discussion) into: oblique, horizontal, and vertical metrics (**Figure 5.10**). Normality of the facial metrics data was tested using the 'Kolmogorov Smirnov' and 'Shapiro tests'. Determination of sexual dimorphism was carried out using t-tests on the residual values of each of the 107 measurements using "R-software" (residuals of standard linear regressions of each facial metric versus the geometric mean of all facial metrics). Those 35 facial metrics out of the 107 for which t-tests returned significance values at or below the adjusted P-value threshold of 0.00047 (0.05/107) were retained and entered into a principal component analysis (PCA) to account for colinearity between variables. The t-statistics and p-values were presented for each individual metric and 16 of those metrics were found to be greater in males (**Figure 5.10**) and were presented with an asterisk (**Table 5.4**), while those greater in females were left without asterisk.

5.4.2 Repeatability (Intra-observer error)

Intra-observer analysis was carried out using the method adopted by Osvaldo et al (Osvaldo *et al.*, 2012), by re-measuring the same 107 metrics on the 25 randomly selected scans 2 weeks after the first 25 sets of measurements and the data were then analysed using paired samples T-Tests. Measurement error was below 5% for all metrics and substantially lower for most, but some metrics differed in their mean values between first and second measurements.

5.4.3 Estimation of the sexual dimorphism

Principal component analysis was performed on the thirty-five (35) sexually dimorphic metrics in this study. The principal component analysis (PCA) generates a small number of principal components, which explain most if not all of the variation in the sample. The methods of Franklin et al. (2006) and Green and Curnoe (2009) were applied, where principal components (PCs) that cumulatively account for a significant percentage (≥ 80% total variance) are used, and based on the results, 8 PCs that explained 90.5% of total variance were selected for further analysis (**Table 5.5**). Those PCs were then saved as .spv file in SPSS, where each individual had a score in each of the eight PCA components. Discriminant Functions Analysis (DFA) was then performed in SPSS using those PC scores to define a metric that could maximally discriminate between male and female facial shape. The classification accuracy of the discriminant functions was tested and individual participant scores on the first Discriminant Function were used as a proxy femininity-masculinity scale.

The result of the DFA from the 8 PCs indicates that out of the 215 males, 70.8 % (153) were correctly classified as males, while 29.2 % (63) were wrongly classified as females. Out of the 211 females, 66.8 % (141) were correctly classified as females, while 33.2 % (70) were wrongly classified as males. Hence, the average accuracy in correct classification for sex determination obtained in this study ranged from 66.8 % to 70.8 % and overall, 68.9 % of the entire sample of 426 was correctly classified (**Table 5.6**).

Table 5:3: Summary of facial landmarks used in this study and their descriptions.

Point	Landmark	Name	Description
P1	ex (r)	Exocanthion	Outer commissure of the right eye fissure
P2	so (r)	Supraorbitale	The most prominent point on the right supraorbitale
P3	en (r)	Endocanthion	Endocanthion of the right eye fissure
P4	N	Nasion	Midpoint between the eyes, just above the bridge of the nose
P5	en (l)	Endocanthion	Endocanthion of the left eye fissure
P6	so (l)	Supraorbitale	The most prominent point on the left supraorbitale
P7	ex (l)	Exocanthion	Exocanthion of the left eye fissure
P8	zy (r)	Zygion	The most lateral point on the right cheek
P9	al (r)	Alar	Most lateral point on the right alar contour
P10	Sn	Subnasale	Mid-point of angle at columella base
P11	al (l)	Alar	Most lateral point on the left alar contour
P12	zy (l)	Zygion	The most lateral point on the left cheek
P13	go (r)	Gonion	The point at the angle of the (r) mandible
P14	ch (r)	Chelion	Point located at right labial commissure
P15	Ls	L. superior	Midpoint of the border of the upper lip
P16	ch (l)	Chelion	Point located at left labial commissure
P17	go (l)	Gonion	The point at the angle of the left mandible
P18	Sto	Stomium	Midpoint of closed lip
P19	Li	L. inferior	Midpoint of the lower vermilion
P20	gn	Gnathion	The lower-most point on the mid-anterior of the menton
P21	pr	Pronasale	The most prominent point on the tip of the nose
P22	sl	Sublabius	Midpoint of the junction between the lower lip and the chin

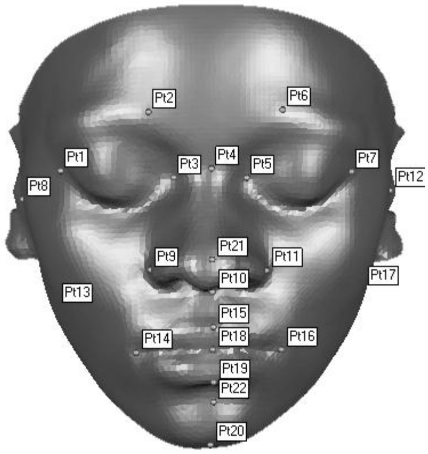


Figure 5:8: Points landmarks.

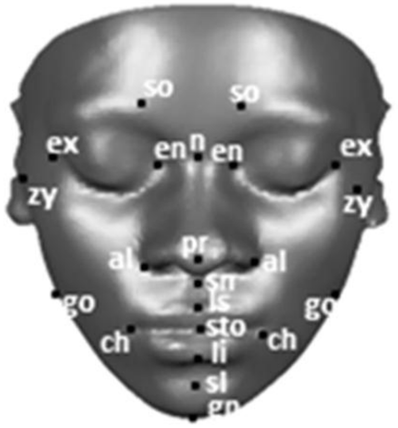


Figure 5:9: 22 landmarks used for quantifying facial shape.

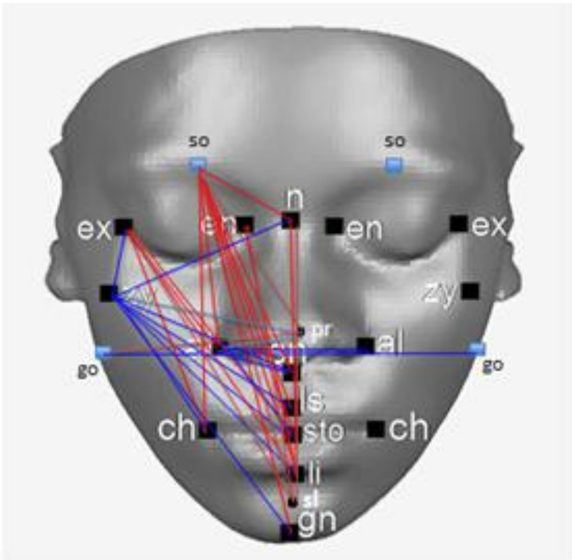


Figure 5:10: 35 sexually dimorphic metrics
19 (red) metrics greater in females & 16 **(**blue) metrics greater in males.

Table 5:4: 35 statistically significantly sexually dimorphic metrics relative to adjusted p-value threshold of 0.000467.

SNO	Landmarks	Landmarks description	Residuals	t.statistic	p.value
1	ex-zy *	Exocanthion to zygion	exzyres	-3.586	0.000375
2	ex-al	Exocanthion to alar of the nose	exalres	6.7457	5.01E-11
3	ex-ch	Exocanthion to cheilion	exchres	4.8769	1.53E-06
4	ex-sto	Exocanthion to stomium	exstores	4.3386	1.80E-05
5	ex-li	Exocanthion to labrum inferius	exlires	5.8053	1.26E-08
6	so-al	Superior orbitale to alar of the nose	soalres	6.7278	5.59E-11
7	so-ch	Superior orbitale to chelion	sochres	6.45	3.05E-10
8	so-n	Superior orbitale to nasion	sonres	3.8397	0.000142
9	so-sn	Superior orbitale to subnasale	sosnres	5.6328	3.24E-08
10	so-ls	Superior orbitale to labrum superius	solsres	6.0813	2.67E-09
11	so-sto	Superior orbitale to stomium	sostores	6.778	4.09E-11
12	so-li	Superior orbitale to labrum inferius	solires	7.4888	4.06E-13
13	so-gn	Superior orbitale to gnathion	sognres	5.1998	3.13E-07
14	en-li	Endocanthion to labrum inferius	enlires	4.1312	4.36E-05
15	zy-ch *	Zygion to chelion	zychres	-3.631	0.000317
16	zy-n *	Zygion to nasion	zynres	-3.728	0.000219
17	zy-sn *	Zygion to subnasale	zysnres	-4.985	9.03E-07
18	zy-ls *	Zygion to labrum superius	zylsres	-5.222	2.80E-07
19	zy-sto *	Zygion to stomium	zystores	-4.886	1.47E-06
20	zy-li *	Zygion to labrum inferius	zylires	-4.128	4.42E-05
21	zy-gn *	Zygion to gnathion	zygnres	-4.815	2.06E-06
22	al-sn *	Alar of the nose to subnasale	alsnres	-8.88	2.20E-16
23	al-ls *	Alar of the nose to labrum superius	allsres	-5.588	4.18E-08
24	al-sto *	Alar of the nose to stomium	alstores	-4.195	3.32E-05
25	ex-sl	Exocanthion to sublabius	exslres	5.5012	6.58E-08
26	so-pr	Superior orbitale to pronasale	soprres	4.89	1.43E-06
27	so-sl	Superior orbitale to sublabius	soslres	6.947	1.41E-11
28	en-sl	Endocanthion to sublabius	enslres	4.1377	4.23E-05
29	zy-pr *	Zygion to pronasale	zyprres	-5.256	2.33E-07
30	al-pr *	Alar of the nose to pronasale	alprres	-7.773	5.85E-14
31	go-pr *	Gonion to pronasale	goprres	-3.743	0.000208
32	n-sl	Nasion to sublabius	nslres	4.3531	1.68E-05
33	al-al *	Alar of the nose to alar of the nose	alalres	-8.527	2.71E-16
34	go-go*	Gonion to gonion	gogores	-5.002	8.30E-07
35	n-li	Nasion to labrum inferius	nlires	4.4438	1.13E-05

*sexually dimorphic metrics which are greater in males than in females (16 of them).

Table 5:5: Principal component analysis of the 35 linear metrics

Total Variance Explained								
Component		Initial Eigenvalues[a]			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings[b]
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
Raw	1	249.006	48.311	48.311	249.006	48.311	48.311	193.063
	2	66.467	12.896	61.206	66.467	12.896	61.206	123.664
	3	45.052	8.741	69.947	45.052	8.741	69.947	139.817
	4	30.907	5.996	75.943	30.907	5.996	75.943	53.737
	5	22.122	4.292	80.235	22.122	4.292	80.235	106.946
	6	19.882	3.857	84.092	19.882	3.857	84.092	54.173
	7	17.342	3.365	87.457	17.342	3.365	87.457	32.882
	8	15.726	3.051	90.508	15.726	3.051	90.508	89.169
	9	9.071	1.760	92.268				
	10	8.130	1.577	93.845				
	11	6.684	1.297	95.142				
	12	4.854	.942	96.084				
	13	3.744	.726	96.810				
	14	3.105	.602	97.413				
	15	2.733	.530	97.943				
	16	1.815	.352	98.295				
	17	1.680	.326	98.621				
	18	1.439	.279	98.900				
	19	1.363	.265	99.165				
	20	1.136	.220	99.385				
	21	1.039	.202	99.587				
	22	.717	.139	99.726				
	23	.417	.081	99.806				
	24	.341	.066	99.873				
	25	.278	.054	99.927				
	26	.173	.034	99.960				
	27	.073	.014	99.974				
	28	.059	.011	99.986				
	29	.028	.005	99.991				
	30	.017	.003	99.995				
	31	.012	.002	99.997				
	32	.008	.002	99.998				
	33	.005	.001	99.999				
	34	.002	.000	100.000				
	35	.001	.000	100.000				

Table 5:6: Classification accuracy of the discriminant function analysis of the 8 extracted principal components (PCs), from the principal component analysis.

Classification Results[a]

			Predicted Group Membership		
		SEX	FEMALE	MALE	Total
Original	Count	F	141	70	211
		M	63	153	216
	%	F	66.8	33.2	100.0
		M	29.2	70.8	100.0

a. 68.9% of original grouped cases correctly classified.

5.5 Rating method of 3D facial models

5.5.1 Rating questionnaire

The questionnaires for rating facial attractiveness and perception consist of 3 sections: ***Section A*** contains the demographic /personal data about age (in years), sex, religion, tribe, marital status, number of children, and the area where the participant grew up (either in the city or village). ***Section B*** has questions about the socioeconomic levels of the participants or their parents. The socioeconomic levels indicators are: levels of education (for the participant, mother and father), occupation (of the father, if the participant is dependent, or of the participant if the participant is independent), assets ownership of the participant or the father (including land, house, and house built, livestock and vehicles acquisition) and total income per month of the participant or the father.

Sections A and B were answered by each participant before the file containing the 3D facial models was opened in the computer. ***Section C*** is the rating part of the questionnaire where male participants were asked to rate 42 female models (in 9 questions) and female participants were asked to rate 42 male models (also in 9 questions) (**Appendix 4 and Appendix 5**).

5.5.2 Recruitment of survey participants

To recruit participants for the purpose of facial symmetry-asymmetry and facial masculinity-femininity rating and perception, written application to the vice chancellor of the North-west University Kano to conduct the survey was approved. The University was newly opened by Kano state government of Nigeria with only 1000 students. The students were gathered and the purpose of the study was explained. The students were recruited from various departments of the University. Most of them were from well-educated families mostly civil servants or business-men with higher monthly revenue. These participants live in the city of Kano where electricity, pure and wholesome drinking water, tarred roads and other social amenities are available. Their family members live in red bricks or block houses containing multiple rooms that are well ventilated, burglar proofed, with mosquito netted windows. In addition, their parents own vehicles such as cars, trucks, bikes and other machines. Furthermore, some parents of the participants were renowned politicians and own many houses for rent, lands for farming and several plots for housing purposes. Ideally, a wider range of socioeconomic backgrounds could have been included, but this was not logistically feasible.

The recruited students were those who volunteered and agreed by giving an informed consent and each subject was also duly informed of the purpose of the study and allowed to back out anytime he/she no longer wished to participate.

5.5.3 Facial asymmetry-symmetry ranking

This rating exercise is the second component of the survey where 3D facial models were rated. The questionnaire was given to each participant to complete and was deliberately made separate, one for males (**Appendix 4**) and the other for females (**Appendix 5**). The questions in the questionnaire were answered concurrently by looking at the models shown on the computer screen. The students ranked the models based 1-6 ranks.

The rating exercise in this section C consists of three parts: The first part, questions 1-3, were on three slides, each consisting of a pair of asymmetric and symmetricised models of the same person. The second part, questions 4-6, were on three slides, each consisting of 6 models of different individuals covering a wide range of asymmetry values, but with similar masculinity-femininity scores. The total models used in asymmetry-symmetry ratings were 21 in this part of the questionnaire either in the male questionnaire or in the female questionnaire.

5.5.4 Facial masculinity ranking

The third part of the rating questionnaire consists of questions 7-9, which also has three slides (each consists of 6 models) of different individuals covering a wide range of masculinity-femininity scores, but with similar asymmetry values.

The models were selected using the masculinity-femininity (posterior classification probability) scores, which were derived from the case-wise discriminant function analysis result. The total number of models used for the masculinity-femininity rating exercise was 18.

Chapter 6 : ENVIRONMENTAL CORRELATES OF FACIAL ASYMMETRY

6.1 Analysis I: Facial asymmetry, Size, Sex and Age

6.1.1 Introduction

Facial asymmetry can be seen as a measure of developmental stability, and the study of its association with body size can be important since for example body height may also relate to developmental stability and has been shown to strongly predicts health (Komlos and Baur, 2004, Deaton, 2007) with taller individuals suggested to survive longer (Inwood and Roberts, 2010). Body height is advantageous, since taller male individuals are reported to be more attractive to women (Manfredini *et al.*, 2010), and have higher reproductive success (Pawlowski *et al.*, 2000, Manfredini *et al.*, 2010).

With regards to sex, facial asymmetry is expected to differ between males and females since in the morphology of animal taxa (including humans), sexual dimorphism is widespread, and evolves ‘’when characters that confer an advantage in competition for mates or mate choice are selected for within one sex’’ as proposed by Darwin’s sexual selection hypothesis (Darwin, 1871). It may also evolve from food competition between the sexes or variations between the reproductive roles of males and females, which is regarded as the ‘dimorphic niche’ hypothesis (Darwin, 1871, Selander, 1972).

Several studies have been conducted on different populations to determine sexual dimorphism in the human face (Farkas and Cheung, 1981, Ferrario *et al.*, 1993b, Bugaighis *et al.*, 2011, Primozic *et al.*, 2012, Claes *et al.*, 2012) under different environmental conditions (e.g, (Özener and Fink, 2010) or the same environmental conditions (Farkas *et al.*, 2007, Bugaighis *et al.*, 2011). However, the literature is deficient on information concerning facial asymmetry outside the Western industrialised countries. Variation in both body size and asymmetry are hypothesised to reflect variation in developmental instability, and most studies concerning the relationship between body size and asymmetry where conducted mainly on animals [e.g.,(Moller, 1994, Wauters *et al.*, 1996, Yngvesson and Keeling, 2001, Liu *et al.*, 2011)], with comparatively few conducted on humans [e.g., (Manning, 1995b, Ozener and Ozener, 2011). Although in the literature, facial asymmetry has previously been reported not to vary with age the subjects in this study were selected to reflect a young adult stage of development that is not greatly affected by ontogeny or ageing. *The aim of this part of the study is to examine the relationship between facial asymmetry, body size and sex amongst young adults (18-25 years) of the Hausa ethnic group in Nigeria. The prediction with regards to this is that: 1) taller and heavier individuals will have lower facial asymmetry values 2) Men will have higher facial asymmetry than women.*

6.1.2 Methodology I

The method of scanning the participants and other protocols for the conduct of the study were fully described in chapter 5. The biometric data of the participants were collected by well-trained community research assistants from Ahmadu Bello University Zaria, Nigeria.

The participants' age range was restricted to between 18-25 years to minimize the effects of both ongoing ontogenetic development and aging on facial asymmetry. Age was nevertheless included as a covariate to ensure that no age effect was present.

Height was measured to the nearest millimetre using a tape measure and each subject was measured bare footed, with no cap (males) or head tie (females) and in anatomical position, face forward and buttocks leaned against the wall. Maximum height was marked on the wall by placing a thin and flat rectangular wood on top of participant's head till it reached the wall. The height was then measured from the ground to the mark. Weight was recorded to the nearest 0.1 kg using a Terraillon electronic scale with large ergonomic platform and large 27mm high LED display (maximum capacity: 160kg; accuracy: 100g).

Descriptive statistics of age, weight (WT), height (HT), whole face asymmetry (WFACE), asymmetry around the eyes (EYES), and whole face surface area (WFSA) were conducted separately for males and for females using SPSS version 22.

Mean differences in age, weight (WT), height (HT), whole face asymmetry (WFACE), asymmetry around the eyes (EYES), and whole face surface area (WFSA) were compared between sexes, using *Mann Whitney U-tests* in *R-statistic software version 3.1.2 (R Core Team., 2014)* because the distribution of WFACE and EYES both departed somewhat from normality. ***The relationship*** of whole face asymmetry (WFACE), or asymmetry around the eyes (EYES) with age, weight (WT), height (HT), and whole face surface area (WFSA) were tested using *linear regression analyses and Analyses of Covariance* (ANCOVA) also in *R-statistic software version 3.1.2 (R Core Team., 2014).*

Multivariate analyses with whole face asymmetry (WFACE), or asymmetry around the eyes (EYES) as the dependent variable and age, weight (WT), height (HT), as the independent variables with whole face surface area (WFSA) and sex as covariates were also conducted using *R-statistic software version 3.1.2 (R Core Team., 2014).*

6.1.3 Results I

6.1.3.1 Descriptive statistics for the facial asymmetry, age and size variables

Table 6.1 shows the *descriptive statistics* for all the variables, that is, age, weight (WT), height (HT), whole face asymmetry (WFACE), and asymmetry around the eyes (EYES). In the table, the females' mean age was 20.6years ± 2.4years, while it was 21.8years ± 2.1years for males and therefore males were a little 5% older than the females (from the ratio of ratio, 1:1.05) although they both had the same age range. The mean WT for females was 51.9kg ± 9.9 SD (range, 30.3kg-117.0kg), whereas mean weight for males was 59.8kg ± 8 SD (range, 39.6kg-95kg). This indicates that the males were 15% heavier than the females (from the ratio of, 1:1.15) even though the lowest and the maximum weight were recorded among the females. The mean HT for females, was found to be 1.57m ± 0.1 (range, 1.42m-1.76m) and 1.68m ± 0.1 SD (range, 1.46m-1.92m) for males. This indicates that males were 7% taller than the females (from the ratio of, 1:1.07) and the minimum and maximum values were also recorded in males. The females' mean of the WFACE was 0.31mm (range, 0.22mm-0.50mm), whereas it was 0.35mm (range, 0.22mm-0.53mm) for males.

This shows that males were 12% more facially asymmetric than the females (from the ratio of, 1:1.12) although the range was similar in both sexes. The mean values of EYES in females was 0.2 mm (range, 0.11mm-0.49mm) while it was 0.23mm (range, 0.11mm-0.47mm) for males. Again, males were 15% more asymmetric around the eyes than females (from the ratio of, 1:1.15) both of which have similar range. The mean WFSA was 33,543mm^2 (range, 22353mm^2-47053mm^2) for females and 40,160mm^2 (range, 31263mm^2-50153mm^2) in males. This also demonstrates that males' faces were 20% larger faces than the females' (from the ratio of, 1:1.20) with the minimum value recorded in females but the maximum recorded in males. **Figures 6.3A & B, 6.4A & B and 6.5** are box plots comparing the measured variables (WT, HT, WFACE, EYES, and WFSA) between sexes. *In summary, males were older, heavier, and taller, with higher whole face asymmetry and asymmetry around the eyes and larger faces than the females*.

Table 6:1: Descriptive statistics for Age, weight (WT), height (HT), whole face asymmetry (WFACE) and asymmetry around the eyes (EYES) and whole face surface area (WFSA).

Variable Sex		N	Minimum	Maximum	Mean	STD	S.E Mean
AGE (years)	F	211	18	25	20.6	2.4	0.2
	M	215	18	25	21.8	2.1	0.1
WT(Kg)	F	211	30.3	117	51.9	9.9	0.7
	M	215	39.6	95	59.8	8	0.5
HT(m)	F	211	1.42	1.76	1.57	0.1	0
	M	215	1.46	1.92	1.68	0.1	0
WFACE (mm)	F	211	0.22	0.5	0.31	0.1	0
	M	215	0.22	0.05	0.35	0.1	0
EYES (mm)	F	211	0.11	0.49	0.20	0	0
	M	215	0.11	0.47	0.23	0.1	0
WFSA (mm^2)	F	211	22353	47053	33543	4020	277
	M	215	31263	50153	40160	3357	229

6.1.3.2 Mann-Whitney U test and linear regression analyses: on facial asymmetry, age and size

The *Mann Whitney U test* indicated a statistically significant sexual dimorphism ($p<0.0001$) in all the tested variables, that is, age, whole face asymmetry (WFACE), asymmetry around the eyes (EYES), weight (WT), height (HT) and whole face surface area (WFSA) as shown in **Table 6.2**.

Table 6:2: Mann-Whitney U tests: between weight (WT), height (HT), Whole face asymmetry values (WFACE), asymmetry around the eyes and SEX

Variables	W	P-value
Weight (WT) & Sex	10594	**2.2e-16**
Height (HT) & Sex	5898.5	**2.2e-16**
Whole face asymmetry (WFACE) &Sex	13134.5	**5.697e-14**
Asymmetry around the eyes (EYES) & Sex	16024.5	**1.604e-07**
Whole face surface area (WFSA) & Sex	4752	**2.2e-16**

In **females**, *linear regression analyses* indicate statistically significant positive association between: whole face asymmetry (WFACE) & age (*F=5.32, P=0.0221*), and WFACE & height (*F=7.37, P=0.0072*). However, there was no association between WFACE & weight (*F=1.26, P=0.26.35*), and WFACE & whole face surface area (WFSA) (*F=0.87, P=0.3518*) as shown in **Table 6.3, Figure 6.1.** A statistically significant positive relation was found between asymmetry around the eyes (EYES) & age (*F=5.10, P=0.0249*), EYES & weight (*F=12.19, P=0.0006*), and EYES & height (*F=4.80, P=0.0295*). No relation was found between EYES and WFSA (*F=0.074, P=0.7864*) as shown in **Table 6.3, Figure 6.2**.

The results however reveal that *as the women get older and taller, their whole face asymmetry and asymmetry around the eyes increase, and as they get* *heavier, their asymmetry around the eyes also increases*.

In **males**, *linear regression* analyses also indicate statistically significant positive association between: whole face asymmetry (WFACE) & age (*F=6.61, P=0.0108*), and WFACE & whole face surface area (WFSA) (*F=8.39, P=0.0042*). However, there was no association between WFACE & weight (*F=02.88, P=0.0910*), and WFACE & height (*F=3.66, P=0.0575*) as shown in **Table 6.3**, **Figure 6.1**. Statistically significant positive relation was found between asymmetry around the eyes (EYES) & WFSA (*F=11.63, P=0.0008*), but none between EYES & age (*F=1.41, P=0.2365*), EYES & weight (*F=1.28, P=0.2585*), and EYES & height (*F=0.37, P=0.5444*) as in **Table 6.3, Figure 6.2**. The results however reveal that *as the men get older, their whole face asymmetry increase, and as their faces grow their whole face asymmetry and asymmetry around the eyes also increase*. *However, it is important to note that, although some relationships are statistically significant, all are weak, with no* r^2 *value higher than 0.05*.

Table 6:3: Separate male (M) and female (F) linear regression analyses, whole face asymmetry (WFACE) or asymmetry around the eyes (EYES) regressed against age, weight (WT), height (HT) and whole surface area (WFSA).

Variables	Sex	Adjusted R^2	F-statistic	DF	P-Value
WFACE & AGE	F	0.0201	5.32	1 and 209	**0.0221**
	M	0.0256	6.61	1 and 213	**0.0108**
EYES & AGE	F	0.0193	5.10	1 and 209	**0.0249**
	M	0.0019	1.41	1 and 213	0.2365
WFACE & WT	F	0.0012	1.26	1 and 209	0.2635
	M	0.0087	2.88	1 and 213	0.0910
EYES & WT	F	0.0506	12.19	1 and 209	**0.0006**
	M	0.0013	1.28	1 and 213	0.2585
WFACE & HT	F	0.0294	7.37	1 and 209	**0.0072**
	M	0.0124	3.66	1 and 213	0.0572
EYES & HT	F	0.0178	4.80	1 and 209	**0.0295**
	M	-0.0040	0.37	1 and 213	0.5444
WFACE & WFSA	F	-0.0006	0.87	1 and 209	0.3518
	M	0.0334	8.39	1 and 213	**0.0042**
EYES & WFSA	F	-0.0044	0.074	1 and 209	0.7864
	M	0.0473	11.63	1 and 213	**0.0008**

6.1.3.3 Multivariate analyses: on facial asymmetry, age and size variables

Multivariate analyses with whole face asymmetry (WFACE) as the dependent variable, and age, weight (WT), and height (HT) as the independent variables with whole surface area (WFSA) and sex as covariates [Call: lm(formula = WFACE ~ AGE +WT +HT+ WFSA +SEX)] yielded a statistically significant model (*F= 17.63, P= 7.286e-16*) with an adjusted r-squared value of *0.1636*.

However, through model optimisation by manual elimination method, a statistically significant best (minimal) model with slightly lower adjusted r-squared (0.1618) but with much higher p-value (F=28.35, P=2.2e-16) than the maximal model was obtained. The best (minimal) model [Call: lm(formula = WFACE ~ AGE + HT + SEX)] was a linear model of whole face asymmetry on AGE, HT & SEX, meaning that 16.2% of the variation in whole face asymmetry is due to age, height and sex and that these variables predict whole face asymmetry across both sexes (**Tables 6.4A & B**). Similarly, multivariate analyses of asymmetry around the eyes as the dependent variable, and age, weight, and height as the independent variables, with whole face surface area and sex as covariates [Call: lm (formula = EYES ~ AGE +WT+ HT + WFSA + SEX)], revealed a statistically significant (maximal) model (F= 8.591, P= 9.204e-08) with an adjusted r-squared value of 0.082, but the minimal model was more statistically significant (F= 38.01, P= 6.578e-16) with much higher r-squared value (0.1483) than the maximal model. The minimal model [Call: lm (formula = EYES ~ AGE+ SEX)] was a linear model of asymmetry around the eyes on age and sex, meaning that AGE and sex predict asymmetry around the eyes (**Table 6.5A & B**).

Table 6:4: Minimum model of Multivariate analyses between whole face asymmetry (WFACE) and AGE, height (HT) & SEX

Min model Call: lm (formula = WFACE ~ AGE + HT + SEX)

A) Residuals:

Min	1Q	Median	3Q	Max
-0.129738	-0.037404	-0.005785	0.033224	0.169634

B) Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.069782	0.059599	1.171	0.2423
AGE	0.003645	0.001188	3.067	**0.0022**
HT	0.102409	0.036634	2.795	**0.0054**
SEXM	0.026582	0.006804	3.907	**0.0001**

Residual standard error: 0.05447 on 422 degrees of freedom Multiple R-squared: 0.1678, Adjusted R-squared: 0.1618, F-statistic: 28.35 on 3 and 422 DF, p-value: < 2.2e-16

Table 6:5: Minimum model of Multivariate analyses between asymmetry around the eyes (EYES) and AGE & SEX. Call: lm (formula = EYES ~ AGE + SEX)

A) Residuals:

Min	1Q	Median	3Q	Max
-0.12317	- 0.03858	- 0.00499	0.03365	0.17986

B) Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.221554	0.024783	8.940	**< 2e-16**
AGE	0.004066	0.001188	3.422	**0.0007**
SEXM	0.037967	0.005495	6.910	**1.79e-11**

Residual standard error: 0.0549 on 423 degrees of freedom Multiple R-squared: 0.1523, Adjusted R-squared: 0.1483, F-statistic: 19.43 on 2 and 423 DF, p-value: 6.578e-16.

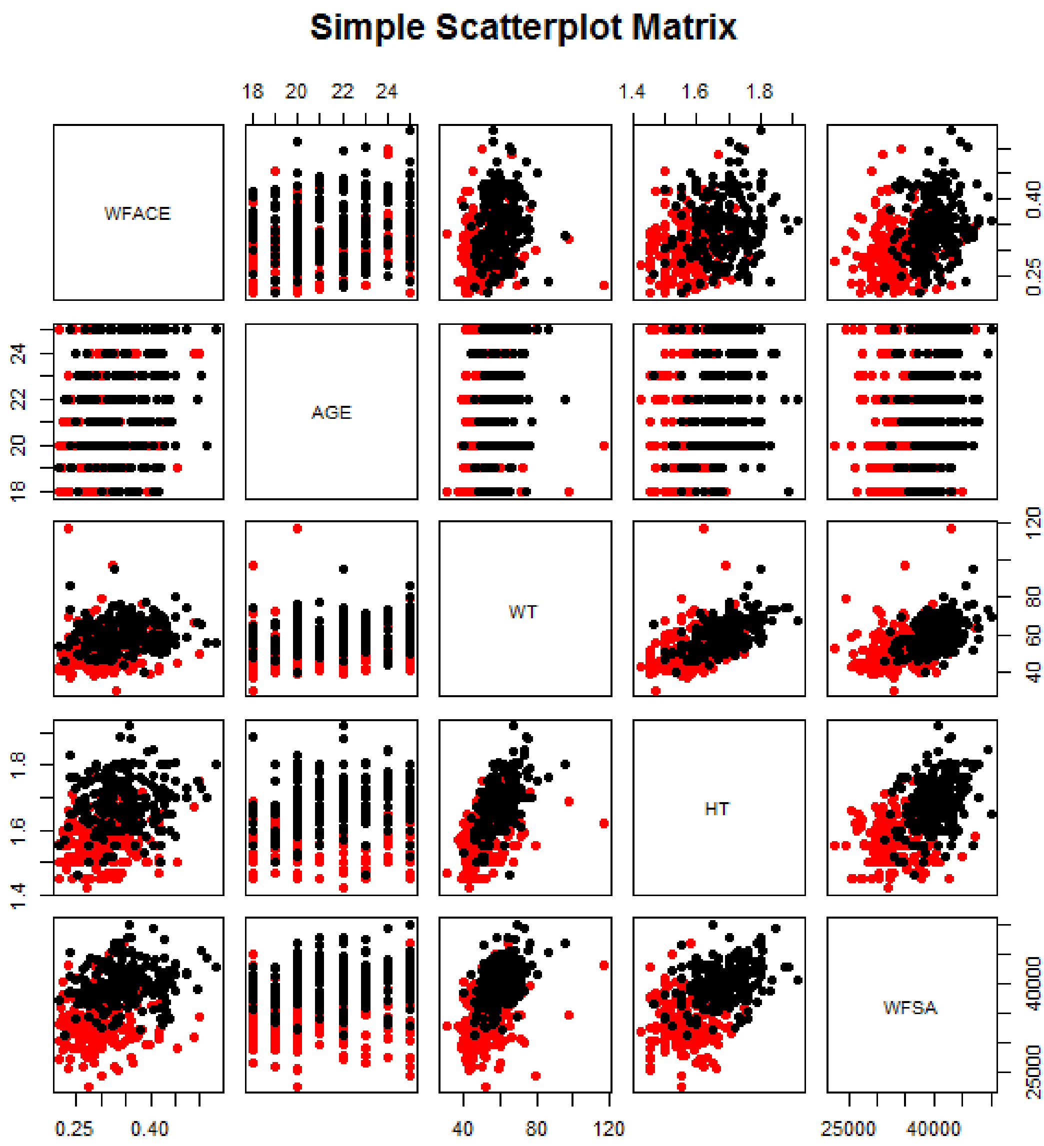


Figure 6:1: Correlation matrix plots between whole face asymmetry (WFACE), weight in Kg (WT), height in meter (HT), and AGE. Red dots represent females, black dots represent males.

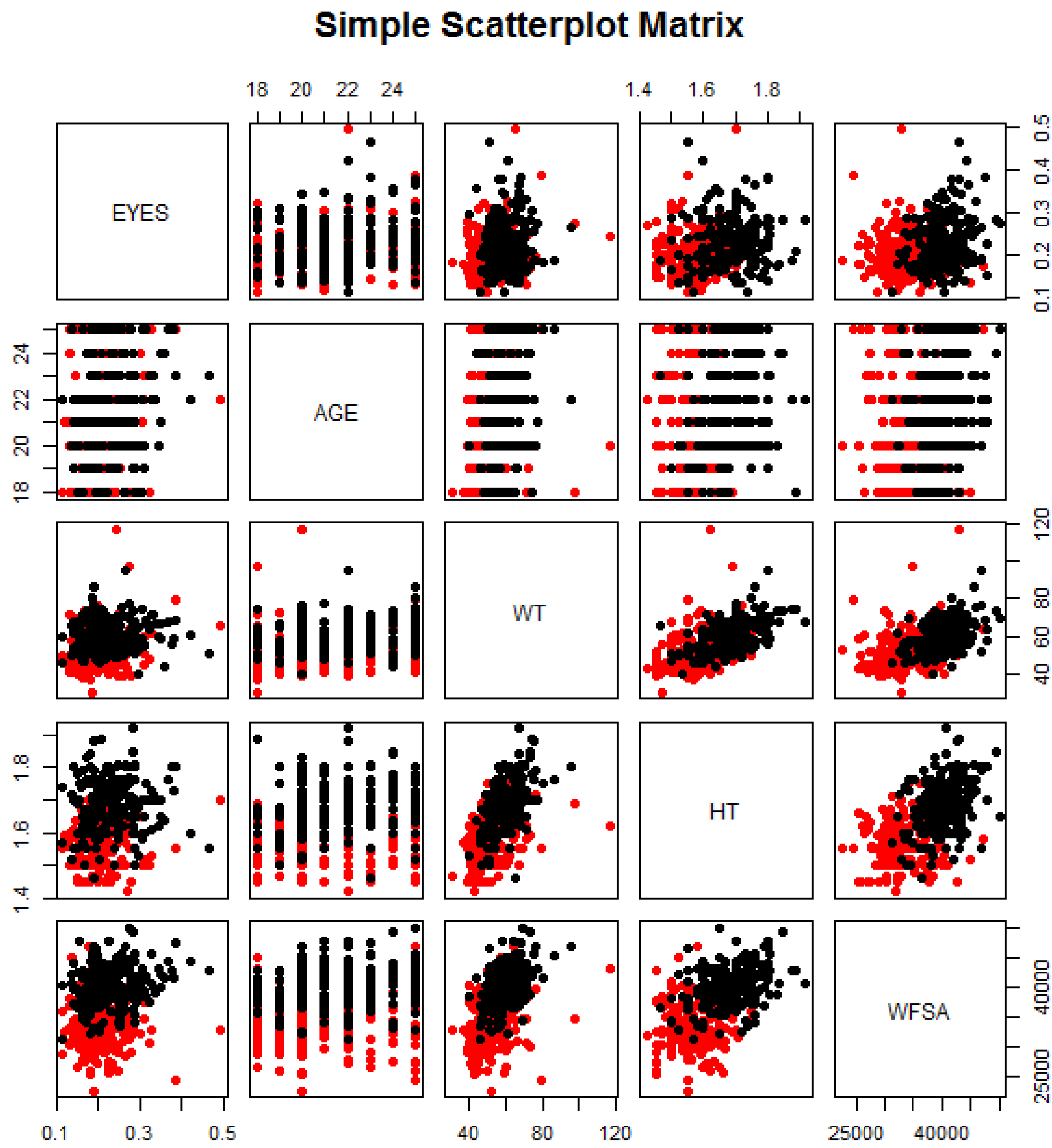
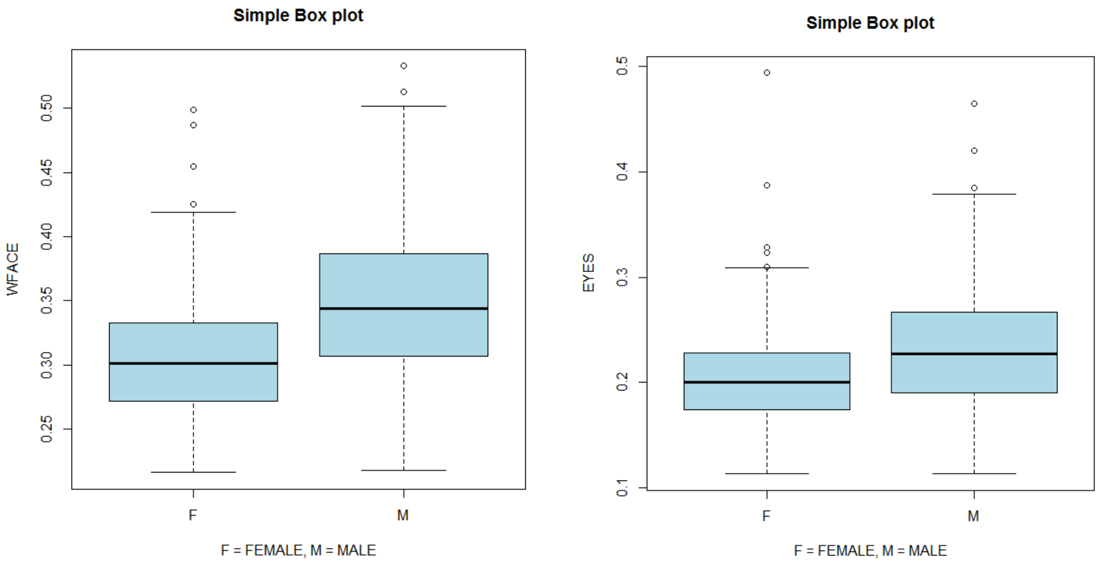
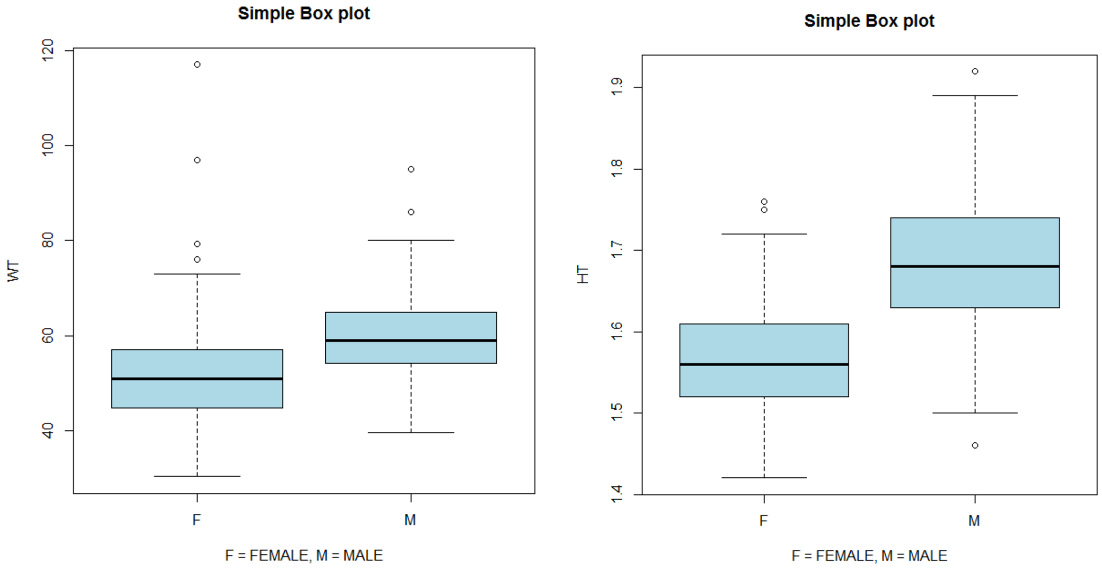


Figure 6:2: Correlation matrix plots between asymmetry around the eyes (EYES), weight in Kg (WT), height in meter (HT), and AGE. Red dots represent females, black dots represent males.



(A) (B)

Figure 6:3: Boxplots of whole face asymmetry (WFACE), asymmetry around the eyes (EYES) & sex



(A) (B)

Figure 6:4: Boxplots of weight (WT), height (HT) & sex

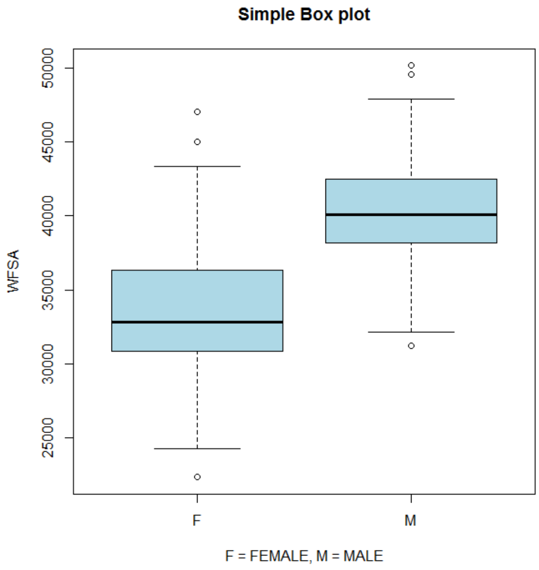


Figure 6:5: Boxplots of whole face surface area (WFSA) & sex

6.1.4 Discussion I

6.1.4.1 Facial asymmetry and Size

In the hominid evolutionary trend, males are taller and heavier than females and this sexual dimorphism seems to be maintained (Styne and McHenry, 1993). As a consequence of this evolutionary diversity between or within sexes, taller and heavier males therefore have a greater intra-sexual or inter-sexual advantage (Andersson, 1994, Thornhill and Moller, 1998) when competing for food or sexual partners., with additional advantage of higher reproductive success (Pawlowski *et al.*, 2000, Sear, 2006), which means tallness might be considered as an indicator of developmental stability since it signals health (Mascie-Taylor and Lasker, 2005). On the other hand, fluctuating asymmetry (FA) is also considered as a measure of developmental stability (Palmer and Strobeck, 1992, Palmer and Strobeck, 1997, Palmer and Strobeck, 2003, Dongen, 2006), and therefore its relationship with body size in populations from different environment should be studied.

The present study therefore examined such relationship and males were found to be taller, heavier, and with greater levels of whole face asymmetry than females. In this study, height was found to be positively associated with the whole face asymmetry and asymmetry around the eyes in females, similar to the finding of a study were body height was demonstrated to positively correlate with body FA in females, but negatively in males (Brown *et al.*, 2008). However, body height in this study has no association with facial asymmetry in males. The positive relationship in females between body height and whole face asymmetry in this study, suggests that developmental stability decreases as female height increases, and in another study, weight rather than height had a positive relationship with non-facial FA in women (Manning, 1995a).

Since tallness (in this study) and heavy weight (in another study) in women are related to asymmetry, it means therefore, large size could be considered as one of the stressors that increase the level of FA in women, apart from other known causes like parasite infection or pollution (Parsons, 1992).

This shows that height is an important size parameter in females with regard to facial asymmetry but why height was positively associated with facial asymmetry in females but not in males, is not clear.

The present study did not find any association between body weight and facial asymmetry in either males or females, but in another study, lighter females were shown to be more symmetric than the heavier ones (Manning, 1995a), and more preferred (Gangestad, 1993). The absence of relation (in this study) between body weight and facial asymmetry in females therefore suggests that intersexual (mate choice) selection is not based only on facial symmetry.

In human males, FA negatively associates with body weight and this type of association is believed to be due to the presence of good genes in symmetric males and their body weight is hypothesized to be a sexually selected character, since no association is documented in pre-pubertal males (Manning, 1995a). However, the absence of any correlation between body weight and facial asymmetry in both males and females in the present study, may possibly mean that the relationships between FA and body weight in men and women, are significant only for mean FA but not for individual traits like whole face asymmetry, as summing FA across characters creates a complex trait (Manning, 1995a).

Generally, tissues gain or lose nutrients due to the influence of exercise or hormonal changes, and therefore loss or gain of subcutaneous fat may also affect the dimensions of paired structures. This may mean that FA could change in adults. Such a possibility is not inconsistent with the use of FA as an indicator of "good genes." The trait of body weight is influenced both by genes and the environment. This is also the case for FA in humans (Livshits and Kobyliansky, 1989).

The absence of correlation between various traits is frequently found in several fluctuating asymmetry studies (Manning and Ockenden, 1994). In the literature, fluctuating asymmetry is strongly believed to be caused by environmental stressors and thus living organisms deviate from completely developing in a symmetrical pathway. The theory of fluctuating asymmetry does not however indicate which traits are most vulnerable to the stressors. However, as suggested

(Forkman and Forkman, 1996), traits which are more closely linked to survival of an organism will possibly be more resistant to stressors and therefore more emphasis should be placed on getting them right as opposed to traits that are there for signalling functions.

6.1.4.2 Facial asymmetry and Sex

There have been numerous studies concerning sexual dimorphism on facial skeletal structures (Uytterschaut, 1986, Dayal *et al.*, 2008, Franklin *et al.*, 2005, Green and Curnoe, 2009) in contrast to those on facial soft-tissue structures and the estimation of facial sexual dimorphism (an outcome of sexual selection) is very important in understanding facial morphology and the influence of sexual selection on the face. Different authors reported different results with some demonstrating no sexual dimorphism on the face [e.g., (Burke, 1971, Melnik, 1992, Farkas, 1994, Ferrario *et al.*, 2001)].

Studies which demonstrated facial sexual dimorphism have indicated that males mostly have higher facial asymmetry values as compared to females [e.g., (Purkait, 2004, Özener and Fink, 2010, Claes *et al.*, 2012)]. Similarly, the current study also found a statistically significant sexual dimorphism in whole face asymmetry and asymmetry around the eyes region, similar to the findings of some authors [e.g., (Koehler *et al.*, 2004c) and (Özener and Fink, 2010)]. Similar to the previous studies, this study also shows that males have higher whole face asymmetry and higher asymmetry around the eyes region than females. Why males have higher facial asymmetry values might simply be because they are known to be more exposed to environmental stress and more susceptible to infectious diseases than females (Klein, 2004).

6.1.4.3 Facial asymmetry and Age

Facial asymmetry is expected to vary across ages since absolute and relative FA was demonstrated to differ in a cross-sectional sample of 680 human participants aged 2–18 years (Wilson and Manning, 1996a). This study of Wilson and Manning showed that asymmetry decreases with age until age 11, followed by an increase that peaks at 13 years in males and 14 years in females. From age 15 a decrease in fluctuating asymmetry is maintained until age 18. They further suggested that this pattern could be explained as the result of the interaction of rapid growth and high metabolic rate in children, and that an increase in fluctuating asymmetry in adolescence may be due to sex steroid secretion.

However, in the literature, several studies have shown no association between facial asymmetry and age in either sex [e.g., (Laspos *et al.*, 1997, Winning *et al.*, 1999, Primozic *et al.*, 2012)] whether in cross-sectional [e.g., (Ferrario *et al.*, 2001, Bugaighis *et al.*, 2011)] or in longitudinal studies [e.g., (Melnik, 1992)]. The results were the same irrespective of the sample size. For example, a study of Farkas and Cheung (1981), with lower sample than the present study, evaluated 308 Caucasian children, adolescents and young adults (6-, 12-, and 18-year-olds) on the degree of facial asymmetry (by direct facial anthropometric measurements), but they did not observe any statistically significant age-related influence on the prevalence and extent of the facial asymmetry. Similarly, another study with a higher sample than the current study, examined 720 normal children (6–18year-old), similar cohort with Farkas and Cheung (1981), also revealed no change with age in the extent of facial asymmetry in both sexes (Skvarilova, 1993). Furthermore, the results were similar irrespective of the methodology, because one study used surface laser scanner to examine 60 Caucasian Finnish children aged 10-13 years longitudinally, but no statistically significant age difference was demonstrated on facial asymmetry (Djordjevic *et al.*, 2011a). Additionally, Primozic et al., (2012) also used 3D surface laser scanner to scan the faces of 27 Caucasian children in Slovenia, with age ranged 4.9-6.2 years, but again, no age variation observed in facial asymmetry (Primozic *et al.*, 2012). However, the findings of those studies are not in keeping with what was found in the present study, even though, they commonly examined pre-pubertal and pubertal subjects. The current study examined post-pubertal subjects (18-25 years) and there was a positive association observed between whole facial asymmetry and age in both males and females and a positive association was also found between age and the asymmetry around the eyes.

The age group of the participants in this study was similar to one of the groups in the study that collected three-dimensional co-ordinates of 16 standardized soft tissue landmarks on 314 healthy white northern Italian subjects, adolescents (12–15 years), young adults (18–30 years), and adults (31–56 years) using stereophotogrammetry in order to assess the effects of gender and age on soft tissue facial asymmetry (Ferrario *et al.*, 2001) but they were not able to observe a statistically significant difference in facial asymmetry based on age. In the current study, height and age were found to be strong predictors of facial asymmetry in both sexes, and weight was a strong predictor of asymmetry around the eyes.

6.1.5 Conclusion I

The results of this study indicate that facial asymmetry is sexually dimorphic and that age, height and whole face surface area are correlates of facial asymmetry, whereas age, weight, height, and whole face surface area are correlates of asymmetry around the eyes. None of the relationships are strong, however, as indicated by the low proportion of overall variance explained by each of them.

6.2 Analysis II: Facial asymmetry, measures of health and medical history

6.2.1 Introduction

Subtle variations in the human face including facial fluctuating asymmetry have been suggested to provide valuable information about identity (Penton Voak *et al.*, 2001, Rhodes *et al.*, 2003), attractiveness (Grammer and Thornhill, 1994, Perrett *et al.*, 1999, Rhodes and Simmons, 2007) and health status (Jones *et al.*, 2001, Fink *et al.*, 2006b, Rhodes *et al.*, 2007). In many animal species, FA is shown to relate to health or reproductive success (see (Moller, 1997) for review), body mass index (Hume and Montgomerie, 2001, Milne *et al.*, 2003), number of symptoms or serious sicknesses (Shackelford and Larsen, 1997b, Gangestad and Thornhill, 1997, Wynforth, 1998, Thornhill and Gangestad, 2006), and health measures [e.g., blood cholesterol, fitness, blood pressure (BP), and lung function] [e.g., (Tomkinson and Olds, 2000, Milne *et al.*, 2003)].

On the other hand, some authors indicated that subtle facial FA did not significantly predict health of either children or adolescents in their studies [e.g., (Rhodes *et al.*, 2001b)]. This was also similar to the findings of Honekopp et al., 2004, which showed no significant association between physical fitness and facial asymmetry in young women (Honekopp *et al.*, 2004). Moreover, Hume and Montgomerie (2001) found no significant association between composite body symmetry score (composed of measurements of both facial and other traits) and self-reported health problems (Hume and Montgomerie, 2001)]. Recently, a large cohort of 4732 British children was longitudinally studied and no association was found between facial FA and health history (Pound *et al.*, 2014).

The controversies about whether or not there is an association between subtle asymmetry and health is likely to continue until evolutionary biologists study such associations in populations living in a highly challenging environments, rather than in industrialized populations. Additionally, many authors who attempted to associate FA and health, mostly examined or observed symptoms which are present for a short while and are unlikely to have any significant impact during the critical periods of growth and development of individuals. The true picture of increased levels of FA and its association with health will better be appreciated if studied in highly stressed population, where individuals are exposed to several endemic and occasionally fatal disease conditions.

While as a measure of developmental stability, only FA is relevant, an observer cannot distinguish between different forms of asymmetry in another individual and in the context of mate choice, the relevant facial characteristic is total facial asymmetry. It is therefore important to establish whether total facial asymmetry correlates with other biometric variables and, ultimately, with those variables hypothesised to be relevant in the context of sexual selection and mate choice, such as disease history and socioeconomic background.

The selection of localized facial features is important in order to quantify areas of the face with increased/decreased levels of asymmetry as this will allow testing of the hypothesis that time-limited developmental stress factors are primarily reflected in the levels of asymmetry of the facial elements that are developing at the time.

Since during every day interpersonal interactions, the eye region is the main area of reference and indeed they begin to develop in the early period of the development of the face, *this study therefore aimed to identify relationships between whole (total) face asymmetry, asymmetry around the eye region and the past medical history/health measures of the non-**WEIRD** [western, educated, industrialized, rich and democratic] participants (the Hausa community of northern Nigeria) from a very high challenging environment.* The study also acquired information on the medical history from the mothers of participants because diseases suffered by the mothers during pregnancy may have affected participants' developmental process during the intra-uterine growth periods (Baker, 1992, Baker, 2000), including facial growth. These medical conditions were generally chronic conditions that may have impact on the prenatal or postnatal period of ontogeny of the participants. Additionally, the subjects were recruited from across the three socioeconomic levels in the northern part of Nigeria. The very good quality 3D facial scans acquired in this study, the inclusion of chronic and endemic (immunizable) diseases' history, and sample from across the three socioeconomic levels and from non-western industrialized region, will provide a strong test of relationship between facial asymmetry and medical conditions.

6.2.2 Methodology II

The scanning protocol was fully described in the general method chapter 5, while the method of measurements of biological characteristics such as weight and height were described in the **methodology 6.1.2**. Body Mass Index (BMI) was calculated as weight in kilogram divided by height in meter squared (m2). The blood pressure (systolic and diastolic) was recorded according to the standard protocols (Perloff *et al.*, 1993). Manual Mercury sphygmomanometer, which is considered to be the gold standard in measuring blood pressure was used in conjunction with a stethoscope (**Figure 6.6**).

The inflatable cuff was placed around an upper arm (just above the elbow joint), assumed to be at the same vertical height as the heart level and the cuff was gradually inflated. Each subject was measured while seated with the arm supported listening with a stethoscope to the brachial artery at the elbow. The pressure in the cuff was slowly released and the pressure at which this sound began was noted and recorded as the systolic blood pressure (SYSTBP). The cuff pressure was further released until the sound can no longer be heard and was then recorded as the diastolic blood pressure (DIASTBP).

Figure 6:6: Manual Mercury sphygmomanometer and Stethoscope

6.2.2.1 Participants' maternal medical history

Information was collected on whether a participant's mother had suffered ill health while pregnant with the participant. In order to maximise information accuracy, participants who were away from their mothers at the time of the interview, for example in schools, had to phone their mothers and get the correct information. Other participants took the questionnaire home to get the correct information before filling in the questionnaires. In the questionnaire, participants were asked to indicate whether 'yes' or 'no' their mother had suffered from a condition, if yes, the time since conception at which they suffered from the condition, and whether or not the condition was treated or not. In addition, information on smoking or alcohol consumption was also included, but nobody admitted to smoking or drinking. The following maternal diseases with "M" before each disease were included (M = maternal): Hypertension *(MBP)*, Diabetes mellitus *(MDM)*, Sickle cell disease *(MSCD)*, Peptic ulcer disease *(MPUD)*, severe malaria *(MSMAL)*, and severe typhoid fever *(MSTYP)*, Tuberculosis *(MTB)*, Leprosy *(MLPSY)*, Human Immunodeficiency Virus *(MHIV)*, and Acquired Immunodeficiency Syndrome *(MAIDS).*

Participants were assigned a score of 0 or 1 according to whether or not their mother had suffered from a condition. For each condition, a *Welch Two Sample T-test* was performed to determine the difference in mean whole face asymmetry (WFACE) & asymmetry around the eyes (EYES) between those whose mothers had suffered from a specific condition and those whose mothers had not. Where only few participants reported a specific condition, a *Mann-Whitney U-test* was performed instead.

Maternal diseases were then summed up resulting in participant-specific maternal disease-load scores and linear regression analyses were performed between whole face asymmetry, asymmetry around the eyes and maternal disease-load.

6.2.2.2 Participants' medical history

The history of diseases collected from the participants with "P" before each disease include (P = Participant): Malnutrition *(PMALNUT)*, Measles *(PMEASLES)*, Sickle cell disease *(PSCD)*, Meningitis *(PCSM)*, Severe malaria *(PSMAL)*, Severe typhoid fever *(PSTYP)*, Tuberculosis *(PTB)*, Poliomyelitis *(PPOL)*, Diphtheria *(PDIP)* and Hepatitis *(PHEPAT)*. Information on smoking and alcohol consumption was also included but none of the participants admitted either.

Participants who had suffered from a condition were assigned a score of 1, those who had not, were assigned a score of zero (0). For each condition, *Welch Two Sample t-tests* or *Mann-Whitney U-test* (where only few participants had suffered a condition) were used to compare mean WFACE and EYES values between participants who had suffered from it and those who had not. Scores were added up resulting in a participant-specific disease load score and linear regression analyses were performed between WFACE, EYES and participant disease-load.

Total disease load was calculated for each participant, by summing up the maternal and the participant's disease-load scores for each participant, and linear regressions were performed between WFACE, EYES and total disease load.

The mean, minimum and maximum values of each of the variables: body mass index (BMI), systolic blood pressure (SYSTBP), diastolic blood pressure

(DIASTBP) and total disease loads (TOTDX), were acquired from the *descriptive statistic* using IBM SPSS software version 22.

Comparison of means between men and women was conducted using *Welch Two Sample t-test* in R (R Core Team., 2014). Determination of the effects of health measures (BMI, SYSTBP, DIASTBP) and medical conditions (TOTDX: total disease loads) on the whole face asymmetry (WFACE) or asymmetry around the eyes (EYES) in both sexes was carried out also in R-software using *linear regression analyses* separately for men and for women.

However, where data were not normally distributed, those data were *rank ordered or log transformed* (to normalize the distribution) and *correlation analyses using Spearman' rho* were conducted. In order to assess sexual differences in WFACE, EYES, BMI, SYSTBP or DIASTBP between participants, *Wilcoxon rank sum tests* were conducted. *Multivariate analyses* was conducted separately for men and for women, with model simplification using the *Akaike information criterion (AIC) backward* method, and were done by including both the measures of health and total disease loads (TOTDX) altogether in order to ascertain the predictors of WFACE or EYES.

6.2.3 Results II

6.2.3.1 Descriptive statistics, Welch Two Sample t-test & linear regression analyses on facial asymmetry and measures of health

The mean values for whole face asymmetry (WFACE), asymmetry around the eyes (EYES), and each of the health measures, that is, body mass index (BMI), systolic blood pressure (SYSTBP), and diastolic blood pressure (DIASTBP) are shown in **Table 6.6**.

From the Welch Two Sample t-tests, there were *statistically significant differences (P<0.0001) observed between male and female in the mean values of whole face asymmetry, asymmetry around the eyes (EYES), and systolic blood pressure (SYSTBP)*, but no difference observed in the mean values of body mass index (BMI) and diastolic blood pressure (DIASTBP) (P>0.05) as shown in **Table 6.6**.

Separate **linear regression analyses** indicate no association between whole face asymmetry (as the dependent variable) and any of the health measures (as independent variable) but *there was a statistically significant association between asymmetry around the eyes (EYES) and body mass index (BMI), and between asymmetry around the eyes (EYES) and the systolic blood pressure (SYSTBP) in females only*. Additionally, *there was statistical association between asymmetry around the eyes (EYES) and diastolic blood pressure (DIASTBP) in both sexes* (**Table 6.7, Figures 6.7 & 6.8**). However, although statistically significant, none of these relationships was strong, as indicated by the low R2 values (**Table 6.7**).

6.2.3.2 Multivariate analyses: facial asymmetry and measures of health

Multivariate analyses on whole face asymmetry (through the best model search) versus body mass index (BMI), systolic BP (SYSTBP), diastolic BP (DIASTBP), and whole surface area (WFSA) and SEX as covariates was also conducted. Starting with all the variables (maximal model), a statistically significant model was found (F=3.291, P=2.935e-08) with an adjusted r-squared value of 0.1432. However, through the use of Akaike information criterion (AIC): model optimisation by the backward model elimination method (gradual removal of model with highest AIC value), a statistically significant best (minimal) model with slightly higher adjusted r-squared (0.1453) but with much lower p-value (F=25.09, P=5.888e-15) than the maximal model was obtained. The best (minimal) model was a linear model of whole face asymmetry on WFSA, DIASTBP & SEX, meaning whole face surface area (WFSA), diastolic blood pressure (DIASTBP) and SEX contribute to variation of whole face asymmetry (**Table 6.8A & B**). Similarly, analysis of asymmetry around the eyes and health measures revealed a statistically significant (maximal) model (F=2.384, P=7.25e-05) with an adjusted r-squared value of 0.0917, but the best (minimal) model was more statistically significant with similar r-squared (0.0946) with much lower p-value (F=15.81, P=9.284e-10) than the maximal model.

The best (minimal) model was a linear model of asymmetry around the eyes on body mass index (BMI), diastolic blood pressure (DIASTBP) and SEX, meaning that SEX, body mass index (BMI) and diastolic blood pressure (DIASTBP) contribute to variation in asymmetry around the eyes (EYES) (**Table 6.9A & B**).

Table 6:6: Welch Two Sample t-test between Whole face asymmetry (WFACE), asymmetry around the eyes (EYES), Body mass indexes (BMI), Systolic blood pressure (SYSTBP), Diastolic blood pressure (DIASTBP) and SEX

Variables	Mean (Males)	Mean (Females)	W-value	DF	P-value
WFACE	0.3480	0.3054	-7.932	416.16	**2.009e-14**
EYES	0.2322	0.2048	-5.291	415.05	**1.974e-07**
BMI	21.11	21.12	0.0285	354.45	0.9772
SYSTBP	115.77	108.14	-5.752	421.16	**1.7e-08**
DIASTBP	72.2	70.7	-1.163	422.88	0.2454

Table 6:7: Linear regression analyses between whole face asymmetry (WFACE), or asymmetry around the eyes (EYES) and measures of health [body mass indexes (BMI), systolic blood pressure (SYSTBP), and diastolic blood pressure (DIASTBP)]

Variables	SEX	Adjusted R^2	F-statistic	DF	P-Value
WFACE ~BMI	F	-0.005	0.0015	1 on 209	0.969
	M	-0.004	0.2289	1 on 213	0.6329
EYES ~ BMI	F	0.0282	7.0940	1 on 209	**0.0083**
	M	-0.0003	0.9262	1 on 213	0.3370
WFACE ~SYSTBP	F	0.0029	1.6000	1 on 209	0.2072
	M	-0.0027	0.4248	1 on 213	0.5152
EYES ~SYSTBP	F	0.0211	5.5230	1 on 209	**0.0197**
	M	-0.0027	0.4225	1 on 213	0.5164
WFACE ~DIASTBP	F	0.0061	2.2950	1 on 209	0.1313
	M	0.0101	3.1820	1 on 213	0.0759
EYES ~DIASTBP	F	0.0342	8.4250	1 on 209	**0.0041**
	M	0.0207	5.5230	1 on 213	**0.0197**

Table 6:8: Multivariate minimal model: whole face asymmetry (WFACE) regressed against diastolic blood pressure (DIASTBP), whole face surface area (WFSA) & SEX
Call: lm (formula = WFACE ~ DIASTBP + WFSA + SEX)

A)Residuals:

Min	1Q	Median	3Q	Max
-0.126558	-0.037031	-0.004376	0.033040	0.182319

B)Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.180e-01	2.701e-02	8.068	**7.48e-15**
DIASTBP	4.145e-04	2.039e-04	2.032	**0.0427**
WFSA	1.732e-06	7.276e-07	2.380	**0.0178**
SEXM	3.059e-02	7.163e-03	4.271	**2.40e-05**

Residual standard error: 0.055 on 422 degrees of freedom, Multiple R-squared: 0.1514.

Table 6:9: Multivariate minimal model: asymmetry around the eyes (EYES), regressed against body mass index (BMI), diastolic blood pressure (DIASTBP), body mass index (BMI) & SEX
Call: lm (formula = EYES ~ BMI + DIASTBP + SEX)

A)Residuals:

Min	1Q	Median	3Q	Max
-0.117456	-0.037541	-0.005609	0.031274	0.280551

B)Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.1195060	0.0212764	5.617	**3.53e-08**
BMI	0.0018326	0.0008320	2.203	**0.0281**
DIASTBP	0.0006591	0.0001941	3.395	**0.0007**
SEXM	0.0263724	0.0050857	5.186	**3.35e-07**

Residual standard error: 0.0524 on 422 degrees of freedom. Multiple R-squared: 0.101

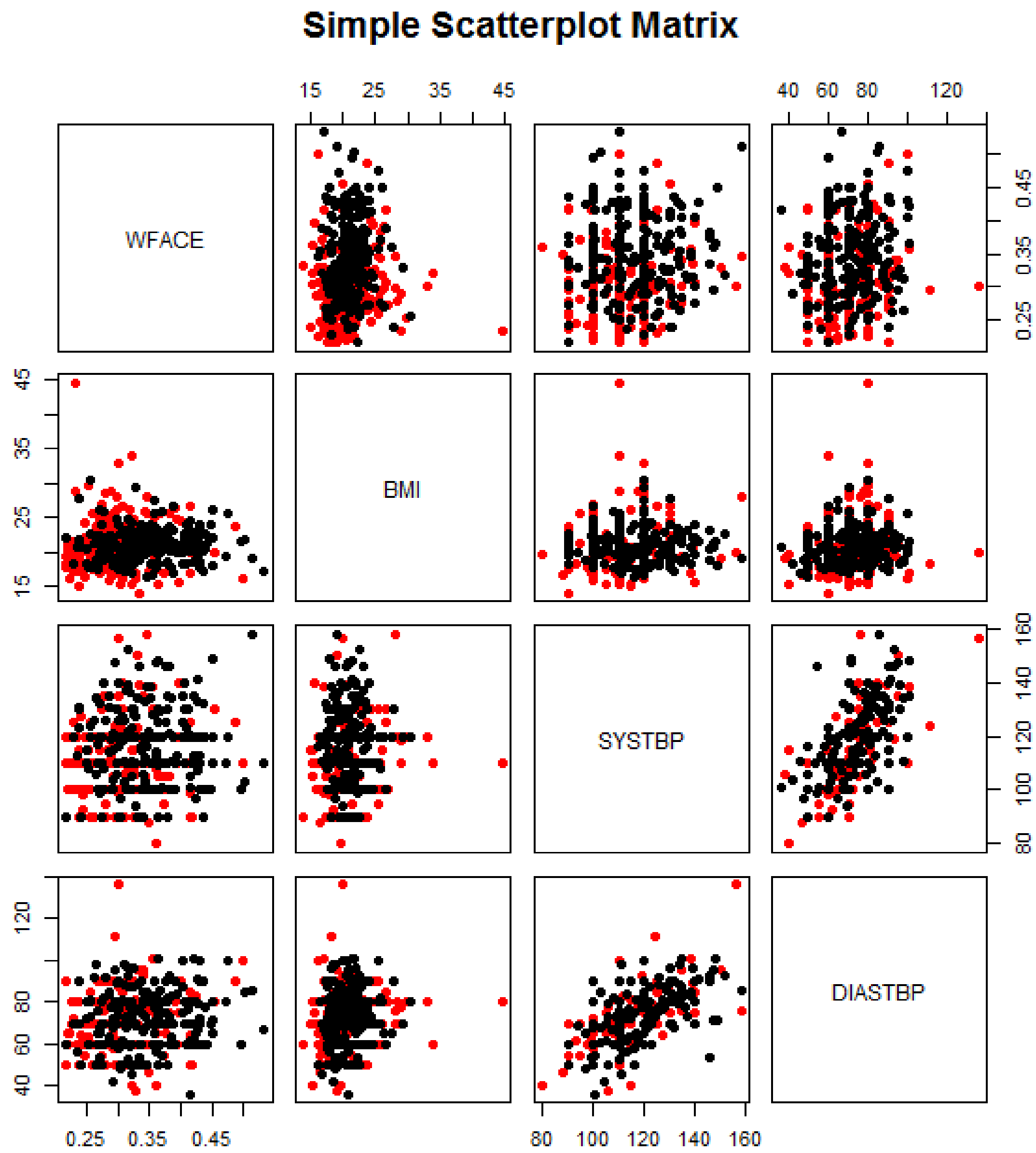


Figure 6:7: Scatterplot matrix of whole face asymmetry (WFACE), body mass index (BMI), systolic blood pressure (SYSTBP), and diastolic blood pressure (DIASTBP)

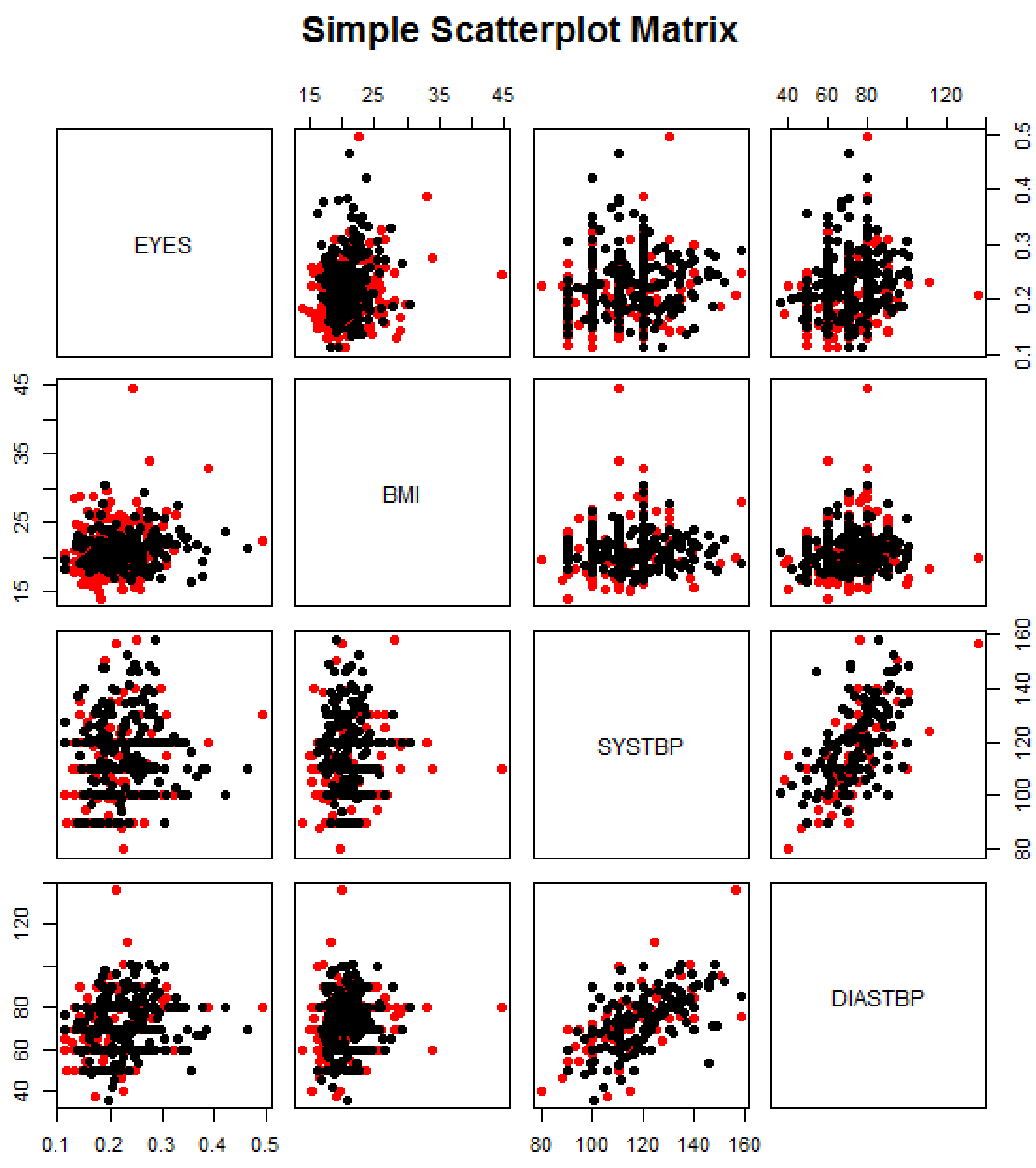


Figure 6:8: Scatterplot matrix of asymmetry around the eyes (EYES), body mass index (BMI), systolic blood pressure (SYSTBP), and diastolic blood pressure (DIASTBP)

6.2.3.3 Mann-Whitney U-test & linear regression analyses on facial asymmetry and past history of maternal/participants 'diseases

The frequency distribution of each of the five past maternal medical history of the participant as well as each of the seven participants' history, is shown in **Table 6.10**. *Mann-Whitney U-tests* were conducted between whole face asymmetry (as the dependent variable) and each of the maternal and participants' disease history variables (as the independent variable) in both sexes. None of the analyses showed any statistically significant difference between those with disease history and those without (**Table 6.10**), with similar findings when asymmetry around the eyes was considered as the dependent variable. Similarly, *simple linear regression analysis* was conducted between whole face asymmetry and the total sum of disease history but no association was found, with the same findings when asymmetry around the eyes was regressed against the total sum of diseases as shown in **Table 6.11** and **Figures 6.8 & 6.9**.

Table 6:10: Mann-Whitney U-test: Between facial asymmetry and medical history

		Frequency		W-statistics		P-values	
Variables	Sex	+History	No history	WFACE	EYES	WFACE	EYES
MHBP	F	57 (27.1%)	154 (72.9%)	3994	4271	0.3164	0.7654
	M	30 (14.0%)	185 (86.0%)	2783.5	2741	0.9798	0.9156
MPUD	F	44 (20.9%)	167 (79.1%)	3376.5	3971.5	0.4097	0.4097
	M	33 (15.3%)	182 (84.7%)	3160.5	2438	0.633	0.0859
MSMAL	F	98 (46.4%)	113 (53.6%)	5654.5	6062.5	0.7914	0.2352
	M	94 (43.7%)	121 (56.3%)	5650	5634	0.9357	0.9076
MSTYP	F	61 (28.9%)	150 (71.1%)	4531.5	4799.5	0.9148	0.5774
	M	68 (31.6%)	147 (68.4%)	4918.5	5260.5	0.8522	0.5368
MDM	F	14 (06.6%)	197 (93.4%)	1295.5	1189	0.7069	0.3906
	M	12 (05.6%)	203 (94.4%)	1319.5	1350.5	0.6296	0.5284
PMALNUT	F	59 (28.0%)	152 (72.0%)	4562	4243	0.8456	0.5457
	M	53 (24.7%)	162 (75.3%)	4392.5	4506	0.8012	0.5888
PMEASLE	F	89 (42.2%)	122 (57.8%)	5338	4875.5	0.8363	0.2067
	M	72 (33.5%)	143 (66.5%)	5461	5565.5	0.4679	0.3327
PSCD	F	01 (00.5%)	210 (99.5%)	10	43	0.1208	0.3126
	M	01 (00.5%)	214 (99.5%)	40	171.5	0.2839	0.3024
PCSM	F	08 (03.8%)	203 (96.2%)	628	611	0.2786	0.2365
	M	03 (01.4%)	212 (98.6%)	188	197	0.2261	0.2600
PSMAL	F	125 (59.2%)	086 (40.8%)	5357	5422.5	0.968	0.9141
	M	105 (48.8%)	110 (51.2%)	5525.5	5740	0.585	0.9397
PSTYP	F	72 (34.1%)	139 (65.9%)	4731	5233.5	0.5169	0.5860
	M	81 (37.7%)	134 (62.3%)	5678.5	5330.5	0.5701	0.8280
PTB	F	06 (02.8%)	205 (97.2%)	338	445.5	0.06067	0.2516
	M	04 (01.9%)	211 (98.1%)	460	433.5	0.7609	0.9289

MHBP = hypertension; MPUD = peptic ulcer disease; MSMAL = severe malaria; MSTYP = severe typhoid fever; MDM = diabetes mellitus; PMALNUT = malnutrition, PMEASLE = measles, PSCD = sickle cell disease, PSMAL = severe malaria, PSTYP = severe typhoid, PTB = pulmonary tuberculosis. Note: ''M'' denotes maternal, & ''P'' denotes participant.

Table 6:11: Linear regression analyses between whole face asymmetry (WFACE), or asymmetry around the eyes (EYES) and total disease loads (TOTDX)

Variables	SEX	Adjusted R^2	F-statistic	DF	P-Value
WFACE & TOTDX	F	-0.0043	0.0996	1 on 209	0.7526
	M	-0.0036	0.2308	1 on 213	0.6314
EYES & TOTDX	F	-0.0047	0.0095	1 on 209	0.9223
	M	-0.0037	0.2207	1 on 213	0.6390

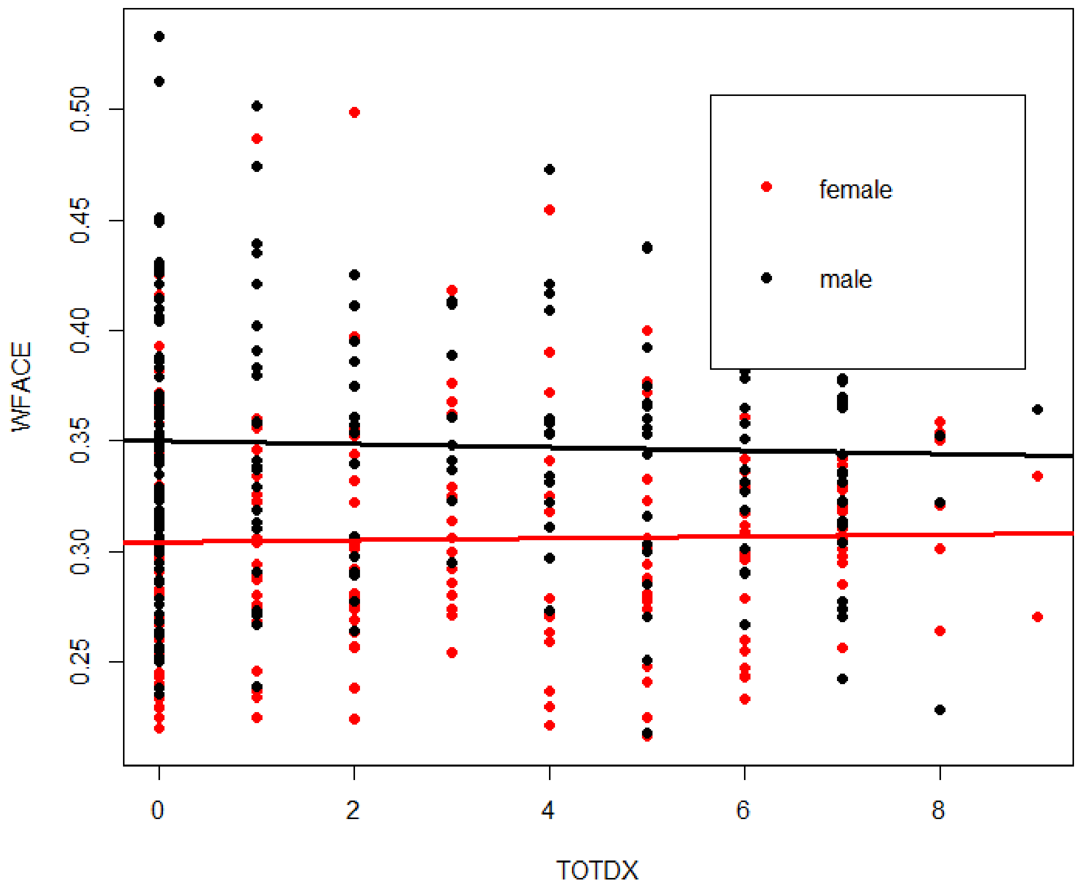


Figure 6:9: Scatterplot matrix of whole face asymmetry (WFACE) and the total sum of diseases of the participants (TOTDX)

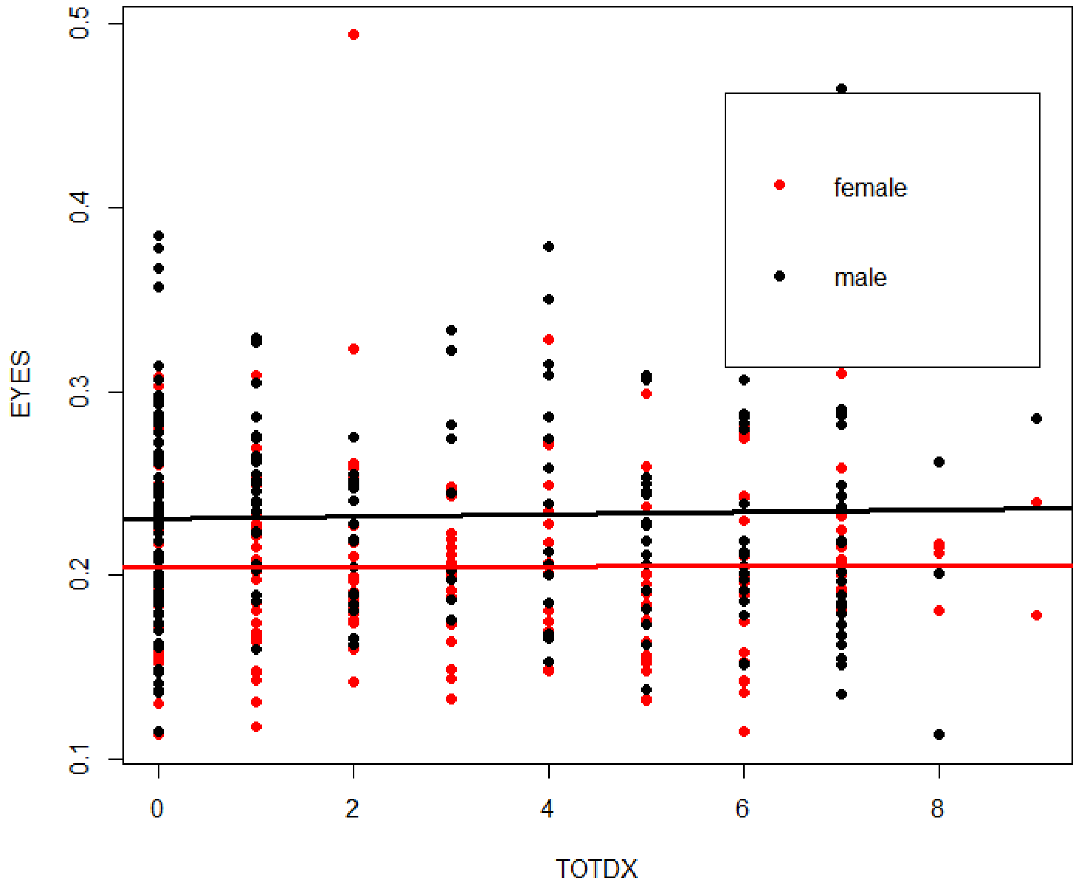


Figure 6:10: Scatterplot matrix of asymmetry around the eyes (EYES) and the total sum of diseases of the participants (TOTDX)

6.2.4 Discussion II

Here, the study tested the hypothesis that people with serious postnatal medical history and/or whose mothers were affected by serious medical conditions while carrying their pregnancy will have higher levels of whole (total) facial asymmetry. Previous studies also hypothesized that individuals with higher exposure to environmental stressors (e.g., health measures, medical conditions etc.) will have higher FA but mostly, the results were inconsistent.

In the present study, body mass index (BMI) demonstrated no association with total facial asymmetry in either males or females in contrast to another study where women's BMI was shown to significantly associate with composite overall asymmetry (Hume and Montgomerie, 2001). However, BMI, and diastolic blood pressure were shown to predict asymmetry around the eyes in both sexes. Why BMI and diastolic pressure predict asymmetry around the eyes may be due to the peculiar micro vasculatures, complexity and inter-individual variations of the orbital vascular bed [see (Hayreh, 2006)]. This is because endothelial function is usually impaired in the presence of cardiovascular risk factors, such as BMI (Schroeder *et al.*, 2000) and hypertension (Charbonneau and Anderson, 1998) and so any increase in diastolic pressure may tamper with the blood supply of that region and therefore affect growth and development of that area. Similar with others [e.g., (Milne *et al.*, 2003)], this study also found no association between total facial asymmetry, Systolic and Diastolic BP and the absence of the relationship might be due to the larger and well vascularized nature of the face.

What about the relationship between human facial fluctuating asymmetry and health? Some studies have shown evidence of association between the two [e.g., (Manning, 1995b, Shackelford and Larsen, 1997b, Wynforth, 1998)]. But other studies failed to find such an association between FA and some medical conditions. For example a study that examined kidney, bladder, and periodontal infections failed to find association between FA and health, although the study used composite body FA, and also the asymmetry values were not corrected for size (Milne *et al.*, 2003). More recently, a longitudinally based study on a large British cohort of over four thousand children also failed to demonstrate an association between facial FA and health (Pound *et al.*, 2014). These authors argued that their failure to detect an association may be due to the availability and accessibility of modern health care facilities, which plausibly reduce the degree of the effects of environmental stressors on ontogeny, but this may particularly be true for the visible facial FA as they are shown to consistently and reliably associate with environmental [e.g., pathogens (Livshits *et al.*, 1988, Moller, 1996)] and genetic stressors [(Meyer-Marcotty *et al.*, 2011a)] affecting individuals' early ontogeny and may require clinical interventions (Cheong, 2011). Therefore, the absence of these visible asymmetries amongst individuals could reliably suggest 'fitness' or 'good genes'.

In the current study, no association was found between total facial asymmetry, asymmetry around the eyes and any one or the sum of the medical conditions recorded. However, the absence of association between health and asymmetry in the non-western population (this study) and in the western population [e.g.,(Pound *et al.*, 2014)], provides a compelling evidence that medical conditions are unlikely to be a significant part of the possible causes of measurable and crucially, perceivable facial asymmetry. Therefore, placing this study's findings in the context of previous findings, it is possible to conclude that developmental stability is associated with low BMI in Caucasians [e.g.,(Hume and Montgomerie, 2001)] and in Black Africans (this study), associated with low systolic and diastolic blood pressures (this study), but not in others (Milne *et al.*, 2003). Similarly, subtle facial asymmetry (including facial FA) is not associated with health in young adults [this study, and (Tomkinson and Olds, 2000)] and in childhood (Pound *et al.*, 2014), possibly because the relationship in whole face asymmetry is masked by variation in directional asymmetry.

Many questions in the study of facial asymmetry remain unanswered, for example: to what level is the overall facial asymmetry considered normal or abnormal? And since FA develops as an accumulation of various environmental stressors and possibly genetic, what is the proportion of contribution of each of the tested stressors? Are there population, regional or cultural variations in the FA levels?

6.2.5 Conclusion II

As individuals' lower levels of facial (and bodily) FA in both sexes have been proposed to signal their resistance to diseases (Thornhill and Gangestad, 2006), the failure of Pound et al. (2014) to find association between subtle human facial fluctuating asymmetry and health in a large sample of over 4000 British children, and the failure of the current study to find association between whole face asymmetry and total sum of diseases in a non-westernized population, further give better understanding in the association of facial asymmetry and health. This study therefore suggests that subtle facial asymmetry is unlikely to serve as a visible marker that provides records of early life environment stress experience.

6.3 Analysis III: Facial asymmetry and Measures of socioeconomic status

6.3.1 Introduction

From the theoretical framework, an association between socioeconomic status (SES) and fluctuating asymmetry (FA) is expected since higher levels of fluctuating asymmetry are considered to be a sign that a population is under stress (Polak, 2003). But in spite of this, the influence of adverse socioeconomic levels on body FA in general, has only been studied by a few researchers (Wynforth, 1998, Flinn *et al.*, 1999, Gray and Marlowe, 2002, Özener, 2010), mainly focussed on Caucasians. The literature is however deficient in demonstrating the adverse effects of socioeconomic status on facial asymmetry in particular and no such study has been conducted in sub-Saharan Africans. Amongst the Caucasians, Özener and Fink (2010) examined 503 young girls and boys aged 17-18 years from Ankara, Turkey, by the use of digital facial images of those participants from two different areas (slum and urban) in order to assess the degree of facial asymmetry and its association with socioeconomic conditions. Facial asymmetry was calculated as a composite score from seven measured paired traits from the digital photographs. Their results indicated that facial asymmetry was significantly higher amongst participants from the slum with males having higher facial asymmetry than females (Özener and Fink, 2010). A similar study examined an elderly sample with measures of both childhood and adult SES, and for whom symmetry of the face and the body were measured in old age (Hope *et al.*, 2013). Their prediction was that early life period will have an influence on developmental stability and, therefore symmetry should associate with early life SES. They said that if stress in early life has a significant influence on developmental disturbance, they expect to find an association between symmetry and early life SES, and if total accumulated stress (from early life to later life) presents in the form of asymmetry, then they expect also to find associations between asymmetry and later-life challenges, as indexed by midlife attained SES. Their findings indicated that there was an association between early life socioeconomic status (SES) and facial symmetry but not with midlife SES, and according to their findings, lower SES in early life in both sexes is significantly associated with lower facial symmetry although stronger in men (Hope *et al.*, 2013).

In the Özener and Fink (2010) study, subjects younger than 18 years of age were included, and would hence still have been growing, and the effects of degenerative changes of later age might question the validity of the findings of Hope et al. (2013), since very old subjects were included at ages 79, 83 and 89 years. The current study therefore deliberately selected subjects between the ages of 18-25 years to avoid such potential confounding factors.

This is the first study to examine the relationship between SES and facial asymmetry amongst the sub-Saharan Africans. It tested *whether lower socioeconomic status signals developmental instability as measured by overall facial asymmetry and whether intra or intersexual competition for resources as measured by the number of siblings and birth order, is reflected in the form of facial asymmetry (as a consequence of increasing competition for the resources: a marker of lower SES)*. The study analysed three measures of SES (educational levels, occupation, and income) and facial asymmetry separately for males and for females in order to determine the effects of intra or intersexual competition for the resources on facial asymmetry.

6.3.2 Methodology III

6.3.2.1 Scanning protocols

The study area, study subjects' recruitments (and their age range), scanning, preparation of the 3D facial models, acquisition of the overall facial asymmetry and asymmetry around the eyes metrics, and repeatability of the protocols are all explained in detail in the general material and methods section (chapter 5).

6.3.2.2 Measures of Socioeconomic status

The three key indicators of socioeconomic status are economic status, measured by income; social status, measured by education; and work status, measured by occupation (Dutton and Levine, 1989).

Since not all the participants were yet working, participants were asked to report their parental economic status (the income) or work status, but the educational levels of both the participants and those of their parents (mother & father) were used as indicators of social status. Other indicators, marital status, birth order, number of siblings in a family and the social class to which each participant belongs, were also included.

In northern Nigeria, there are two routes in the educational system, the first of which is the Islamic education route that was introduced by Arab Muslim clerics from the Western and central Sudan in the 14th century [see (Jayeola-Omoyeni and Omoyeni, 2014)]. This Islamic education was purposely meant for the Muslim converts to be able to read and write Arabic language and understand how to practice Islam, Islamic law, poetry, grammar and literature and its main source of information is the Qur'an and Hadith [see (Sulaiman, 2012)].

The second educational system is the Western (formal) education, which was introduced by Christian missionaries in the 15th century specifically to propagate Christianity and to ensure Christian converts know how to read the Bible and understand Christianity (Sulaiman, 2012, Jayeola-Omoyeni and Omoyeni, 2014). But in the 19th century the British colonial government in Nigeria gave the missionaries full support for their missionary work but modified the Christian

Missionary Educational system (CME) by enacting colonial education ordinances that yielded several churches and schools for formal (modern) education (Sulaiman, 2012). The participants or their parents in the present study may have followed both or either of the two educational levels. For the purpose of the present study, only the influence of Western education on facial variations (asymmetry) is of interest to conform with similar studies [e.g, (Özener, 2010, Özener and Fink, 2010)]. The participants and their parents (mother and father) were thus categorised as having received a Western education or not and coded as follows: no Western education = 0, Western education = 1. Influence on asymmetry values was tested separately according to the participant's level of education (ELP), the mother's level of education (ELM) and the father's level of education (ELF). In order to determine differences in mean WFACE and mean EYES values between education categories, a *Wilcoxon two sample test* was applied if one of the counts (educated and non-educated) was very small compared to the other. A *Welch Two-Sample t-test* was carried out where counts in the two groups were more comparable. In addition, the participants were assigned to one of four groups according to a combination of their own and their parents' levels of education:

Group 4 = participant and both parents had received a western education (1, 1, 1); group 3 = participant and one parent had received a western education (0, 1, 1); group 2 = participant but neither of the parents had received a western education (0, 0, 1); group 1 = neither participant nor the parents had received a western education (0, 0, 0).

Because of uneven sample sizes in the 4 groups, a *Kruskal-Wallis test*, rather than ANOVA was performed to test for differences in the mean WFACE and mean EYES values between education level groups.

The Marital Status (MS) of the participants was considered as part of the socioeconomic context because, in the Hausa community, less educated and poorer young adults especially in the villages tend to get married earlier than the educated ones, who become wealthier by getting employment and other businesses after schooling before getting married. Initial categories included: married, widowed, separated, divorced, and single, but for easy analysis, these were combined into two groups: married = 1 and not married = 0. A *Welch Two Sample t-test or a Wilcoxon test* was performed following the criteria set out above to test for differences in mean *WFACE* values and mean *EYES* values between the married and unmarried participants.

For easy analysis, occupation of the participants was categorized into 2: recorded as zero (0) if the participant is a student and one (1) if non-student because most of the non-student participants were involved in several types of paid work. A *Welch Two Sample t-test or a Wilcoxon test* was performed following the criteria set out above to test for differences in mean WFACE values and mean EYES values between the student and non-student participants.

The Income (INCOM) of each participant was recorded as total earnings per month whether as earnings from business or from any other source and was recorded in Nigerian currency (Naira). The income data were not normally distributed and therefore were log-transformed to normalise their distribution and their influence on WFACE or EYES was tested using Spearman's correlation.

Overall Socio-Economic Status (SES) was assessed for each participant based on the following criteria: Educational levels (primary, secondary or post-secondary education) of the participant and his or her parent (mother and father), occupation of the participant (if independent) or parent (if dependent), and assets ownership by participant or parents such as: lands, houses, livestock or vehicles such as bikes and cars (see **Questionnaire in Appendix 2**).

Participants' indicators of wealth were compiled using questionnaires and were socially stratified into three categories (see Appendix 4) based on three key indicators of wealth that include education, income, and assets (land ownership, houses and valuables). Based on the information obtained from the questionnaires, each participant was placed into SES 1 = rich, SES 2 = average, SES 3 = poor. *Kruskal-Wallis tests* were used to test for differences in mean WFACE values and mean EYES values between the three socio-economic categories.

Birth order (BO) of each participant was recorded as the paternal birth order, because it is one of the aim of the present study to explore the influence of resource distribution within (mostly polygynous) families. The potential influence of birth order on WFACE or EYES was tested by *Spearman's correlation*. The Number of siblings (NOS) in each of the participant families was also recorded and its potential influence on WFACE or EYES was tested by *Spearman's correlation*.

6.3.3 Results III

6.3.3.1 Mann-Whitney U-test and linear regression analyses on facial asymmetry, marital status, occupation and educational levels

Table 6.12 shows the socioeconomic characteristics of the sample (of Hausa ethnic group), while **Table 6.13** shows the frequency distribution of the marital status: MS (married/un-married), occupation: OCCUP (student/non-student), educational level of the participant: ELP (educated/uneducated), educational level of the mother: ELM (educated/uneducated), and educational level of the participant's father (educated/uneducated). **Table 6.14** indicates the mean whole face asymmetry and asymmetry around the eyes values of married/unmarried, student/non-student, and educated/uneducated in both males and females. *Wilcoxon' (Mann-Whitney U)* test of differences in the mean whole face asymmetry or asymmetry around the eyes shows that *Married men have greater mean WFACE than the unmarried men and the difference is statistically significant* (*P<0.05*) as shown in **Table 6.15**. Married women also have higher mean WFACE than the unmarried but the difference is insignificant (*P>0.05*). With regard to the mean EYES, there is no significant difference between the married and the unmarried in both sexes (*P>0.05*). Although the non-student subjects (both males and females) have greater mean WFACE and EYES than the student subjects, there is also no statistical difference found (*P>0.05*) either in the mean WFACE or in the mean EYES.

Uneducated participants (both males and females) have higher mean WFACE than the educated subjects with a statistically significant difference in female subjects only as indicated in **Table 6.15**.

Similarly, analyses between the participants with educated mothers (ELM) or educated fathers (ELF) and participants with uneducated mothers or fathers did not yield any difference in the mean WFACE or mean EYES (P>0.05) in both sexes.

Table 6:12: Socioeconomic characteristic of the sample (of Hausa ethnic group)

Variable	Poor N = **225**	Average N = **178**	Rich N = **23**	Total N = **426**
Number of siblings				
0-5	57	23	1	81
6-10	133	74	10	217
11-15	26	47	8	81
16-20	4	10	1	15
>20	5	24	3	32
				426
Educational level (Mother)				
No formal education	201	20	0	221
Formal education	24	158	23	205
				426
Educational level (Father)				
No formal education	192	14	0	207
Formal education	33	164	23	220
				426
Educational level (Participant)				
No formal education	110	0	0	110
Formal education	115	178	23	316
				426
Occupational status (Participant)				
Student	21	177	23	221
Non-student	204	1	0	205
				426
Residential status				
Muddy	222	5	0	227
Non-muddy	3	173	23	199
				426
Number of rooms per house				
<3	86	50	1	137
4	124	100	3	227
>4	15	28	19	62
				426

Table 6:13: Frequency distribution of the participants' marital status (MS), occupation (OCCUP), educational levels of the participant (ELP), educational levels of the participant 'mother (ELM), and educational levels of the participant' father (ELF).

Variable	Sex	Married	Unmarried	TOTAL
MS	F	137	74	211
	M	41	174	215
		Student	Non-student	
OCCUP	F	82	129	211
	M	138	77	215
		Educated	Uneducated	
ELP	F	115	96	211
	M	200	15	215
ELM	F	84	127	211
	M	120	95	215
ELF	F	90	121	211
	M	129	86	215

Table 6:14: Mean whole (total) face asymmetry (WFACE) by measures of socioeconomic status and asymmetry around the eyes (EYES) of the participants in both sexes

Variables	Sex	Mean WFACE		Mean EYES	
		Married	Un-married	Married	Un-married
MS	F	0.3078	0.3008	0.2039	0.2065
	M	0.3674	0.3434	0.2468	0.2287
		Student	Non-student	Student	Non-student
OCCUP	F	0.3010	0.3081	0.2072	0.2033
	M	0.3450	0.3534	0.2297	0.2367
		Educated	Un-educated	Educated	Un-educated
ELP	F	0.2982	0.3140	0.2038	0.2060
	M	0.3473	0.3579	0.2320	0.2341
ELM	F	0.3003	0.3087	0.2064	0.2038
	M	0.3485	0.3474	0.2307	0.2340
ELF	F	0.3014	0.3083	0.2055	0.2043
	M	0.3469	0.3497	0.2321	0.2323

Marital status (MS), occupation (OCCUP), educational levels of the participant (ELP), educational levels of the participant' mother (ELM), and educational levels of the participant' father (ELF).

Table 6:15: Wilcoxon rank sum tests between whole face asymmetry, asymmetry around the eyes, and socioeconomic measures of the participants.

Variables	Sex	W-statistic		P-value	
		WFACE	EYES	WFACE	EYES
MS	F	4840.5	5118	0.5900	0.9088
	M	2721.5	3028	0.0184*	0.1329
OCCUP	F	5633.5	5057	0.4261	0.5923
	M	5861	5476.5	0.2106	0.7093
ELP	F	6422	5595	0.0412*	0.8660
	M	1655.5	1397	0.5047	0.6591
ELM	F	5757	5218.5	0.3304	0.7911
	M	5767.5	5739	0.8824	0.9323
ELF	F	5730.5	5420.5	0.5158	0.9564
	M	5792	5333	0.5843	0.6328

MS (marital status: married/unmarried), OCCUP (occupation: student/non-student), ELP (educational level of participant: educated/uneducated), ELM (educational level of the participant's mother: educated/uneducated), ELF (educational level of the participant's father: educated/uneducated).
*Significant at $P<0.05$

6.3.3.2 Spearman's correlation & Kruskal-Wallis test: facial asymmetry versus measures of socioeconomic status

Spearman's correlation between whole face asymmetry (WFACE) and birth order (BO) and between whole face asymmetry (WFACE) and number of siblings (NOS) yielded no associations in both sexes as indicated in **Table 6.16**, **Figures 6.11 & 6.12**. However, *there was marginally negative correlation between whole face asymmetry (WFACE) and income (INCOM) of female subjects but no such association in male subjects* (**Table 6.16, Figure 6.13**). Similar analyses between asymmetry around the eyes (EYES) and BO, EYES & NOS and EYES and INCOM indicate no relationship in either sex as shown in **Table 6.16, Figures 6.14, 6.15 & 6.16**.

The frequency and the mean WFACE and EYES values for each of 4 educational level groups are shown in **Tables 6.17** for both sexes. *Kruskal-Wallis test revealed a statistically significant difference (P<0.05) in the mean WFACE of the four groups of the educational levels in female subjects only* but no such difference is observed in the mean EYES of the four groups of the educational levels either in both sexes as indicated in **Table 6.18**.

Table 6.19 shows the frequency distribution of the three social classes of the sample of Hausa ethnic group in Nigeria together with the mean whole face asymmetry (WFACE) and asymmetry around the eyes (EYES) in each class in both males and females. **Table 6.20** indicates the Kruskal-Wallis Test amongst the three classes but the analysis reveals no difference in the mean WFACE or EYES between the three social classes.

Table 6:16: Non-parametric correlation between whole face asymmetry or asymmetry around the eyes and Birth order, Number of siblings & Income

Correlation type	Variable	SEX	Correlation coefficient WFACE	Correlation coefficient EYES
Spearman's rho	BO	F	0.086	0.025
		M	-0.038	-0.127
	NOS	F	0.040	0.060
		M	-0.020	-0.130
	LogIncm	F	0.117	0.072
		M	-0.044	-0.058

WFACE = whole face asymmetry values, EYES = asymmetry around the eyes values, BO = birth order, NOS = number of siblings, and LogIncm = income log-transformed:

Table 6:17: Frequency distribution, mean whole face asymmetry (WFACE) and asymmetry around the eyes (EYES) of each grouped total educational level of participants (GTOTEDU)

Groups	Sex	Frequency	Mean WFACE	Mean EYES
Group1	F	94	0.3142	0.2070
	M	15	0.3579	0.2341
Group 2	F	29	0.2884	0.1929
	M	65	0.3506	0.2339
Group 3	F	4	0.3250	0.2080
	M	21	0.3221	0.2277
Group 4	F	84	0.3003	0.2064
	M	114	0.3500	0.2317

Group 1 = neither the participant nor parents had western education
Group 2 = only participant had western education
Group 3 = participant and one of the parents had western education
Group 4 = participant and both parents had western education

Table 6:18: Kruskal-Wallis test, whole face asymmetry (WFACE) by grouped total educational level of participants (GTOTEDU), and asymmetry around the eyes (EYES) by total educational level of participants (GTOTEDU)

Variables	Sex	Kruskal-Wallis	DF	P-value
WFACE	F	8.0807	3	**0.0444**
	M	4.3476	3	0.2263
EYES	F	1.5306	3	0.6752
	M	0.2051	3	0.9768

Table 6:19: Frequency distribution of the SES and the mean WFACE & EYES of the three groups

Groups	Sex	Frequency	Mean WFRES	Mean EYERES
SES1	F	7	0.2926	0.2204
	M	15	0.3419	0.2274
SES2	F	70	0.2989	0.2055
	M	108	0.3443	0.2279
SES3	F	134	0.3094	0.2037
	M	92	0.3534	0.2379

SES1 (Social class 1: rich), SES2 (Social class 2: average), SES3 (Social class 3: poor). WFACE (Whole face asymmetry), EYES (Asymmetry around the eyes).

Table 6:20: Kruskal-Wallis test, WFACE by SES

Variables	Sex	Kruskal-Wallis	DF	P-value
WFACE	F	2.3121	2	0.3147
	M	2.183	2	0.3357
EYES	F	1.5166	2	0.4685
	M	0.8815	2	0.6435

SES (Social class), WFACE (Whole face asymmetry), EYES (Asymmetry around the eyes).

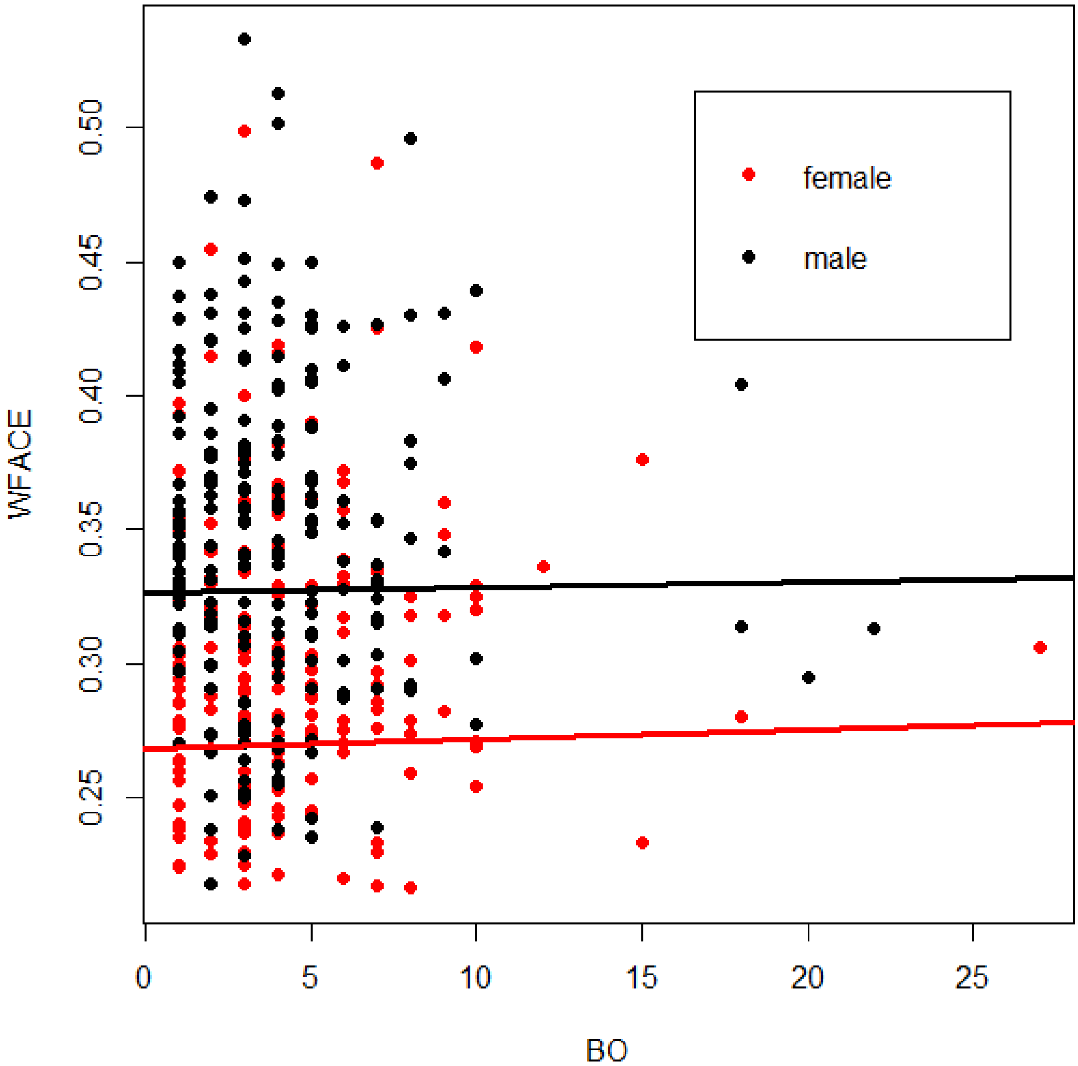


Figure 6:11: Regression analysis linear association graph between whole face asymmetry (WFACE) and birth order (BO)

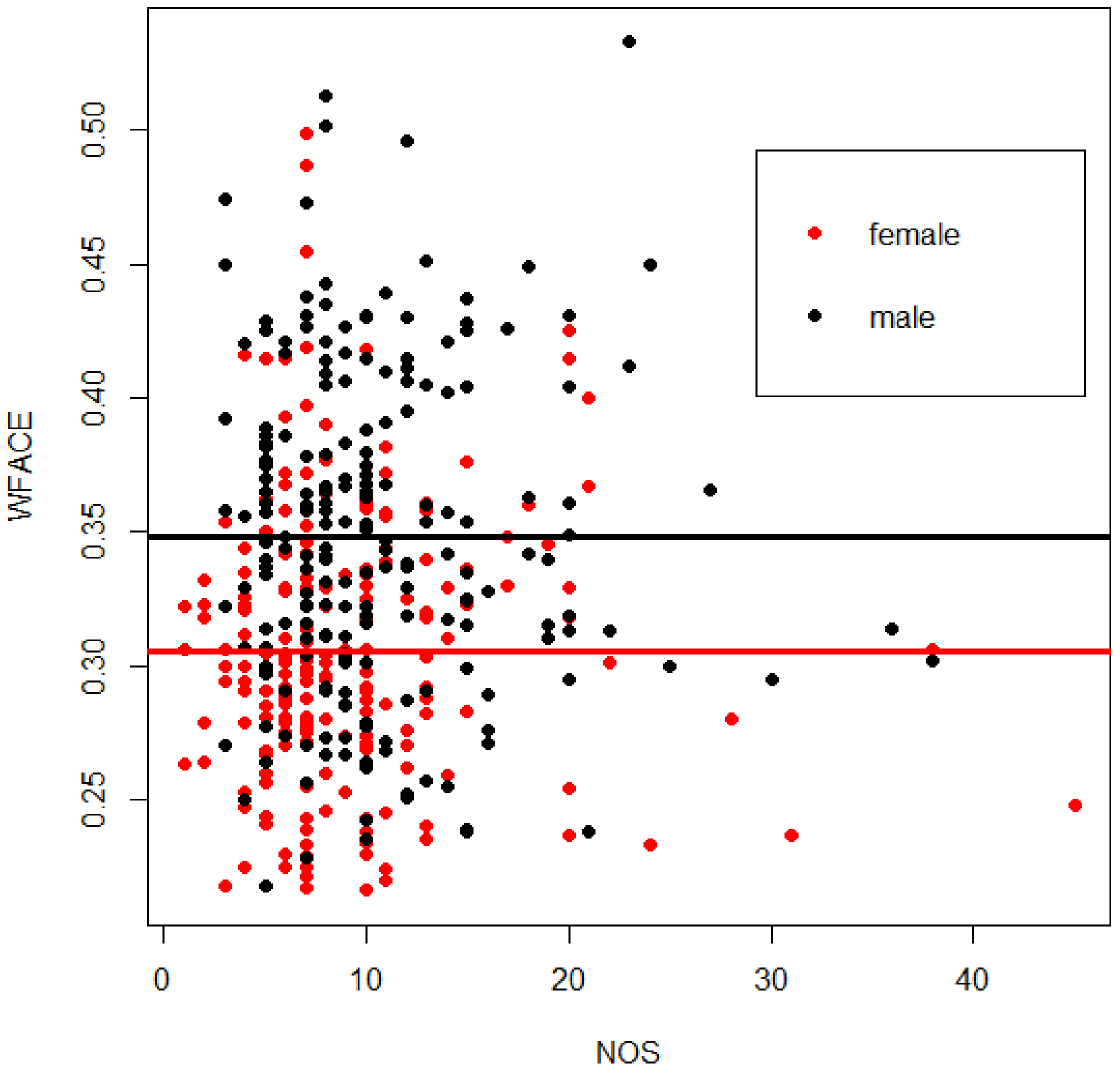


Figure 6:12: Regression analysis linear association graph between whole face asymmetry (WFACE) and number of siblings in a family of participants (NOS)

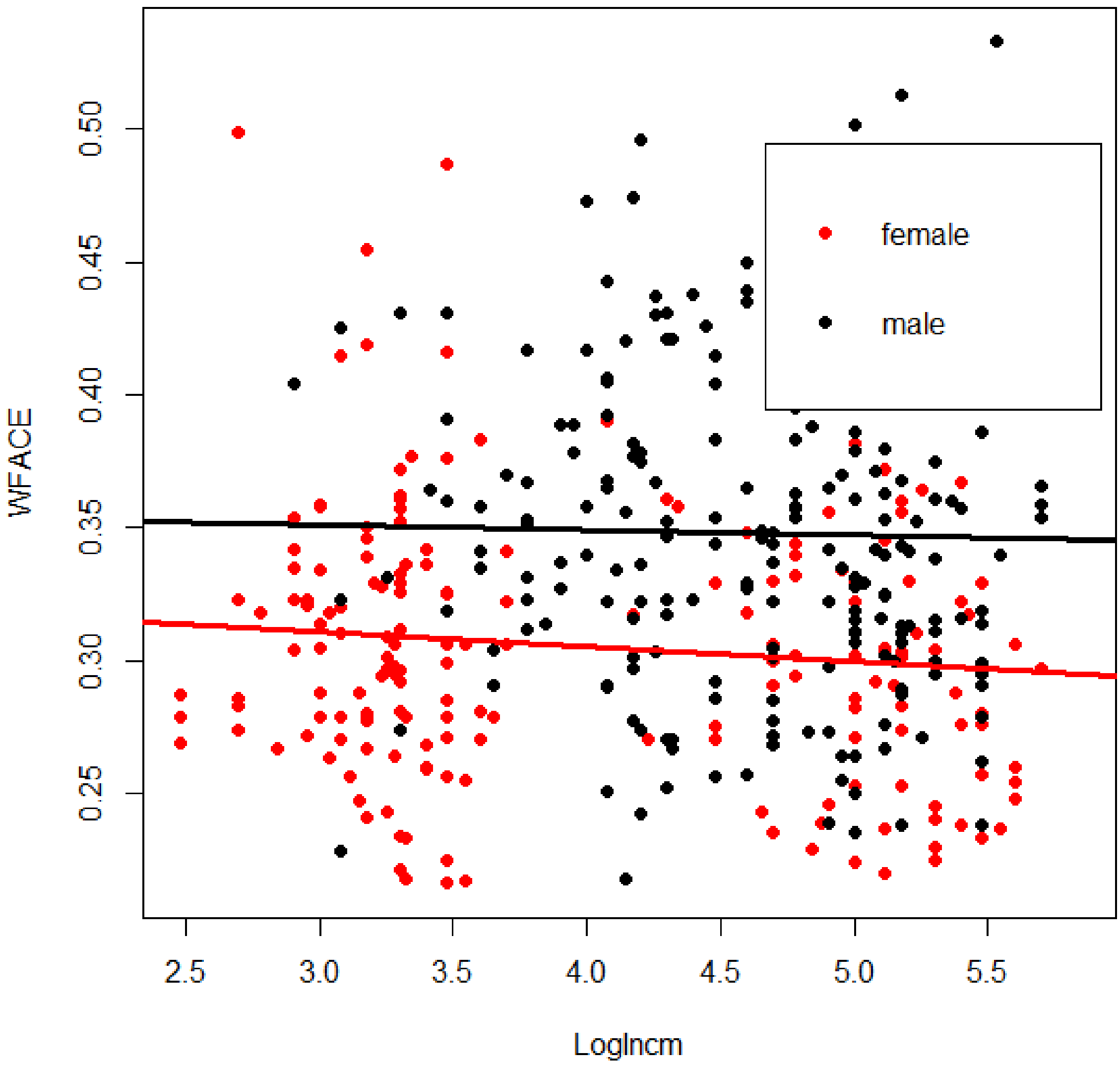


Figure 6:13: Regression analysis linear association graph between whole face asymmetry (WFACE) and Log-transformed income of participants or their parents' income (LogIncm)

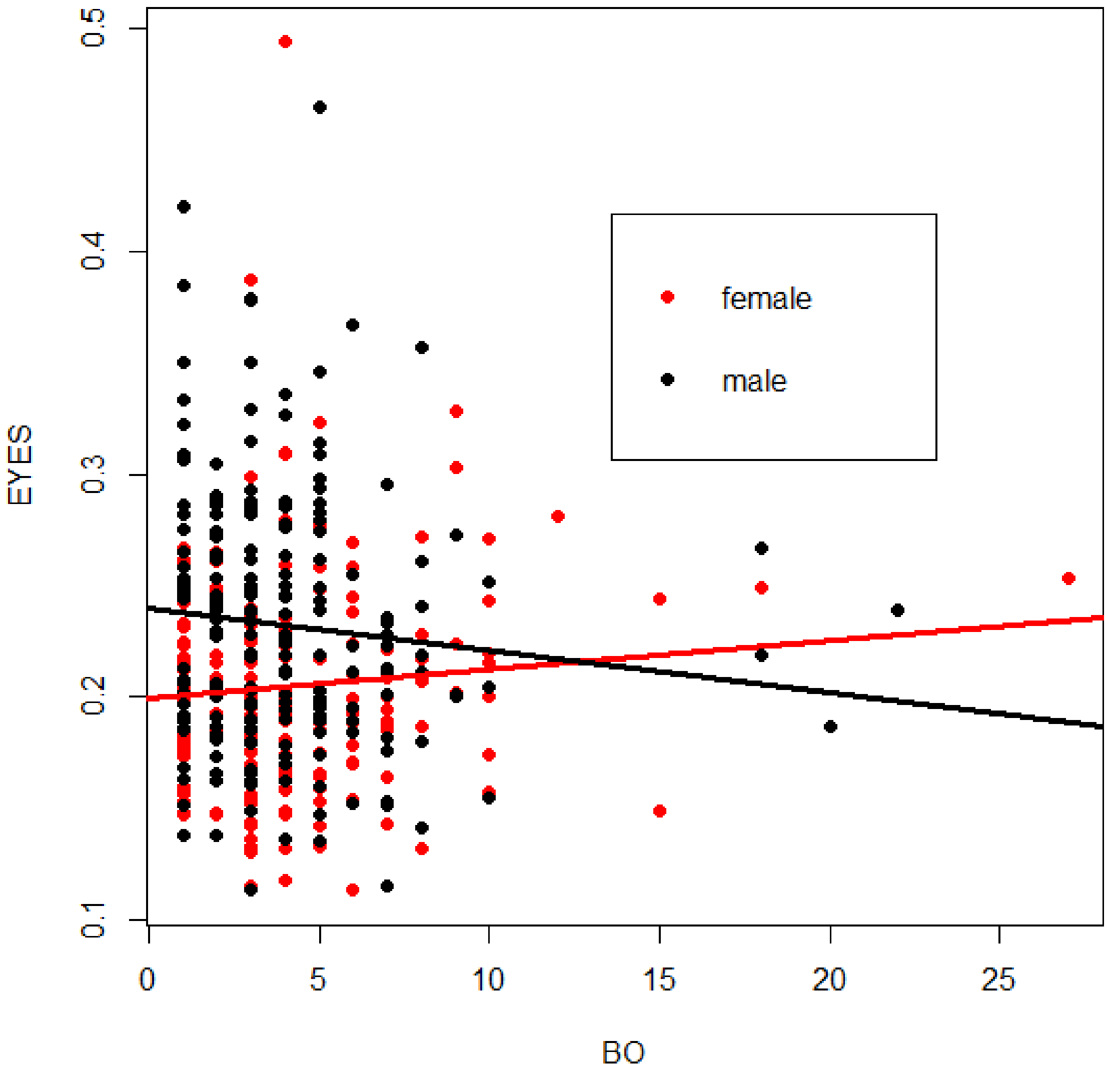


Figure 6:14: Regression analysis linear association graph between asymmetry around the eyes (EYES) and birth order (BO)

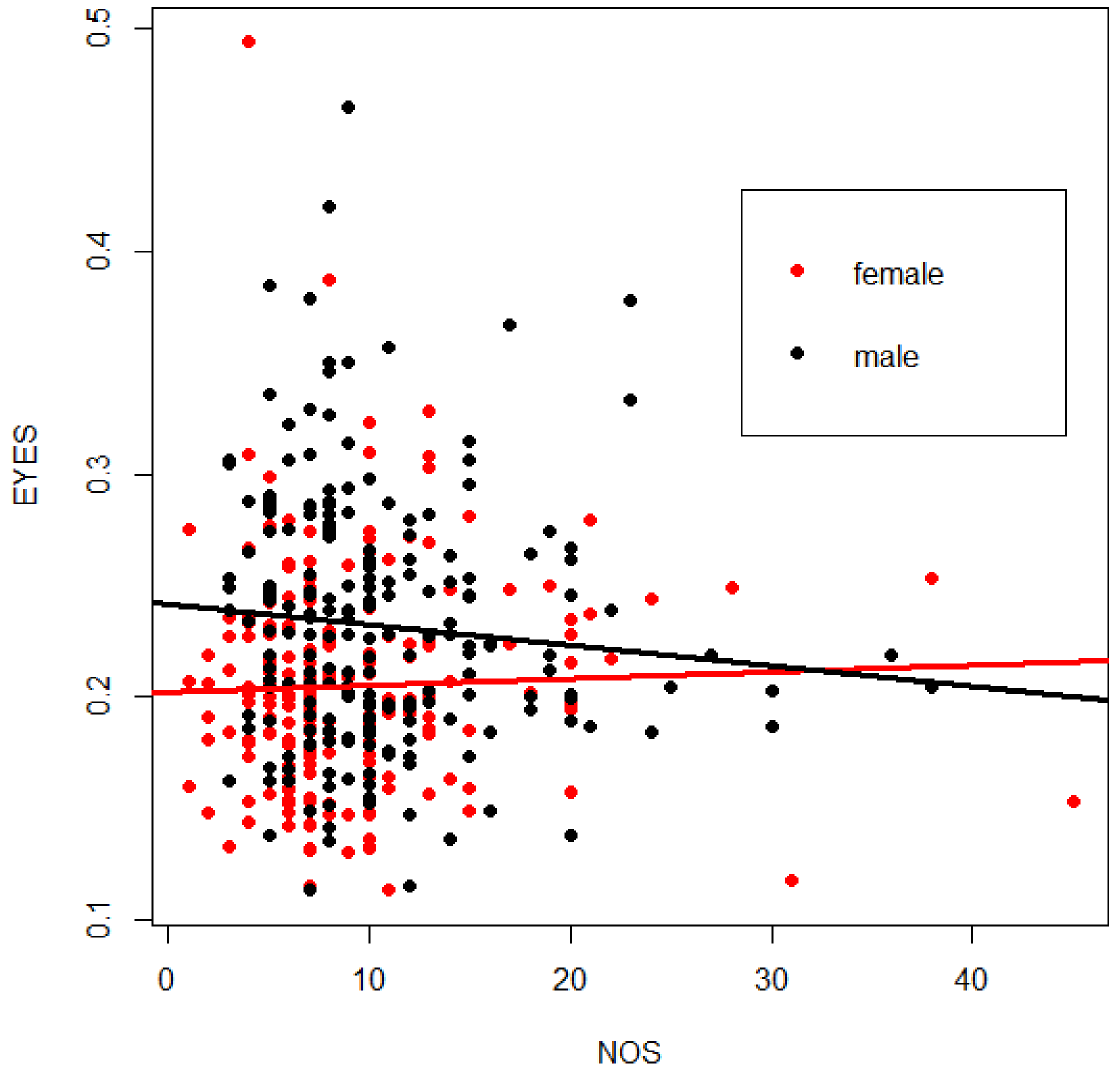


Figure 6:15: Regression analysis linear association graph between asymmetry around the eyes (EYES) and number of siblings in a family of participants (NOS)

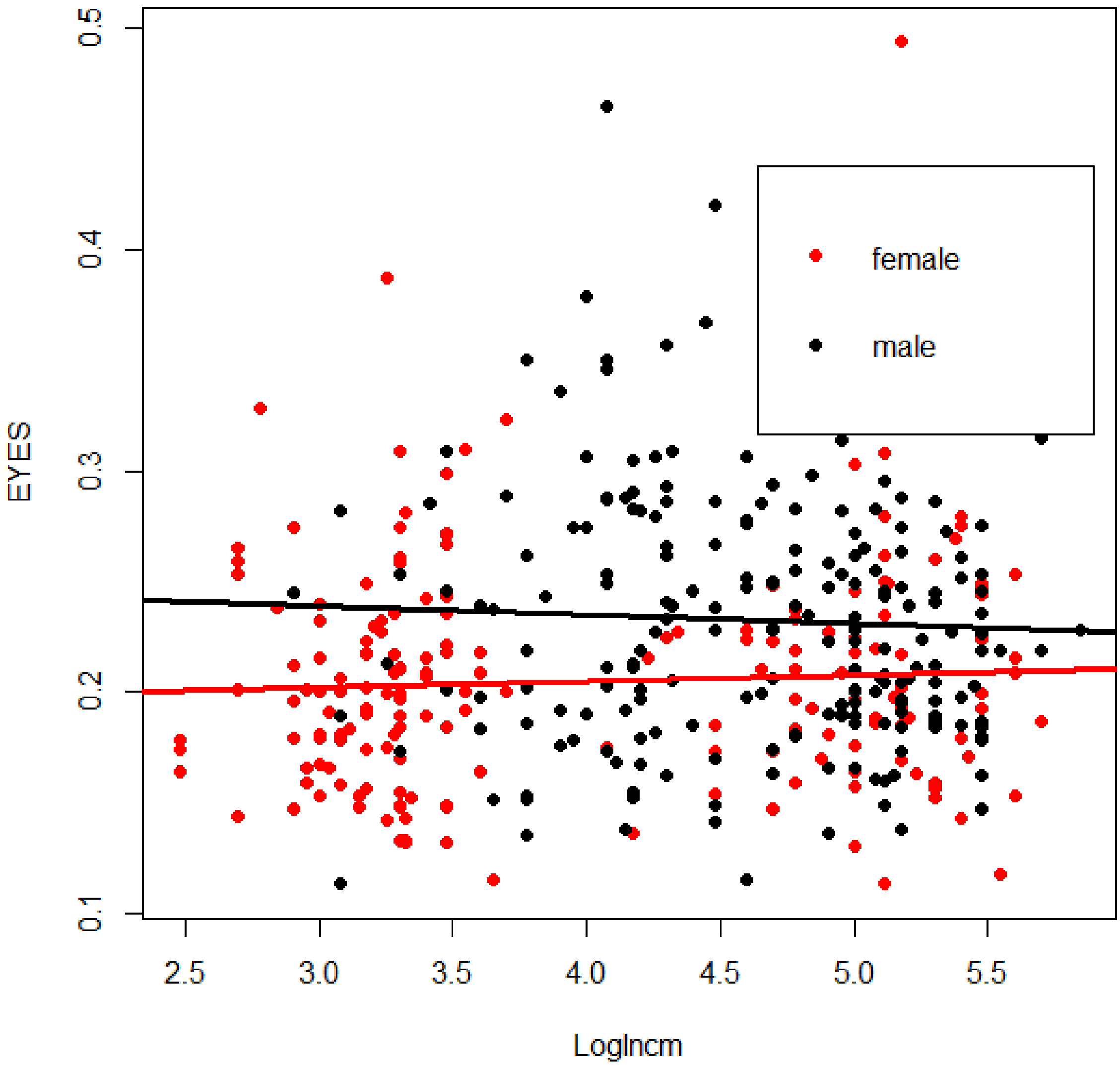


Figure 6:16: Regression analysis linear association graph between asymmetry around the eyes (EYES) and Log-transformed income of participants or their parents' income (LogIncm)

6.3.3.2 Multivariate analyses: whole face asymmetry regressed against all measures of SES

Multivariate analyses on whole face asymmetry (through the best model search) versus all the measures of socioeconomic levels [marital status (MS), occupation (OCCUP), total educational levels (ELP, ELM, ELF), birth order (BO), number of siblings (NOS), income (INCOM) and socioeconomic status (SES)] with whole face surface area (WFSA) and SEX as covariates were conducted. Starting with all the variables (maximal model), a *statistically significant model* was found (*F=1.683, P=7.768e-05*) with an adjusted r-squared value of *0.247*. However, through the use of *Akaike information criterion* (AIC): model optimisation by the backward model elimination method (gradual removal of model with highest AIC value), a *statistically significant minimal model with lower adjusted r-squared value (0.146)* but with much lower p-value (*F=25.2, P=5.135e-15*) than the maximal model was obtained. The best (minimal) model was a *linear model of whole face asymmetry on WFSA, ELP & SEX, meaning whole face surface area (WFSA), educational level of the participants (ELP) and SEX* are predictors of whole face asymmetry (**Table 6.21**). Similarly, a *model between asymmetry around the eyes and all the socioeconomic measures revealed a statistically significant (maximal) model* also (*F=1.309, P=0.0250*) with an adjusted r-squared value of *0.129*, but the best (minimal) model was *more statistically significant with higher r-squared (0.139)* and much lower p-value **(***F= 35.31, P= 6.577e-15*) than the maximal model. The best (minimal) model was a *linear model of asymmetry around the eyes on whole face surface area (WFSA) and SEX*, meaning that WFSA and sex are predictors of asymmetry around the eyes (**Table 6.22**).

Multivariate analyses were also conducted separately for males and for females. The female maximum model was *statistically insignificant (F=1.492, P=0.1620)* *with an adjusted r-squared of 0.018, but the minimum model was statistically significant* (*F=4.961, P=0.0270*) but with a slightly higher adjusted r-squared of *0.019*. The minimum model was a linear model of WFACE on INCOME, meaning that income is a predictor, albeit weak, of WFACE in females (**Table 6.23**). For the males, *maximal model was significant* (*F=2.692, P=0.0078*) with an adjusted r-squared of *0.060* but the minimum model was the best model with more statistical significance (*F=5.918, P=0.0007*) and with a slightly higher adjusted r-squared of *0.064* than the maximum model. The minimum model was a linear model of WFACE on INCOME and SES, meaning that income and socioeconomic status are predictors of WFACE in males (**Table 6.24)**.

Table 6:21: Multivariate minimal model of whole face asymmetry (WFACE) against measures of SES
Call: lm (formula = WFACE ~ WFSA + ELP + SEX)

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.501e-01	2.488e-02	10.055	< 2e-16 ***
WFSA	1.877e-06	7.218e-07	2.600	0.00964 **
ELP	-1.419e-02	6.756e-03	-2.100	0.03631 *
SEXM	3.571e-02	7.657e-03	4.664	4.16e-06 ***

SES = socioeconomic status, WFSA = whole face surface area, ELP = participants educational level
Significant codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05. Residual standard error: 0.05498 on 422 degrees of freedom. Multiple R-squared: 0.1519

Table 6:22: Multivariate minimal model for EYES against SES measures
Call: lm (formula = EYES ~ WFSA + SEX)

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	2.411e-01	2.460e-02	9.800	< 2e-16 ***
WFSA	1.917e-06	7.245e-07	2.646	0.0085**
SEX (M)	2.998e-02	7.183e-03	4.174	3.63e-05 ***

Significant codes: 0 '***' 0.001 '**' 0.01 '*' 0.05. Residual standard error: 0.0552 on 423 degrees of freedom. Multiple R-squared: 0.1431.

Table 6:23: Multivariate female minimal model, whole face asymmetry (WFACE) versus income
Call: lm (formula = WFACE ~ INCOME)

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	3.101e-01	4.087e-03	75.880	<2e-16
INCOME	-7.799e-08	3.502e-08	-2.227	0.027

Residual standard error: 0.05056 on 209 degrees of freedom, Multiple R-squared: 0.02319, Adjusted R-squared: 0.01851, F-statistic: 4.961 on 1 and 209 DF, p-value: 0.027

Table 6:24: Multivariate male minimal model, whole face asymmetry (WFACE) versus income and socioeconomic status (SES)
Call: lm (formula = WFACE ~ WFSA+INCOME + SES)

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.118e-01	5.757e-02	1.942	0.0534
WFSA	3.646e-06	1.183e-06	3.083	0.0023
INCOME	1.586e-07	6.004e-08	2.642	0.0089
SES	3.185e-02	1.069e-02	2.978	0.0032

Residual standard error: 0.05776 on 211 degrees of freedom, Multiple R-squared: 0.07761, Adjusted R-squared: 0.06449, F-statistic: 5.918 on 3 and 211 DF, p-value: 0.0006787.

6.3.4 Discussion III

Socioeconomic levels of a society are mainly measured using three important components: income, education, and occupation (Dutton and Levine, 1989).

This study is the first to look into variations in the levels of total facial asymmetry between different social classes of sub-Saharan Africans, specifically the Hausa community of northern Nigeria. Although the study aimed at testing the hypothesis that individuals of lower socioeconomic status (SES) will have higher facial asymmetry, other supplementary measures of SES such as marital status, birth order, number of siblings in a family, are also investigated. As an additional incidental finding, the study showed that married men have higher whole face asymmetry values than the unmarried men with a high statistical significance. Similarly, married women were also observed to have higher facial asymmetry than the un-married ones although the variation between them was not significant.

However, a question might arise from these findings as to why married men should have higher facial asymmetry than unmarried men?

Given the level of poverty and high rate of unemployment in the living environment of these study subjects (OPHI, 2013), it is not surprising for the married men to have higher facial asymmetry than the unmarried men. The married men in northern Nigeria are continuously and consistently exposed to daily environmental stresses believed to be causes of the increased levels of fluctuating asymmetry [e.g., (Parsons, 1990, Parsons, 1992)] or directional asymmetry from the effect of heavy working conditions [e.g.,(Ozener *et al.*, 2007, Özener, 2010)]. The majority of the married men in this study are drawn from remote villages and are unemployed, therefore living on hand-to-mouth only on petty paid work such as brick laying, loading and up-loading heavy weight goods in markets, petty trading, foraging, subsistence farming and other stressful work. While the married men are exposed to various sort of environmental stresses in the course of looking on what to sustain/maintain themselves and their families, the unmarried men in this study are not because they are mostly students dependent on parental and other support.

Whole face asymmetry is found to differ significantly between educated and uneducated women, and uneducated women were demonstrated in this study to have a greater facial asymmetry than the educated women. But why should uneducated women have higher facial asymmetry than the educated women? It is possible that uneducated women have higher facial asymmetry than the educated ones because in northern Nigeria, they (uneducated) get married earlier (Niles, 1989, Uzoma, 2013) and by so doing, they are exposed to stresses involved in matrimonial house for example, childbearing and childcare at early ages, foraging, water fetching etc.

An alternative explanation may still hold for the uneducated women, who if they do not get a husband to marry, become involved in street hawking and other stressful paid work in markets (Unicef, 2007) for hours and are therefore exposed to serious psychological, emotional and physiological stresses demonstrated to associate with facial asymmetry (Shackelford and Larsen, 1997a). The western educated women in this study have lower levels of facial asymmetry possibly because they might have acquired knowledge of preventing certain conditions (AHI, 2011) known to increase levels of asymmetry such as: infections [e.g.,(Livshits *et al.*, 1988, Moller, 1996)], body size and nutrition [e.g.,(Manning, 1995b, Gray and Marlowe, 2002, Hoover and Matsumura, 2008)], and symptoms [e.g.,(Shackelford and Larsen, 1997a)]. Additionally, educated women are not involved in street hawking like their uneducated counterparts and rarely get married at early ages, with an improved health [see (AHI, 2011) for facts] and therefore not as stressful as their uneducated counterparts.

Birth order and number of siblings in the present study did not show any association with whole face asymmetry or asymmetry around the eyes and therefore competition for resources amidst families of these study subjects is unlikely. This is particularly true because of early marriage of women siblings amongst the Hausa culture, independency of siblings even at younger age, and possibly inter-family support of Hausa culture.

In this study, women with lower monthly income have significantly higher whole face asymmetry than women with higher monthly income.

In the northern part of Nigeria where this study was conducted, women are under considerable environmental stress as they are involved in stressful paid work while still in their matrimonial houses (Hill, 1972, Schildkrout, 1983, Yakubu, 2001), for example grain grinding, grain pounding, winnowing etc. Overall, this present study, however, indicated that mean whole face asymmetry and that of the asymmetry around the eyes did not differ between the three social classes of the study subjects, which is in keeping with the findings of a similar study (Hume and Montgomerie, 2001). Although other studies found higher asymmetry values among people of lower social class, for example, the Hadza population of Tanzania as compared to US college students (Gray and Marlowe, 2002); the higher asymmetry values were on composite body FA rather facial FA. It is clear that individuals involved in heavy working conditions, for example labourers, have higher composite body FA (Özener, 2010), but whether the same is the case for facial asymmetry, has not yet been demonstrated. However, plausible explanations for the lack of differences between social classes in the present study might be due to the higher number of educated participants in the sample irrespective of their social class because three-quarter of the participants (316) as against one-quarter (110), had received a formal education (see Table 6.12). Education is a very important factor (even in this study) in improving health quality of an individual and also living standards (AHI, 2011, Uzoma, 2013) because poor living conditions are demonstrated to also increase levels of facial asymmetry (Özener and Fink, 2010). It is possible that the subjects from the slum area in Turkey have higher facial asymmetry than those from the urban area not because they live in a slum and survive in a large family but because they lack educated mothers. This is suggested in the Özener and Fink (2010) urban group that these subjects from the group with significantly lower facial asymmetry than those from the slum area had small family size and more educated mothers (Özener and Fink, 2010). It is expected that educated mothers will offer better care to their children than the uneducated ones.

The current study suggests that income and SES in males predict whole face surface area, and income in females also is a predictor of whole face asymmetry. Although the hypothesis that individuals with lower SES will have higher facial asymmetry is not proven in the present study, socioeconomic status does have some effects on the whole face asymmetry in both sexes especially in men.

6.3.5 Conclusion III

In summary, this study found no differences in facial symmetry or asymmetry around the eyes values between individuals of lower SES and higher SES and also no difference between facial asymmetry or asymmetry around the eyes and occupation, birth order, number of siblings and educational levels of the participants' mothers or fathers. However, significant differences were obtained between facial asymmetry and marital status (in males) and educational level (in females) of the participants. Overall, though, none of the reported relationships were strong. It is possible that more detailed analyses will help clarify any relationships between asymmetry and aspects of socio-economic background. Specifically, further stratification of the educational levels might help clarify the relationship between education and asymmetry.

Chapter 7 : ENVIRONMENTAL CORRELATES OF FACIAL SEXUAL DIMORPHISM

7.1 Analysis IV: Correlates of facial sexual dimorphism

7.1.1 Introduction

Interest in facial sexual dimorphism has greatly developed over the last two decades, and factors influencing facial masculinity (FacM**)** a measure of sexual dimorphism, such as health (Rhodes *et al.*, 2003, Thornhill and Gangestad, 2006, Boothroyd *et al.*, 2007, Little *et al.*, 2011c, Gray and Boothroyd, 2012, Boothroyd *et al.*, 2013, Scott *et al.*, 2014), age (Peccei, 2001, Boothroyd *et al.*, 2005, Tamsin *et al.*, 2011, Moore *et al.*, 2011), social status (Muller and Mazur, 1997, Moore *et al.*, 2011), and economic status (Brooks *et al.*, 2011) have been widely studied. Similarly, the role of FacM in human face sex classification (Hoss *et al.*, 2005), human facial attractiveness (Rennels *et al.*, 2008, Scott *et al.*, 2010, Van Dongen, 2014), human mate choice (DeBruine *et al.*, 2006, Little *et al.*, 2007, Little *et al.*, 2008a, Little *et al.*, 2011c, Pisanski and Feinberg, 2013) and assessment of high quality potential mates (Rhodes *et al.*, 2003, Boothroyd *et al.*, 2013, Rantala *et al.*, 2013) were demonstrated with some inconsistent results. And the assessment of high quality potential mate is particularly relevant with regards to male masculinity as it has been shown to signal an innate immunity to infections [(reviewed in (Thornhill and Gangestad, 1999)]; and therefore highly masculine males are presumed to be of higher genetic quality, because it indicates their ability to resist the immunosuppressive effect of their high testosterone levels (Thornhill and Gangestad, 1999), with decreased incidence of infections (Thornhill and Gangestad, 2006). Masculine facial characteristics are also associated with indices of men's dominance (Undurraga *et al.*, 2010), including measures of physical strength (Fink *et al.*, 2007, Sell *et al.*, 2009).

Although FacM studies have greatly progressed in the fields of evolutionary biological and psychological sciences, such studies are largely limited to developed and urbanized western participants, the so called WEIRD population (western, educated, industrialized, rich and democratic) [(Henrich *et al.*, 2010)]. The ecological factors that may possibly influence sexual dimorphism in general, and facial sexual dimorphism in particular, will better be understood by conducting research between two extreme societies with different environmental settings especially with regards to health and diseases. The present study therefore aims at determining the influence of health, socioeconomic status and other biological factors on FacM in a sub-Saharan African population, the Hausa ethnic group in Nigeria. The working hypotheses in this part of the present study are: *(1) Men and women with a more extensive medical history of diseases will express higher levels of sexual dimorphism reflecting their living under increased selective pressure to fight infections (2) Men and women from lower socioeconomic backgrounds are expected to show higher levels of sexual dimorphism, reflecting increased selective pressure for access to resources*.

Since almost all human adult face physical features carry information about gender, estimation of FacM using multiple features is more reliable than individual features (Bruce *et al.*, 1993, Burton *et al.*, 1993, Brown and Perrett, 1993, Wild *et al.*, 2000, Campanella *et al.*, 2001). This study therefore estimated FacM from multiple features representing the whole face.

7.1.2 Methodology IV

The scanning protocol, estimation of the whole face surface area, and the quantification of facial sexual dimorphism were fully described in the general method chapter 5. Similarly, the demographic questionnaires and the process of acquiring information about socioeconomic status (SES) and medical history (MH) of the participants or of their parents, were described in the same chapter. However, the method of measurements of biological characteristics (weight, height, and body mass index, systolic and diastolic blood pressures) was fully described in chapter 6.

The mean, minimum and maximum values of each of the variables: Age, weight (WT), height (HT), body mass index (BMI), systolic blood pressure (SYSTBP), diastolic blood pressure (DIASTBP), whole face surface area (WFSA), and masculinity scores (FacM) were acquired from the *descriptive statistic* using *SPSS 22 version.* Comparison of means between men and women was conducted using *Welch Two Sample t-test* in *R (R Core Team., 2014)*. Determination of the effects of age, size (weight, height and whole face surface area), health measures (BMI, SYSTBP, DIASTBP) and medical conditions (TOTDX: total disease loads) on the facial masculinity in both sexes was carried out also in R-software using *linear regression analyses* separately for men and for women. Where data were not normally distributed, that data were analysed by *rank correlation using Spearman' rho*. Similarly, the effects of measures of socioeconomic status (income, educational level, occupation, marital status, birth order, and number of siblings in a family) on FacM were tested by conducting *linear regression analyses* in R. In order to assess sexual differences in FacM between married and unmarried subjects, or between students and non-students, *Wilcoxon rank sum test was conducted* but *Kruskal-Wallis tests* was also conducted in order to assess FacM differences between the three social classes and four educational groups. *Multivariate analyses* were conducted separately for men and for women using the *Akaike information criterion (AIC) backward* method for model simplification, and were done by including both the qualitative and the quantitative data altogether in order to ascertain the predictors of FacM.

7.1.3 Results IV

7.1.3.1 Descriptive statistics of the measured variables and Welch Two Sample t-test

The quantitative (measured) variables in this study are: Age, weight (WT), height (HT), body mass index (BMI), systolic blood pressure (SYSTBP), diastolic blood pressure (DIASTBP), whole face surface area (WFSA), and facial masculinity scores (FacM) as shown in **Table 7.1**. **Age** ranges of the participants were the same (18-25 years), but on average, males were slightly older. The mean FacM in the females was *0.40*, while that of the male subjects was *0.61* with the same standard deviations of 0.2. This indicates that women of Hausa ethnic group are only *40%* masculine and *60%* feminine and men are *61%* masculine but *39%* feminine on average. The minimum FacM value recorded for women was *0.02 (2%)*, the maximum FacM value recorded was *0.87 (87%)*.

The minimum FacM recorded for men was *0.11 (11%)*, and the maximum FacM value was *0.97 (97%)*. In terms of **weight**, males were found to be heavier than the females on average, although the maximum value in the whole sample was recorded among females. With regards to **height**, males were taller with wider range than that of the females. Despite the fact that both sexes have similar mean **body mass index**, the highest index was recorded in females though males were found to be heavier on average. These results reflect the underlying facts, i.e. males were taller and females are known to have more body fat than males [e.g., (Gallagher *et al.*, 2000)]. The mean face sizes differ between the sexes; males were found to have larger faces than the females with a wider range. The mean **systolic blood pressure** was found to be higher in males but this showed a narrower range compared to that of the females. Similarly, mean **diastolic blood pressure** was also higher in males, with a narrower range than that of the females. This finding is in keeping to the high exposure of males to various environmental stresses compared to females, especially in a very high challenging environment where this study was conducted. *Welch Two Sample t-test* was conducted and there was a statistically significant difference in the mean age, FacM, weight, height, systolic blood pressure and whole face surface area between the sexes (all $p<0.0001$). However, there was no statistically significant difference in the mean body mass index, and diastolic blood pressure between the sexes ($p>0.05$) as shown in **Table 7.1**.

Table 7:1: Descriptive statistics and Welch Two Sample t-test: Age, facial masculinity (FacM), weight (WT), height (HT), body mass index (BMI), whole face surface area (WFSA), systolic blood pressure (SYST BP) and diastolic blood pressure (DIAST BP).

Variables	Sex	Min	Max	Mean	STD	t	df	p-value
AGE (yrs)	F	18	25	20.6	2.4	-5.31	415.71	**1.781e-07**
	M	18	25	21.8	2.1			
FacM	F	0.02	0.87	0.40	0.2	-10.02	423.36	**2.2e-16**
	M	0.11	0.97	0.61	0.2			
WT (kg)	F	30.3	117.0	51.9	9.9	-9.09	401.94	**2.2e-16**
	M	39.6	95.0	59.8	8.0			
HT (m)	F	1.42	1.76	1.57	0.1	-16.46	416.07	**2.2e-16**
	M	1.50	1.90	1.68	0.1			
BMI (kg/m^2)	F	14.0	44.6	21.1	3.7	0.03	354.45	0.9772
	M	16.4	30.5	21.1	2.3			
WFSA (mm^2)	F	22352	47053	33543	4020	-18.42	408.15	**2.2e-16**
	M	31263	50153	40159	3356			
SYSTBP (mmHg)	F	80	158	108	13	-5.75	421.16	**1.699e-08**
	M	90	158	116	14			
DIASTBP (mmHg)	F	38	136	71	13	-1.16	422.88	0.2454
	M	36	101	72	13			

7.1.3.2 Facial masculinity (FacM), Age & Size

In order to ascertain factors associated with FacM in the Hausa ethnic group, biological factors are investigated.

The analyses show that FacM scores did not associate with age (**Table 7.2**) and weight (WT) (**Figure 7.1**) in the sample as a whole. However, FacM associated *negatively with height (HT) only in females* (**Figure 7.2**) *with a statistical significance* (*$p<0.0001$*). This indicates that taller women have more facial femininity than the shorter ones (which have more FacM) as shown in Figure 7.2. However, FacM associates *significantly with whole face surface area (WFSA) only in males with a negative* relationship (**Figure 7.3**). This finding means that men with smaller faces have more FacM features than men with larger faces.

Table 7:2: Linear regressions analyses: Facial masculinity scores (MAS.SC) versus Age & Size [weight (WT), height (HT), whole face surface area (WFSA)]

Variables	SEX	Adjusted R^2	F-statistic	DF	P-Value
MAS.SC & AGE	F	-0.0001	0.9746	1 & 209	0.3247
	M	-0.0045	0.0450	1 & 213	0.8286
MAS.SC & WEIGHT	F	0.0134	3.8440	1 & 209	0.0513
	M	-0.0030	0.3545	1 & 213	0.5522
MAS.SC & HEIGHT	F	0.0947	22.9700	1 & 209	**3.117e-06**
	M	0.0094	3.0230	1 & 213	0.0835
MAS.SC & WFSA	F	0.0060	2.2790	1 & 209	0.1327
	M	0.0272	6.9990	1 & 213	**0.0087**

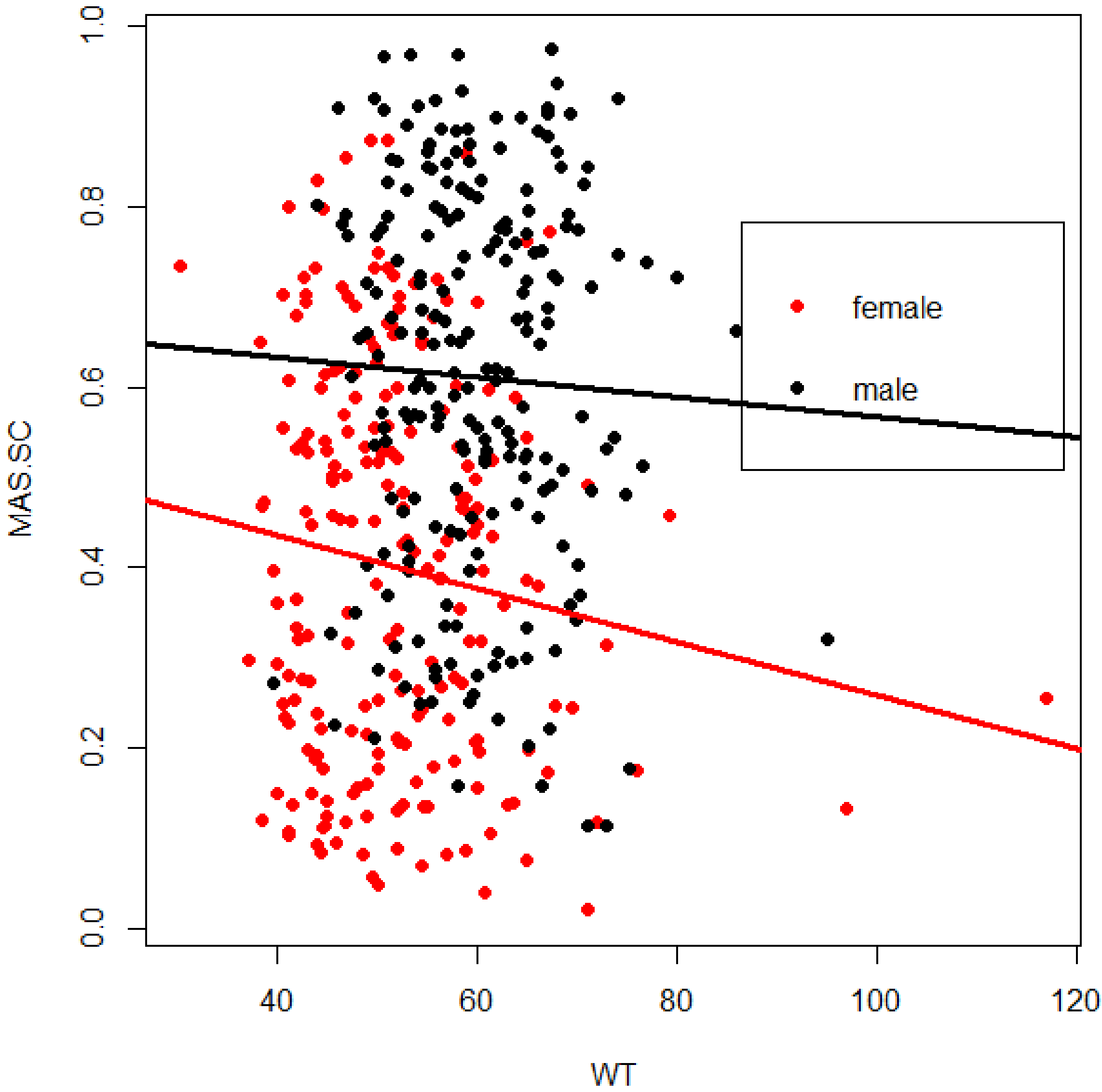


Figure 7:1: Linear regression graph, facial masculinity scores (MAS.SC) versus weight (WT) in kilogram of the Hausa ethnic group

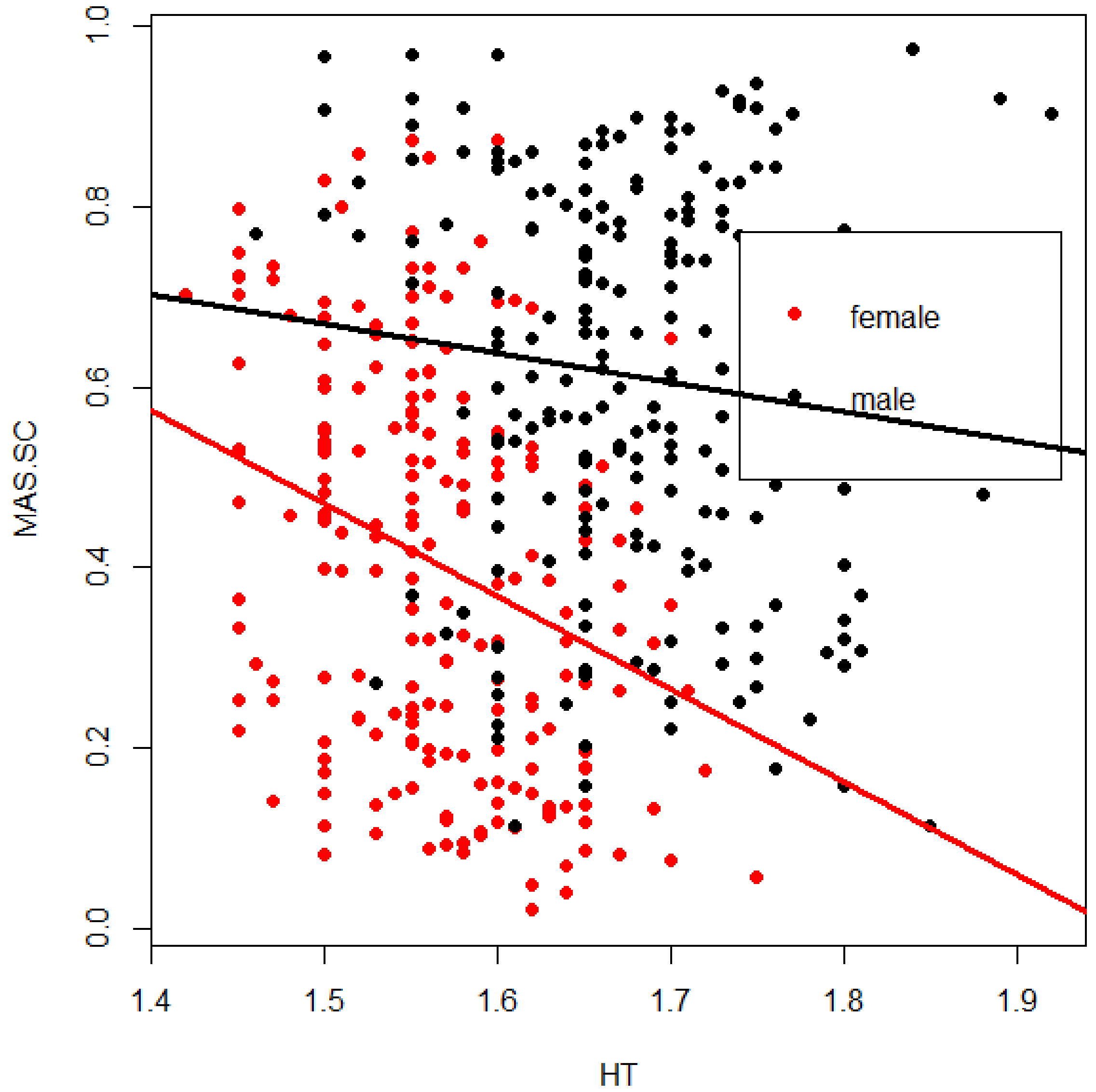


Figure 7:2: Linear regression graph, facial masculinity scores (MAS.SC) versus height (HT) in meters of the Hausa ethnic group

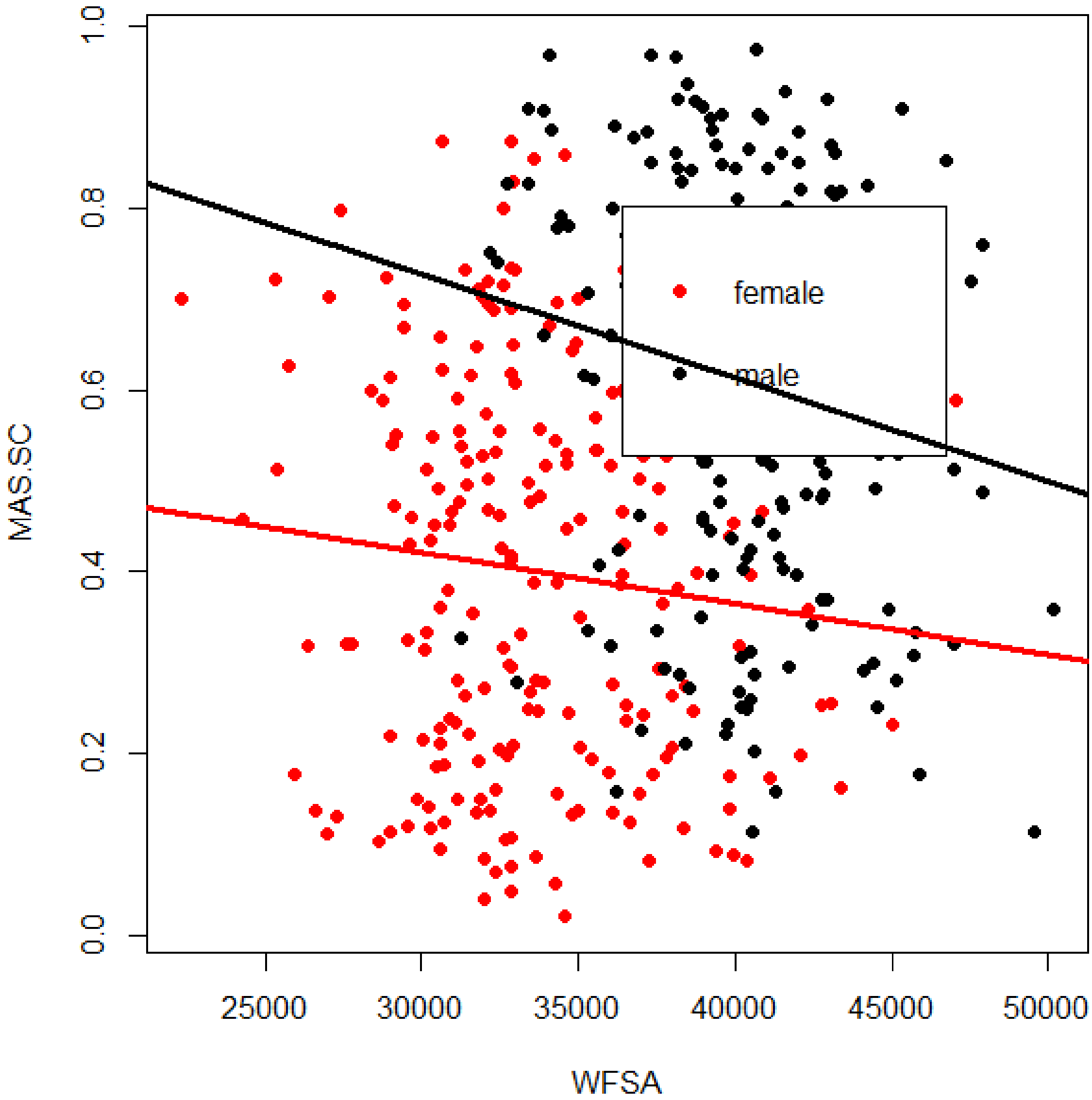


Figure 7:3: Linear regression graph, FacM scores (MAS.SC) versus whole face surface area (WFSA) of the Hausa ethnic group

7.1.3.3 Facial Masculinity (FacM) and Measures of health/ Medical history.

Measures of health such as body mass index (BMI), systolic (SYSTBP) and diastolic (DIASTBP) blood pressures have no relationship with FacM scores in both men and women as the p-values of those analyses were all greater than 0.05 as in **Table 7.3**. However, the analyses from the Spearman' rho correlation revealed that *FacM scores (MAS.SC) in women correlated positively* (*rho= 0.25, p<0.0001*) *with total disease history* (TOTDX) of participants (and their parents: mother & father); i.e., *women with a higher past combined disease load tend to be more masculine*, but no such correlation was found in men (**Table 7.4 & Figure 7.4)**.

Table 7:3: Linear regressions analyses: facial masculinity scores (MAS.SC) versus Measures of health [body mass index (BMI), systolic blood pressure (SYST BP) and diastolic blood pressure (DIAST BP)].

Variables	SEX	Adjusted R^2	F-statistic	DF	P-Value
MAS.SC & BMI	F	-0.0047	0.0107	1 & 209	0.9177
	M	-0.0010	0.7847	1 & 213	0.3767
MAS.SC & SYST BP	F	0.0037	1.7710	1 & 209	0.1847
	M	0.0057	2.2170	1 & 213	0.1380
MAS.SC & DIAST BP	F	0.0063	2.3430	1 & 209	0.1274
	M	0.0024	1.5140	1 & 213	0.2199

Table 7:4: Nonparametric Correlation between facial masculinity scores (MAS.SC) in females and total disease loads (TOTDX)

Correlation type	Variable	SEX	Correlation coefficient MAS.SC	P-value
Spearman's rho	TOTDX	F	0.249**	**<0.0001**
		M	0.114	0.096

**. Correlation is significant at the 0.01 level (2-tailed).

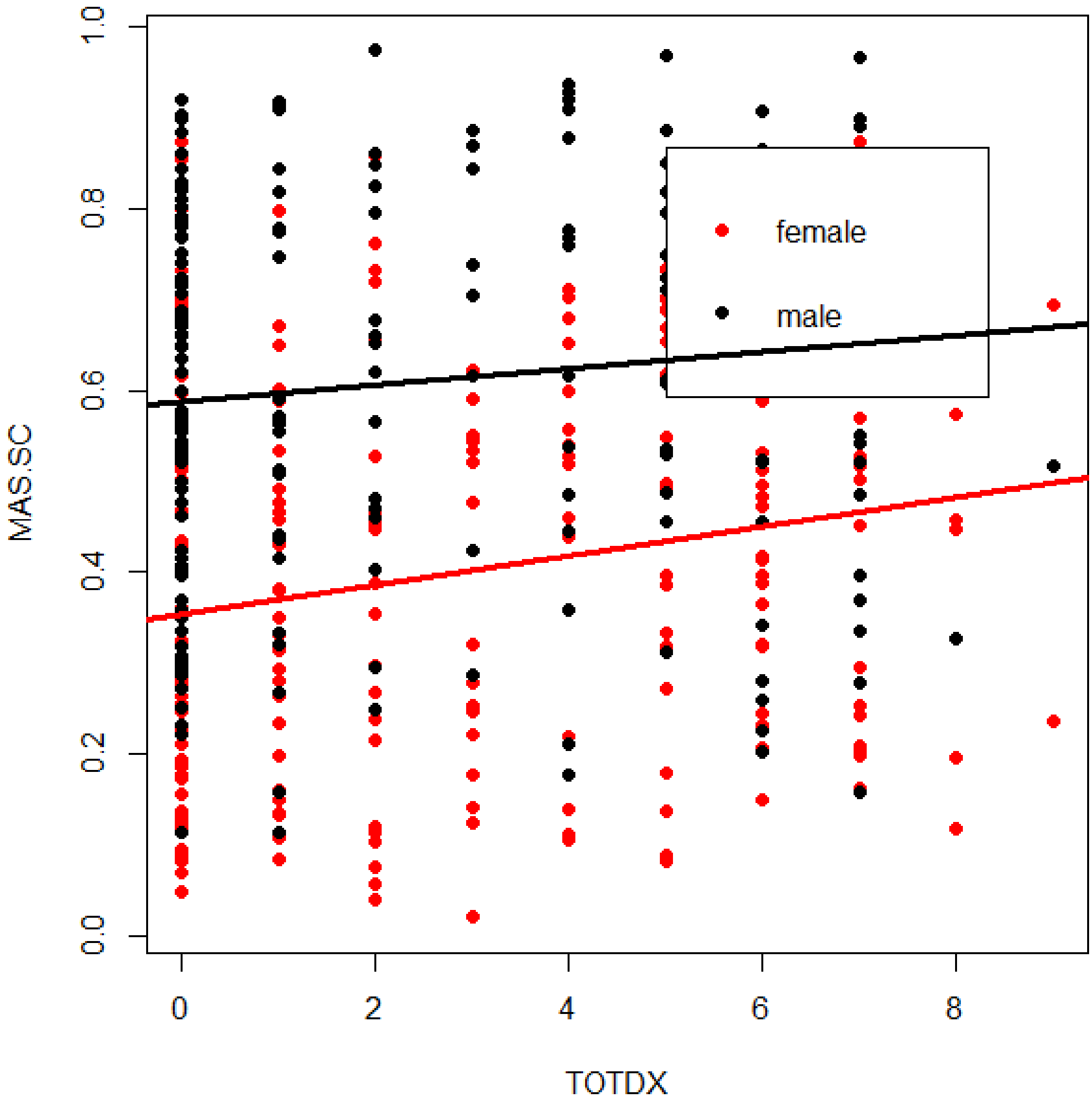


Figure 7:4: Linear regression graph, facial masculinity scores (MAS.SC) versus total number of diseases (participant, mother, father) (TOTDX) of the Hausa ethnic group

7.1.3.4 Facial masculinity (FacM) and Measures of Socioeconomic Status (SES)

Table 7.5 shows the frequency distribution of the marital status and occupation of the studied participants. However, since the distribution of the participants in either marital status or occupation is somewhat un-equal, a non-parametric test, the Wilcoxon rank sum test with continuity correction, was conducted in order to test for the differences in mean FacM in each level. From the *Wilcoxon rank sum test, there was a statistically significant difference in the mean FacM between married and the unmarried women (p<0.0001) with the unmarried having more feminine facial features than the married* (**Tables 7.6, Figure 7.5**). Such mean difference was not observed amongst the males. Similarly, *mean FacM scores differed significantly for females between students and those who are not students (p<0.0001), with female non-students having higher mean FacM scores than the female students* (**Table 7.6, Figure 7.6**). From the *Spearman's correlation, FacM correlated negatively with the number of siblings in a family* (NOS) *in females (rho= -0.14, p=0.043) with a statistical significance* but birth order (BO) did not show any association with FacM (**Table 7.7**, **Figures 7.7 & 7.8**). This means that *the fewer the number of siblings the more facial masculinity the women would have in a family.* Additionally, *FacM was found to be negatively correlated with income in women* (*rho= -0.33, p<0.0001*) but not in men (**Table 7.7, Figure 7.9**).

Table 7.9 shows the frequency distribution of the participants in each of the four educational groups together with the mean FacM in each group. In the table, participants in groups 3 and 4 have lower FacM than those in group 1 and 2 but in females only. What it means is that facial masculinity is less pronounced in women who have at least 2 levels of western education (see details in **Table 7.9**).

Table 7.10 shows the frequency distribution of the participants in each of the three social classes together with the mean FacM scores in each social class. It was also observed from the table that female participants in social classes 1 & 2 have lower FacM than the social class 3. It means wealthier and average women have more facial femininity than the poorer women.

To determine if those variations in female FacM scores between total educational groups and that of the social classes are significant, Kruskal-Wallis (non-parametric) test was conducted since the participant distribution was unequal among the groups or the social classes. Results indicated that *there was a statistically significant difference in the mean female FacM between educational levels and social classes in females* (**Table 7.11**).

Table 7:5: Frequency distribution of the married, unmarried, students and non-students.

Variables	Status	Female (n=211)	Male (n=215)
MS	Married	137	41
	Unmarried	74	174
OCCUPAT	Student	82	138
	Non-student	129	77

MS = Marital status, OCCUPAT = Occupation

Table 7:6: Wilcoxon rank sum test with continuity correction: facial masculinity scores (MAS.SC) mean difference between married/un-married and students/non-students

Variables	Sex	Married Mean MAS SC	Un-married Mean MAS SC	W	df	P-value
MS	F	0.45	0.32	3338	151.47	**4.332e-05**
	M	0.63	0.61	3277	55.587	0.4192
		Student	Non-student			
OCCUPAT	F	0.31	0.46	7385	175.593	**1.251e-06**
	M	0.61	0.61	5299	145.466	0.9754

MS = Marital status, OCCUPAT = Occupation

Table 7:7: Nonparametric Correlation between Facial masculinity scores, Birth order, Number of siblings and Income

Correlation type	Variable	SEX	Correlation coefficient MAS.SC	P-value
Spearman's rho	BO	F	0.004	0.954
		M	-0.095	0.165
	NOS	F	-0.14*	**0.043**
		M	-0.104	1.28
	LogIncm	F	-0.325**	**<0.0001**
		M	0.004	0.956

MAS.SC = facial masculinity scores, BO = birth order, NOS = number of siblings, and LogIncm = income log-transformed:
*. Correlation is significant at the 0.05 level, **Correlation is significant at the 0.01 level.

Table 7:8: Linear regressions analyses between facial masculinity scores (MAS.SC) and measures of socioeconomic status (SES)

Variables	SEX	Adjusted R^2	F-statistic	DF	P-Value
MAS.SC & OCCUPATION	F	0.1080	26.4400	1 & 209	**6.245e-07**
	M	-0.0047	0.0058	1 & 213	0.9392
MAS.SC & MS	F	0.0760	18.2600	1 & 209	**2.921e-05**
	M	-0.0023	0.5180	1 & 213	0.4725
MAS.SC & TOTEDU	F	0.0873	21.0800	1 & 209	**7.587e-06**
	M	-0.0045	0.04098	1 & 213	0.8398

MAS.SC = facial masculinity scores, MS = Marital status, TOTEDU = Total educational levels of participant (participant, mother, father)

Table 7:9: Frequency distribution of the grouped educational levels of the participants and the mean facial masculinity scores (MAS.SC)

Educational groups	Sex	Frequency	Mean MAS.SC
Group 1	F	94	0.4563
	M	15	0.6166
Group 2	F	29	0.4775
	M	65	0.6108
Group 3	F	4	0.2785
	M	21	0.5718
Group 4	F	84	0.3208
	M	114	0.6183

Group 1 = neither the participant nor parents had western education
Group 2 = only participant had western education
Group 3 = participant and one of the parent had western education
Group 4 = participant and all the parent had western education

Table 7:10: Descriptive statistics: Frequency and mean distribution of the facial masculinity scores (MAS.SC) in the three socioeconomic status (SES) of the Hausa ethnic group in Nigeria

Social class	Sex	Frequency	Mean MAS.SC
SES 1	F	7	0.3343
	M	15	0.6022
SES 2	F	70	0.3079
	M	108	0.6080
SES 3	F	134	0.4545
	M	92	0.6170

SES 1 = Rich, SES 2 = Average, SES 3 = Poor

Table 7:11: Kruskal-Wallis rank sum test: Comparing the mean facial masculinity scores (MAS.SC) difference among the socioeconomic (SES) and the grouped educational levels (GTOTEDU)

Variables	Sex	Kruskal-Wallis chi-squared	DF	P-value
SES	F	21.4528	2	2.196e-05
	M	0.0909	2	0.9555
GTOTEDU	F	21.7268	3	7.435e-05
	M	1.3098	3	0.7268

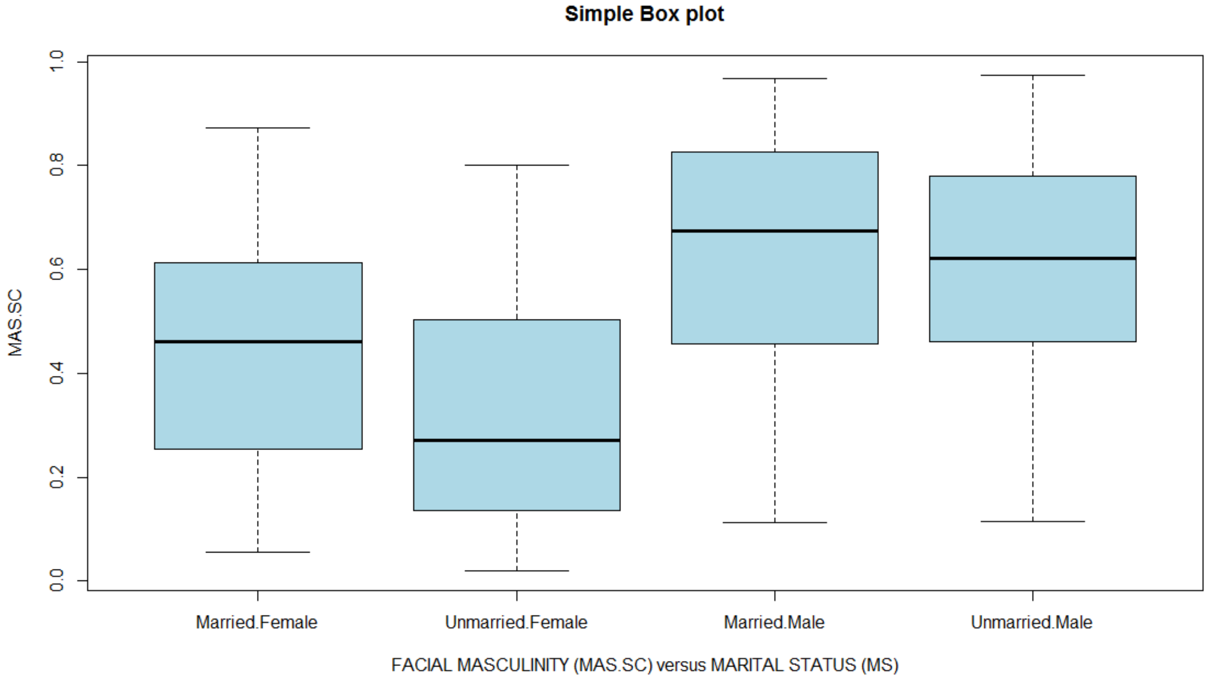


Figure 7:5: Boxplot, facial masculinity scores (MAS.SC) versus Marital status of the Hausa ethnic group

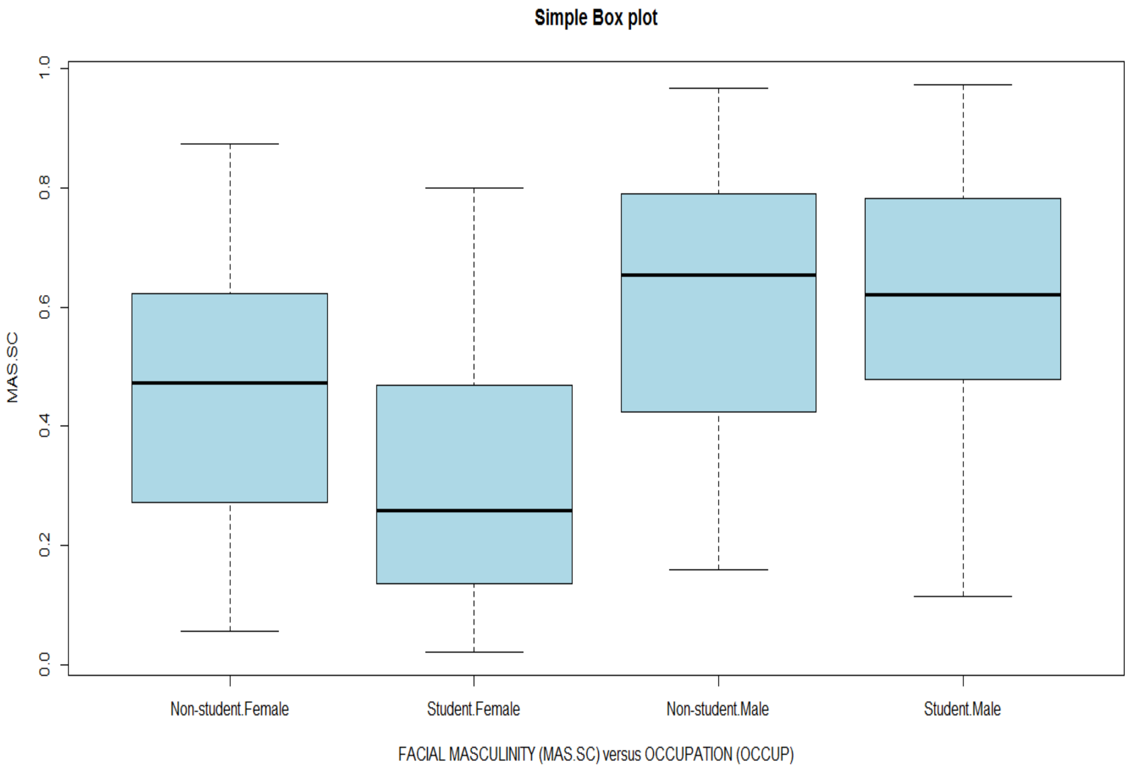


Figure 7:6: Boxplot, facial masculinity scores (MAS.SC) versus Occupational status of the Hausa ethnic group

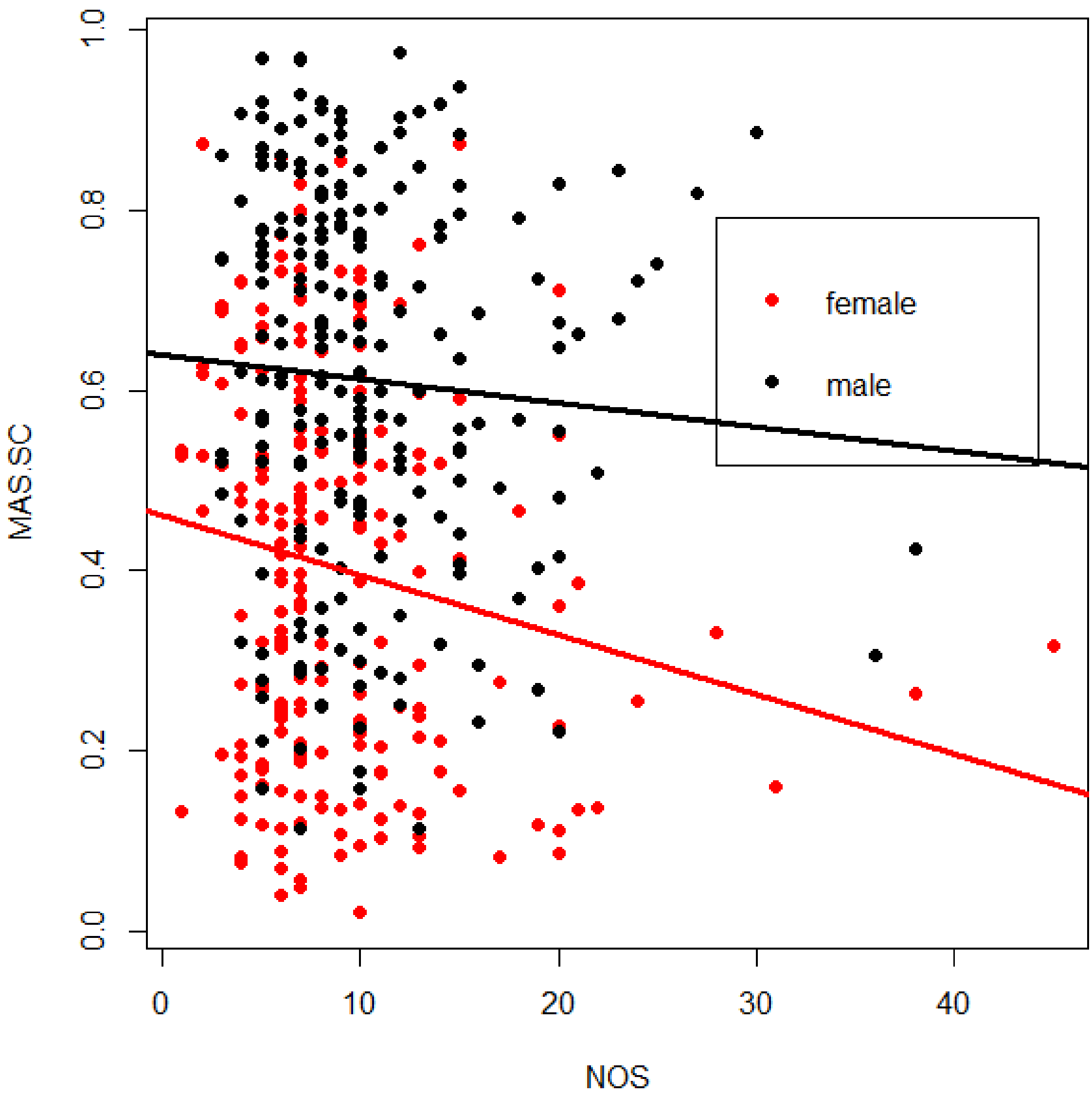


Figure 7:7: Linear regression graph, facial masculinity scores (MAS.SC) versus number of siblings (NOS) of the Hausa ethnic group

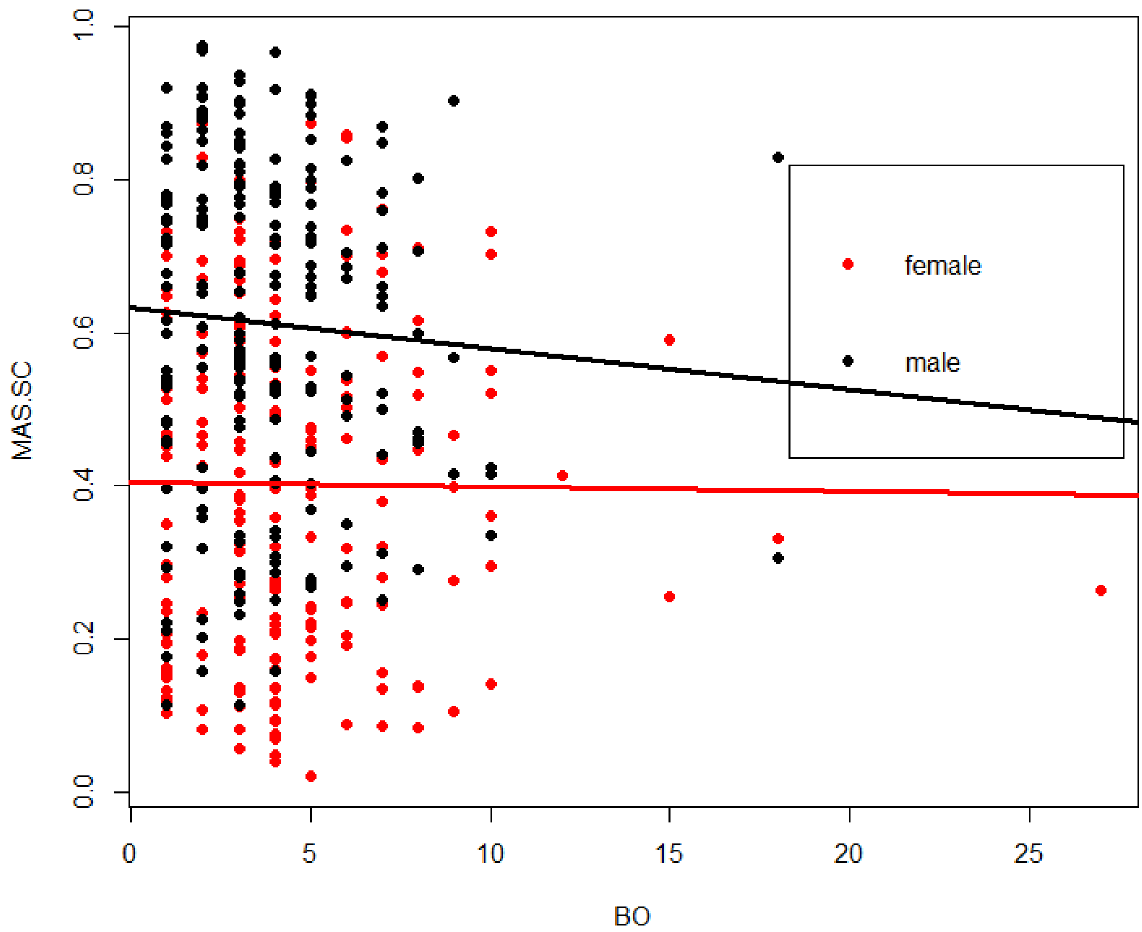


Figure 7:8: Linear regression graph, facial masculinity scores (MAS.SC) versus birth order (BO) of the Hausa ethnic group

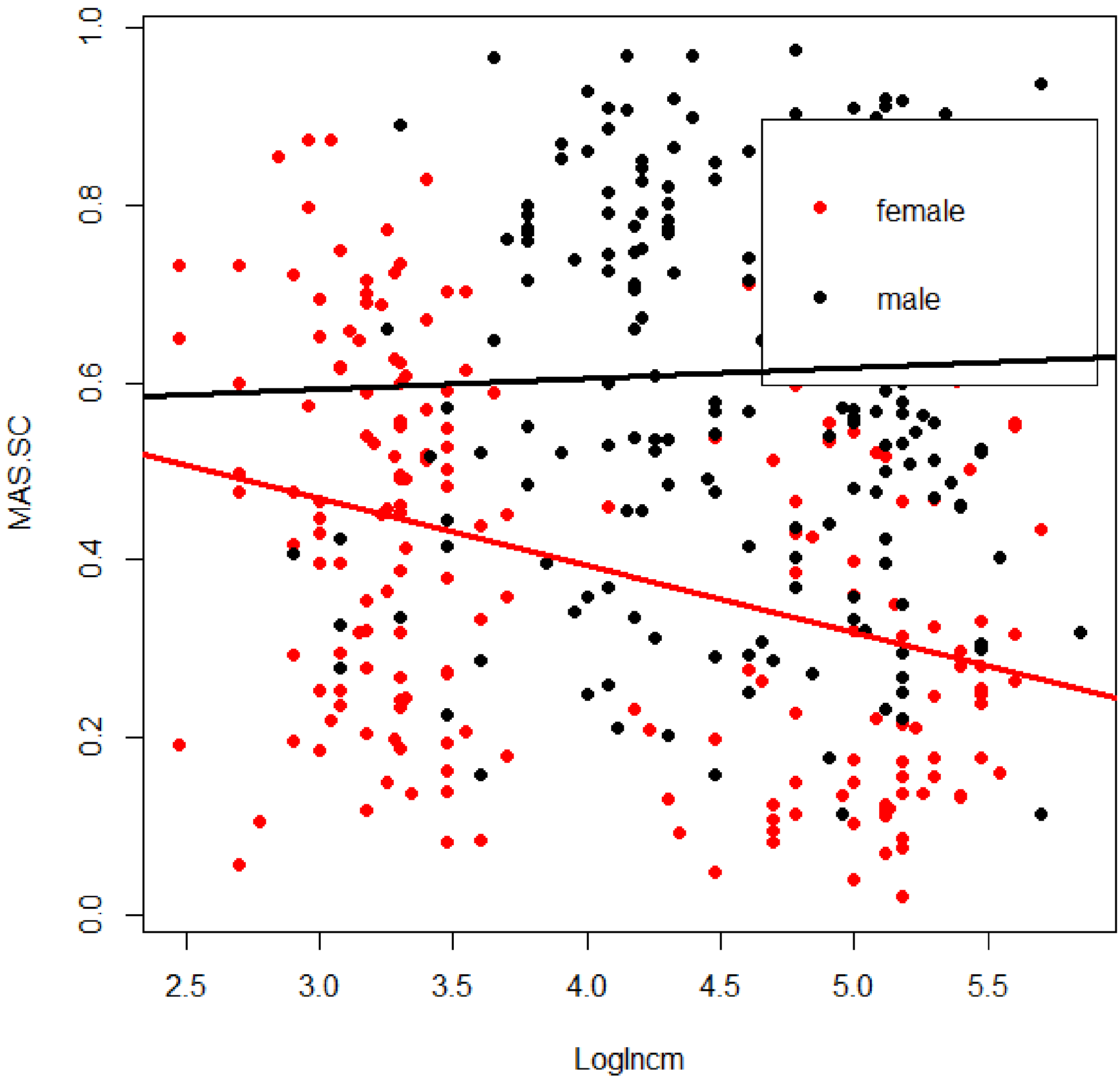


Figure 7:9: Linear regression graph, facial masculinity scores (MAS.SC) versus log-transformed income (LogIncm) of the participant or his/her father of the Hausa ethnic group

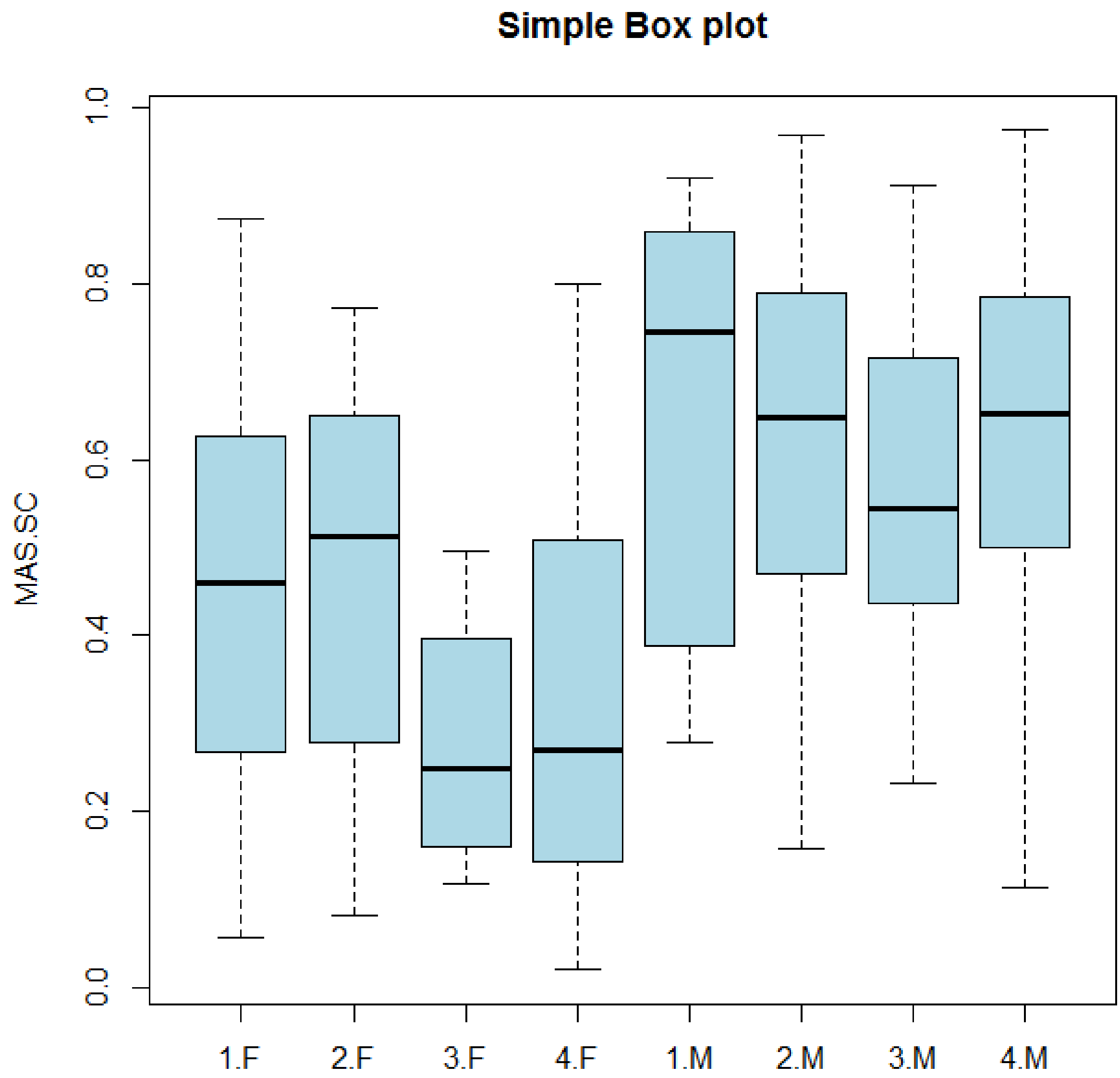


Figure 7:10: Boxplot, facial masculinity scores (MAS.SC) versus 4 groups of educational levels of the Hausa ethnic group (Group 1 = neither the participant nor parents had western education, Group 2 = only participant had western education, Group 3 = participant and one of the parent had western education, Group 4 = participant and all the parent had western education). F=Female, M=Male

7.1.3.5 Multivariate analyses between facial masculinity scores (MAS.SC) and all the quantitative and qualitative variables

Multivariate analyses were conducted separately for women and men with facial masculinity scores (MAS.SC) as the dependent variable, and the following independent variables: AGE, weight (WT), height (HT), measures of health (body mass index (BMI), systolic blood pressure (SYSTBP), diastolic blood pressure (DIASTBP)), measures of socioeconomic levels (marital status (MS), occupation (OCCUP), total educational levels (TOTEDU), birth order (BO), number of siblings (NOS), income (INCOM), socioeconomic status (SES), whole face asymmetry (WFACE), asymmetry around the eyes (EYES), and whole face surface area (WFSA).

In **women**, starting with all the variables (maximal model), a *statistically significant model was found* (*F=2.669, P=0.0006*) with an adjusted r-squared value of *0.119*. However, through the use of *Akaike information criterion* (AIC): model optimisation by the backward model elimination method (gradual removal of model with highest AIC value), a *statistically significant best (minimal) model with higher adjusted r-squared* (*0.137*) *and with much lower p-value* (*F=17.66, P=8.269e-08*) than the maximal model was obtained. The best (minimal) model was a linear model of occupation (OOCUP), and height (HT), implying that OCCUP and HT contribute to variation in MAS.SC in women (**Table 7.12a & b**).

In **men**, starting with all the variables (maximal model), no *statistically significant model was found* (*F=1.637, P=0.0579*, adjusted r-squared: *0.048*). However, through the use of *Akaike information criterion* (AIC): model optimisation by the backward model elimination method (gradual removal of model with highest AIC value), a *statistically significant best (minimal) model with higher adjusted r-squared* (*0.054*) *and with lower p-value* (*F=5.034, P=0.0022*) than the maximal model was obtained. The best *(minimal) model was a linear model of whole face surface area (WFSA) and occupation (OCCUP), implying that whole face surface area (WFSA) and occupation (OCCUP) contribute to variation in MAS.SC in men* (**Table 7.13a & b**).

Table 7:12: Minimum model of Multivariate analyses in women between facial masculinity score (MAS.SC) and occupation (OCCUP) & height (HT)
Call: lm (formula = MAS.SC ~ OCCUP + HT)

a)Residuals:

Min	1Q	Median	3Q	Max
-0.40475	-0.17394	-0.00483	0.16231	0.45172

b)Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	1.48558	0.36326	4.090	**6.17e-05**
OCCUP	-0.10771	0.03216	-3.349	**0.0010**
HT	-0.66498	0.23524	-2.827	**0.0052**

Residual standard error: 0.2024 on 208 degrees of freedom Multiple R-squared: 0.1451, Adjusted R-squared: 0.1369 F-statistic: 17.66 on 2 and 208 DF, p-value: 8.269e-08

Table 7:13: Minimum model of Multivariate analyses in men between facial masculinity score (MAS.SC), whole face surface area (WFSA), occupation (OCCUP) & total disease loads of participants (TOTDX)
Call: lm (formula = MAS.SC ~ WFSA + OCCUP)

a)Residuals:

Min	1Q	Median	3Q	Max
-0.51954	-0.14126	0.00155	0.16200	0.37834

b)Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	8.789e-01	1.840e-01	4.777	**3.33e-06**
WFSA	-1.026e-05	4.306e-06	-2.383	**0.0181**
OCCUP	1.267e-01	5.036e-02	2.515	**0.0127**

Residual standard error: 0.2077 on 211 degrees of freedom Multiple R-squared: 0.06679, Adjusted R-squared: 0.05352 F-statistic: 5.034 on 3 and 211 DF, p-value: 0.002173

7.1.4 Discussion IV

7.1.4.1 Facial masculinity (FacM), age, and size

The purpose of this part of the thesis is to determine environmental correlates of sexual dimorphism in a sub-Saharan African population, members of the Hausa ethnic group in Nigeria. To that effect, size (weight, height, whole face surface area), health measures (body mass index, systolic and diastolic blood pressures), past medical history of diseases, and socioeconomic status of the participants and of their parents were investigated. Previous studies have indirectly examined the relationship between facial sexual dimorphism in the form of FacM.

For example, part of the study of Perrett et al (1998) in Caucasian and Japanese male faces, was to create facial composites of both male and females, to increase FacM of those composites by 50%, and to ask raters to rate those images on dominance, masculinity, age, and other attributes. They found that with increasing the masculinity of face shape, there was an increased ranking of perceived dominance, masculinity and age. However, their UK and Japanese female raters preferred male face shapes that were slightly feminized and they therefore suggested that the preference may reflect the effects of masculinity on perceived age (Perrett *et al.*, 1998). Similarly, Boothroid et al (2005), examined the relationship between FacM, age and health in Caucasian males of two separate age groups of 8-12 years and 45-55 years using three textured composite male base faces (15 composites for the young group and 19 composites for the older group). They found that participants perceived the facial composite of older people as having more FacM than those of the younger ones (Boothroyd *et al.*, 2005). Given the results of Perrett et al (1998) and Boothroid et al. (2005), FacM is apparently related with age. Given the theoretical and empirical knowledge of the influence of high testosterone-oestrogen ratio on the growth of the craniofacial features and other related secondary sexual characteristics on males at puberty (Penton-Voak and Chen, 2004, Koehler *et al.*, 2004c, Law Smith *et al.*, 2006), the findings of Boothroid et al (2005) are expected since members of the first group in their study, aged 8-12 years, are unlikely to have all attained puberty, and even those who did, would have been in the early period when masculine facial features were not fully present. Although the present study did not find any relationship between FacM and age in either sex, this is likely due to the narrow age range of the participants in the study or it might be that FacM does not increase or decrease significantly with age after maturity.

In the present study, facial size as measured by whole face surface area, negatively associated with FacM in male subjects, and FacM was also negatively associated with body height in females but not in males, but why this is so is not clear.

7.1.4.2 Facial masculinity (FacM), and health measures

Systolic and diastolic blood pressures are important for the normal growth and development of the entire body [e.g., (Cruickshank *et al.*, 2005)], and their association with FacM is expected due to their importance in regulating blood flow [see (Haddy *et al.*, 2006)], but this was not demonstrated in the present study. The lack of their association is however not surprising since almost all the participants' systolic and diastolic blood pressures were within normal range at least for their age [e.g., (Miyai *et al.*, 2002)].

Similarly, FacM did not show any association with body mass index (BMI) although is one of the most important indices that cues health (Flint *et al.*, 2014), but why no association was found is not clear.

7.1.4.3 Facial masculinity (FacM), and past medical history

The current study also examined the influence of past medical history of medical conditions or diseases on FacM. And FacM negatively associated with total disease loads of the participant, but why this finding was only in females is very much clear, because in as much as men are able to be highly masculine, it indicates their inherent strong immunity to fight infections vis-à-vis their high testosterone levels which is immunosuppressive (Messingham *et al.*, 2001, Roberts *et al.*, 2004, Alonso-Alvarez *et al.*, 2007).

This clearly shows the inapplicability of the handicap hypothesis to female facial masculinity, since oestrogen which is responsible for the female sexual characters including feminine facial features (Law Smith *et al.*, 2006), is not immunosuppressive. Testosterone suppresses both T-cell and B-cell immunity, oestrogen depresses T cell-dependent immunity, but enhances humoral immunity [(Alexander and Stimson, 1988) but see review in (Da Silva, 1999)].

It means therefore, oestrogen is disadvantageous in one hand (as it suppresses T-cell mediated immunity), but advantageous on the other hand (as it enhances humoral immunity).

In the present study, total disease load negatively associated with femininity in females, which is similar to others [e.g., (Gray and Boothroyd, 2012)], and thus female femininity might then be appropriately considered as a direct cue of health, with humoral immunity enhancement from oestrogen. Although the findings of Gray and Boothroid is similar to the present study, the association they found was between femininity and only to some aspect of the investigated self-reported health history (Gray and Boothroyd, 2012).

7.1.4.4 Facial masculinity (FacM), and measures of socioeconomic status (SES)

The socioeconomic status (SES) of the participants was also investigated to determine if there is any association between it and FacM. It is assumed that older siblings may possibly be at advantage of having better parental care, better education and better nutrition necessary for better growth and development as compared to the younger ones.

Given this assumption, this study *hypothesized that birth order (BO) may be negatively related to the FacM owing to the competition for resources in the family*. However, results did not show any association between BO and FacM in both sexes. One possible explanation is that a person may be the 10th in the family, but there are only 4 remaining, the rest either having died (due to high mortality from poverty) or having been sent away within the country for Islamic education (the so called Al-majiri system of education) typical of northern Nigerian population where the data were collected. An additional explanation which may be particularly true in the remote villages where some of this study's data were collected, is independency of family members because of poverty especially males, and thus every male child in the family will source for sustenance for himself and for others in the family. Therefore it is not surprising to find negative relationship between number of siblings (NOS) in a family and FacM in females because the more the number of male child in a family, the more resources to their female siblings and thus the females were less masculine (less competition). And if masculine traits are associated with testosterone levels, they would also be associated with more competitive behaviour, which may be more important in a poorer socioeconomic context, including in women, resulting in more masculine traits becoming established in poorer socio-economic context and this confirms why married women were more facially masculine than their unmarried counterparts, since the married women in northern Nigerian settings are full housewives exposed to various stresses including for example child bearing and child rearing stresses, housekeeping, and paid work to maintain themselves (Hill, 1972, Schildkrout, 1983, Yakubu, 2001) and less educated.

This is confirmed in the finding of educated women (with any or both parent being educated) more feminine possibly because the un-educated get married earlier (Niles, 1989, Uzoma, 2013) or get involved in street hawking (Unicef, 2007).

7.1.5 Conclusion IV

The current study is the first to examine directly the influence of biological markers, health and diseases on facial masculinity using modern 3D laser scanning technique, and it is also the first to study these factors and their association with FacM in the sub-Saharan Africans.

In summary, upper class women have more facial femininity, they are also taller, healthier, better educated, more likely to be students and, presumably as a result, less likely to marry early. Interestingly, they also seem to come from smaller families, which would suggest a similar effect to that seen in WEIRD populations, i.e., that more educated and wealthier people have fewer children. Broadly, then, the study confirms that facial masculinity is more pronounced in more competitive environments, but interestingly, the effect is only clearly seen in women. Further study is recommended especially in the sub-Saharan African population.

Chapter 8 : CORRELATES OF BOTH FACIAL ASYMMETRY AND FACIAL SEXUAL DIMORPHISM

8.1 Introduction

Although there are several other traits associated with facial attractiveness, for example, facial averageness (Apicella *et al.*, 2007, Rhodes *et al.*, 2001a), skin health (Jones *et al.*, 2004), skin colour (Fink *et al.*, 2006a), age (Korthase and Trenholme, 1982), facial adiposity (Coetzee *et al.*, 2009), hair and eye colour (Little *et al.*, 2003), facial hair in men (Neave and Shields, 2008), evolutionary biologists and other related fields have focused (in the recent times) on human mate selection vis-à-vis human facial symmetry, facial attractiveness [e.g., (Grammer *et al.*, 2003, Honekopp *et al.*, 2004, Puts, 2010, Zaidel and Hessamian, 2010) and for review see (Wade, 2010)] and facial masculinity [e.g., (DeBruine *et al.*, 2006, Thompson and O'Sullivan, 2013)]. Facial symmetry and facial masculinity are the key elements of facial attractiveness [e.g., (Perrett *et al.*, 1998, Perrett *et al.*, 1999, Scheib *et al.*, 1999, Rhodes *et al.*, 2001a, Rhodes and Simmons, 2007, Little *et al.*, 2008c, Tamsin *et al.*, 2011, Pisanski and Feinberg, 2013, Little *et al.*, 2014)] and for human mate selection (Thornhill and Gangestad, 1993, Grammer and Thornhill, 1994, Scheib *et al.*, 1999, Conwell *et al.*, 2006, Rhodes and Simmons, 2007, Thompson and O'Sullivan, 2013) and reviews in (Grammer *et al.*, 2003, Gangestad and Scheyd, 2005) because they cue both genetic and phenotypic qualities (Thornhill and Gangestad, 1999), as in the "good genes" theory of human mate choice (Hamilton and Zuk, 1982).

In some studies, facial symmetry correlated positively with facial masculinity (Gangestad and Thornhill, 2003a, Little *et al.*, 2008c); Little et al., 2008), but not in others (Koehler *et al.*, 2004b).

In the literature, attractive individuals are speculated to possess a diverse set of heterozygous genes coding for proteins (involved in immune response) resistant to parasitic infections (Thornhill and Gangestad, 1993), and are therefore healthier (Mitton and Grant, 1984, Thornhill and Gangestad, 1993). Thus facial attractiveness is an important correlate of both facial symmetry and facial sexual dimorphism.

From the evolutionary theory of human mate choice, the selection of mate especially for long term relationship (as in marriage), evolved specifically to maximize success in reproduction and also to gain healthy or physically fit future offspring (Epstein and Guttman, 1984). Therefore individuals with greater reproductive potential and reproductive investment would have better selective advantage as mates (Geary *et al.*, 2004). And such physical traits offering reproductive potential are testosterone-dependent, such as masculine skeletal facial features which were hypothesized to be health signals [e.g., (Folstad and Karter, 1992, Rhodes *et al.*, 2003)].

Given the genetic and phenotypic benefits believed to be accrued by male individuals with more symmetrical or masculine faces, it is expected that such individuals should on average be preferred by females. However, data from the previous studies have yielded equivocal results with preferences for men with more masculine faces in some [e.g., (Perrett *et al.*, 1998, DeBruine *et al.*, 2006)] but less masculine men in others [e.g., (Penton-Voak *et al.*, 2003)], and no preferences for either masculinity or femininity in another (Swaddle and Reierson, 2002).

Interestingly, and in contrast, some studies have shown that men with more masculine faces are reviewed as antisocial, that is, they are seen as less friendly, dishonest, less cooperative, and bad parents (Perrett *et al.*, 1998, Boothroyd *et al.*, 2007) and even more aggressive (Macapagal *et al.*, 2011) and thus un-caring. But whether all such positive or negative findings will be the same in less developed societies is yet to be established. Most of the evolutionary studies to date concerning human mate selection were conducted in industrialized populations, and no single study has yet addressed the question of overall facial asymmetry and facial masculinity as determinants of marriage, or caring (for a spouse or off-spring). The question of the role of the overall facial asymmetry in human mate choice is intriguing since to the observer, differentiating between FA and DA in the face is absolutely impossible.

Therefore, in this part of the study, things that people appreciate in social partners such as facial attractiveness, suitability for marriage, and caring are considered as correlates of facial asymmetry and facial sexual dimorphism.

The method employed here, differs from, and offers advantages over most of the previous studies which artificially created masculinized and feminized versions of a given face [e.g., (Perrett *et al.*, 1998, DeBruine *et al.*, 2010, Morrison *et al.*, 2010)], because it reflects the real life decision in the human mate choice, specifically because the rated stimuli are more natural than artificially created facial stimuli. In the present study, I aimed at testing the following hypotheses: *1) Men and women will prefer individuals with lower facial asymmetry (more symmetrical faces) as most attractive, most likely as marital partners, and most caring than women with higher facial asymmetry (less symmetrical faces). 2) Facial asymmetry is not expected to have an effect of perceived aggressiveness in this study 3) Men will show preference for women with more feminine faces,* *and women will show preference for men with more masculine faces, with the effect emphasised in individuals from lower socioeconomic backgrounds*.

8.2 Materials and Method

The study area, the details of the participants, method of recruitment of the participants, the demographic and the rating questionnaires for the rating exercise were all described in details in the general material and method chapter 5. Similarly, the scanning method of the scans used for the rating, and the process of quantifying facial sexual dimorphism in the form of facial masculinity (FacM) were also described in chapter 5.

8.2.1 Specific method of three-dimensional facial models preparation for facial asymmetry and facial sexual dimorphism rating exercise

For the purpose of the facial asymmetry rating exercise, 21 3D male facial scans and 21 3D female facial scans of the Hausa ethnic group were used. Out of the 21 scans in each sex, 18 were used for facial asymmetry rating and the remaining 3 for facial asymmetry-symmetry pairwise rating (asymmetric versus symmetricised). And for the purpose of facial masculinity rating exercise, another set of 18 3D male and 18 3D female facial scans was also used.

The selection of these scans was conducted in 3 stages: Firstly, 3 male and 3 female facial scans, each with high facial asymmetry values were selected for the pairwise rating, where raters were presented with both an original and a symmetricised scan image of the same face. Secondly, 3 sets of 6 male scans each and 3 sets of 6 female scans each were selected for the facial asymmetry rating exercise, with each set having similar facial masculinity/femininity scores but a wider range of facial asymmetry values.

Thirdly, 3 sets of 6 male scans and another 3 sets of 6 female scans were selected for the facial masculinity rating exercise, with each having similar whole face asymmetry values but a wider range of facial masculinity values. However, the preparation of the 3 sets of 6 scans for facial asymmetry and facial masculinity rating was the same and involved only *cleaning and trimming* of each of the original facial scans among the sets. For the preparation of the pairwise 3D facial models for facial asymmetry-symmetry rating, each of the 3 male scans and 3 female scans was prepared by *cleaning, trimming, mirroring, aligning, merging and re-trimming* (as described in chapter 5). The process of producing symmetricised 3D facial models was similar to but with modification of the previously employed methods of other studies (Swaddle and Cuthill, 1995, Rhodes, 1998, Perrett *et al.*, 1999).

After the 3D facial models were prepared, each was then smooth shaded, saved as a jpeg object, opened in Microsoft office 2010 and cropped, so that the distance between the eyebrows and the top of the 3D facial model was similar in all of them, and no gap left between either side of the face or the chin and the black double frame containing the 3D facial model. The 3D facial models were presented to the raters in 2 separate Microsoft PowerPoint files (one female's file & one male's file), and since the 3D facial models were in unnatural blue colours (from the Geomagic software program), they were modified and presented to the raters in grey colours (looking more like natural Black African facial skin colours) similar to the method adopted in a previous study (Honekopp *et al.*, 2004).

8.2.2 Ranking process and the raters

The total number of raters was one hundred and seventy nine (98 males and 81 females) who participated in the ranking with compensation for their travel expenses (£ 1.00 equivalent in Nigerian currency), or as volunteers.

Each participant sat down in front of a computer screen **(Figure 8.1)** showing the first page of the contained file of 3D facial models of the Hausa ethnic group. Males had female models on their screens, while females had male models on theirs. The sitting arrangement was made in such a way that females sat separate to avoid distractions from male colleagues. The raters were in no way to be identified, to preserve anonymity and were allowed to view the models as long as they wished and they could scroll forward or backward through the models sequentially until they were satisfied with their rating. All the raters had no knowledge of the individuals in the facial models as that has been demonstrated to influence rating (Hume and Montgomerie, 2001).

Raters were also not aware of the facial asymmetry or facial masculinity scores of the models they rated, nor were they informed about the hypotheses being tested. All the raters completed a brief demographic questionnaire giving information on their age, sex, religion, ethnicity, relationship status, their occupations, where the participants grew up and their socioeconomic status or of their parents. Sessions lasted for about two hours (including completing the questionnaires).

Figure 8:1: Cross-section of the females' participants rating male facial scans

8.2.3 Facial asymmetry-symmetry/ Facial masculinity/femininity ranking

Facial asymmetry-symmetry ranking: Male session

For slides 1 to 3 of their PowerPoint file (**Figures 8.2, 8.3 & 8.4)**, the male raters were asked to rank the 3 paired 3D female facial models according to their perceived attractiveness, suitability as marriage partners, caring nature, and aggressiveness. Pairs were presented side by side in random order, similar to the method adopted by Perrett et al. (Perrett et al., 1999).

For slides 4 to 6 (**Figures 8.5, 8.6 & 8.7**), the male raters were asked to rank the 3 sets of 6 female 3D facial scans according to their perceived attractiveness, suitability as marriage partners, caring nature, and aggressiveness (**appendix 4**).

Facial masculinity/femininity ranking: Male session

For slides 7 to 9 (**Figures 8.8, 8.9, & 8.10**), the male raters were again asked to rank another 3 sets of 6 female 3D facial scans according to their perceived attractiveness, suitability as marriage partners, caring nature, and aggressiveness (**appendix 4**).

Facial asymmetry-symmetry ranking: Female session

In slide 1 to 3 of their PowerPoint file (**Figures 8.11, 8.12 & 8.13**), the female raters were asked to rank the 3 paired 3D male facial models according to their perceived attractiveness, suitability as marriage partners, caring nature, and aggressiveness. For slide 4 to 6 (**Figures 8.14, 8.15 & 8.16**), the female raters were asked to rank the 3 sets of 6 male 3D facial scans according to their perceived attractiveness, suitability as marriage partners, caring nature, and aggressiveness (**appendix 5**).

Facial masculinity/femininity ranking: Female session

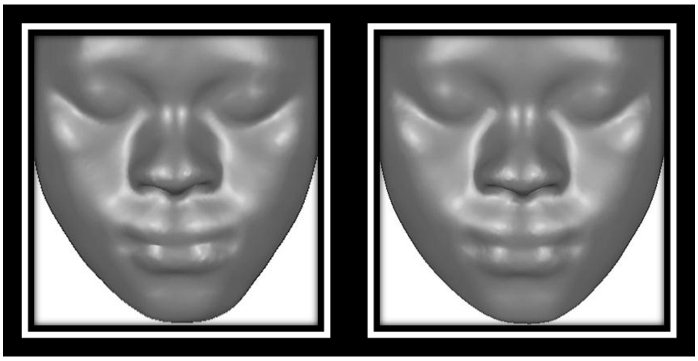
For slides 7 to 9 (**Figures 8.17, 8.18, & 8.19**), the female raters were asked to rank another 3 sets of 6 male 3D facial scans according to their perceived attractiveness, suitability as marriage partners, caring nature, and aggressiveness (**appendix 5**).

In the rating questionnaire, four main questions were asked about the scans (but see **appendix 4 & 5**): 1) How ATTRACTIVE they are 2) How likely it is that the rater would choose them as their MARRIAGE PARTNER 3) How CARING the rater perceived them to be 4) How AGGRESSIVE the rater perceived them to be.

A *ratee ranked the most will have a rating rank of 6, whereas a ratee ranked the least will have a rating rank of 1* in each question.

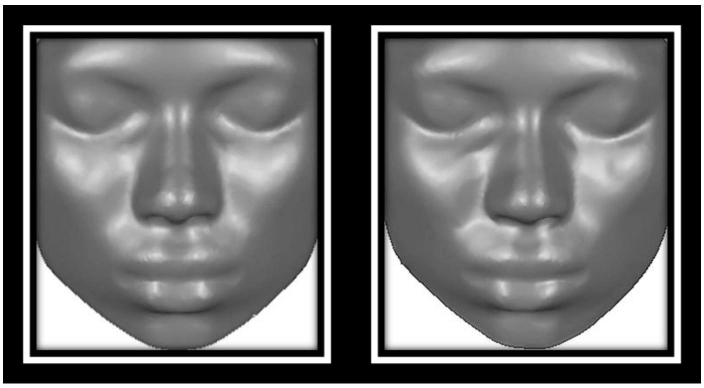
The questions were the same for both facial asymmetry and facial masculinity ranking. Analyses of the data were conducted in *R-statistic software version 3.1.2 (R Core Team., 2014)*. And since this part of study will test the hypothesis of whether individuals with lower facial asymmetry (more symmetric face) will be more preferred, a scan of each slide was also ranked according to its whole face asymmetry value (WFACE) where a *scan with highest WFACE was given a rank of 1, and the one with lowest was given a rank of 6* (note: there were six scans in each slide). Similarly, scans in the slides for the facial masculinity ranking were also ranked according to each scan's facial masculinity/femininity score (MAS.SC), with the most feminine face being ranked 1 and the most masculine face 6.

Correlation of facial symmetry with facial masculinity has previously been reported exclusively for male faces (Gangestad and Thornhill, 2003a), which suggests that the correlation between facial symmetry and facial attractiveness may possibly be as a result of the positive correlation between symmetry and masculinity. Therefore in order to confirm that raters were reliably ranking a particular trait at a time (facial asymmetry-symmetry or facial masculinity) and not just rating both whole face asymmetry & facial masculinity together, whole face asymmetry values of the 18 female facial scans were regressed against facial masculinity scores of the same 18 female facial scans, and same was also done for males, using linear regression analysis in *R-statistic software version 3.1.2 (R Core Team., 2014)*.



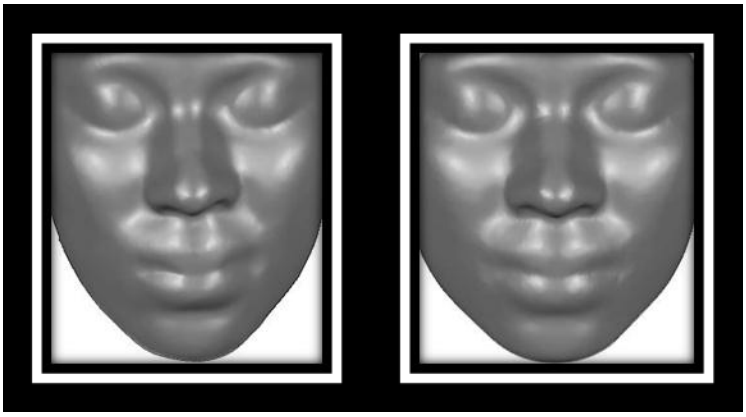
A1 **A2**

Figure 8:2: First pair of the females’ 3D facial models: A1 (original), & A2 (symmetricised) models.



B1 **B2**

Figure 8:3: Second pair of the females’ 3D facial models: B1 (symmetricised), & B2 (original) models.



C1 **C2**

Figure 8:4: Third pair of the females' 3D facial models: C1 (original), & C2 (symmetricised) models.

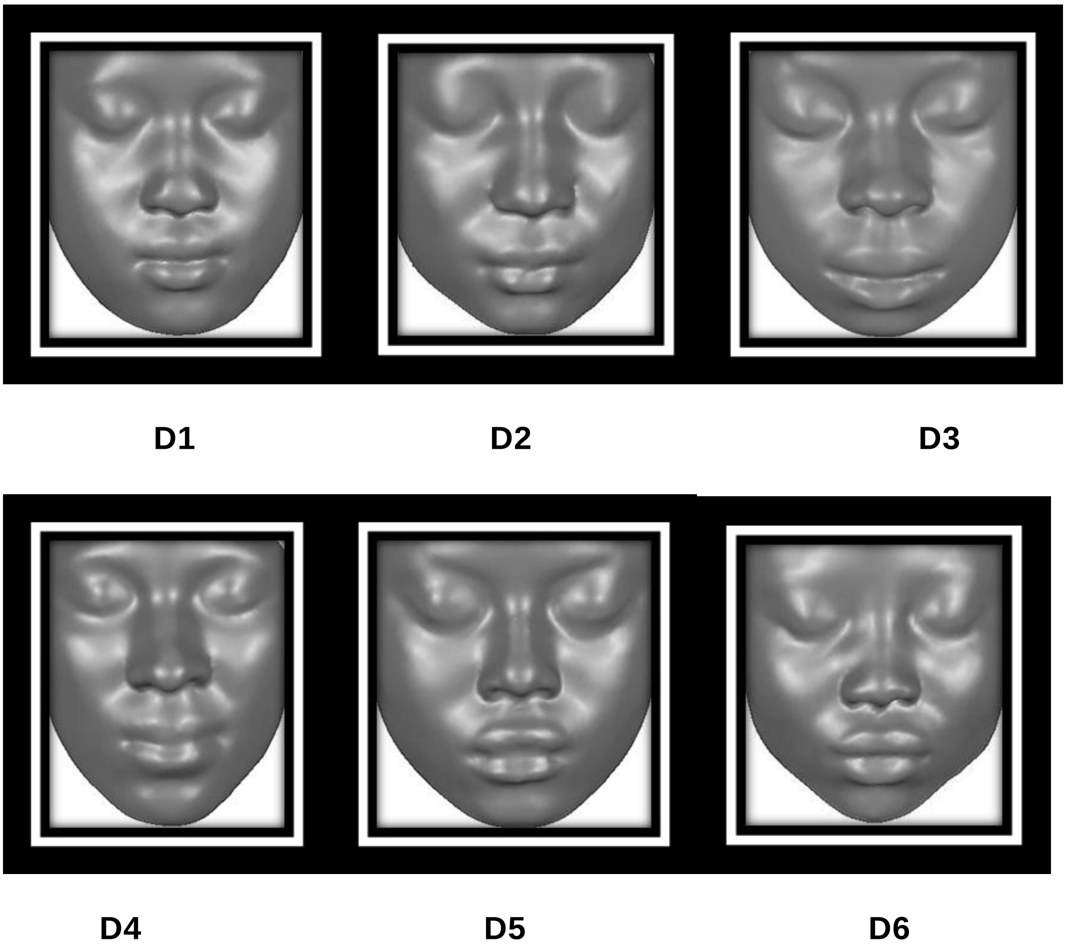
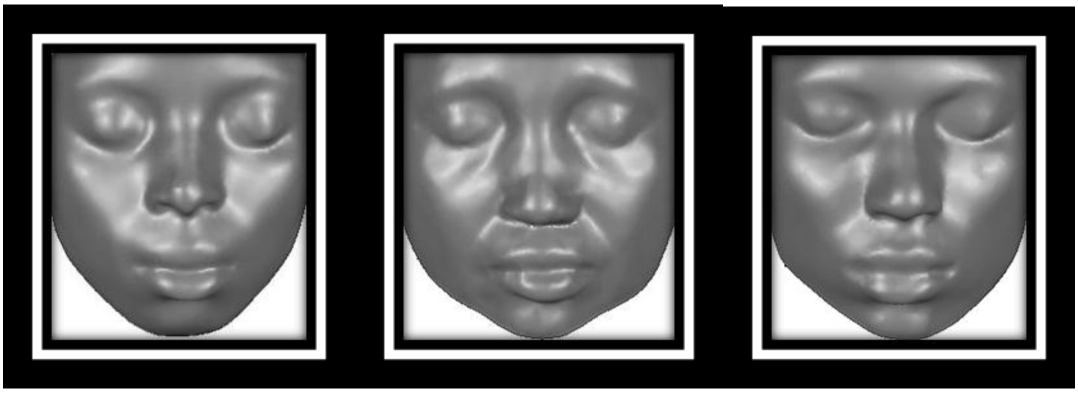


Figure 8:5: First set of six females' 3D facial scans with similar facial masculinity/femininity scores but wider range of whole facial asymmetry values

E1 **E2** **E3**

E4 **E5** **E6**

Figure 8:6: Second set of six females' 3D facial scans with similar facial masculinity/femininity scores but wider range of whole facial asymmetry values

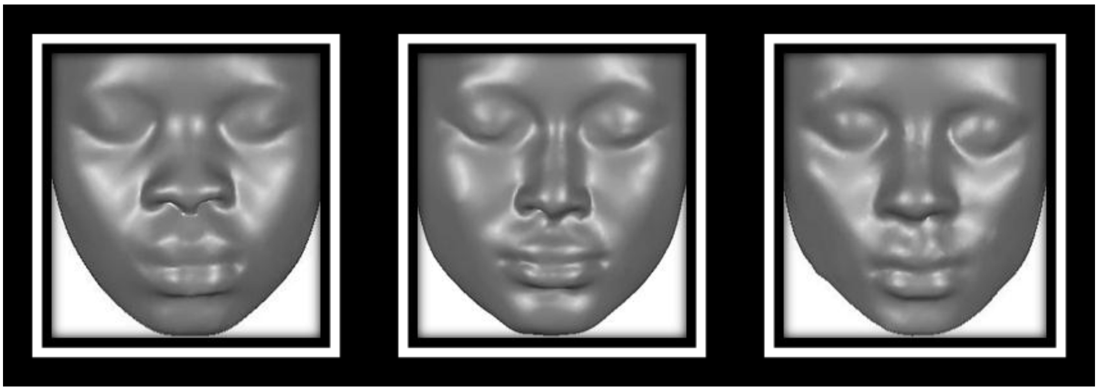


F1 **F2** **F3**

F4 **F5** **F6**

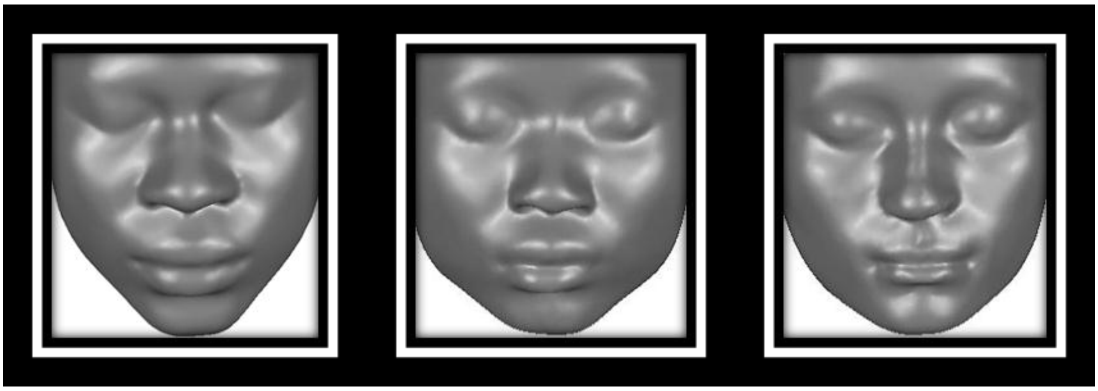
Figure 8:7: Third set of six females' 3D facial scans with similar facial masculinity/femininity scores but wider range of whole facial asymmetry values

G1 **G2** **G3**

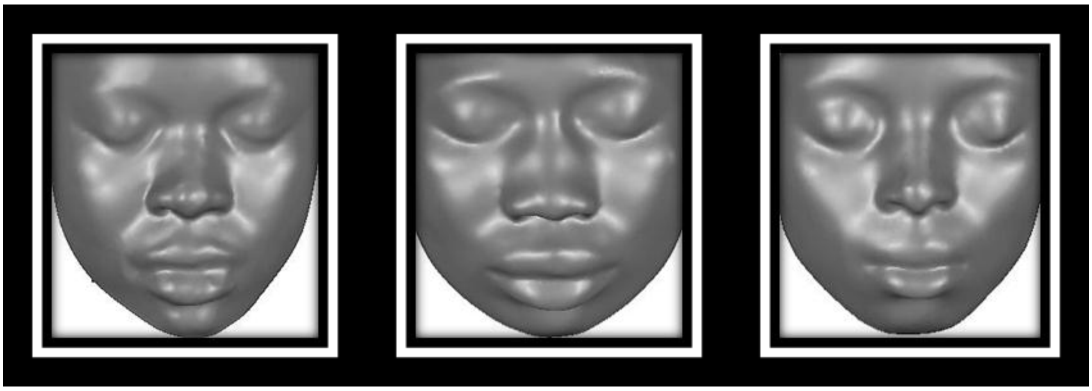


G4 **G5** **G6**

Figure 8:8: First set of six females' 3D facial scans with similar whole facial asymmetry values but wider range of facial masculinity/femininity scores



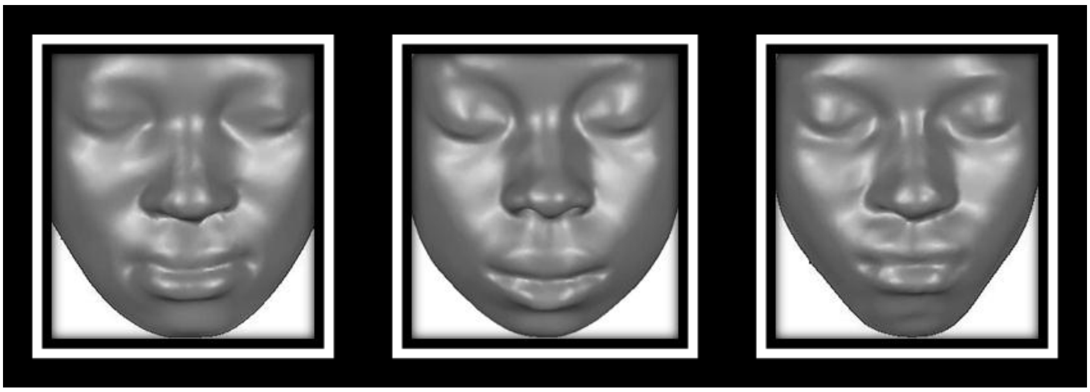
H1 **H2** **H3**



H4 **H5** **H6**

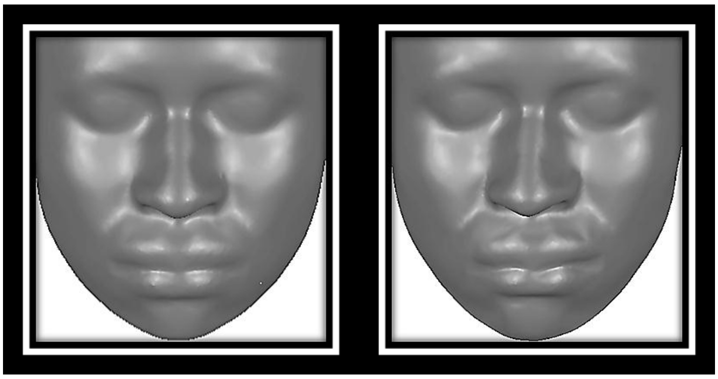
Figure 8:9: Second set of six females' 3D facial scans with similar whole facial asymmetry values but wider range of facial masculinity/femininity scores

I1 I2 I3



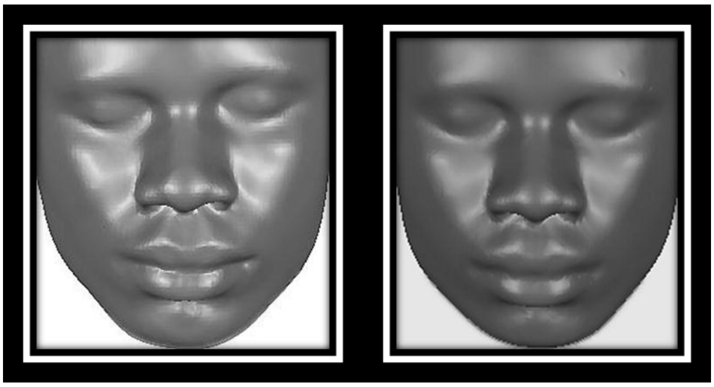
I4 I5 I6

Figure 8:10: Third set of six females' 3D facial scans with similar whole facial asymmetry values but wider range of facial masculinity/femininity scores



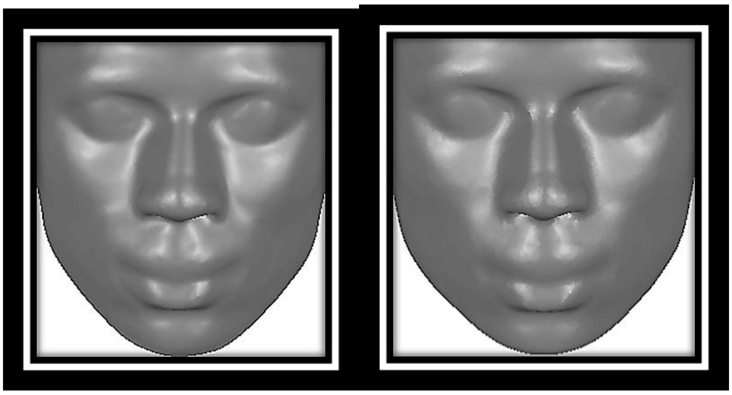
A1 **A2**

Figure 8:11: First pair of the males' 3D facial models: A1 (symmetricised), & A2 (original)



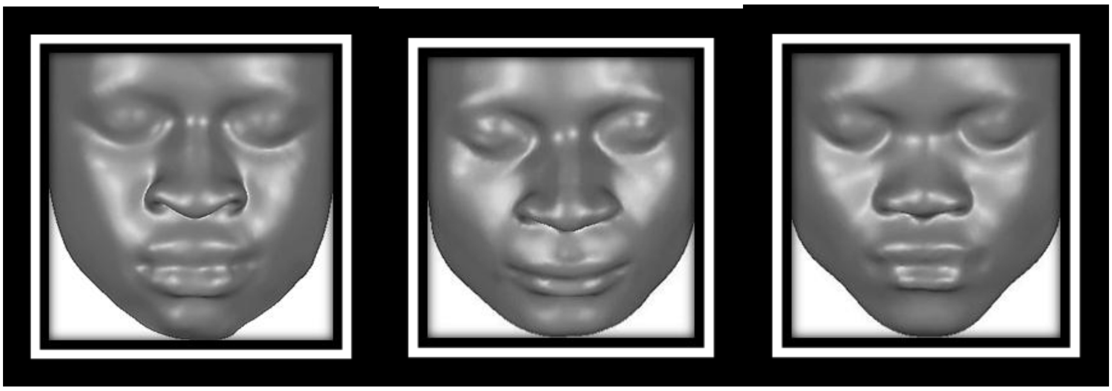
B1 **B2**

Figure 8:12: Second pair of the males' 3D facial models: B1 (original), & B2 (symmetricised)



C1 **C2**

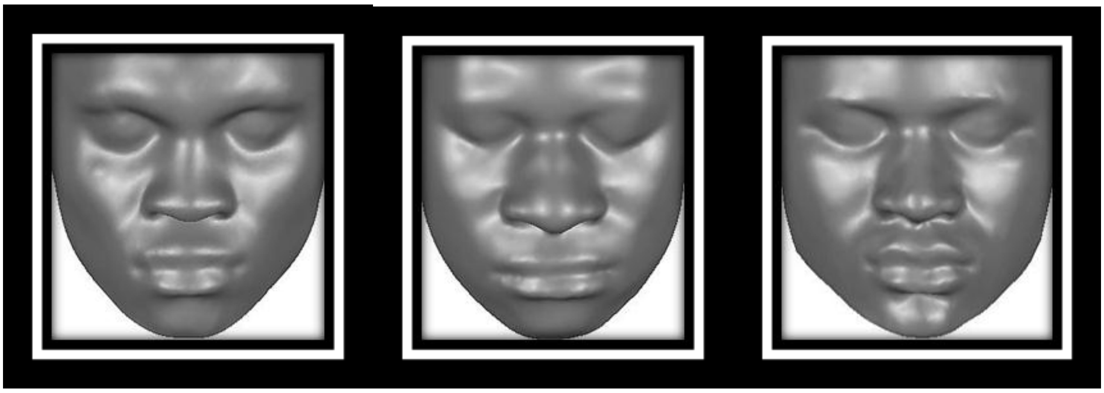
Figure 8:13: Third pair of the males' 3D facial models: C1 (original), & C2 (symmetricised)



D1 **D2** **D3**

D4 **D5** **D6**

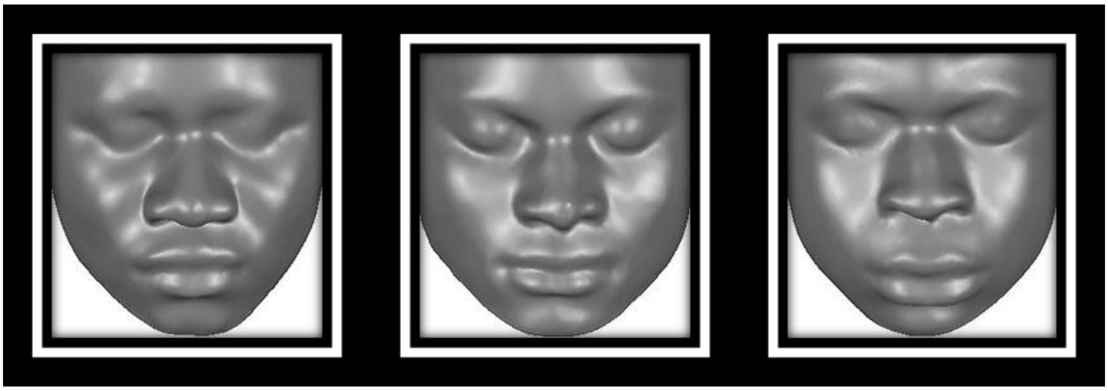
Figure 8:14: First set of six males' 3D facial scans with similar facial masculinity/femininity scores but wider range of whole facial asymmetry values



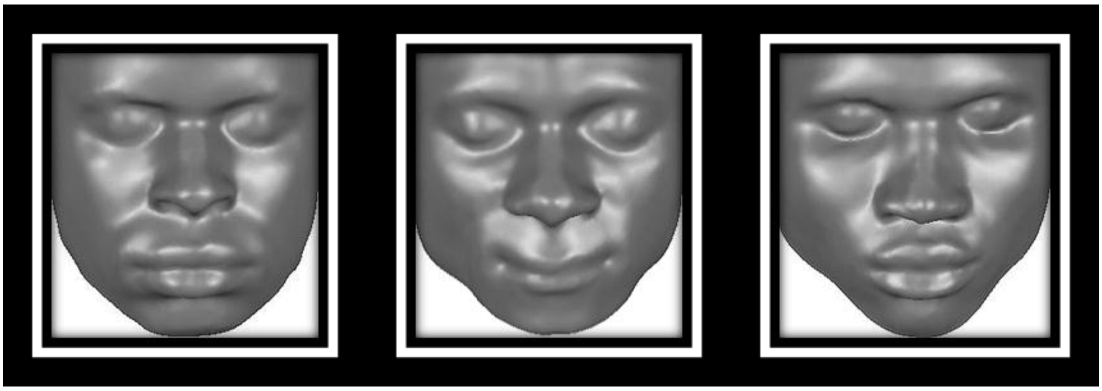
E1 E2 E3

E4 E5 E6

Figure 8:15: Second set of six males' 3D facial scans with similar facial masculinity/femininity scores but wider range of whole facial asymmetry values

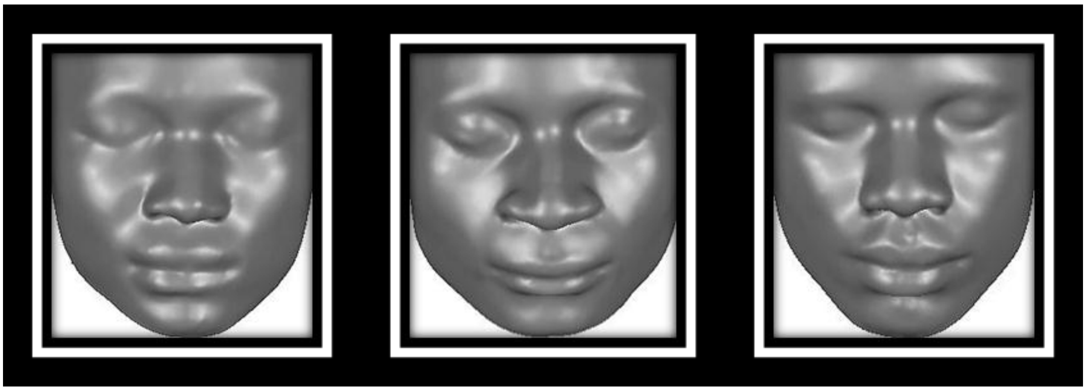


F1 **F2** **F3**



F4 **F5** **F6**

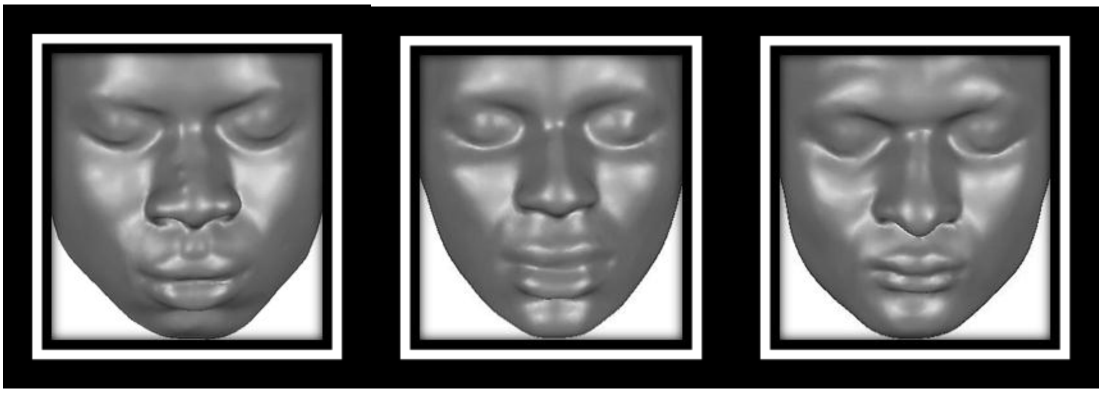
Figure 8:16: Third set of six males' 3D facial scans with similar facial masculinity/femininity scores but wider range of whole facial asymmetry values



G1 **G2** **G3**

G4 **G5** **G6**

Figure 8:17: First set of six males' 3D facial scans with similar whole facial asymmetry values but wider range of facial masculinity/femininity scores

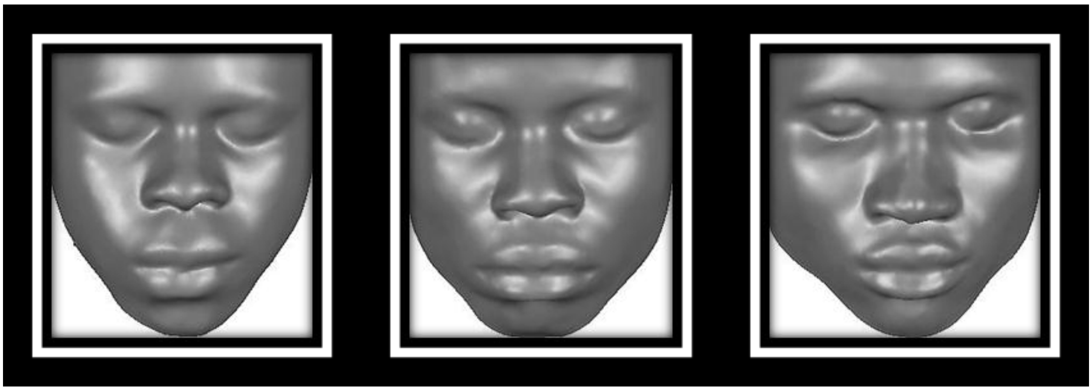


H1 **H2** **H3**

H4 **H5** **H6**

Figure 8:18: Second set of six males' 3D facial scans with similar whole facial asymmetry values but wider range of facial masculinity/femininity scores

I1 **I2** **I3**



I4 **I5** **I6**

Figure 8:19: Third set of six males' 3D facial scans with similar whole facial asymmetry values but wider range of facial masculinity/femininity scores

8.2.4 Method of analyses

From the 3 pairwise models A, B and C, counts of raters selecting the original and the symmetricised version of the face were summed for each question (attractiveness, suitability as marital partner, caring, aggressiveness) and analysed using Binomial sign tests . For the 3 sets of six slides, a table of 3222 rows (179 raters*18 scans) and columns (1 for the rated rank and the other for the true rank) was made, with additional columns for the sex of the raters, their income, marital status and the whole face asymmetry value or facial masculinity score corresponding to each facial scan. *Spearman's rank and Kendall's rank correlations* were conducted in order to ascertain correlations between the rated rank by each sex and the true rank of each scan for each question in both facial symmetry and facial masculinity ranking. *Analyses of covariance* (ANCOVA) was carried out for each slide (containing six scans) and for each question between the rated rank of either whole face asymmetry (WFACE) values or facial masculinity scores and income/marital as covariates. Results from the ANCOVA that returned statistically significant values were subjected to ANOVA to determine the minimum model for each slide. All the analyses were conducted in *R-statistic software version 3.1.2 (R Core Team., 2014)*.

8.2.5 Inter-rater reliability (IRR) determination using intra-class correlation (ICC)

Although Pearson correlation is a valid estimator of inter-rater reliability, it is only appropriate when there are two raters and alternatively, intra-class correlation (ICC) could be used in case there are more than two raters. ICC is classified into three:

ICC1 (used when raters are not consistently rating the same ratees: “One-Way Random”), ICC2 (when raters are consistently rating the same ratees but a sample of raters is used in computing inter-rater reliability: “Two-Way Random”) and ICC3 (when raters consistently rated the same ratees and the whole population of raters is used rather than sample: “Two-Way Mixed”). Results of the analysis of ICC are commonly interpreted using Cronbach’s alpha, which ranges between 0 to 1, and the frequently accepted value is between 0.7 to 0.95 (Nunnaly and Bernstein, 1994, Bland and Altman, 1997, Mohsen and Reg, 2011). And since the rating scores in this study are quantitative, with more than two raters, all raters consistently rated the same ratees, and the entire population raters are used in assessing their rating reliability, therefore intra-class correlation type three (ICC3) Two-Way Mixed was the best option and was employed and the analysis was conducted in IBM SPSS Statistic version 22.

8.3 Results

The male raters’ mean age was 22.8 years (SD: 3.1, range: 18–37 years), whereas female raters’ mean age was 19.9 years (SD: 1.9, range: 17–32 years).

8.3.1 Inter-rater reliability result

From the intra-class correlation analyses for all the four questions of whether facial symmetry or facial masculinity is most attractive, most likely as a married partner, most caring or the most aggressive, results indicated that both male and female raters were consistent in their ranking and that their ranking pattern was reliable from the intra-class coefficients, which were all greater than *0.7 (70%)* as shown in **Tables 8.1, 8.2, 8.3 & 8.4**.

Regression analyses showed no association between whole face asymmetry and facial masculinity scores of the 18 facial models in females (*F=0.2006, P=0.6603*), and in males *(F=0.1392, P=0.7140*). This means that raters were rating a particular trait at a time.

Table 8:1: Female facial asymmetry raters Intra-class Correlation (ICC) in all the four questions: facial asymmetry as most attractive (ASAT), most likely as marital partners (ASMP), most caring (ASCAR) or most aggressive (ASAG): N = 81

			95% Confidence Interval		F Test with True Value 0			
		Intra-class Correlation[b]	Lower Bound	Upper Bound	Value	df1	df2	Sig
ASAT	Single Measures	.142[a]	.086	.252	14.370	23	1840	<0.0001
	Average Measures	.930[c]	.884	.965	14.370	23	1840	<0.0001
ASMP	Single Measures	.119[a]	.071	.217	11.917	23	1840	<0.0001
	Average Measures	.916[c]	.860	.957	11.917	23	1840	<0.0001
ASCAR	Single Measures	.105[a]	.062	.196	10.503	23	1840	<0.0001
	Average Measures	.905[c]	.842	.952	10.503	23	1840	<0.0001
ASAG	Single Measures	.046[a]	.023	.096	4.863	23	1840	<0.0001
	Average Measures	.794[c]	.658	.896	4.863	23	1840	<0.0001

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 8:2: Male facial asymmetry raters Intra-class Correlation (ICC) in all the four questions: facial asymmetry as most attractive (ASAT), most likely as marital partners (ASMP), most caring (ASCAR) or most aggressive (ASAG): N = 98

			95% Confidence Interval		F Test with True Value 0			
		Intra-class Correlation[b]	Lower Bound	Upper Bound	Value	df1	df2	Sig
ASAT	Single Measures	.124[a]	.075	.225	14.910	23	2231	<0.0001
	Average Measures	.933[c]	.889	.966	14.910	23	2231	<0.0001
ASMP	Single Measures	.127[a]	.077	.229	15.304	23	2231	<0.0001
	Average Measures	.935[c]	.891	.967	15.304	23	2231	<0.0001
ASCAR	Single Measures	.059[a]	.033	.118	7.164	23	2231	<0.0001
	Average Measures	.860[c]	.768	.929	7.164	23	2231	<0.0001
ASAG	Single Measures	.056[a]	.031	.113	6.820	23	2231	<0.0001
	Average Measures	.853[c]	.756	.926	6.820	23	2231	<0.0001

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C Intra-class correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 8:3 Female facial masculinity raters Intra-class Correlation (ICC) in all the four questions: facial masculinity as most attractive (MAT), most likely as marital partners (MMP), most caring (MCAR) or most aggressive (MAG): N = 81

			95% Confidence Interval		F Test with True Value 0			
		Intraclass Correlation[b]	Lower Bound	Upper Bound	Value	df1	df2	Sig
MAT	Single Measures	.275[a]	.171	.465	31.699	17	1360	<0.0001
	Average Measures	.968[c]	.944	.986	31.699	17	1360	<0.0001
MMP	Single Measures	.278[a]	.174	.469	32.237	17	1360	<0.0001
	Average Measures	.969[c]	.945	.986	32.237	17	1360	<0.0001
MCAR	Single Measures	.278[a]	.174	.470	32.257	17	1360	<0.0001
	Average Measures	.969[c]	.945	.986	32.257	17	1360	<0.0001
MAG	Single Measures	.084[a]	.044	.182	8.431	17	1360	<0.0001
	Average Measures	.881[c]	.788	.947	8.431	17	1360	<0.0001

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C Intra-class correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 8:4: Male facial masculinity raters Intra-class Correlation (ICC) in all the four questions: facial masculinity as most attractive (MAT), most likely as marital partners (MMP), most caring (MCAR) or most aggressive (MAG): N = 98

			95% Confidence Interval		F Test with True Value 0			
		Intraclass Correlation[b]	Lower Bound	Upper Bound	Value	df1	df2	Sig
MAT	Single Measures	.158[a]	.091	.303	19.334	17	1649	<0.0001
	Average Measures	.948[c]	.908	.977	19.334	17	1649	<0.0001
MMP	Single Measures	.162[a]	.094	.309	19.891	17	1649	<0.0001
	Average Measures	.950[c]	.910	.978	19.891	17	1649	<0.0001
MCAR	Single Measures	.103[a]	.056	.213	12.229	17	1649	<0.0001
	Average Measures	.918[c]	.854	.964	12.229	17	1649	<0.0001
MAG	Single Measures	.078[a]	.041	.168	9.245	17	1649	<0.0001
MAT	Average Measures	.892[c]	.807	.952	9.245	17	1649	<0.0001

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C Intra-class correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

8.3.2 Analysis V: Facial asymmetry-symmetry preferences

8.3.2.1 Facial asymmetry-symmetry preferences as most attractive (ASAT)

From the 3 pairwise slides, statistically significant women preference for male facial symmetry of male slides A (*P=1.694e-05*) and B (*P=0.02565*) was obtained from the binomial sign test as shown in **Table 8.5**. Similarly, men only preferred facial symmetry of female slide B as most attractive (ASAT) with statistical significance (*P=0.0004*) from the binomial sign test as in **Table 8.6**.

From **Table 8.7**, there were significant positive correlations from both Spearman's rank rho and Kendall's rank tau between rating rank of facial asymmetry (WFACE) as attractive (ASAT) and true rank of male slides D (*tau=0.1023, rho=0.1269, p<0.01*), and F (*tau=0.2284, rho=0.2984, p<0.001*). This shows that as male facial asymmetry true rank increases (note: individual with highest WFACE value was ranked 1, lowest was ranked 6), rating rank as the most attractive (note: individual ranked the most attractive was scored 6) also increases, and therefore males with lower facial asymmetry were more attractive to women. However, statistically significant negative correlation was observed between rating rank and true rank of male slide E (*tau=-0.1278, rho=-0.1682, p<0.01*), which means that males with higher facial asymmetry in slide E were more attractive to women in contrast to the findings for the other individuals in slide D and F. The analyses of the female slides show significant positive correlations in all the slides D (*tau=0.2428, rho=0.3066, p<0.0001*), E (*tau=0.1099, rho=0.1371, p<0.01*) and F (*tau=0.1031, rho=0.1180, p<0.01*), which indicates that female facial symmetry was also more attractive to men.

The overall results therefore suggest that facial symmetry is preferred as most attractive by both men and women in the study.

However, Spearman's rho is low in all analyses, indicating that the influence, while significant, is relatively small.

Analyses of covariance (ANCOVA) was conducted (**Table 8.8**) with rating rank of facial asymmetry as attractive (ASAT) [for the individual female-rated or male rated slides] as the dependent variable, whole face asymmetry (WFACE) values (for the individual female-rated or male rated slides) as the independent variable and income/marital status (MS) of the female or male raters as covariates.

Women ranking men (slides D, E and F)

For the predictors of the women's rating rank of men's facial symmetry as most attractive, a statistically significant maximum model was only obtained for male slide F (*Adjusted R2=0.0951; F=8.29, P=1.478e-09*), with an adjusted r-squared value of *0.0951*. Male slides D (*Adjusted R2=0.0038; F=1.267, P=0.2649*) and E (*Adjusted R2=-0.0037; F=0.7413, P=0.637*) returned non-significant full models. Model simplification resulted in improved, statistically significant minimum models for slides D, E, and F (**Table 8.9**) and WFACE was found to predict the women's rating rank of male facial symmetry as most attractive better than a combination of income and marital status of the female raters in all the three slides.

Men ranking women (slides D, E and F)

For the male raters, significant maximum models were found in female slides D (*Adjusted* R^2*=0.1239, F=12.86, P=2.072e-15*) and E (*Adjusted* R^2*=0.0942, F=9.729, P=1.754e-11*), but not F (*Adjusted R2=0.0063, F=1.532, P=0.1537*).

Model simplification resulted in improved, statistically significant minimum models for slides D, E, and F (**Table 8.10**) and also indicates the influence of WFACE and MS but not income in predicting men's rating rank of female facial symmetry as the most attractive. Similarly, the models in slide E and F also indicate that single men ranked women with lower facial asymmetry more favourably than the married men.

Table 8:5: Female choice on 3 pairs of male facial models, (original *versus* symmetricised) as most attractive (ASAT). N = 81

Rating	3D facial model	Slide A	Slide B	Slide C
ASAT	Symmetricised	60 (74.1%)	50 (61.7%)	46 (56.8%)
	Original	21 (25.9%)	31 (38.3%)	35 (43.2%)
	Total	81 (100%)	81 (100%)	81 (100%)
	Sign test (p-value)	**1.694e-05**	**0.02565**	0.2664

Table 8:6: Male choice on 3 pairs of female facial models, (original *versus* symmetricised) as most attractive (ASAT). N = 98

Rating	3D facial model	Slide A	Slide B	Slide C
ASAT	Symmetricised	43 (43.9%)	67 (68.4%)	50 (51%)
	Original	55 (56.1%)	31 (31.6%)	48 (49%)
	Total	98 (100%)	98 (100%)	98 (100%)
	Sign test (p-value)	0.2664	**0.0004**	0.9196

Table 8:7: Kendall's and Spearman's rank correlations between FACIAL ASYMMETRY rated rank as most attractive (ASAT) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	z	Tau	S	Rho
ASAT	D	M	2.8956	0.1023**	16703022	0.1269**
		F	7.5634	0.2428***	23492721	0.3066***
	E	M	-3.6208	-0.1278**	22350386	-0.1682**
		F	3.4236	0.1099**	29235315	0.1371**
	F	M	6.4669	0.2284***	13421100	0.2984***
		F	3.2106	0.1031**	29884469	0.1180**

Significant codes ***0, **0.001, *0.05, ¶ = P>0.05

Table 8:8: Analyses of covariance (ANCOVA): FACIAL ASYMMETRY rated rank as most attractive (ASAT) regressed against whole face asymmetry values (WFACE), income and marital status (MS) for individual male-rated slides and individual female-rated slides (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	Adjusted R^2	F-stat	P-value
ASAT	D	M	0.0038	1.267	0.2649
		F	0.1239	12.86	**2.072e-15**
	E	M	-0.0037	0.7413	0.637
		F	0.0942	9.729	**1.754e-11**
	F	M	0.0951	8.285	**1.478e-09**
		F	0.0063	1.532	0.1537

Table 8:9: Statistically significant minimum models of predictors for **WOMEN**'s ranking of men facial scans for facial asymmetry as the most attractive (ASAT).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	4.6508	0.4115	11.302	< 2e-16
WFACE	-3.2706	1.1467	-2.852	0.0045
Adjusted R-squared: 0.0145; F-statistic: 8.135; DF: 1 and 484; **P=0.0045**				
Slide E				
Intercept	2.6749	0.4046	6.611	1.01e-10
WFACE	2.3379	1.1199	2.088	0.0374
Adjusted R-squared: 0.006876; F-statistic: 4.358; DF: 1 and 484; **P=0.0374**				
Slide F				
Intercept	7.332	0.528	13.885	< 2e-16
WFACE	-11.177	1.524	-7.336	9.35e-13
Adjusted R-squared: 0.0982; F-statistic: 53.82; DF: 1 and 484; **P=9.346e-13**				

WFACE: Whole Face Asymmetry.

Table 8:10: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for facial asymmetry as the most attractive (ASAT).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	7.712	0.452	17.060	<2e-16
WFACE	-12.735	1.348	-9.444	<2e-16
Adjusted R-squared: 0.1306; F-statistic: 89.19; DF: 1 and 586; **P<2.2e-16**				
Slide E				
Intercept	2.6048	0.7428	3.507	0.0005
MS(Single)	2.0171	0.7584	2.660	0.0080
MS(Single):WFACE	-3.1794	0.3915	-8.121	2.75e-15
Adjusted R-squared: 0.0994; F-statistic: 22.59; DF: 3 and 584; **P= 7.548e-14**				
Slide F				
Intercept	9.796	2.335	4.195	3.15e-05
MS(Single)	-5.576	2.384	-2.339	0.0197
MS(Married):WFACE	-18.794	6.893	-2.726	0.0066
Adjusted R-squared: 0.0114; F-statistic: 3.258; DF: 3 and 584; **P= 0.02128**				

WFACE: Whole Face Asymmetry; MS: Marital Status

8.3.2.2 Facial asymmetry-symmetry preferences as most likely as marital partner (ASMP)

The analyses of the 3 pairwise slides, results indicate that men only preferred facial symmetry of female slide B as most likely as marital partners (ASMP) with a statistical significance (*P=0.0061*) from the binomial sign test as in **Table 8.11**. Similarly, there was a statistically significant female preference for male facial symmetry of male slides A (*P=0.0036*) and C (*P=0.0073*) as shown in **Table 8.12**. Similar to the findings in the question of facial asymmetry-symmetry as most attractive, significant positive correlations between rating rank and true rank of facial asymmetry were found in male slides D (*tau=0.0792, rho=0.0988, p<0.05*) and F (*tau=0.2351, rho=0.3069, p<0.0001*) but negative in male slide E (*tau=-0.1398, rho=-0.1835, p<0.0001*) from both Spearman's rank rho and Kendall' rank tau (**Table 8.13**). This shows that male individuals with facial symmetry were also more preferred as long-term partners (as in marriage). And the same statistically significant correlations were also obtained in female slides D (*tau=0.0962, rho=0.1239, p<0.01*) and F (*tau=0.0919, rho=0.1043, p<0.0001*) but negative in female slide E (*tau=-0.0711, rho=-0.1050, p<0.05*). Thus men also preferred women with more symmetric faces as long term partners. Although facial asymmetry was preferred as in slide E of both men and women, but the overall results suggest that individuals with facial symmetry were considered to be more suitable future marital partners by both sexes.

Analyses of covariance (ANCOVA) with the rating rank of facial asymmetry as most likely as marital partners (ASMP) [for the individual female-rated or male rated slides] as the dependent variable, whole face asymmetry (WFACE) values (for the individual female-rated or male rated slides) as the independent variable and income/marital status (MS) of the female or male raters as covariates was also carried out with regards to the question of how most likely individuals will be preferred as marital partners (**Table 8.14**).

Women ranking men (slides D, E and F)

For this question, the predictors of the women's rating rank of men's facial symmetry as most likely as marital partner, statistically significant maximum model was obtained for male slide F (*Adjusted R2=0.1014*, *F=8.814, P=3.249e-10*), but insignificant for slides D (*Adjusted R2= -0.0055*, *F=0.6197, P=0.7398*), and E (*Adjusted R2=0.0001*, *F=1.007, P=0.4252*). Model simplification resulted in improved, statistically significant minimum models for all the slides D, E, and F (**Table 8.15**) and also demonstrates WFACE as main predictor for the women's rating rank of male facial symmetry as long term partners.

Men ranking women (slides D, E and F)

In the analyses of the male raters, significant maximum model was found in female slide D (*Adjusted* R^2*=0.0255, F=3.194, P=0.0025*), but not in slides E (*Adjusted* R^2*= -0.0025, F=0.7871, P=0.5983*) and F (*Adjusted* R^2*= -0.0086, F=0.2823, P=0.9609*). Model simplification resulted in improved, statistically significant minimum model for only female slide D (**Table 8.16**) indicating WFACE of the rated females as the major contributing element in predicting men's rating rank of female facial symmetry as most likely as marital partners (*Adjusted* R^2*=0.0343 F=21.86, P=3.64e-06*).

Table 8:11: Female choice on 3 pairs of male facial models, (original *versus* symmetricised) as most likely as marital partner (ASMP). N = 81

Rating	3D facial model	Slide A	Slide B	Slide C
ASMP	Symmetricised	54 (66.7%)	42 (51.9%)	53 (65.4%)
	Original	27 (33.3%)	39 (48.1%)	28 (34.6%)
	Total	81 (100%)	81 (100%)	81 (100%)
	Sign test (p-value)	**0.0036**	0.8243	**0.0073**

Table 8:12: Male choice on 3 pairs of female facial models, (original *versus* symmetricised) as most likely as marital partner (ASMP). N = 98

Rating	3D facial model	Slide A	Slide B	Slide C
ASMP	Symmetricised	46 (46.9%)	63 (64.3%)	54 (55.1%)
	Original	52 (53.1%)	35 (35.7%)	44 (44.9%)
	Total	98 (100%)	98 (100%)	98 (100%)
	Sign test (p-value)	0.6137	**0.0061**	0.3634

Table 8:13: Kendall's and Spearman's rank correlations between FACIAL ASYMMETRY rated rank as most likely as marital partner (ASMP) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	z	Tau	S	Rho
ASMP	D	M	2.2429	0.07923*	17242148	0.09877*
		F	2.9955	0.0962**	29682081	0.1239**
	E	M	-3.9588	-0.1398***	22643409	-0.1835***
		F	-2.209	-0.0711*	37443276	-0.1050*
	F	M	6.6565	0.2351***	13259387	0.3069***
		F	2.8625	0.0919*	30346442	0.1043*

Significant codes ***0, **0.001, *0.05

Table 8:14: Analyses of covariance (ANCOVA): FACIAL ASYMMETRY rated rank as most likely as marital partner (ASMP) regressed against whole face asymmetry values (WFACE), income and marital status (MS) for individual male-rated slides and individual female-rated slides (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	Adjusted R^2	F-stat	P-value
ASMP	D	M	-0.0055	0.6197	0.7398
		F	0.0255	3.194	**0.0025**
	E	M	0.0001	1.007	0.4252
		F	-0.0025	0.7871	0.5983
	F	M	0.1014	8.814	**3.249e-10**
		F	-0.0086	0.2823	0.9609

Table 8:15: Statistically significant minimum models of predictors for **WOMEN**'s ranking of men facial scans for most likely as marital partners (ASMP).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	4.3286	0.4132	10.477	<2e-16
WFACE	-2.3565	1.1514	-2.047	0.0412
Adjusted R-squared: 0.0065; F-statistic: 4.189; DF: 1 and 484; **P= 0.0412**				
Slide E				
Intercept	2.5022	0.4039	6.196	1.24e-09
WFACE	2.7959	1.1178	2.501	0.0127
Adjusted R-squared: 0.0107; F-statistic: 6.257; DF: 1 and 484; **P= 0.0127**				
Slide F				
Intercept	7.4305	0.5265	14.113	< 2e-16
WFACE	-11.4656	1.5192	-7.547	2.22e-13
Adjusted R-squared: 0.1034; F-statistic: 56.96; DF: 1 and 484; **P= 2.224e-13**				

WFACE: Whole Face Asymmetry.

Table 8:16: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for most likely as marital partners (ASMP).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	5.7017	0.4756	11.989	< 2e-16
WFACE	-6.6333	1.4187	11.989	<2e-16
Adjusted R-squared: 0.0343; F-statistic: 21.86; DF: 1 and 586; **P=3.64e-06**				

WFACE: Whole Face Asymmetry.

8.3.2.3 Facial asymmetry-symmetry preferences as most caring (ASCAR)

From the 3 pairwise slides, men preferred facial symmetry only of female slide B as most caring (ASCAR) with a statistical significance (*P=0.0197*) from the binomial sign test as in **Table 8.17**. Similarly, statistically significant women preference for male facial symmetry was only found in male slide A (*P=0.0003*) as shown in **Table 8.18**.

In **Table 8.19**, statistically significant positive Spearman's and Kendall' ranks correlations between rating rank as most caring and true rank of facial asymmetry in male slides D (*tau=0.0992, rho=0.1234, p<0.01*) and F (*tau=0.1878, rho=0.2435, p<0.0001*) were found, but negative correlations in slide E (*tau=-0.1301, rho=-0.1703, p<0.0001*). This result is also similar to the findings in both the most attractive and most likely as marital partner questions, which thus suggests that women are attracted to male individuals with facial symmetry, and will consider them to be suitable future marital partners and feel they will be more caring.

With regards to the female slides in respect to this question, statistically significant positive correlations were also obtained in female slides D (*tau=0.1040, rho=0.1312, p<0.01*) and F (*tau=0.1212, rho=0.1517, p<0.0001*) but insignificant in slide E.

Thus men also rated women with more symmetric faces as most caring and therefore the overall results show that individuals with facial symmetry were considered as most caring by both sexes.

Analyses of covariance (ANCOVA) with the rating rank of facial asymmetry as most caring (ASCAR) [for the individual female-rated or male rated slides] as the dependent variable, whole face asymmetry (WFACE) values (for the individual female-rated or male rated slides) as the independent variable and income/marital status (MS) of the female or male raters as covariates was also carried out with regards to the question of how most likely individuals will be preferred as most caring (**Table 8.20**).

Women ranking men (slides D, E and F)

In this analyses, the predictors of the women's rating rank of men's facial symmetry as most caring, statistically significant maximum model was only obtained for male slide F (*Adjusted* R^2*=0.0641*, *F=5.75, P=2.105e-06*). Male slides D (*Adjusted* R^2*=0.0021, F=1.146, P=0.3328*), and E (*Adjusted* R^2*= -0.0017, F=0.8797, P=0.5223*) returned non-significant full models. Model simplification resulted in improved, statistically significant minimum models for slides D, E, and F (**Table 8.21**) and also shows WFACE of the rated men as the major predictor of the women's rating rank of male facial symmetry as most caring in all the slides.

Men ranking women (slides D, E and F)

With regard to the male raters, significant maximum models were found in female slides E (*Adjusted* R^2*=0.0409, F=4.577, P=5.424e-05*) and F (*Adjusted*

R^2=*0.0133, F=2.13, P=0.0387*) but not D (*Adjusted* R^2=*0.0117, F=1.996, P=0.0536*).

Model simplification resulted in improved, statistically significant minimum models for all the three female slides D, E, and F (**Table 8.22**) demonstrating the significant influence of WFACE of the rated females as the predictor of the men's rating rank of female facial symmetry as most caring in all the slides.

Table 8:17: Female choice on 3 pairs of male facial models, (original *versus* symmetricised) as most caring (ASCAR)). N = 81

Rating	3D facial model	Slide A	Slide B	Slide C
ASCAR	Symmetricised	57 (70.4%)	46 (56.8%)	41 (50.6%)
	Original	24 (29.6%)	35 (43.2%)	40 (49.4%)
	Total	81 (100%)	81 (100%)	81 (100%)
	Sign test (p-value)	**0.0003**	0.2664	1

Table 8:18: Male choice on 3 pairs of female facial models, (original *versus* symmetricised) as most caring (ASCAR). N = 98

Rating	3D facial model	Slide A	Slide B	Slide C
ASCAR	Symmetricised	49 (50%)	61 (62.2%)	44 (44.9%)
	Original	49 (50%)	37 (37.8%)	54 (55.1%)
	Total	98 (100%)	98 (100%)	98 (100%)
	Sign test (p-value)	1	**0.0197**	0.3634

Table 8:19: Kendall's and Spearman's rank correlations between FACIAL ASYMMETRY rated rank as most caring (ASCAR) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	Z	Tau	s	Rho
ASCAR	D	M	2.8093	0.0992**	16770173	0.1234**
		F	3.2415	0.1040**	29435693	0.1312**
	E	M	-3.6844	-0.1301***	22390960	-0.1703***
		F	0.878	0.0281¶	32573424	0.0386¶
	F	M	5.3189	0.1878***	14472360	0.2435***
		F	3.776	0.1212***	28740332	0.1517***

Significant codes ***0, **0.001, *0.05, ¶ = P>0.05

Table 8:20: Analyses of covariance (ANCOVA): FACIAL ASYMMETRY rated rank as most caring (ASCAR) regressed against whole face asymmetry values (WFACE), income and marital status (MS) for individual male-rated slides and individual female-rated slides (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	Adjusted R^2	F-stat	P-value
ASCAR	D	M	0.0021	1.146	0.3328
		F	0.0117	1.996	0.0536
	E	M	-0.0017	0.880	0.5223
		F	0.0409	4.577	**5.424e-05**
	F	M	0.0641	5.748	**2.105e-06**
		F	0.0133	2.132	**0.0387**

Table 8:21: Statistically significant minimum models of predictors for **WOMEN**'s ranking of men facial scans for most caring (ASCAR).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	4.565	0.412	11.079	< 2e-16
WFACE	-3.026	1.148	-2.636	0.0087
Adjusted R-squared 0.0121; F-statistic: 6.947; DF: 1 and 484; **P= 0.0087**				
Slide E				
Intercept	2.6673	0.4046	6.592	1.14e-10
WFACE	2.3596	1.1199	2.107	0.0356
Adjusted R-squared: 0.0070; F-statistic: 4.44; DF: 1 and 484; **P= 0.0356**				
Slide F				
Intercept	6.6192	0.5378	12.307	< 2e-16
WFACE	-9.1014	1.5519	-5.865	8.34e-09
Adjusted R-squared: 0.0644; F-statistic: 34.4; DF: 1 and 484; **P= 8.34e-09**				

WFACE: Whole Face Asymmetry.

Table 8:22: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for most caring (ASCAR).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	5.2026	0.4776	10.894	< 2e-16
WFACE	-5.1847	1.4246	-3.639	0.0003
Adjusted R-squared: 0.0204; F-statistic: 13.24; DF: 1 and 586; **P=0.0003**				
Slide E				
Intercept	4.2765	0.1547	27.652	< 2e-16
WFACE	-2.2096	0.3951	-5.592	3.45e-08
Adjusted R-squared: 0.0490; F-statistic: 31.27; DF: 3 and 584; **P=3.445e-08**				
Slide F				
Intercept	5.0826	0.4699	10.817	< 2e-16
WFACE	-4.7699	1.3871	-3.439	0.0006
Adjusted R-squared: 0.0181; F-statistic: 11.83; DF: 3 and 584; **P= 0.0006**				

WFACE: Whole Face Asymmetry.

8.3.2.4 Facial asymmetry-symmetry preferences as most aggressive (ASAG)

The 3 pairwise slides analyses indicate that men regarded facial asymmetry of female slide B as most aggressive (ASAG) with a statistical significance (*P=0.0002*) from the binomial sign test as in **Table 8.23**. Also, statistically significant women consideration for male facial asymmetry of male slide A (*P=0.0073*) as aggressive was obtained as shown in **Table 8.24**.

In the case of the question pertaining whether individuals with higher facial asymmetry will be more aggressive, result reveals that there was a statistically significant negative correlation between rating rank and true rank of facial asymmetry of the male slide D (*tau=-0.1385, rho=-0.1788, p<0.0001*) only, which means that as the male facial asymmetry (true rank) increases (note: individual with highest facial asymmetry value was ranked 1, lowest ranked 6), rating rank as aggressive decreases, which shows that males with lower facial asymmetry are not considered aggressive to women or vice-versa. Similarly, significant negative correlation was also found between the true rank and the rating rank of the females in slide D (*tau=-0.1593, rho=-0.2029, p<0.0001*) and this also indicates that females with lower facial asymmetry were considered less aggressive to men. However, no significant correlations were obtained between the rating rank and the true rank of slides E and F of both sexes (P>0.05) as in **Table 8.25**.

Analyses of covariance (ANCOVA) with the rating rank of facial asymmetry as most aggressive (ASAG) [for the individual female-rated or male rated slides] as the dependent variable, whole face asymmetry (WFACE) values (for the individual female-rated or male rated slides) as the independent variable and income/marital status (MS) of the female or male raters as covariates was also carried out with regards to the question of how most likely individuals will be considered as most aggressive (**Table 8.26**).

Women ranking men (slides D, E and F)

In this question, the predictors of the women's rating rank of men's facial asymmetry as most aggressive, statistically significant maximum model was only obtained for male slide D (*Adjusted R2=0.0265; F=2.89, P=0.0057*). Male slides E (*Adjusted* R^2*=0.0037; F=1.26, P=0.2683*) and F (*Adjusted* R^2*= -0.0046; F=0.6819, P=0.6875*) returned non-significant full models. Model simplification resulted in improved, statistically significant minimum models only for male slides D (*Adjusted* R^2*=0.03405; F=18.1, P=2.521e-05*), and E (*Adjusted* R^2*=0.0076; F=2.865, P=0.0579*). The models demonstrates the significant influence of WFACE of the rated men in slide D in predicting women's rating rank of male facial asymmetry as most aggressive, as well as the influence of income of the female raters and the interaction effect of WFACE (of the rated men) and income in slide E (**Table 8.27**).

Men ranking women (slides D, E and F)

In case of the male raters, significant maximum model was only obtained in female slide D (*Adjusted* R^2*=0.0527, F=5.669, P=2.382e-06*) but not E (*Adjusted* R^2*= -0.0044, F=0.6297, P=0.7315*) and F (*Adjusted* R^2*=-0.0066, F=0.4423, P=0.8755*). Model simplification resulted in improved, statistically significant minimum model for female slide D only revealing that WFACE of the rated females predicts the men's rating rank of the female facial asymmetry as most aggressive more significantly than a combination of income and marital status (*Adjusted* R^2*=0.0608, F=39.03, P=8.04e-10*) as shown in **Table 8.28**.

Table 8:23: Female choice on 3 pairs of male facial models, (original *versus* symmetricised) as most aggressive (ASAG). N = 81

Rating	3D facial model	Slide A	Slide B	Slide C
ASAG	Symmetricised	28 (34.5%)	36 (44.4%)	48 (59.3%)
	Original	53 (65.5%)	45 (55.6%)	33 (40.7%)
	Total	81 (100%)	81 (100%)	81 (100%)
	Sign test (p-value)	**0.0073**	0.3742	0.1193

Table 8:24: Male choice on 3 pairs of female facial models, (original *versus* symmetricised) as most aggressive (ASAG). N = 98

Rating	3D facial model	Slide A	Slide B	Slide C
ASAG	Symmetricised	50 (51%)	30 (30.6%)	52 (53.1%)
	Original	48 (49%)	68 (69.4%)	46 (46.9%)
	Total	98 (100%)	98 (100%)	98 (100%)
	Sign test (p-value)	0.9196	**0.0002**	0.6137

Table 8:25: Kendall's and Spearman's rank correlations between FACIAL ASYMMETRY rated rank as most aggressive (ASAG) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	z	Tau	S	Rho
ASAG	D	M	-3.9234	-0.1385***	22553248	-0.1788***
		F	-4.9636	-0.1593***	40757586	-0.2029***
	E	M	-1.056	-0.0373¶	20035505	-0.0472¶
		F	2.3458	0.0753¶	30810017	0.0907¶
	F	M	-1.3759	-0.0486¶	20301111	-0.0611¶
		F	-1.559	-0.0500¶	36095569	-0.0653¶

Significant codes ***0, ¶ = P>0.05

Table 8:26: Analyses of covariance (ANCOVA): FACIAL ASYMMETRY rated rank as most aggressive (ASAG) regressed against whole face asymmetry values (WFACE), income and marital status (MS) for individual male-rated slides and individual female-rated slides (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated scans in the slide	Adjusted R^2	F-stat	P-value
ASAG	D	M	0.0265	2.888	**0.0057**
		F	0.0527	5.669	**2.382e-06**
	E	M	0.0037	1.26	0.2683
		F	-0.0044	0.6297	0.7315
	F	M	-0.0046	0.6819	0.6875
		F	-0.0066	0.4423	0.8755

Table 8:27: Statistically significant minimum models of predictors for **WOMEN**'s ranking of men facial scans for facial asymmetry as most aggressive (ASAG).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	1.7999	0.4068	4.424	1.20e-05
WFACE	4.8229	1.1337	4.254	2.52e-05
Adjusted R-squared: 0.03405; F-statistic: 18.1; DF: 1 and 484; **P= 2.521e-05**				
Slide E				
Intercept	3.466e+00	1.553e-01	22.324	<2e-16
INCOME	-2.616e-06	1.238e-06	--2.114	0.0350
WFACE:INCOME	7.731e-06	3.252e-06	2.377	0.0178
Adjusted R-squared: 0.0076; F-statistic: 2.865; DF: 2 and 483; **P= 0.0579**				

WFACE: Whole Face Asymmetry.

Table 8:28: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for facial asymmetry as most aggressive (ASAG).

Coefficient	Estimate	Std error	t-value	P-value
Slide D				
Intercept	0.5978	0.4696	1.273	0.204
WFACE	8.7504	1.4007	6.247	8.04e-10
Adjusted R-squared: 0.0608; F-statistic: 39.03; DF: 1 and 586; **P= 8.04e-10**				

WFACE: Whole Face Asymmetry.

8.3.3 Analysis VI: Facial masculinity-femininity preferences

8.3.3.1 Facial masculinity-femininity preferences as most attractive (MAT)

From **Table 8.29**, there were significant negative correlations from both Spearman's rank rho and Kendall' rank tau between rated rank of facial masculinity as most attractive (MAT) and true rank of all the male slides G (*tau=-0.1249, rho=-0.1560, p<0.01*), H (*tau=-0.2170, rho=-0.2921, p<0.0001*) and I (*tau=-0.3578, rho=-0.4405, p<0.0001*). This shows that as men facial masculinity true ranking increases (*that is men with more masculine faces*) [note: individual with lowest facial masculinity score was ranked 1, highest was ranked 6], rating rank as the most attractive (note: individual ranked the least attractive was scored 1, the most attractive was scored 6) decreases, and therefore *men with higher facial masculinity were less attractive to women than men with less masculine faces*. Similarly, significant negative correlations were obtained in female slides G (*tau=-0.1178, rho=-0.1592, p<0.01*), and H (*tau=-0.2913, rho=-0.3639, p<0.0001*), but slide I correlation was insignificant. This shows that as female facial masculinity true ranking increases (*that is women with more masculine faces*) [note: woman with lowest facial masculinity score was also ranked 1, highest was ranked 6], rating rank as the most attractive (note: woman ranked the least attractive was also scored 1, the most attractive was ranked 6) decreases, and therefore wo*men with higher facial masculinity were less attractive to men than women with less masculine faces*. The overall results therefore signify that facial femininity is more attractive to both men and women in the study.

Analyses of covariance (ANCOVA) was conducted with rated rank of facial masculinity as attractive (MAT) [for the individual female-rated or male rated slides] as the dependent variable, masculinity score (MAS.SC) [for the individual female-rated or male rated slides] as the independent variable and income/marital status (MS) of the female or male raters as covariates (**Table 8.30**).

Women ranking men (slides G, H and I)

For the predictors of the women's rating rank of men's facial masculinity as most attractive, statistically significant maximum models were obtained for male slides H (*Adjusted* R^2*=0.1561, F=13.82, P=2.453e-16*) and I (*Adjusted* R^2*=0.2019, F=18.53, P< 2.2e-16*) but not G (*Adjusted* R^2*=0.0007, F=1.047, P=0.3969*).

Model simplification resulted in improved, statistically significant minimum models for all the men slides G, H, and I (**Table 8.31**). Facial masculinity scores (MAS.SC) of the rated men (but not income or MS) was the significant contributing element in slides G (*Adjusted* R^2*=0.0117, F=6.76, P=0.0096*) and H (*Adjusted* R^2*=0.1602, F=93.05, P<2e-16*) and therefore the best predictor for the women's rating rank of male facial masculinity as most attractive. In slide I, MAS.SC and income (but not marital status) were significant including their significant interaction effect (*Adjusted* R^2*=0.2045, F=42.57, P<2e-16*).

Men ranking women (slides G, H and I)

For the male raters, significant maximum models were obtained for female slides G (*Adjusted* R^2*=0.0388, F=4.387, P=9.302e-05*) and H (*Adjusted* R^2*=0.056, F=5.975, P=9.84e-07*) but not I (*Adjusted* R^2*= -0.0096, F=0.199, P=0.9856*). Model simplification resulted in improved, statistically significant minimum models for slides G (*Adjusted* R^2*= 0.0402, F=9.197, P=5.938e-06*), and H (*Adjusted* R^2*= 0.0599, F=38.41, P=1.082e-09*) as in **Table 8.32**. The masculinity scores

(MAS.SC) of the rated females in both slides was shown to be the best predictor of men's ranking of women's facial masculinity as most attractive.

Table 8:29: Kendall's and Spearman's rank correlations between FACIAL MASCULINITY rated rank as the most attractive (MAT) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated slide	Z	tau	S	Rho
MAT	G	M	-3.5351	-0.1249**	22117113	-0.1560**
		F	-3.6702	-0.1178**	39276405	-0.1592**
	H	M	-6.1437	-0.2170***	24720449	-0.2921***
		F	-9.0738	-0.2913***	46212048	-0.3639***
	I	M	-10.1295	-0.3578***	27558638	-0.4405***
		F	1.0004	0.0321	32480085	0.0414

Significant codes ***0, **0.001, *0.01

Table 8:30: Analyses of covariance (ANCOVA): rating rank of facial masculinity as most attractive (MAT) regressed against facial masculinity scores (MAS.SC), income and marital status (MS) for all male-rated slides and female-rated slides and for individual male-rated slides and individual female-rated slides

Items	Slides	Sex of the rated scans	Adjusted R^2	F-stat	P-value
MAT	G	M	0.0007	1.047	0.3969
		F	0.0388	4.387	**9.302e-05**
	H	M	0.1561	13.82	**2.453e-16**
		F	0.056	5.975	**9.84e-07**
	I	M	0.2019	18.53	**< 2.2e-16**
		F	-0.0096	0.199	0.9856

Table 8:31: Statistically significant minimum models of predictors for **WOMEN**'s ranking of men facial scans for facial masculinity as most attractive.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	3.9386	0.1884	20.91	< 2e-16
MAS.SC	-0.7064	0.2717	-2.60	0.0096
Adjusted R-squared: 0.0117; F-statistic: 6.76; DF: 1 and 484; **P=0.0096**				
Slide H				
Intercept	5.1720	0.1855	27.874	<2e-16
MAS.SC	-3.1585	0.3266	-9.669	<2e-16
Adjusted R-squared: 0.1602; F-statistic: 93.5; DF: 1 and 484; **P < 2.2e-16**				
Slide I				
Intercept	4.217e+00	3.227e-01	13.067	< 2e-16
MAS.SC	-1.397e+00	5.737e-01	-2.435	0.0152
INCOME	2.864e-06	9.334e-07	3.069	0.0023
MAS.SC:INCOME	-5.641e-06	1.659e-06	-3.399	0.0007
Adjusted R-squared: 0.2045; F-statistic: 42.57; DF: 3 and 482; **P < 2.2e-16**				

MAS.SC: Masculinity scores.

Table 8:32: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for facial masculinity as most attractive.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	2.8517	0.6704	4.254	2.45e-05
MAS.SC:MS(S)	-1.6585	0.3232	-5.131	3.93e-07
Adjusted R-squared: 0.0402; F-statistic: 9.197; DF: 3 and 584; **P=5.938e-06**				
Slide H				
Intercept	4.2605	0.1402	30.388	< 2e-16
MAS.SC	-1.9216	0.3101	-6.197	1.08e-09
Adjusted R-squared: 0.0599; F-statistic: 38.41; DF: 1 and 586; **P=1.082e-09**				

MAS.SC: Masculinity scores.

8.3.3.2 Facial masculinity-femininity preferences as most likely as marital partner (MMP)

In **Table 8.33**, both Spearman's rank rho and Kendall' rank tau analyses returned a statistically significant negative correlations between rated rank of facial masculinity as most likely as marital partners (MMP) in the male slides G (*tau=-0.1214, rho=-0.1518, p<0.01*), and H (*tau=-0.2152, rho=-0.2907, p<0.0001*) but positive in slide I (*tau=0.3515, rho=-0.1362, p<0.0001*). This therefore indicates that as men facial masculinity true ranking increases rating rank as the most likely as marital partner decreases, and therefore *men with lower facial masculinity (i.e., men with more feminine faces) were more preferred as long term partners to women than men with more masculine faces*. *In contrast, men with higher facial masculinity were more preferred as long term partners in slide I*. In the female slides, significant negative correlations were also found in slides G (*tau=-0.0889, rho=-0.1207, p<0.05*), and H (*tau=-0.2899, rho=-0.3646, p<0.0001*), with insignificant correlations in slide I. This shows that as female facial masculinity true ranking increases (*that is women with more masculine faces*) rating rank as the most likely as marital partner decreases and therefore wo*men with lower facial masculinity (i.e., women with more feminine faces) were more preferred as long term partners to men than women with more masculine faces*.

Analyses of covariance (ANCOVA) was conducted with rated rank of facial masculinity as most likely as marital partner (MMP) [for the individual female-rated or male rated slides] as the dependent variable, masculinity score (MAS.SC) [for the individual female-rated or male rated slides] as the independent variable and income/marital status (MS) of the female or male raters as covariates (**Table 8.34**).

Women ranking men (slides G, H and I)

Here, the predictors of the women's rating rank of men's facial masculinity as most likely as marital partners, statistically significant maximum model was found for male slides H (*Adjusted* R^2*=0.156, F=13.81, P=2.545e-16*) and I (*Adjusted* R^2*=0.1998, F=18.3, P< 2.2e-16*) but male slide G (*Adjusted R2= -0.0002, F=0.983, P=0.4426*) returned non-significant full model. Model simplification resulted in improved, statistically significant minimum models for slides G (*Adjusted* R^2*=0.0107, F=6.237, P=0.0128*), H (*Adjusted* R^2*=0.16, F=93.4, P< 2.2e-16*), and I (*Adjusted* R^2*=0.2024, F=42.03, P<2.2e-16*) The minimum models also show that masculinity scores (MAS.SC) of the rated men significantly predicts the women's rating rank of men's facial masculinity as most likely as marital partners in slide G and H. However, in slide I, MAS.SC of the rated men and income of the women raters also significantly predicts women's rating rank (*F=113.94, P< 2.2e-16*) with an additional interaction effect between MAS.SC of the rated men and the income of the ranking women (**Table 8.35**).

Men ranking women (slide G, H and I)

With regard to the male raters, significant maximum models were also found for female slides G (*Adjusted* R^2*=0.0322, F=3.789, P=0.0005*) and H (*Adjusted* R^2*=0.0624, F=6.583, P=1.688e-07*) but slide I (*Adjusted* R^2*= -0.0083, F=0.318, P=0.946*) returned non-significant full model. Model simplification resulted in improved, statistically significant minimum models for slides G (*Adjusted* R^2*=0.0332, F=7.713, P=4.635e-05*), and H (*Adjusted* R^2*=0.0589, F=13.26, P=2.211e-08*) as in **Table 8.36**.

The model indicates that masculinity scores (MAS.SC) of the ranked women and the income of the men raters significantly predict men's rating rank of women's facial masculinity as most likely as marital partners in slide G (*F= 15.84, P=7.76e-05*) with an additional significant interaction effect between MAS.SC and income. In slide H, only MAS.SC was a significant predictor of the men's rating rank.

Table 8:33: Kendall's and Spearman's rank correlations between FACIAL MASCULINITY rated rank as most likely as marital partner (MMP) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated slide	Z	tau	S	Rho
MMP	G	M	-3.4355	-0.1214**	22036881	-0.1518**
		F	-2.7685	-0.0889*	37972460	-0.1207*
	H	M	-6.0919	-0.2152***	24693371	-0.2907***
		F	-9.028	-0.2899***	46235433	-0.3646***
	I	M	-10.0368	-0.3545***	27477490	-0.4362***
		F	-0.2154	-0.0070	33127409	-0.0082

Significant codes ***0, **0.001, *0.01

Table 8:34: Analyses of covariance (ANCOVA): rating rank of facial masculinity as most likely as marital partner (MMP) regressed against facial masculinity scores (MAS.SC), income and marital status (MS) for all male-rated slides and female-rated slides and for individual male-rated slides and individual female-rated slides

Items	Slides	Sex of the rated scans	Adjusted R^2	F-stat	P-value
MMP	G	M	-0.0002	0.983	0.4426
		F	0.0322	3.789	**0.0005**
	H	M	0.156	13.81	**2.545e-16**
		F	0.0624	6.583	**1.688e-07**
	I	M	0.1998	18.3	**< 2.2e-16**
		F	-0.0083	0.318	0.946

Table 8:35: Statistically significant minimum models of predictors for WOMEN's ranking of men facial scans for facial masculinity as most likely as marital partners.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	3.9212	0.1885	20.807	<2e-16
MAS.SC	-0.6789	0.2718	-2.497	0.0128
Adjusted R-squared: 0.0107; F-statistic: 6.237; DF: 1 and 484; **P= 0.0128**				
Slide H				
Intercept	5.1712	0.1856	27.868	<2e-16
MAS.SC	-3.1571	0.3267	-9.664	<2e-16
Adjusted R-squared: 0.16; F-statistic: 93.4; DF: 1 and 484; **P < 2.2e-16**				
Slide I				
Intercept	4.197e+00	3.231e-01	12.988	< 2e-16
MAS.SC	-1.358e+00	5.745e-01	-2.364	0.0185
INCOME	2.896e-06	9.347e-07	3.098	0.0021
MAS.SC:INCOME	-5.703e-06	1.662e-06	-3.432	0.0007
Adjusted R-squared: 0.2024; F-statistic: 42.03; DF: 3 and 482; **P < 2.2e-16**				

MAS.SC: Masculinity scores.

Table 8:36: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for facial masculinity as most likely as marital partners.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	4.265e+00	1.874e-01	22.764	< 2e-16
MAS.SC	-2.078e+00	4.379e-01	-4.746	2.61e-06
INCOME	-1.064e-06	4.584e-07	-2.321	0.0206
MAS.SC:INCOME	2.891e-06	1.071e-06	2.699	0.0072
Adjusted R-squared: 0.0332; F-statistic: 7.713; DF: 3 and 584; **P= 4.635e-05**				
Slide H				
Intercept	4.262e+00	1.404e-01	30.363	< 2e-16
MAS.SC	-1.849e+00	3.425e-01	-5.400	9.69e-08
Adjusted R-squared: 0.0589; F-statistic: 13.26; DF: 3 and 584; **P=2.211e-08**				

MAS.SC: Masculinity scores.

8.3.3.3 Facial masculinity-femininity preferences as most caring (MCAR)

Spearman's rank rho and Kendall' rank tau analyses were also conducted (**Table 8.37**) and returned a statistically significant negative correlations between rated rank of facial masculinity as most caring (MCAR) in all the male slides G (*tau=-0.1146, rho=-0.1433, p<0.01*), H (*tau=-0.2168, rho=-0.2921, p<0.0001*) and I (*tau=-0.3487, rho=-0.4292, p<0.0001*). This also demonstrates that as men facial masculinity true ranking increases, rating rank as the most caring decreases, and therefore *men with lower facial masculinity (i.e., men with more feminine faces) were more preferred as more caring to women than men with more masculine faces*. In the female slides, significant negative correlations were also found in only two slides G (*tau=-0.1795, rho=-0.2350, p<0.0001*), and H (*tau=-0.2743, rho=-0.3488, p<0.0001*), with an insignificant correlations in slide I. This also indicates that as female facial masculinity true ranking increases (*that is women with more masculine faces*), rating rank as the most caring decreases, and thus wo*men with lower facial masculinity (i.e., women with more feminine faces) were regarded as more caring to men than women with more masculine faces*.

From the analyses of covariance (ANCOVA) with rated rank of facial masculinity as most caring (MCAR) [for the individual female-rated or male rated slides] as the dependent variable, masculinity score (MAS.SC) [for the individual female-rated or male rated slides] as the independent variable and income/marital status (MS) of the female or male raters as covariates, maximum models were obtained (**Table 8.38**).

Women ranking men (slides G, H and I)

Here, the predictors of the women's rating rank of men's facial masculinity as most likely as most caring, statistically significant maximum model was found for male slides H (*Adjusted* R^2*=0.1559, F=13.8, P=2.624e-16*) and I (*Adjusted* R^2*=0.1943, F=17.7, P< 2.2e-16*) but G (*Adjusted R2= -0.0015; F=0.899,* *P=0.5072*) returned non-significant full model. Model simplification resulted in improved, statistically significant minimum models for all the slides G (*Adjusted R2=0.010; F=5.53, P=0.0191*), H (*Adjusted R2=0.1599; F=93.32, P<2.2e-16*), and I (*Adjusted R2= 0.1968; F=40.61, P<2.2e-16*) as in **Table 8.39**. The most contributing factor in the minimum model was the masculinity scores (MAS.SC) of the rated males in both slide G and H. However, MAS.SC, income and the interaction between MAS.SC & income were all significant predictors of women's rating rank of men's facial masculinity as most caring.

Men ranking women (slides G, H and I)

With regard to the male raters, significant maximum models were found in all the female slides G (*Adjusted* R^2*=0.0732, F=7.626, P=8.077e-09*)**,** H (*Adjusted* R^2*=0.0672, F=7.042, P=4.427e-08*) and I (*Adjusted* R^2*=0.0144, F=2.227, P=0.0307*). Model simplification resulted in improved, statistically significant minimum models for female slides G (*Adjusted R2=0.070, F=15.67, P=8.129e-10*) and H (*Adjusted* R^2*=0.0741, F=47.94, P=1.158e-11*) with marginal significance in I (*Adjusted* R^2*=0.0074, F=2.462, P=0.0616*) as in **Table 8.40**. Minimum model shows that MAS.SC of the rated females predicts the men's rating rank of female facial masculinity as most caring better than the combined income and marital status of the male raters for both female slides G and H.

Table 8:37: Kendall's and Spearman's rank correlations between FACIAL MASCULINITY rated rank as the most caring (MCAR) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated slide	Z	Tau	S	Rho
MCAR	G	M	-3.2437	-0.1146**	21874335	-0.1433**
		F	-5.591	-0.1795***	41844781	-0.2350***
	H	M	-6.1382	-0.2168***	24720866	-0.2921***
		F	-8.5448	-0.2743***	45700190	-0.3488***
	I	M	-9.8729	-0.3487	27343187	-0.4292***
		F	-0.2783	-0.0089	34258192	-0.0111

Significant codes ***0, **0.001, *0.01

Table 8:38: Analyses of covariance (ANCOVA): rating rank of facial masculinity as most caring (MCAR) regressed against facial masculinity scores (MAS.SC), income and marital status (MS) for all male-rated slides and female-rated slides and for individual male-rated slides and individual female-rated slides

Items	Slides	Sex of the rated scans	Adjusted R^2	F-stat	P-value
MCAR	G	M	-0.0015	0.899	0.5072
		F	0.0732	7.626	**8.077e-09**
	H	M	0.1559	13.8	**2.624e-16**
		F	0.0672	7.042	**4.427e-08**
	I	M	0.1943	17.7	**< 2.2e-16**
		F	0.0144	2.227	**0.0307**

Table 8:39: Statistically significant minimum models of predictors for WOMEN's ranking of men facial scans for facial masculinity as most caring.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	3.8964	0.1886	20.661	<2e-16
MAS.SC	-0.6397	0.2720	-2.352	0.0191
Adjusted R-squared: 0.010; F-statistic: 5.53; DF: 1 and 484; **P= 0.0191**				
Slide H				
Intercept	5.1707	0.1856	27.86	<2e-16
MAS.SC	-3.1560	0.3267	-9.66	<2e-16
Adjusted R-squared: 0.1599; F-statistic: 93.32; DF: 1 and 484; **P < 2.2e-16**				
Slide I				
Intercept	4.143e+00	3.243e-01	12.777	< 2e-16
MAS.SC	-1.252e+00	5.765e-01	-2.173	0.0302
INCOME	2.981e-06	9.380e-07	3.178	0.0016
MAS.SC:INCOME	-5.870e-06	1.667e-06	-3.520	0.0005
Adjusted R-squared: 0.1968; F-statistic: 40.61; DF: 3 and 482; **P < 2.2e-16**				

MAS.SC: Masculinity scores.

Table 8:40: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for facial masculinity as most caring.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	3.1967	0.6600	4.844	1.64e-06
MAS.SC:MS(S)	-2.1755	0.3182	-6.837	2.05e-11
Adjusted R-squared: 0.070; F-statistic: 15.67; DF: 3 and 584; P= 8.129e-10				
Slide H				
Intercept	4.3435	0.1392	31.198	<2e-16
MAS.SC	-2.1318	0.3079	-6.924	1.16e-11
Adjusted R-squared: 0.0741; F-statistic: 47.94; DF: 1 and 586; P=1.158e-11				
Slide I				
Intercept	3.257e+00	1.689e-01	19.289	< 2e-16
INCOME	9.902e-07	4.345e-07	2.279	0.02304
INCOME:MAS.SC	-2.160e-06	7.946e-07	-2.718	0.00676
Adjusted R-squared: 0.0074; F-statistic: 2.462; DF: 3 and 584; **P=0.06162**				

MAS.SC: Masculinity scores.

8.3.3.4 Facial masculinity-femininity preferences as most aggressive (MAG)

In this question of whether facial masculinity will be regarded as most aggressive, Spearman's rank rho and Kendall' rank tau analyses were also conducted (**Table 8.41**) and returned a statistically significant positive correlations between rated rank of facial masculinity as most aggressive (MAG) in only two male slides H (*tau=0.1745, rho=0.2244, p<0.0001*), and I (*tau=0.1901, rho=0.2333, p<0.0001*) with insignificant correlations in slide G. This however demonstrates that as men's facial masculinity true ranking increases [note: individual with lowest facial masculinity was ranked 1, highest was ranked 6], rating rank as the most aggressive also increases (note: scan ranked the least aggressive was scored 1, the most aggressive was ranked 6), and therefore *men with higher facial masculinity were considered as more aggressive to women than men with less masculine faces*. In the female slides, significant positive correlations were also found in only two slides G (*tau=0.0855, rho=0.1131, p<0.01*), and H (*tau=0.2134, rho=0.2695, p<0.0001*), with an insignificant correlations in slide I. This also indicates that as female facial masculinity true ranking increases (*that is women with more masculine faces*) [note: woman with lowest facial masculinity score was ranked 1, highest ranked 6], rating rank as the most aggressive (note: woman ranked the least was scored 1, the most was ranked 6) increases, and therefore wo*men with higher facial masculinity were regarded as more aggressive to men than women with less masculine faces*.

From the analyses of covariance (ANCOVA), with rated rank of facial masculinity as most aggressive (MAG) [for the individual female-rated or male rated slides] as the dependent variable, masculinity score (MAS.SC) [for the individual female-rated or male rated slides] as the independent variable and income/marital status

(MS) of the female or male raters as covariates, maximum models were obtained (**Table 8.42**).

Women ranking men (slides G, H and I)

Here, the predictors of the women's rating rank of men's facial masculinity as most aggressive, statistically significant maximum models were found for male slides H (*Adjusted* R^2*=0.0705, F=6.257, P=4.914e-07*) and I (*Adjusted* R^2*=0.0619, F=5.573, P=3.462e-06*). However, male slide G (*Adjusted R2= -0.0104; F=0.288, P=0.9587*) returned non-significant full model. Model simplification resulted in improved, statistically significant minimum models for the 2 slides H (*Adjusted R2=0.0770; F=41.48, P=2.875e-10*), and I (*Adjusted R2=0.0662; F=12.46, P=7.315e-08*) as shown in **Table 8.43**. The minimum models show that masculinity scores (MAS.SC) of the rated males predict the women's rating rank of male facial masculinity as most aggressive better in slide H but income and interaction of MAS.SC and income slide I.

Men ranking women (slide G, H, and I)

With regard to the male raters, significant maximum models were also found only in female slides G (*Adjusted* R^2*=0.0166, F=2.416, P=0.0191*) and H (*Adjusted* R^2*=0.0406, F=4.549, P=5.874e-05*). However, female slide I (*Adjusted R2= -0.0004; F=0.963, P=0.4577*) returned non-significant full model. Model simplification resulted in improved, statistically significant minimum models for the 2 slides G (*Adjusted R2=0.0173; F=6.156, P=0.0023*), and H (*Adjusted R2=0.0436; F=27.76, P=1.931e-07*) as shown in Table 8.43.The minimum models show that MAS.SC of the rated females was the most contributing element in the 2 models and thus predicts the men's rating rank of female facial masculinity as most aggressive better than the maximum model as in **Tables 8.44**.

Table 8:41: Kendall's and Spearman's rank correlations between FACIAL MASCULINITY rated rank as the most aggressive (MAG) and true rank within individual slides of females rated by males and males rated by females (n = 179: females, 81; males, 98).

Items	Slides	Sex of the rated slide	Z	Tau	S	Rho
MAG	G	M	-0.6383	-0.0225	19678336	-0.0286
		F	2.663	0.0855**	30050006	0.1131**
	H	M	4.94	0.1745***	14837776	0.2244***
		F	6.6493	0.2135***	24749816	0.2695***
	I	M	5.3839	0.1901***	14668991	0.2333***
		F	0.9686	0.0311	32606990	0.0377

Significant codes ***0, **0.001, *0.01

Table 8:42: Analyses of covariance (ANCOVA): rating rank of facial masculinity as most aggressive (MAG) regressed against facial masculinity scores (MAS.SC), income and marital status (MS) for all male-rated slides and female-rated slides and for individual male-rated slides and individual female-rated slides

Items	Slides	Sex of the rated scans	Adjusted R^2	F-stat	P-value
MAG	G	M	-0.0104	0.288	0.9587
		F	0.0166	2.416	**0.0191**
	H	M	0.0705	6.257	**4.914e-07**
		F	0.0406	4.549	**5.874e-05**
	I	M	0.0619	5.573	**3.462e-06**
		F	-0.0004	0.963	0.4577

Table 8:43: Statistically significant minimum models of predictors for **WOMEN**'s ranking of men facial scans for facial masculinity as most aggressive.

Coefficient	Estimate	Std error	t-value	P-value
Slide H				
Intercept	2.3302	0.1952	11.937	<2e-16
MAS.SC	2.2133	0.3436	6.441	2.87e-10
Adjusted R-squared: 0.0770; F-statistic: 41.48; DF: 1 and 484; **P**=**2.875e-10**				
Slide I				
Intercept	3.640e+00	3.494e-01	10.418	< 2e-16
INCOME	-3.139e-06	1.011e-06	-3.106	0.0020
MAS.SC:INCOME	6.156e-06	1.797e-06	3.427	0.0007
Adjusted R-squared: 0.0662; F-statistic: 12.46; DF: 3 and 482; **P**=**7.315e-08**				

MAS.SC: Masculinity scores.

Table 8:44: Statistically significant minimum models of predictors for **MEN**'s ranking of women facial scans for facial masculinity as most aggressive.

Coefficient	Estimate	Std error	t-value	P-value
Slide G				
Intercept	3.0917	0.1371	22.56	<2e-16
MAS.SC:MS(S)	1.1284	0.3221	3.503	0.0005
Adjusted R-squared: 0.0173; F-statistic: 6.156; DF: 2 and 585; **P**= **0.0023**				
Slide H				
Intercept	2.8493	0.1414	20.149	< 2e-16
MAS.SC	1.6478	0.3127	5.269	1.93e-07
Adjusted R-squared: 0.0436; F-statistic: 27.76; DF: 1 and 586; **P**= **1.931e-07**				

MAS.SC: Masculinity scores.

8.4 Discussion

8.4.1 Facial asymmetry-symmetry preferences

8.4.1.1 Symmetry preferences

The present study used both manipulated (symmetricised) and un-manipulated (asymmetric) faces of both men and women. And in keeping with previous studies, individuals with symmetric faces were on average preferred in all the three rated items, that is: most attractive, most likely as marital partners or most caring and facial asymmetry was regarded as most aggressive. Therefore facial symmetry preferences (FSP) in this study of asymmetry, has further complemented the previous studies.

In the literature, variation in the facial attractiveness rating between sexes was shown to exist, where women's ratings of facial attractiveness of men appear to vary more than men's ratings of women, as personal circumstances such as menstrual-cycle, pursuit of short/long-term relationships, and trade-off between attractiveness and material gains in mate choice play a more significant role in women's ratings more than men's (Wiederman and Dubois, 1998). However, some authors have shown that FSP as attractive are similar for both male and female faces [e.g., (Little and Jones, 2006)], and the findings of the current study also indicated the same.

The fact that facial symmetry is more attractive in this and other studies (Grammer and Thornhill, 1994, Perrett *et al.*, 1999, Scheib *et al.*, 1999, Jones *et al.*, 2001, Simmons *et al.*, 2004, Peters *et al.*, 2007, Rhodes *et al.*, 2007, Currie and Little, 2009, Zaidel and Hessamian, 2010, Pisanski and Feinberg, 2013) and reviews in (Gangestad and Scheyd, 2005, Johnston, 2006, Wade, 2010, Little *et al.*, 2014), further supports the hypothesis that facial symmetry and facial attractiveness are inter-related.

Facial symmetry preference is known to emanate from facial attractiveness, and a person's facial symmetry reflects their high genetic quality (Jones *et al.*, 2001) and heterozygosity (Roberts *et al.*, 2005), which are both important markers of general health (Shackelford and Larsen, 1997b, Shackelford and Larsen, 1999, Thornhill and Gangestad, 1999, Rhodes *et al.*, 2001b, Rhodes *et al.*, 2007), and thus facial attractiveness remains also a marker of general health. As in this study, FSP as most likely as marital partners may have evolved because of direct benefit of high quality genes transfer to offspring from preference of symmetric mate, which are essential for the offspring survival or may be due to the greater parental investment ability of symmetrical individuals.

Whereas some previous studies only reported symmetric preferences for male faces [e.g., (Komori *et al.*, 2009) but reviewed in (Weeden and Sabini, 2005, Honn and Gernot, 2007)], in the current study, both symmetric male and symmetric female faces were preferred, possibly due to methodological variations. While others [e.g., (Komori *et al.*, 2009)] used real facial images, the current study created symmetric facial stimuli by merging an original face and its mirror image similar to others [reviewed in (Rhodes, 1998)] which also demonstrated similar findings to the current study.

8.4.1.2 Predictors of facial symmetry preferences (FSP)

In the 2nd rating method, where 6 individuals (males or females with wider range of facial asymmetry values) were presented to the raters, both sexes preferred faces with lower facial asymmetry values, that is more symmetrical faces as attractive, as marital partners or as caring faces than those with higher values.

In both sexes, attractiveness covaried with the degree of symmetry, because the association between the average facial attractiveness scores and facial asymmetry values was negative and significant in both sexes which means the lower the facial asymmetry value, the more the face is rated as attractive.

In the literature, FSP by both men and women has an evolutionary advantage, an evolutionary adaptation mechanism to identify mates with higher phenotypic and genetic quality [e.g.,(Thornhill and Gangestad, 1999, Little and Jones, 2003) but reviewed in (Little *et al.*, 2014)]. Such a mechanism reflects selection pressures on partner choice, which are in turn responsible for the general FSP (Little and Jones, 2003, Little and Jones, 2006). And if individuals with higher facial symmetry are of higher quality and appear healthy to the perceivers [e.g., (Jones *et al.*, 2001, Rhodes *et al.*, 2007)] then, FSP is expected to be greater in environments with higher pathogen loads (Little *et al.*, 2011c, Young *et al.*, 2011) such as the environment where the present study was conducted. However, from the findings of the current study, FSP was not due to pathogen loads, because no association was found between whole face asymmetry (WFACE) and the total disease loads of the participants (**see chapter 6, analysis II**) but may most likely be due to markers of health risks such as body mass index (BMI) and systolic blood pressure as they associated with WFACE in the present study.

Moreover, as BMI is shown to be one of the predictors of female facial attractiveness (Hume and Montgomerie, 2001) and of men's choice as a partner (Kurzban and Weeden, 2005) this further suggest the importance of BMI as a strong biological marker of facial attractiveness.

Facial asymmetry (WFACE) of the rated participants was the single most important predictor of rated rank for the majority of the ranked individuals in the study. Although marital status of the raters had some influence in predicting their choice of facial symmetry as most attractive, most likely as marital partners or most caring, single men ranked more symmetrical women more favorably than the married men. The fact that most of the single men in the study were younger and in their youthful exuberance than the un-married, higher androgen levels in their ages might be the influencing factor in their favorable ranking.

8.4.2 Facial masculinity-femininity preferences

8.4.2.1 Women's preference in men's faces

In this study, women preferred men's faces with lower facial masculinity significantly as most attractive, most likely as marital partners and most caring.

Although women were expected to show preference for men with highly masculine faces in this study because they are from high challenging environment, their preference for men's facial femininity can be explained in some ways: Firstly, the *evolutionary perspective hypothesis*, men's masculinity in terms of paternal investment (in time and earnings: the *paternal investment hypothesis*) is related to low partner quality (Perrett *et al.*, 1998, Penton-Voak *et al.*, 2003, Kruger, 2006) albeit masculinity is plausibly a cue to good genes and therefore good health (Little and Hancock, 2002, Fink and Penton-Voak, 2002b, Rhodes *et al.*, 2003, Rhodes *et al.*, 2007, Boothroyd *et al.*, 2013).

Masculine men are perceived by women as dishonest (more likely to cheat on their partners), uncooperative, and even 'bad parents' (Perrett *et al.*, 1998, Kruger, 2006, Boothroyd *et al.*, 2007), they are antisocial, and more likely to have poor relationships with their partners and children (Kogcifiski 2007). Secondly, women in the present study preferred more feminine men's faces as most attractive, most likely as marital partner and most caring, potentially because in general, facial masculinity is a signal to aggression, and dominance (Muller and Mazur, 1997, Swaddle and Reierson, 2002, Neave *et al.*, 2003, Neave and Shields, 2008, Quist *et al.*, 2011) and physical strength (Fink *et al.*, 2007). This might be particularly true in a very high challenging environment where men are more aggressive towards their spouses which might end up in divorce and other abuses (Ezechi *et al.*, 2004, Oyediran and Isiugo-Abanihe, 2005), especially in northern Nigeria where these data were collected (Hadiza, 2009, John *et al.*, 2010). It is possible that the exaggerated-aggression in more masculine men in this society is possibly enhanced by high rate of poverty, so that women prefer men with more feminine faces who are less aggressive. Moreover, feminine faces are often believed to reveal sympathy, care and emotional understanding, and is therefore perceived by females as a signal of a strong partnership in raising children and resource provision. And while this is so, women in less developed societies might prefer more feminine men's, because they think of safety, sympathy, care and paternal investments as priori when making choice for a long term partner as in marriage rather than just the reproductive benefits. This argument is supported by the women's preference in this study for masculinity as aggressive. This indicates that women in the present study may trade-off benefits of traits presumed to be associated with health (masculinity) and chose those traits associated with social behaviours (femininity).

In general, masculinity preference as attractive in many empirical studies remains highly inconsistent and from Rhodes' meta-analytical review, clear evidence to indicate that masculinity is attractive to women is still mixed (Rhodes, 2006) and others have also indicated no relationship between masculinity and attractiveness (Koehler *et al.*, 2004b, Thornhill and Gangestad, 2006, Scott *et al.*, 2010) even among populations exposed to higher level of disease load (Stephen *et al.*, 2012), which is consistent with the lack of association between testosterone and attractiveness (Neave *et al.*, 2003, Peters *et al.*, 2008).

8.4.2.2 Men's preference in women's faces

In the present study, men rated women with lower facial masculinity as most attractive, and are therefore more preferred as marital partners and as more caring than those with lower facial femininity, similar to the findings of other studies [e.g., (Perrett *et al.*, 1998, Fraccaro *et al.*, 2010, Glassenberg *et al.*, 2010, Gray and Boothroyd, 2012)]. Moreover, the preferences of men for women with less masculine faces over women with more masculine faces in the present study and that of the most recent study across 28 studied countries, including Nigeria (Marcinkowska *et al.*, 2014), has further re-affirmed that women with less masculine faces are indeed more attractive to men than those with more masculine faces.

The men's preference for women with more feminine faces as marital partners or perception that they are more caring, may be explained in several ways. Firstly, men might prefer women with more feminine faces just because they are attractive, as women perceived as less feminine were shown previously to have lower attractiveness ratings (Burke and Sulikowski, 2010, Morrison *et al.*, 2010, Van Dongen, 2014).

Secondly, given the proposal of "*fertility hypothesis*" (Johnston, 2000, Penton-Voak *et al.*, 2004, Rhodes, 2006), it is possible that men prefer women with more feminine faces to derive reproductive advantage (Thornhill and Thornhill, 2006), because facial femininity is a cue to fertility (Perrett *et al.*, 1998). Moreover, women with less masculine faces show more desire for higher numbers of offspring (Law Smith *et al.*, 2012), they are more fertile (Moore *et al.*, 2011), and more likely to conceive (Venners *et al.*, 2006) because of their higher oestrogen levels. Thirdly, from the "*pathogen disgust hypothesis*", men's scores on a scale of pathogen disgust, positively associated with men's preferences for more feminine women's faces (Jones *et al.*, 2013) and this suggests that health is another potential fitness benefits of men's preferences for female facial femininity. This is particularly true even in the present study where women's facial masculinity increases with increased total disease load at a statistically significant level (**see chapter 7**). Fourthly, if women with less masculine faces are much healthier than the those with more masculine faces (Gray and Boothroyd, 2012), then certainly, men's preferences for women with less masculine faces in a very high challenging environment where pathogen load is high and health care is poor, are in keeping with the findings in this study, because offspring may indirectly have heritable health benefits (Little *et al.*, 2011b). And since in less developed societies with poor health and high pathogens, men are on average shown to have lower testosterone levels (Muehlenbein and Bribiescas, 2005) than those in developed societies, especially if less than 45 years old (Ellison *et al.*, 2002), and circulating testosterone levels have been demonstrated to correlate positively with preferences for femininity (Welling *et al.*, 2008), the participants in the present study might have preferred women with more feminine faces as long term partners as in marriage, possibly because they have lower testosterone levels since all of them were under 40 years of age.

Although in developed societies with good National Health Insurance (NHI) and low morbidity and mortality, men are expected to show preference for women with more masculine faces because they might have higher testosterone levels than those in less developed societies, men in such societies still preferred women with less masculine faces most likely from less sexual attitudes restriction in such societies (Schaller and Murray, 2008).

In general, women facial femininity is a cue to maternal tendencies and maternal qualities (Perrett *et al.*, 1998, Law Smith *et al.*, 2012) and as such, men's preferences for less masculine women faces is not surprising in any society whether less or well developed, especially for long term relationship as in this study.

Chapter 9 : GENERAL DISCUSSION

In the history of evolutionary biological studies, the present study is the first to quantify and determine causes and consequences of facial asymmetry among sub-Saharan Africans. It is also the first to use overall facial asymmetry rather than fluctuating or directional asymmetries in assessing the preferences of facial asymmetry/symmetry in relation to four questions (i.e., attractiveness, suitability as marital partners, perceived caring nature and aggressiveness). Additionally, the study is also the first to isolate and quantify asymmetry around the eye region since in our daily inter-personal communications, the eye region is always the main focus of attention.

In studies of facial masculinity-femininity, facial masculinity was previously assessed by subjective ratings [e.g., (Little and Hancock, 2002, Hoss *et al.*, 2005, DeBruine *et al.*, 2006)] or objectively by simple measurements of facial features such as facial ratios (Pound *et al.*, 2009). In the present study, a multi-trait morphometric quantification was used to assess facial masculinity, which generated a morphological facial masculinity measure based on a discriminant function that classified faces as male or female with similar accuracy to others (Scott *et al.*, 2010, Stephen *et al.*, 2012, Boothroyd *et al.*, 2013). The current study is the first to objectively quantify facial masculinity outside Western populations with the aim of determining correlates of facial sexual dimorphism and raters' preferences for facial masculinity or femininity.

Overall, the study involved 6 analyses. The **first analysis** was able to showcase that non-clinical whole face asymmetry, which is the subject of the present study, exists in all the faces of the studied population, and therefore the study supports the view that no perfect symmetry exists in the human faces as reported by others [e.g., (Ferrario *et al*., 1994, Ercan *et al*., 2008, Primozic *et al*., 2012, Pound *et al*., 2014)]. The study also demonstrated that males were taller, heavier, had greater whole face surface area, greater facial asymmetry and asymmetry around the eyes than females, which seems to maintain the trend of sexual dimorphism in the hominid evolutionary history (Styne and McHenry, 1993).

In the present study, the greater facial asymmetry and asymmetry around the eyes seen in males suggests their greater developmental instability [e.g., (Klingenberg, 2003, Gangestad and Thornhill, 2003b, Dongen, 2006, Polak, 2008)] but their greater body size suggests their greater advantage in intra-sexual or inter-sexual competition for access to resources or to sexual partners (Andersson, 1994, Thornhill and Moller, 1998) based on the 'dimorphic niche' hypothesis (Darwin, 1871, Selander, 1972).

However, greater body size (weight and height) may not advantageus for females in the present study since it was positively associated with whole face asymmetry and asymmetry around the eyes in females. This implies that heavier and taller women had higher facial asymmetry and asymmetry around the eyes than the shorter ones making them potentially less attractive, less likely to be preferred as marital partners, perceived to be less caring and more aggressive to men as suggested by the last part of the present study.

In the present study biological factors that associated with facial asymmetry are age and height, and age, weight and height for the asymmetry around the eyes in females; whereas in males they were age and whole face surface area for the facial asymmetry and whole face surface area for the asymmetry around the eyes.

Although facial asymmetry was suggested to remain stable during an individual's lifetime, with no tendency to increase or decrease with growth in the pre-pubertal period [e.g., (Ferrario *et al.*, 2001, Primozic *et al.*, 2012)], the present study revealed that age positively associated with facial asymmetry even with the limited age range (of 18-25 years) of the participants.

In the second analysis, the study found no relationship of health measures such as body mass index (BMI), systolic and diastolic blood pressures with facial asymmetry. Additionally, the study did not find any relationship between facial asymmetry and asymmetry around the eyes with total disease loads. The finding thus implies that health status and medical history do not influence facial asymmetry of the sub-Saharan Africans in this study. However, BMI and systolic blood pressure in females and diastolic blood pressure in both men and women are associated with asymmetry around the eyes (EYES). It can therefore be inferred that BMI, systolic and diastolic blood pressure only affect the developmental stability of the eye region rather than the overall face in this study.

The third analysis tested relationships between facial asymmetry, marital status, education level, income and socioeconomic status. Across sexes, multivariate analysis implies a mild negative correlation between educational level and whole face asymmetry, with individuals from less educated backgrounds being less symmetrical. In men, both income and socioeconomic status had a weak positive relationship with whole face asymmetry, implying that men of higher socioeconomic status and income tend to be slightly less symmetrical, perhaps reflecting the stress experienced by men in the study environment in trying to look for resources. On the other hand, female education was a contributing factor in female facial morphology since females with no formal education had slightly higher facial asymmetry, as shown by the results of the multivariate analysis across the sexes. Multivariate analysis of female data suggested a weak negative relationship between income and whole face asymmetry, implying that more symmetrical women tend to benefit from higher incomes. In general, however, there was an absence of any strong relationship between socioeconomic status and facial asymmetry or asymmetry around the eyes.

The fourth analysis dealt with correlates of facial sexual dimorphism as measured on a femininity-masculinity scale. According to the literature, sexual selection favours any trait that gives success in reproduction and this process results in the evolution of extravagant secondary sexual characteristics in males (Anderson, 1994), in support of intra-sexual male-male competition for food (Slatkin, 1984, Shine, 1989) or inter-sexual competition to acquire females. However, extravagant secondary sexual characters also manifest in the face in the form of elaborate facial masculinity in males compared to females [reviewed in (Gangestad and Scheyd, 2005)] resulting in facial sexual dimorphism that was also found in the present study.

In the present study, three negative (body height, income and number of siblings) and one positive (total disease loads) correlates of facial masculinity were demonstrated in females, whereas only one negative (whole face surface area) correlate was demonstrated in males.

Analysis 5 was on preferences for facial asymmetry/symmetry showing that symmetry was mainly preferred by both sexes, considered more attractive, more suitable as marital partners and more caring, although facial asymmetry in some participants was also preferred by both sexes. Thus the result indicates that facial symmetry is not always the most important element of facial morphology to determine levels of attractiveness as seen in the study of Swaddle and Cuthill (Swaddle and Cuthill, 1995), even in cases where potential effects of masculinity-femininity have been minimised as was the case in the present study.

Analysis 6 showcased preferences for individuals with lower facial masculinity in both men and women. Given that male androgenic hormone (testosterone) influences the growth of sex-typical characters [e.g., (Penton-Voak and Chen, 2004, Pound *et al.*, 2009)], and also acts as an immunosuppressant [e.g., (Duffy *et al.*, 2000, Messingham *et al.*, 2001, Muehlenbein and Bribiescas, 2005)], development of highly masculine face characters is very costly, and therefore an honest signal of male quality (Scott *et al.*, 2013). From this framework, men with higher facial masculinity were expected to be preferred by women in this part of the study and *men to prefer women with more feminine faces.* Interestingly, women preferred *men with lower facial masculinity and men preferred women with lower facial masculinity*.

For the men's choice of women with lower facial masculinity (more feminine women), the result supported the initial hypothesis as well as the *fertility hypothesis* in which women with more facial femininity were hypothesized to be *attractive (Jones, 1995, Penton-Voak et al., 2004, Rhodes, 2006).*

Similarly the study was in keeping with others that demonstrated weak preferences for facial masculinity *(Scott et al., 2010, Stephen et al., 2012)* in the Western population. But the women's choice of men with lower facial masculinity was intriguing in this study although previous evidence for a relationship between facial masculinity in men and heritable health in humans is inconclusive [e.g.,(Scott *et al.*, 2013)].

However the finding may on the other hand be anticipated since men with more masculine faces are associated with negative personality traits, which make women to consider them antisocial (Perrett *et al.*, 1998, Boothroyd *et al.*, 2007) and more aggressive (Macapagal *et al.*, 2011). Such was the finding in the current study, and women ranked men with higher facial masculinity as most aggressive in keeping with the previous studies and in line with the perception of the negative personality traits of men with more masculine faces.

Chapter 10 : GENERAL CONCLUSION

Although the present study was not a comparative study between areas with higher and lower pathogen prevalence, the findings in the study are still consistent with an evolutionary psychological perspective on the link between physical attractiveness and health since certain health risk factors examined in the present study predicted facial asymmetry which in turn predicted preference rating rank in this study. Thus the study supports the hypothesis that physical attractiveness is not an arbitrary social construct, but at least in part a cue to the general health.

As with other studies, many facial dimensions vary across the two sides (left versus right) resulting in facial asymmetry and also vary between sexes, resulting in perceptions of masculinity or femininity. And as the literature has shown, many of these features have interacting effects on the perception of facial attractiveness. The present study is also consistent with this assertion, as the facial symmetry or femininity preferences in this study were not just dependent on single, but rather on multiple facial features and in accordance with the following three hypotheses [reviewed in (Fink and Penton-Voak, 2002a): Firstly, the *multiple-message hypothesis* which states "that each ornament signals a specific, unique property of the condition of an individual" (Cunningham *et al.*, 1995) pg 261-279. Secondly, the *multiple-fitness model* (similar to multiple-message) which states that "perceived attractiveness varies across multiple features, rather than a single, with each feature signaling a different aspect of mate value" (Cunningham *et al.*, 1995). Thirdly, the *redundant-signal hypothesis* which states that"there are multiple features, each signaling a different aspect of mate quality, and that these features are considered together in arriving at an evaluation, meaning that mate choosers pay attention to several sexual ornaments in combination to obtain a better estimate of general condition than if they paid attention to any single ornament" (Møller and Pomianowski, 1993).

Limitations

The important limitations to the present study is that of the small rated participants sample size in which only 18 male and 18 female faces were used. This limited certain analyses with regard to socioeconomic status. Similarly, it would have been more useful to include older age groups beyond 25 years of age and also to include non-university students to compare ratings. However, despite the limitations, this facial rating study indicates that facial symmetry is attractive to both men and women and that asymmetry is perceived as aggressive to both men and women. Similarly, facial femininity is attractive to both men and women and that masculinity is perceived as aggressive to both men and women.

Chapter 11 : BIBLIOGRAPHY

AHI (2011) Action Health Incorporated: Fact Sheet on Islam and Girl-Child Education. www.actionhealthinc.org.

ALEXANDER, J. & STIMSON, W. H. (1988) Sex hormones and the course of parasitic infection. *Parasitology Today,* 4**,** 189-193.

ALONSO-ALVAREZ, C., BERTRAND, S., FAIVRE, B., CHASTEL, O. & SORCI, G. (2007) Testosterone and oxidative stress: the oxidation handicap hypothesis. *Proceedings of the Royal Society of London B: Biological Sciences,* 274**,** 819-825.

ANDERSON, N. D. & GLEDDIE, C. (2013) Comparing sensitivity to facial asymmetry and facial identity. *i-Perception,* 4**,** 396-406.

ANDERSSON, M. (1994) Sexual selection. . *Princeton, New Jersey, Princeton University Press*.

ANUBHAV, B. & BRIJESH, C. (2014) Facial attractiveness. *Cognitive Science,* SE367A.

APICELLA, C. L., LITTLE, A. C. & MARLOWE, F. W. (2007) Facial averageness and attractiveness in an isolated population of hunter-gatherers. *Perception,* 36**,** 1813-1820.

ARSLAN, H., GUNDUZ, S., SUBASY, M., KESEMENLI, C. & NECMIOGLU, S. (2002) Frontal cephalometric analysis in the evaluation of facial asymmetry in torticollis, and outcomes of bipolar release in patients over 6Â years of age. *Archives of Orthopaedic and Trauma Surgery,* 122**,** 489-493.

AUERBACH, B. M. & RUFF, C. B. (2006) Limb bone bilateral asymmetry: variability and commonality among modern humans. *Journal of Human Evolution,* 50**,** 203-218.

AUNG, S. C., NGIM, R. C. K. & LEE, S. T. (1995) Evaluation of the laser scanner as a surface measuring tool and its accuracy compared with direct facial anthropometric measurements. *British Journal of Plastic Surgery,* 48**,** 551-558.

AYOUB, A. F., GARRAHY, A., HOOD, C., WHITE, J., BOCK, M., SIEBERT, J. P., SPENCER, R. & RAY, A. (2003) Validation of a vision-based, three-dimensional facial imaging system. *Cleft Palate Craniofac J,* 40**,** 523-529.

BAKER, D. (1992) Fetal and infant origins of adult disease. *London, UK: BMJ Publishing Group*.

BAKER, D. (2000) Fetal programming: influences on development and disease in later life. *New York, NY: Marcel Dekler*.

BARDIN, C. W. & CATTERRAL, J. F. (1981) Testosterone: A major Determinant of Extragenital Sexual Dimorphism. *Science,* 211**,** 1285-1294.

BARROS, A. & SOLIGO, C. (2013) Bilateral Asymmetry of Humeral Torsion and Length in African Apes and Humans. *Folia Primatologica,* 84**,** 220-238.

BAUDOUIN, J.-Y. & TIBERGHIEN, G. (2004) Symmetry, averageness, and feature size in the facial attractiveness of women. *Acta Psychologica,* 117**,** 313-332.

BENÍTEZ, H. A., LEMIC, D., BAŽOK, R., GALLARDO-ARAYA, C. M. & MIKAC, K. M. (2014) Evolutionary directional asymmetry and shape variation in Diabrotica virgifera virgifera (Coleoptera: Chrysomelidae): an example using hind wings. *Biological Journal of the Linnean Society,* 111**,** 110-118.

BIGONI, L., VELEMINSKA, J. & BRUZEK, J. Three-dimensional geometric morphometric analysis of cranio-facial sexual dimorphism in a Central European sample of known sex. *HOMO - Journal of Comparative Human Biology,* 61**,** 16-32.

BISHARA, S. E., BURKEY, P. S. & KHAROUF, J. G. (1994) DENTAL AND FACIAL ASYMMETRIES - A REVIEW. *Angle Orthodontist,* 64**,** 89-98.

BLACKBUM, A. (2011) Bilateral asymmetry of the humerus during growth and development. *Am J Phys Anthropol,* 145**,** 639-646.

BLAND, J. & ALTMAN, D. (1997) Statistics notes: Chronbach's alpha. *BMJ,* 314**,** 275.

BODER, E. & BODER (1953) A COMMON FORM OF FACIAL ASYMMETRY IN THE NEWBORN INFANT - ITS ETIOLOGY AND ORTHODONTIC SIGNIFICANCE. *American Journal of Orthodontics,* 39**,** 895-910.

BOOTHROYD, L. G., JONES, B. C., BURT, D. M., CORNWELL, R. E., LITTLE, A. C., TIDDEMAN, B. P. & PERRETT, D. I. (2005) Facial masculinity is related to perceived age but not perceived health. *Evolution and Human Behavior,* 26**,** 417-431.

BOOTHROYD, L. G., JONES, B. C., BURT, D. M. & PERRETT, D. I. (2007) Partner characteristics associated with masculinity, health and maturity in male faces. *Personality and Individual Differences,* 43**,** 1161-1173.

BOOTHROYD, L. G., SCOTT, I., GRAY, A. W., COOMBES, C. & POUND, N. (2013) Male facial masculinity as a cue to health outcomes. *Evolutionary psychology : an international journal of evolutionary approaches to psychology and behavior.,* 11**,** 1044-1058.

BRENO, M., BOTS, J. & VAN DONGEN, S. (2013) Heritabilities of Directional Asymmetry in the Fore- and Hindlimbs of Rabbit Fetuses. *PLoS ONE,* 8**,** e76358.

BRIONNE, C., CADRE, B., LAROCHE, Y., LHOTELLIER, J., MAZE, M., RAFFRE, A. & SOREL, O. (2013) The diagnosis of mandibular asymmetries. *J Dentofacial Anom Orthod,* 16**,** 302.

BROOKS, R., SCOTT, I. M., MAKLAKOV, A. A., KASUMOVIC, M. M., CLARK, A. P. & PENTON-VOAK, I. S. (2011) National income inequality predicts women's preferences for masculinized faces better than health does. *Proceedings of the Royal Society of London B: Biological Sciences*.

BROWN, F. & PERRETT, D. I. (1993) What gives a face its gender? *Perception,* 22**,** 829-840.

BROWN, W. M., PRICE, M. E., KANG, J., POUND, N., ZHAO, Y. & YU, H. (2008) Fluctuating asymmetry and preferences for sex-typical bodily characteristics. *Proceedings of the National Academy of Sciences,* 105**,** 12938-12943.

BRUCE, V., BURTON, A. M., HANNA, E., HEALEY, P., MASON, O., COOMBES, A., FRIGHT, R. & LINNEY, A. (1993) Sex discrimination: How do we tell the difference between male and female faces? *Perception,* 22**,** 131-152.

BUGAIGHIS, I., MATTICK, C., TIDDEMAN, B. & HOBSON, R. (2011) Three-dimensional gender differences in facial form of children in the North East of England. *The European Journal of Orthodontics*.

BULYGINA, E., MITTEROECKER, P. & AIELLO, L. (2006) Ontogeny of Facial Dimorphism and Patterns of Individual Development Within One Human Population. *American Journal of Physical Anthropology,* 131**,** 432-443.

BURKE, D. & SULIKOWSKI, D. (2010) A new viewpoint on the evolution of sexually dimorphic human faces. *Evolutionary Psychology,* 8**,** 573–585.

BURKE, P. H. (1971) Stereophotogrammetric measurement of normal facial asymmetry in children. *Human Biology (United States),* 43**,** 536-548.

BURKE, P. H. & HEALY, M. J. R. (1993) A SERIAL STUDY OF NORMAL FACIAL ASYMMETRY IN MONOZYGOTIC TWINS. *Annals of human biology,* 20**,** 527-534.

BURTON, A. M., BRUCE, V. & DENCH, N. (1993) What is the difference between men and women? Evidence from facial measurement. *Perception,* 22**,** 153-176.

CAMPANELLA, S., CHRYSOCHOOS, A. & BRUYER, R. (2001) Categorical perception of facial gender information: Behavioural evidence and face-space metaphor. *Visual Cognition,* 8**,** 237-262.

CARLES, S., JUKKA, K., MANUEL, N., MARÍA, S., JAVIER, N., IVÁN, Y. & RICARDO, G. (2012) Male facial anthropometry and attractiveness. *Perception,* 41**,** 1234 – 1245.

CARRE, J. M. & MCCORMICK , C. M. (2008) In your face: facial metrics predict aggressive behaviour in the laboratory and in varsity and professional hockey players. *P Roy Soc Lond B Bio,* 275**,** 2651-2656.

CARTER, A. J. R., OSBORNE, E. & HOULE, D. (2009) Heritability of Directional Asymmetry in Drosophila melanogaster. *International Journal of Evolutionary Biology,* 2009**,** 7.

CHARBONNEAU, F. & ANDERSON, T. J. (1998) Effects of antihypertensive agents on endothelial dysfunction: rationale for the brachial artery normalization of forearm function study. *Am J Cadiol,* 82**,** 345-65.

CHEONG, Y.-W. (2011) Facial Asymmetry: Etiology, Evaluation, and Management. *Chang Gung medical journal,* 34**,** 341.

CHIPPENDALE, A. K. & PALMER, A. R. (1993) Persistence of subtle departures from symmetry over multiple molts in individual Brchyuran crabs: relevance to developmental stability. *Genetica,* 89**,** 185-199.

CHIPPINDALE, A. K. J. R., GIBSON, G. & RICE, W. R. (2001) Negative genetic correlation for adult fitness between sexes reveals ontogenetic confliction in Drosophilia. *Proceedings of the National Academy of Sciences of the USA,* 98**,** 1671-1675.

CHIU, R. K. & BABCOCK, R. D. (2002) The relative importance of facial attractiveness and gender in Hong Kong selection decisions. *Int. Y. Hum. Resour. Manage,* 13**,** 141-155.

CHRISTIAN, A. (2006) Pure foy "Cencus stirs old Rivalries Between Nigeria's Tribes". . *The independent. accessed online at:* http://news.independent.co.uk.

CLAES, P., WALTERS, M., SHRIVER, M., PUTS, D. & GIBSON, G. (2012) Sexual dimorphism in multiple aspects of 3D facial symmetry and asymmetry defined by spatially dense geometric morphometrics. *Journal of anatomy,* 221**,** 97-114.

CLARK, G. M. (1995) The genetic basis of developmental staability II. Asymmetry of extreme phenotypes revisited. *Am. Nat,* 146**,** 708-725.

COETZEE, V., PERRETT, D. I. & STEPHEN, I. D. (2009) Facial adiposity: a cue to health? *Perception,* 38**,** 1700-1711.

CONWELL, R. E., LAW SMITH, M. J., BOOTHROYD, L. G., MOORE, F. R., DAVIS, H. P., STIRRAT, M., TIDDEMAN, B. & PERRETT, D. I. (2006) Reproductive strategy, sexual development and attraction to facial characteristics. *Philos Trans R Soc Lond B Biol Sci,* 361**,** 2143-2154.

CRUICKSHANK, J. K., MZAYEK, F., LIU, L., KIELTYKA, L., SHERWIN, R., WEBBER, L. S., SRINAVASAN, S. R. & BERENSON, G. S. (2005) Origins of the "Black/White"• Difference in Blood Pressure: Roles of Birth Weight, Postnatal Growth, Early Blood Pressure, and Adolescent Body Size: The Bogalusa Heart Study. *Circulation,* 111**,** 1932-1937.

CUNNINGHAM, M. R., ROBERTS, A. R., WU, C. H., BARBEE, A. P. & DRUEN, P. B. (1995) Their ideas of beauty are, on the whole, the same as ours: Consistency and variability in the cross-cultural perception of female attractiveness. *Journal of Personality and Social Psychology,* 68**,** 261-279.

CURRIE, T. E. & LITTLE, A. C. (2009) The relative importance of the face and body in judgments of human physical attractiveness. *Evolution and Human Behavior,* 30**,** 409-416.

DA SILVA, J. A. P. (1999) Sex Hormones and Glucocorticoids: Interactions with the Immune System. *Annals of the New York Academy of Sciences,* 876**,** 102-118.

DA SILVEIRA, A. C., DAW, J. L., JR., KUSNOTO, B., EVANS, C. & COHEN, M. (2003) Craniofacial Applications of Three-Dimensional Laser Surface Scanning. *Journal of Craniofacial Surgery,* 14**,** 449-456.

DARWIN, C. (1871) The Descent of Man and Selection in Relation to Sex. *John Mury*.

DAYAL, M. R., SPOCTER, M. A. & BIDMOS, M. A. (2008) An assessment of sex using the skull of black South Africans by discriminant function analysis. *HOMO - Journal of Comparative Human Biology,* 59**,** 209-221.

DE VISSER, J. A. G. M., HERMISSION, J., WAGNER, G. P., ANCEL MEYERS, L. & BAGHERI-CHAICHIAN, H., ET AL. (2003) Perspective: evolution and detection of genetic robustness. *Evolution,* 57**,** 1959-1972.

DEAN, C. & PEGINGTON, J. (2002) Core Anatomy for students: The Head and Neck. *W. B. Sunders Company. An imprint of Elsevier Science Limited,* Vol. 3**,** 117-120.

DEATON, A. (2007) Height, health, and development. *Proc Natl Acad Sci USA,* 104**,** 13232-13237.

DEBAT, V., ALIBERT, P. & DAVID, P. (2000) Independence between developmental stability and canalization in the skull of the house mouse. *Proc. R. Soc. London. B,* 267**,** 423-430.

DEBRUINE, L. M., JONES, B. C., LITTLE, A. C., BOOTHROYD, L. G., PERRETT, D. I., PENTON-VOAK, I. S., COOPER, P. A., PENKE, L., FEINBERG, D. R. & TIDDEMAN, B. P. (2006) Correlated preferences for facial masculinity and ideal or actual partner's masculinity. *Proceedings of the Royal Society B: Biological Sciences,* 273**,** 1355-1360.

DEBRUINE, L. M., JONES, B. C., TYBUR, J. M., LIEBERMAN, D. & GRISKEVICIUS, V. (2010) Women's preferences for masculinity in male faces are predicted by pathogen disgust, but not by moral or sexual disgust. *Evolution and Human Behavior,* 31**,** 69-74.

DELEON, V. B. (2007) Fluctuating asymmetry and stress in a medieval Nubian population. *American Journal of Physical Anthropology,* 132**,** 520-534.

DITCHKOFF, S. S., LOCHMILLER, R. L., MASTERS, R. E., STARRY, W. R. & M., L. J. D. (2001) Does fluctuating asymmetry of antlers in white-tailed deer (Odocoileus virginianus) follow patterns predicted for sexually selected traits? *Proceedings of the Royal Society of London B***,** 891-898.

DJORDJEVIC, J., PIRTTINIEMI, P., HARILA, V., HEIKKINEN, T., TOMA, A. M., ZHUROV, A. I. & RICHMOND, S. (2011a) Three-dimensional longitudinal assessment of facial symmetry in adolescents. *The European Journal of Orthodontics,* 35**,** 143-151.

DJORDJEVIC, J., TOMA, A. M., ZHUROV, A. I. & RICHMOND, S. (2011b) Three-dimensional quantification of facial symmetry in adolescents using laser surface scanning. *The European Journal of Orthodontics,* 36**,** 125-132.

DONG, Y., ZHAO, Y., BAI, S., WU, G. & WANG, B. (2009) Three-dimensional anthropometric analysis of the Chinese nose. *Journal of Plastic, Reconstructive & Aesthetic Surgery,* 63**,** 1832-1839.

DONGEN, S. V. (2006) Fluctuating asymmetry and developmental instability in evolutionary biology: past, present and future. *Journal of Evolutionary Biology,* 19**,** 1727-1743.

DOWNS, A. C. & LYONS, P. M. (1991) Natural observations of the links between attractiveness and initial legal judgments. *Pers. Soc. Psychol.,* 17**,** 541-547.

DRAKE, R. L., VOGL, W., MITCHELL, A. W. M., GRAY, H. & GRAY, H. (2010) *Gray's anatomy for students,* Philadelphia, PA, Churchill Livingstone/Elsevier.

DUFFY, D. L., BENTLEY, G. E., DRAZEN, D. L. & BALL, G. F. (2000) Effects of testosterone on cell-mediated and humoral immunity in non-breeding adult European starlings. *Behavioral Ecology,* 11**,** 654-662.

DUTTON, D. B. & LEVINE, S. (1989) Overview, methodological critique, and reformation. In J, R Bunker, D. S. Gomby, & B. H. Kehrer (Eds.). *Pathways to health. Menlo Park, CA: The Henry J. Kaiser Family Foundation***,** 29-69.

DUYAR, İ. & ÖZENER, B. (2005) Growth and nutritional status of male adolescent laborers in Ankara, Turkey. *American Journal of Physical Anthropology,* 128**,** 693-698.

ELLISON, P. T., BRIBIESCAS, R. G., BENTLEY, G. R., CAMPBELL, B. C., LIPSON, S. F., PANTER-BRICK, C. & HILL, K. (2002) Population variation in age-related decline in male salivary testosterone. *Hum. Reprod,* 17**,** 3251–3253.

EMLEN, J. M., FREEMAN, D. C. & GRAHAM, J. H. (1993) Nonlinear growth dynamics and the origin of fluctuating asymmetry. *Genetica,* 89**,** 77-96.

EPSTEIN, E. & GUTTMAN, R. (1984) Mate selection in man: evidence, theory and outcome. *Soc Biol,* 31**,** 243-277.

ERCAN, I., OZDEMIR, S. T., ETOZ, A., SIGIRLI, D., TUBBS, R. S., LOUKAS, M. & GUNEY, I. (2008) Facial asymmetry in young healthy subjects evaluated by statistical shape analysis. *Journal of Anatomy,* 213**,** 663-669.

ERKAN, I., SENEM T. O., ABDULLAH, E., DENIZ, S., SHANE, R. T., MARIOS, L. & IBRAHIM, G. (2008) Facial asymmetry in young healthy subjects evaluated by statistical shape analysis. *J. Anat*, 663-669.

ETIM, N. A. & EDET, G. E. (2009) Estimating the determinants of Poverty Among Peri-urban farming Households Farmers in Uyo, Nigeria. *Nigerian Journal of Agriculture, Food and Environment,* 5**,** 38-43.

EZECHI, O. C., KALU, B. K., EZECHI, L. O., NWOKORO, C. A., NDUBUBA, V. I. & OKEKE, G. C. E. (2004) Prevalence and pattern of domestic violence against pregnant Nigerian women. *Journal of Obstetrics & Gynaecology,* 24**,** 652-656.

FARKAS, L., KATIC, M. & FORREST, C. (2007) Comparison of craniofacial measurements of young adult african-american and north American white males and. *Annals of plastic surgery,* 59**,** 692-698.

FARKAS, L. G. (1994) Anthropometry of the Head and Face (ed 2). *New York, NY, Raven Press***,** 103-111.

FARKAS, L. G. (1996) Accuracy of Anthropometric Measurements: Past, Present, and Future. *The Cleft Palate-Craniofacial Journal,* 33**,** 10-22.

FARKAS, L. G. (2002) Differences between direct (anthropometric) and indirect (cephalometric) measurements of the skull. *The Journal of craniofacial surgery,* 13**,** 105-108.

FARKAS, L. G. & CHEUNG, G. (1981) Facial asymmetry in healthy North American caucasians. *Angle Orthod,* 51**,** 70-77.

FARKAS, L. G., HRECZKO, T. A., KOLAR, J. C. & MUNRO, I. R. (1995) Vertical and horizontal proportions of the face in young adult North American Caucasians: revision of neoclassical canons. *The American Society of Plastic and Reconstructive Surgeons, Plastic and Reconstructive Surgery,* 75**,** 328-338.

FARKAS, L. G., HRECZKO, T. M., KATIC, M. J. & FORREST, C. R. (2003) Proportion indices in the craniofacial regions of 284 healthy North American white children between 1 and 5 years of age. *The Journal of craniofacial surgery,* 14**,** 13-28.

FARKAS, L. G. & MUNRO, I. R. (1987) Anthropometric Facial Proportions in Medicine. *Charles C. Thomas, Illinois*.

FERAGEN, K. J. B., SEMB, G. & MAGNUSSEN, S. (1999) Asymmetry of left versus right unilateral cleft impairments: an experimental study of face perception. *Cleft Palate-Craniofacial Journal,* 36**,** 527-532.

FERRARIO, V. F., SFORZA, C., CIUSA, V., DELLAVIA, C. & TARTAGLIA, G. M. (2001) The effect of sex and age on facial asymmetry in healthy subjects: A cross-sectional study from adolescence to mid-adulthood. *Journal of Oral and Maxillofacial Surgery,* 59**,** 382-388.

FERRARIO, V. F., SFORZA, C., DELLAVIA, C., TARTAGLIA, G. M. & COLOMBO, A. (2003) A quantitative three-dimensional assessment of soft tissue facial asymmetry of cleft lip and palate adult patients. *The Journal of craniofacial surgery,* 14**,** 739-746.

FERRARIO, V. F., SFORZA, C., MIANI, A. & SERRAO, G. (1995) A 3-DIMENSIONAL EVALUATION OF HUMAN FACIAL ASYMMETRY. *Journal of anatomy,* 186**,** 103-110.

FERRARIO, V. F., SFORZA, C., MIANI, A. & TARTAGLIA, G. (1993a) Craniofacial morphometry by photographic evaluations. *American Journal of Orthodontics and Dentofacial Orthopedics,* 103**,** 327-337.

FERRARIO, V. F., SFORZA, C., PIZZINI, G., VOGEL, G. & MIANI, A. (1993b) SEXUAL DIMORPHISM IN THE HUMAN FACE ASSESSED BY EUCLIDEAN DISTANCE MATRIX ANALYSIS. *Journal of anatomy,* 183**,** 593-600.

FERRARIO, V. F., SFORZA, C., POGGIO, C. E. & TARTAGLIA, G. (1994) Distance from symmetry: A three-dimensional evaluation of facial asymmetry. *Journal of Oral and Maxillofacial Surgery,* 52**,** 1126-1132.

FINK, B., GRAMMER, K. & MARTS, P. J. (2006a) Visible skin color distribution plays a role in perception of age, attractiveness, and health in female faces. *Evol. Hum. Behav,* 27**,** 433-442.

FINK, B., GRAMMER, K., MITTEROECKER, P., GUNZ, P., SCHAEFER, K., BOOKSTEIN, F. L. & MANNING, J. T. (2005) Second to Fourth Digit Ratio and Face Shape. *Proceedings: Biological Sciences,* 272**,** 1995-2001.

FINK, B., NEAVE, N., MANNING, J. T. & GRAMMER, K. (2006b) Facial symmetry and judgements of attractiveness, health and personality. *Personality and Individual Differences,* 41**,** 491-499.

FINK, B., NEAVE, N. & SEYDEL, H. (2007) Male facial appearance signals physical strength to women. *American Journal of Human Biology,* 19**,** 82-87.

FINK, B. & PENTON-VOAK, I. (2002a) Evolutionary Psychology of Facial Attractiveness. *Current Directions in Psychological Science,* 11**,** 154-158.

FINK, B. & PENTON-VOAK, I. (2002b) Evolutionary psychology of facial attractiveness. *Current Directions in Psychological Science. http://dx.doi.org/10.1111/1467-8721.00190,* 11**,** 154-158.

FLINN, M. W., LEONE, D. V. & ENGLAND, B. G. (1999) Fluctuating asymmetry stress and health among children in Caribbean village. *Am J Phys Anthropol Suppl,* 28**,** 128-129.

FLINT, E., CUMMINS, S. & SACKER, A. (2014) Associations between active commuting, body fat, and body mass index: population based, cross sectional study in the United Kingdom. *BMJ,* 349.

FMOH. (2009) Federal Ministry of Health. Strategic Plan 2009-2003 "A road Map for Malaria Control in Nigeria. Nigeria and National Malaria Control Programme (NMCP). . *ABUJA, Nigeria***,** 1-39.

FOLSTAD, I. & KARTER, A. J. (1992) Parasite, bright males, and the immunocompetence handicap. *American Naturalist,* 139**,** 603-622.

FORKMAN, B. & FORKMAN, S. (1996) Influence of size and asymmetry of sexual characters in the rooster and hen on the number of eggs laid. *Applied animal behaviour science,* 49**,** 285-291.

FRACCARO, P. J., FEINBERG, D. R., DEBRUINE, L. M., LITTLE, A. C. & WATKINS, C. D. E. A. (2010) Correlated male preferences for femininity in female faces and voices. *Evol Psychol,* 8**,** 447-461.

FRANKLIN, D., CARDINI, A., FLAVEL, A. & KULIUKAS, A. (2012) The application of traditional and geometric morphometric analyses for forensic quantification of sexual dimorphism: preliminary investigations in a Western Australian population. *International Journal of Legal Medicine,* 126**,** 549-558.

FRANKLIN, D., FREEDMAN, L. & MILNE, N. (2005) Sexual dimorphism and discriminant function sexing in indigenous South African crania. *Homo,* 55**,** 213-228.

GALLAGHER, D., HEYMSFIELD, S. B., HEO, M., JEBB, S. A., MURGATROYD, P. R. & SAKAMOTO, Y. (2000) Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. *The American Journal of Clinical Nutrition,* 72**,** 694-701.

GALTON, F. (1879) Composite portraits, made by combining those of many different persons in a single resultant figure. *Journal of the Anthropological Institute,* 8**,** 132-144.

GANGESTAD, S. (1993) Sexual selection and physical attractiveness. *Human Nature,* 4**,** 205-235.

GANGESTAD, S. W. & SCHEYD, G. J. (2005) The evolution of human physical attractiveness. *Ann Rev Anthropol,* 34**,** 523-548.

GANGESTAD, S. W. & THORNHILL, R. (1997) Human sexual selection and developmental stability. *In Evolutionary Social Psychology (ed. J. A. Simpson and D. T. Kenrick), Lawrence Erlbaum, Hillsdale, New Jersey***,** 169-195.

GANGESTAD, S. W. & THORNHILL, R. (2003a) Facial musculinity and fluctuating asymmetry. *Evol. Hum. Behav,* 24**,** 231-241.

GANGESTAD, S. W. & THORNHILL, R. (2003b) Fluctuating asymmetry, developmental stability, and fitness: toward model-based interpretation. In Developmental instability: causes and consequencies (ed. M Polak), pp. 62-82. Oxford, UK: Oxford University Press.

GANGESTAD, S. W., THORNHILL, R. & YEO, R. A. (1994) Facial attractiveness, developmental stability, and fluctuating asymmetry. *Ethology and Sociobiology,* 15**,** 73-85.

GARG, K. (2006. Editor) BD Chaurasia' Human Anatomy, Regional and Applied, Dissection and Clinical. *CBS Publishers & Distributors, New Delhi Bangalore. 4th Edition,* 3**,** 49-59.

GEARY, D. C., VIGIL, J. & BYRD-CRAVEN, J. (2004) Evolution of Human Mate Choice. *The Journal of Sex Research,* 41**,** 27-42.

GEST, T. R., SIEGEL, M. I. & ANISTRANSKI, J. (1986) The long bones of neonatal rats by cold, heat, and noise exhibit increased fluctuating asymmetry. *Growth,* 50**,** 385-389.

GHODDOUSI, H., EDLER, R., HAERS, P., WERTHEIM, D. & GREENHILL, D. (2007) Comparison of three methods of facial measurement. *International Journal of Oral and Maxillofacial Surgery,* 36**,** 250-258.

GIBSON, G. & WAGNER, G. P. (2000) Canalization in evolutionary genetics: a stabilizing theory? *BioEssays,* 22**,** 372-380.

GLASSENBERG, A. N., FEINBERG, D. R., JONES, B. C., LITTLE, A. C. & DEBRUINE, L. M. (2010) Sex-Dimorphic Face Shape Preference in Heterosexual and Homosexual Men and Women. *Arch Sex Behav,* 39**,** 1289-1296.

GRAHAM, J. H. (1992) Growth models and the expected distribution of fluctuating asymmetry. *Biol. J. Linn Soc,* 80**,** 57-65.

GRAHAM, J. H., EMLEN, J. M. & FREEMAN, D. C. (1993a) Developmental stability and its applications in ecotoxicology. *Ecotoxicology,* 2**,** 175-184.

GRAHAM, J. H., EMLEN, J. M., FREEMAN, D. C., LEAMY, L. J. & KIESER, J. A. (1998) Directional asymmetry and the measurement of developmental instability. *Biological Journal of the Linnean Society,* 64**,** 1-16.

GRAHAM, J. H., FREEMAN, D. C. & EMLEN, J. M. (1993b) Antisymmetry, directional asymmetry, and dynamic morphogenesis. *Genetica,* 89**,** 121-137.

GRAHAM, J. H., FREEMAN, D. C. & EMLEN, J. M. (1993c) ANTISYMMETRY, DIRECTIONAL ASYMMETRY, AND DYNAMIC MORPHOGENESIS. *Genetica,* 89**,** 121-137.

GRAHAM, J. H., FREEMAN, D. C. & EMLEN, J. M. (1993d) Developmental stability: Asensitive indicator of population under stress. In Environmental Toxicology and Risk Assessment (ed. W. G. Landis, J. S. Hughes and M. A. Lewis). *American Society for Testing and Materials, Philadelphia***,** 136-158.

GRAMMER, K., FINK, B., MOLLER, A. P. & THORNHILL, R. (2003) Darwinian aesthetics: Sexual selection and the biology of beauty. *Biological Reviews,* 78**,** 385-407.

GRAMMER, K. & THORNHILL, R. (1994) Human (Homo Sapiens) facial attractiveness and sexual selection: the role of symmetry and averageness. *Journal of comparative psychology,* 108**,** 233-242.

GRAY, A. W. & BOOTHROYD, L. G. (2012) Female facial appearance and health. *Evolutionary psychology : an international journal of evolutionary approaches to psychology and behavior.,* 10**,** 66-77.

GRAY, P. B. & MARLOWE, C. M. (2002) Fluctuating asymmetry of a foraging population: the Hadza of Tanzania. *Annals of human biology,* 29**,** 495-501.

GREEN, H. & CURNOE, D. (2009) Sexual dimorphism in Southeast Asian crania: A geometric morphometric approach. *HOMO - Journal of Comparative Human Biology,* 60**,** 517-534.

GWANDU, A., ALIU (1977) Abdullahi b. fodio as a Muslim jurist. *Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/8030/*.

HADDY, F. J., VANHOUTTE, P. M. & FELETOU, M. (2006) Role of potassium in regulating blood flow and blood pressure. *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology,* 290**,** R546-R552.

HADIZA, I. B. (2009) Domestic Violence and Women's Rights in Nigeria. *Societies Without Borders,* 4**,** 175-192.

HALLAM, W. K. R. (1966) THE BAYAJIDA LEGEND IN HAUSA FOLKLORE. *Journal of African History,* VII**,** 47-60.

HALLGRIMSSON, B. (1993) Fluctuating asymmetry in Macaca fascicularis: a study of the etiology of developmental noise. *International Journal of Primatology,* 14**,** 421-444.

HALLGRIMSSON, B. (1998) Fluctuating asymmetry in the mammalian skeleton: evolutionary and developmental implications. *Evolutionary Biology,* 30**,** 187-251.

HALLGRIMSSON, B. (1999) Ontogenetic patterning of skeletal fluctuating asymmetry in rhesus macaques and humans: evolutionary and developmental implications. *International Journal of Primatology,* 20**,** 121-151.

HAMILTON, W. & ZUK, M. (1982) Heritable true fitness and bright birds: a role for parasites? *Science,* 218**,** 384-387.

HARAGUCHI, S., IGUCHI, Y. & TAKADA, K. (2008) Asymmetry of the face in orthodontic patients. *The Angle orthodontist,* 78**,** 421-426.

HASELHUHN, M. P. & WONG, E. M. (2011) Bad to the bone: facial structure predicts unethical behaviour. *P Roy Soc Lond B Bio,* 279**,** 571-576.

HATA, H., YASUGI, M., HORI., MICHIO, B. & HOWARD. (2011) Jaw Laterality and Related Handedness in the Hunting Behavior of a Scale-Eating Characin, Exodon paradoxus (Laterality in Scale-Eating Characin). *PLoS ONE,* 6**,** e29349.

HAYREH, S. S. (2006) Orbital vascular anatomy. *Eye,* 20**,** 1130-1144.

HEIKE, C., UPSON, K., STUHAUG, E. & WEINBERG, S. (2010) 3D digital stereophotogrammetry: a practical guide to facial image acquisition. *Head & Face Medicine,* 6**,** 18.

HELMKAMP, R. C. & FALK, D. (1990) Age-and sex-associated variations in the directional asymmetry of Rhesus macaque forelimb bones. *Am J Phys Anthropol,* 83**,** 211-218.

HENDERSON, J. J. A. & ANGLIN, J. M. (2003) Facial attractiveness predicts longevity. *Evolution and Human Behavior,* 24**,** 351-356.

HENNESSY, R. J., MCLEARIE, S., KINSELLA, A. & WADDINGTON, J. L. (2005) Facial surface analysis by 3D laser scanning and geometric morphometrics in relation to sexual dimorphism in cerebralâ€“craniofacial morphogenesis and cognitive function. *Journal of Anatomy,* 207**,** 283-295.

HENRICH, J., HEINE, S. J. & NORENZAYAN, A. (2010) The weirdest people in the world? *Behav Brain Sci,* 33**,** 61-83, discussion 83-135.

HERSHKOVITZ, I., RING, B. & KOBYLIANSKY, E. (1992) Craniofacial asymmetry in Bedouin adults. *American Journal of Human Biology***,** 83-92.

HILL, A. K., JOHN, H., LISA, L. M. W., RODRIGO, A. C., MICHELLE, A. R., JOHN, R. W., KHYTAM, D., MARK, D. S. & DAVID, A. P. (2013) Quantifying the strength and form of sexual selection on men's traits. *Evol. Hum. Behav,* 34**,** 334-341.

HILL, K. & HURTADO, A. M. (1996) Ache Life History: The Ecology and Demography of a Foraging People. *New York: Aldine de Gruyter*.

HILL, P. (1972) *Rural Hausa: A Village and a Setting*.

HOGAN, M. C., FOREMAN, I. C. J., NAGHAVI, M., AHN, S. Y., WANG, M., MAKELA, S. M. & AL, E. (2010) Maternal mortality for 181 countries, 1980-2008: a systematic analysis of progress towards Millennium Development Goal 5. *Lancet,* 375**,** 1609-1623.

HONEKOPP, J., BARTHOLOME, T., HÖNEKOPP, J., BARTHOLOMÉ, T. & JANSEN, G. (2004) Facial attractiveness, symmetry, and physical fitness in young women. *Human nature,* 15**,** 147-167.

HONN, M. & GERNOT, G. (2007) The Ideal of Facial Beauty: A Review. *Journal of Orofacial Orthopedics / Fortschritte der KieferorthopÃ¤die,* 68**,** 6-16.

HOODER, S. & SOUZA, M. (2012) Evaluation of Facial Asymmetry Using Digital Photographs with Computer Aided Analysis. *Journal of Indian Prosthodontic Society,* 12**,** 8.

HOOVER, K. C. & MATSUMURA, H. (2008) Temporal variation and interaction between nutritional and developmental instability in prehistoric Japanese populations. *Am J Phys Anthropol,* 137**,** 469-478.

HOPE, D., BATES, T., PENKE, L., GOW, A. J., STARR, J. M. & DEARY, I. J. (2013) Symmetry of the face in old age reflects childhood social status. *Economics & Human Biology,* 11**,** 236-244.

HOSS, R. A., RAMSEY, J. L., GRIFFIN, A. M. & LANGLOIS, J. H. (2005) The role of facial attractiveness and facial masculinity/femininity in sex classification of faces. *Perception,* 34**,** 1459-1474.

HOUSTON, W. J. B. (1983) The analysis of errors in orthodontic measurements. *American journal of orthodontics,* 83**,** 382-390.

HOYME, H. E. (1993) Minor anomalies: Diagnostic clues to aberrant human morphogenesis. *Genetica,* 89**,** 307-315.

HUME, D. K. & MONTGOMERIE, R. (2001) Facial attractiveness signals different aspects of "quality"• in women and men. *Evolution and Human Behavior,* 22**,** 93-112.

HWANG, H.-S., YUAN, D., JEONG, K.-H. & UHM, G.-S. (2012) Three-dimensional soft tissue analysis for the evaluation of facial asymmetry in normal occlusion individuals. *Korean Journal of Orthodontics,* 42**,** 56-63.

INUI, M., FUSHIMA, K. & SATO, S. (1999) Facial asymmetry in temporomandibular joint disorders. *Journal of Oral Rehabilitation,* 26**,** 402-406.

INWOOD, K. & ROBERTS, E. (2010) Longitudinal studies of human growth and health: a review of recent historical research. *J Econ Surv,* 24**,** 801-840.

JAMES, R. K. & ROSS, A. A. (2003) The Ontogeny of Fluctuating Asymmetry. *The American Naturalist,* 161**,** 931-947.

JAYEOLA-OMOYENI, M. S. & OMOYENI, J. O. (2014) Contributions of Western Education to the making of modern Nigeria during and after the first World war

European Scientific Journal, 10**,** ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431.

JENNIONS, M. D., MOLLER, A. P. & PETRIE, M. (2001) Sexually selected traits and adult survival: A meta-analysis. *Quarterly Review of Biology,* 76**,** 3-36.

JOE, P. S., ITO, Y., SHIH, A. M., OESTENSTAD, R. K. & LUNGU, C. T. (2012) Comparison of a Novel Surface Laser Scanning Anthropometric Technique to Traditional Methods for Facial Parameter Measurements. *Journal of Occupational and Environmental Hygiene,* 9**,** 81-88.

JOHN, I. A., LAWOKO, S., SVANSTRÃ¶M, L. & MOHAMMED, A. Z. (2010) Health Care Providers' Readiness to Screen for Intimate Partner Violence in Northern Nigeria. *Violence and Victims,* 25**,** 689-704.

JOHNSTON, V. S. (2000) Female facial beauty: The fertility hypothesis. *Pragmatics & Cognition,* 8**,** 107-122.

JOHNSTON, V. S. (2006) Mate choice decisions: the role of facial beauty. *Trends in Cognitive Sciences,* 10**,** 9-13.

JOKELA, M. (2009) Physical attractiveness and reproductive success in humans: Evidence from the late 20th century United States. *Evolution and Human Behavior,* 30**,** 342-350.

JONES, B. C., FINCHER, C. L., WELLING, L. L. M., LITTLE, A. C. & FEINBERG, D. R., ET AL. (2013) Salivary cortisol and pathogen disgust predicts men's preferences for feminine shape cues in women's faces. *Biol Psychol,* 92**,** 233-240.

JONES, B. C., LITTLE, A. C., BURT, D. M. & PERRETT, D. I. (2004) When facial attractiveness is only skin deep. *Perception,* 33**,** 569-576.

JONES, B. C., LITTLE, A. C., PENTON-VOAK, I. S., TIDDEMAN, B. P., BURT, D. M. & PERRETT, D. I. (2001) Facial asymmetry and judgments of apparent health: support for a 'good genes' explanation of the attractiveness-symmetry relationship. *Evol. Hum. Behav,* 22**,** 417-429.

JONES, D. (1995) Sexual selection, physical attractiveness and facial neoteny. *Curr Anthropol,* 36**,** 723-748.

KANNIKESWARAN, N., MAHAJAN, P. V. & KAMAT, D. (2006) Acute Facial Asymmetry. *Clinical Pediatrics,* 45**,** 289-292.

KETTERSON, E. D., NOLAN, V. & SANDELL, M. (2005) Testesteron in females: mediator of adaptive traits, constraint on sexual dimorphism, or both? *American Naturalist,* 166**,** 585-598.

KHARLAMOVA, A. V., TRUT, L. N., CHASE, K., KUKEKOVA, A. V. & LARK, K. G. (2010) Directional asymmetry in the limbs, skull and pelvis of the silver fox (V. vulpes). *Journal of Morphology,* 271**,** 1501-1508.

KIMMERLE, E. H. & JANTZ, R. L. (2005) Secular trends in craniofacial asymmetry studied by geometric morphometry and generalized procrustes methods. *In Modern Morphometrics in Physical Anthropology (ed Slice D)***,** 247-263.

KLEIN, S. L. (2004) Homornal and immunological mechanisms mediating sex differences in parasite infection. *Parasite Immunol,* 26**,** 247-264.

KLINGENBERG, C. P. (2003) A developmental perspective on developmental instability: theory, models, and mechanism. In: Developmental Instability: Causes and Consequences (M. Polak, ed). *Oxford University Press, Oxford.***,** 14-34.

KOEHLER, N., SIMMONS, L. W. & RHODES, G. (2004a) How well does secondto-fourth-digit ratio in hands correlate with other indications of masculinity in males? *Proc R Soc B 271(Suppl 5):***,** 5296–5298.

KOEHLER, N., SIMMONS, L. W., RHODES, G. & PETERS, M. (2004b) The relationship between sexual dimorphism in human faces and fluctuating asymmetry. *Proceedings of the Royal Society of London. Series B: Biological Sciences,* 271**,** S233-S236.

KOEHLER, N., SIMMONS, W. L. & RHODES, G. (2004c) The relationship between sexual dimorphism in human faces and fluctuating asymmetry. *Proc R Soc Lond B Biol,* 271**,** 233-236.

KOMLOS, J. & BAUR, M. (2004) From the tallest to (one of) the fattest: The enigmatic fate of the American population in the 20th century. *Econ Hum Biol,* 2**,** 57-74.

KOMORI, M., KAWAMURA, S. & ISHIHARA, S. (2009) Averageness or symmetry: Which is more important for facial attractiveness? *Acta Psychologica,* 131**,** 136-142.

KONTULAINEN, S., SIEVANEN, H., KANNUS, P., PASANEN, M., VUORI, I (2003) Effect of long-term impact-loading on mass, size and estimated strength of humerus and radius of female racquet-sports players: a peripheral quantitative computed tomography study between young and old starters and controls. *J. Bone Miner Res,* 18**,** 352-359.

KORTHASE, K. M. & TRENHOLME, I. (1982) Percieved age and percieved physical attractive attractiveness. *Motor Skills,* 54**,** 1251-1258.

KOSCINSKI, K. (2007) Facial attractiveness: General patterns of facial prefernces. *Anthropol. Rev,* 70**,** 45-79.

KOWNER, R. (1996) Facial asymmetry and attractiveness judgment in developmental perspective. *J. Exp. Psychol. Human,* 22**,** 662-675.

KRAMER, R. S. S., KRAMER, A., JONES, R. & WARD, T. (2012) A Lack of Sexual Dimorphism in Width-to-Height Ratio in White European Faces

Using 2D Photographs, 3D Scans, and Anthropometry. *PLoS ONE,* 7**,** e42705.
KRUGER, D. J. (2006) Male facial masculinity influences attributions of personality and reproductive strategy. *Personal Relationships,* 13**,** 451-463.
KUJANOVA, M., BIGONI, L., VELEMINSKA, J. & VELEMINSKY, P. (2008) Limb bones asymmetry and stress in Medieval and recent populations of Central Europe. *Int J Osteoarchaeol,* 18**,** 476-491.
KURZBAN, R. & WEEDEN, J. (2005) Hurry Date: Mate preferences in action. *Evol. Hum. Behav.,* 26**,** 227-244.
KUSNOTO, B. & EVANS, C. A. (2002) Reliability of a 3D surface laser scanner for orthodontic applications. *American Journal of Orthodontics and Dentofacial Orthopedics,* 122**,** 342-348.
LADEIRA, P. R. S. D., BASTOS, E. O., VANINI, J. V. & ALONSO, N. (2013) Use of stereophotogrammetry for evaluating craniofacial deformities: a systemic review. *Revista Brasileira de Cirurgia PlÃ¡stica,* 28**,** 147-155.
LANGE, D. (1987) The Evolution of the Hausa Story: From Bawo to Bayajidda. *Afrika and Ubersee,,* Band 70**,** 195-209.
LANGLOIS, J. H., KALAKANIS, L., RUBENSTEIN, A. J., LARSON, A., HALLAM, M. & SMOOT, M. (2000) Maxims or myths of beauty? A meta-analytic and theoretical review. *Psychological Bulletin,* 126**,** 390-423.
LANGLOIS, J. H. & ROGGMAN, L. A. (1990) Attractive Faces Are Only Average. *Psychological Science,* 1**,** 115-121.
LANGLOIS, J. H., ROGGMAN, L. A. & MUSSELMAN, L. (1994) What Is Average and What Is Not Average about Attractive Faces? *Psychological Science,* 5**,** 214-220.
LASPOS, C. P., KYRKANIDES, S., TALLENTS, R. H., MOSS, M. E. & D., S. J. (1997) Mandibular asymmetry in noncleft and unilateral cleft lip and palate individuals. *Cleft Palate-Craniofacial Journal,* 34**,** 410-416.
LAW SMITH, M. J., DEADY, D. K., MOORE, F. R., JONES, B. C. & CORNWELL, R. E., ET AL. (2012) Maternal tendencies in women are associated with estrogen levels and facial femininity. *Horm Behav,* 61**,** 12-16.
LAW SMITH, M. J., PERRETT, D. I., JOHNS, B. C., CORNWELL, R. E., MOORSE, F. R. & FEINBERG, D. R. E. A. (2006) Facial appearance is a cue to estrogen levels in women. *Pro R Soc B,* 273.
LEAMY, L. J. (1999) Heritability of directional and fluctuating asymmetry for mandibular characters in random-bred mice. *J Evol Biol***,** 146-155.
LEAMY, L. J., DOSTER, M. J. & HUET-HUDSON, Y. M. (1999) Effects of methoxychlor on directional and fluctuating asymmetry of mandible characters in mice. *Ecotoxicology,* 8**,** 63-71.
LEAMY, L. J. & KLINGENBERG, C. P. (2005) Genetics and evolution of fluctuating asymmetry. *Annu Rev Ecol Evol Syst,* 36**,** 1-21.
LEAMY, R. F. & ALLENDORF, F. W. (1989) Fluctuating asymmetry as an indicator of stress: implication for conservation biology. *Trends Ecol. Evol.,* 4**,** 214-217.
LEE, M.-S., CHUNG, D. H., LEE, J.-W. & CHA, K.-S. (2010) Assessing soft-tissue characteristics of facial asymmetry with photographs. *American Journal of Orthodontics and Dentofacial Orthopedics,* 138**,** 23-31.

LEFEVRE, C., LEFEVRE, G., LEWIS, D. & PERRETT, L. (2013) Telling facial metrics: facial width is associated with testosterone levels in men. *Evolution and Human Behavior,* 34**,** 273-279.

LEFEVRE, C., LEFEVRE, G., LEWIS, T., BATES, M., DZHELYOVA, V., COETZEE, I. & DEARY, D. (2012) No evidence for sexual dimorphism of facial width-to-height ratio in four large adult samples. *Evolution and Human Behavior,* 33**,** 623-627.

LENS, L., VAN DONGEN, S. & MATTHYEN, E. (2002) Fluctuating asymmetry as an indicator of fitness: can we bridge the gap between studies? *Biological Reviews***,** 27-38.

LEUNG, B. & FORBES, M. R. (1996) Fluctuating asymmetry in the mouse mandible. In: Markow TA, editor. Developmental instability: its origins and evolutionary implications. *Dordrecht: Kluwer***,** 141-155.

LI, J., GOLDBERG, G., MUNIN, M. C., WAGNER, A. & ZAFONTE, R. (2004) Post-traumatic bilateral facial palsy: a case report and literature review. *Brain Injury,* 18**,** 315-320.

LITTLE, A. C., BENEDICT, J. & LISA, M. D. (2011a) Facial attractiveness: evolutionary based research. *Phil. Trans. R. Soc. B.,* 366**,** 1638-1659.

LITTLE, A. C., CONNELY, J., FEINBERG, D. R., JONES, B. C. & ROBERTS, S. C. (2011b) Human preference for masculinity differs according to context in faces, bodies, voices, and smell. *Behav. Ecol,* 22**,** 862–868.

LITTLE, A. C., DEBRUINE, L. M. & JONES, B. C. (2011c) Exposure to visual cues of pathogen contagion changes preferences for masculinity and symmetry in opposite-sex faces. *Proceedings of the Royal Society of London B: Biological Sciences,* 278**,** 2032-2039.

LITTLE, A. C. & HANCOCK, P. J. (2002) The role of masculinity and distinctiveness in judgments of human male facial attractiveness. *British Journal of Psychology. http://dx.doi.org/10.1348/000712602761381349 Medline:12519528,* 93(Pt 4)**,** 451–464.

LITTLE, A. C. & JONES, B. C. (2003) Evidence against perceptual bias views for symmetry preferences in human faces. *Proc. Biol. Sci. R. Soc,* 270**,** 1759–1763.

LITTLE, A. C. & JONES, B. C. (2006) Attraction independent of detection suggests special mechanisms for symmetry preferences in human face perception. *Proc. Biol. Sci. R. Soc,* 273**,** 3093–3099.

LITTLE, A. C., JONES, B. C. & BURRISS, R. P. (2007) Preferences for masculinity in male bodies change across the menstrual cycle. *Hormones and Behavior,* 51**,** 633-639.

LITTLE, A. C., JONES, B. C. & DEBRUINE, L. M. (2008a) Preferences for variation in masculinity in real male faces change across the menstrual cycle: Women prefer more masculine faces when they are more fertile. *Personality and Individual Differences,* 45**,** 478-482.

LITTLE, A. C., JONES, B. C. & DEBRUINE, L. M. (2014) Facial attractiveness: evolutionary based research. *Philosophical Transactions of the Royal Society B: Biological Sciences,* 366**,** 1638-1659.

LITTLE, A. C., JONES, B. C., FEINBERG, D. R. & PERRETT, D. I. (2013) Men's strategic preferences for femininity in female faces. *Br. J. Psychol.*

LITTLE, A. C., JONES, B. C., WAITT, C., TIDDEMAN, B. P., FEINBERG, D. R., PERRETT, D. I., APICELLA, C. L. & MARLOWE, F. W. (2008b) Symmetry

Is Related to Sexual Dimorphism in Faces: Data Across Culture and Species. *PLoS ONE,* 3**,** e2106.

LITTLE, A. C., JONES, B. C., WAITT, C., TIDDEMAN, B. P., FEINBERG, D. R. & PERRETT, D. I., ET AL. (2008c) Symmetry is related to sexual dimorphism in faces: Data across culture and species. *PLoS One. 2106 (DOI 10.1371/journal.pone.0002106),* 3.

LITTLE, A. C., PENTON-VOAK, I. S., BURT, D. M. & PERRETT, D. I. (2003) Investigating an imprinting-like phenomenon: partners and opposite-sex parents have similar hair and air color. *Evol. Hum. Behav,* 24**,** 43-51.

LITTLE, B. B., BUSCHANG, P. H. & MALINA, M. (2002) Anthropometric asymmetry in chronically undernourished children from Southern Mexico. . *Ann Hum Biol***,** 526-537.

LIU, Y. H., LIAO, W. B., ZHOU, C. Q., MI, Z. P. & MAO, M. (2011) Asymmetry of testes in Guenther's Frog. Hylarana guentheri (Anura: Ranidae). *Asian Herpetological Research,* 2**,** 234-239.

LIVSHITS, G., DAVIDI, L., KOBYLIANSKY, E., BEN-AMITAI, D., LEVI, Y. & MERLOB, P. (1988) Decreased developmental stability as assessed by fluctuating asymmetry of morphometric traits in preterm infants *Am J Med Genet,* 29**,** 793-805.

LIVSHITS, G. & KOBYLIANSKY, E. (1989) Study of genetic variance in the fluctuating asymmetry of anthropometrical traits. *Hum. Biol,* 16**,** 121-129.

LOEHR, J., LEINONEN, T., HERCZEG, G., O' HARA, R. B. & MERILA, J. (2012) Heritability of Asymmetry and Lateral Plate Number in the Threespine Stickleback. *PLoS ONE,* 7**,** e39843.

LUNDSTROM, A. (1961) Some asymmetries of the dental arches, jaws, and skull, and their etiological significance. *American journal of orthodontics,* 47**,** 81-106.

MACAPAGAL, K. R., RUPP, H. A. & HEIMAN, J. R. (2011) Influences of observer sex, facial masculinity, and gender role identification on first impressions of men's faces. *Journal of social, evolutionary & cultural psychology : JSEC,* 5**,** 92-105.

MANFREDINI, M., BRESCHI, M. & MAZZONI, S. (2010) Spouse selection by health status and physical traits. Sardinia, 1856-1925. *Am J Phys Anthropol,* 141**,** 290-296.

MANK, J. E., AVELSSON, E. & ELLEGREN, H. (2007) Fast-X on the Z: rapid evolution of sex-linked genes in birds. *Genome Research,* 17**,** 618-624.

MANNING, J. T. (1995a) Fluctuating asymmetry and body weight in men and women: implication for sexual selection. *Ethol Sociobiol,* 16**,** 145-153.

MANNING, J. T. (1995b) Fluctuating asymmetry and body weight in men and women: Implications for sexual selection. *Ethology and Sociobiology,* 16**,** 145-153.

MANNING, J. T., KOUKOURAKIS, K. & BRODIE, D. A. (1997) Fluctuating asymmetry, metabolic rate and sexual selection in human males. *Evolution and Human Behavior,* 18**,** 15-21.

MANNING, J. T. & OCKENDEN, L. (1994) Fluctuating asymmetry in racehorses. *Nature.,* 370**,** 185-186

MARCHI, D. & SHAW, C. N. (2011) Variation in fibular robusticity reflects variation in mobility patterns. *J Hum Evol,* 61**,** 609-616.

MARCINKOWSKA, U. M., KOZLOV, M. V., CAI, H., CONTRERAS-GARDUÃ±O, J., DIXSON, B. J., OANA, G. A., KAMINSKI, G. L., LI, N. P., LYONS, M. T., ONYISHI, I. E., PRASAI, K., PAZHOOHI, F., PROKOP, P., ROSALES CARDOZO, S. L., SYDNEY, N., YONG, J. C. & RANTALA, M. J. (2014) Cross-cultural variation in men's preference for sexual dimorphism in women's faces. *Biology Letters,* 10.

MARKOW, T. A. & MARTIN, J. F. (1993) Inbreeding and developmental stability in a small population *Annals of human biology,* 20**,** 389-394.

MARLOWE, C. M., SCHNEIDER, S. L. & NELSON, C. E. (1996) Gender and attractiveness biases in hiring decisions: are more experienced manager less biassed? *Appl. Psychol.,* 81**,** 11-21.

MARY, W., BIVINS (1997) Daura and gender in the creation of a Hausa national epic *African Languages and Cultures,* 10**,** 1-28.

MASCIE-TAYLOR, C. G. N. & LASKER, G. W. (2005) Biosocial correlates of stature in a British national cohort. *J. Biosoc. Sci,* 37**,** 245-251.

MATHER, K. (1953) Genetical control of stability in development. *Heredity***,** 297-336.

MCAVINCHEY, G., MAXIM, F., NIX, B., DJORDJEVIC, J., LINKLATER, R. & LANDINI, G. (2014) The perception of facial asymmetry using 3-dimensional simulated images. *The Angle Orthodontist,* 84**,** 957-965.

MCCOY, K. A. & HARRIS, R. N. (2003) Integrating developmental stability analysis and current amphibian monitoring techniques: an experimental evaluation with the salamander *Ambystoma maculatum. Herpetologia***,** 22-36.

MCKENZIE, J. A. & CLARK, G. M. (1988) Diazanon resistance, fluctuating asymmetry and fitness in the Australian sheep blowfly, lucilia cuprina. *Genetica,* 120**,** 213-220.

MEALEY, L., BRIDGSTOCK, R. & TOWNSEND, G. C. (1999) Symmetry and percieved facial attractiveness: a monozygotic co-twin comparison
J. Pers. Soc. Psychol., 76**,** 157-165.

MEIKLEJOHN, C. D. & HARTL, D. L. (2002) A single mode of canalization. *Trends in Ecology and Evolution,* 17**,** 468-473.

MELNIK, A. K. (1992) A cephalometric study of mandibular asymmetry in a longitudinally followed sample of growing children. *American Journal of Orthodontics and Dentofacial Orthopedics,* 101**,** 355-366.

MESSINGHAM, K. A. N., SHIRAZI, M., DUFFNER, L. A., EMMANUEL, M. A. & KOVACS, E. J. (2001) Testosterone receptor blockade restores cellular immunity in male mice after burn injury. *J. Endocrinol,* 169**,** 299-308.

MEYER-MARCOTTY, P., ALPERS, G. W., GERDES, A. B. M. & STELLZIG-EISENHAUER, A. (2010) Editor's Summary and Q&A: Impact of facial asymmetry in visual perception: A 3-dimensional data analysis. *American Journal of Orthodontics and Dentofacial Orthopedics,* 137**,** 168-169.

MEYER-MARCOTTY, P., KOCHEL, J., BOEHM, H., LINZ, C., KLAMMERT, U. & STELLZIG-EISENHAUER, A. (2011a) Face perception in patients with unilateral cleft lip and palate and patients withÂ severe Class III malocclusion compared to controls. *Journal of Cranio-Maxillofacial Surgery,* 39**,** 158-163.

MEYER-MARCOTTY, P. & STELLZIG-EISENHAUER, A. (2009) Dentofacial self-perception and social perception of adults with unilateral clept lip and palate. *J Orofac Orthop,* 70**,** 224-36.
MEYER-MARCOTTY, P., STELLZIG-EISENHAUER, A., BAREIS, U., HARTMANN, J. & KOCHEL, J. (2011b) Three-dimensional perception of facial asymmetry. *The European Journal of Orthodontics,* 33**,** 647-653.
MILNE, B. J., BELSKY, J., POULTON, R., THOMSON, W. M., CASPI, A. & KIESER, J. (2003) Fluctuating asymmetry and physical health among young adults. *Evolution and Human Behavior,* 24**,** 53-63.
MITRA, S., LAZAR, N. & LIU, Y. (2007) Understanding the role of facial asymmetry in human face identification. *Statistics and Computing,* 17**,** 57-70.
MITRA, S. & SAVVIDES, M. (2006) Face identification using novel frequency-domain representation of facial asymmetry. *IEEE Transactions on Information Forensics and Security,* 1**,** 350-359.
MITTON, J. B. & GRANT, M. C. (1984) Associations among proteins heterozygosity, growth rate, and developmental homeostasis. *Ann. Rev. Ecol. Syst.,* 15**,** 479-499.
MIYAI, N., ARITA, M., MIYASHITA, K., MORIOKA, I., SHIRAISHI, T. & NISHIO, I. (2002) Blood Pressure Response to Heart Rate During Exercise Test and Risk of Future Hypertension. *Hypertension,* 39**,** 761-766.
MOFFAT, D. B. (1993) Lecture Notes on Anatomy. *Blackwell Scientific Publications,* 2nd Edition**,** 367-375.
MOHSEN, T. & REG, D. (2011) Making sense of Cronbach's alpha. *International Journal of Medical Education,* 2**,** 53-55.
MOLLER, A. P. (1992) Parasites differentially increase the degree of fluctuating asymmetry in secondary sexual characters. *J Evol Biol,* 5**,** 691-699.
MOLLER, A. P. (1994) Directional asymmetry: testes size and secondary sexual characters in birds. *Proceedings of the Royal Society of London B,* 258**,** 147-151.
MOLLER, A. P. (1996) Parasitism and developmental stability of host: a review. *Oikos,* 77**,** 189-196.
MOLLER, A. P. (1997) Developmental stability and fitness: A review. *American Naturalist,* 149**,** 916-932.
MOLLER, A. P., CHRISTIE, P. & LUX, E. (1999) Parasitism, host immune function, and sexual selection. *The Quarterly Review of Biology,* 74**,** 3-74.
MØLLER, A. P. & POMIANOWSKI, A. (1993) Why have birds got multiple sexual ornaments? *Behavioral Ecology and Sociobiology,* 32**,** 167-176.
MOLLER, A. P. & SWADDLE, J. P. (1997a) Asymmetry, developmental stability, and evolution. *Oxford Univ. Press, Oxford*.
MOLLER, A. P. & SWADDLE, J. P. (1997b) Developmental Stability and Evolution. *Oxford Univ. Press, Oxford*.
MOLLER, A. P. & SWADDLE, J. P. (1997c) Developmental stability and evolution. *Oxford University Press, Oxford.*
MOOR, K. L. & PERSAUD, T. V. N. (2005) The developing Human. Clinically oriented Embryology. 7th Edition. *W. B. Saunders Company Harcourt Brace, Joyannorich inc. Philadelphia, Pennsylvania***,** 227-228.
MOORE, F. R., LAW SMITH, M. J., TAYLOR, V. & PERRETT, D. I. (2011) Sexual dimorphism in the female face is a cue to health and social status but not age. *Pers Individ Dif,* 50**,** 1068-1073.

MORO, A. (2009) Three-dimensional analysis in facial asymmetry: comparison with model analysis and conventional two-dimensional analysis. *The Journal of craniofacial surgery,* 20**,** 417.

MORRISON, E. R., CLARK, A. P., TIDDEMAN, B. P. & PENTON-VOAK, I. S. (2010) Manipulating Shape Cues in Dynamic Human Faces: Sexual Dimorphism is Preferred in Female but not Male Faces. *Ethology,* 116**,** 1234-1243.

MUEHLENBEIN, M. P. & BRIBIESCAS, R. G. (2005) Testosterone mediated immune functions and male life histories. *Am. J. Hum. Biol,* 17**,** 527-558.

MULLER, U. & MAZUR, A. (1997) Facial dominance in Homo sapiens as honest signaling of male quality. *Behavioral Ecology,* 8**,** 569-579.

NAINI, F. B. & GILL, D. S. (2006) Facial aesthetics: 1. Concepts and canons. *Dent. Update,* 35**,** 102-107.

NEAVE, N., LAING, S., FINK, B. & MANNING, J. T. (2003) Second to fourth digit ratio, testosterone and perceived male dominance. *Proc R Soc B,* 270**,** 2167–2172.

NEAVE, N. & SHIELDS, K. (2008) The effects of facial hair manipulation on female perceptions of attractiveness, masculinity, and dominance in male faces. *Pers. Indiv. Differ.,* 45**,** 373-377.

NIJHOUT, H. F. & DAVID, G. (2003) Developmental perspectives on phenotypic variation: canalization, and fluctuating asymmetry. In: Developmental Instability: Causes and consequences (M. Polak, ed.). 3-13.

NILES, F. S. (1989) Parental Attitudes toward Female Education in Northern Nigeria. *The Journal of Social Psychology,* 129**,** 13-20.

NNPC (2013) Nigerian National Petroleum Corporation. NNPC Business > Upstream Ventures > Oil Production. Accessed online on 31 May 2013 at:. http://www.nnpcgroup.com/NNPCBusiness/UpstreamVentures/OilProduction.aspx.

NOYAN, A., BRENT, E. L., VLADIMIR, L.-S. & SORAYA, B. (2011) Accuracy and precision of a 3D anthropometric facial analysis with and without landmark labeling before image acquisition. *Angle Orthod,* 81**,** 245-252.

NPC (2006a) National Population Commission of Nigeria. 2006 final census results. *accessed online at:* www.population.gov.ng.

NPC (2006b) National Population Commission: Population and Housing Census of the Federal Republic of Nigeria. Accessed online at: . *www.population .gov.ng*.

NPC (Macro; 2009) National Population Commission of Nigeria, la' Macro. 2008 Nigeria Demographic and Health Survey. . *Abuja, Nigeria: National Population Commission and ICI, Macro;*.

NPC & ORCM (2004) National Population Commission (NPC) [Nigeria] and ORC Macro. Nigeria Demographic and Health Survey 2003. . *Calverton, Maryland: National Population Commission and ORC Macro.*

NUNNALY, J. & BERNSTEIN, L. (1994) Psychometric theory. *New York: McGraw-Hill Higher, INC*.

NUPPONEN, K. (2009) Scythris antisymmetrica Nupponen, sp n. from Central Spain, an example of antisymmetric male genitalia in the order Lepidoptera (Lepidoptera: Scythrididae). *SHILAP,* 37**,** 439-444.

O'CONNOR, J. J. M., FRACCARO, P. J., PISANSKI, K., TIGUE, C. C. & FEINBERG, D. R. (2013) Men's Preferences for Women's Femininity in Dynamic Cross-Modal Stimuli. *PLoS ONE,* 8**,** e69531.

OPHI (2013) Oxford Poverty and Human Development Initiative. "Nigeria Country Briefing ", Multidimensional Poverty Index Data Bank. OPHI, University of Oxford. *Accessed online at:* *www.ophi.org.uk/multidimensional-poverty-index/mpi-country-briefings/*.

OSVALDO, F., RACHAEL, L., EDUARDO, D. J., ANDREA, S. & SILVEIRA, D. (2012) Sexual Dimorphism in Brazilian Human Skulls: Discriminant Function Analysis. *Journal of Forensic Odontostomatology,* 30**,** 26-33.

OYEDIRAN, K. A. & ISIUGO-ABANIHE, U. C. (2005) Perceptions of Nigerian Women on Domestic Violence: Evidence from 2003 Nigeria Demographic and Health Survey. *African Journal of Reproductive Health / La Revue Africaine de la SantÃ© Reproductive,* 9**,** 38-53.

OZENER, B. (2012) Facial width-to-height ratio in a Turkish population is not sexually dimorphic and is unrelated to aggressive behaviour. *Evol. Hum. Behav,* 33**,** 169-173.

ÖZENER, B. (2010) Fluctuating and directional asymmetry in young human males: Effect of heavy working condition and socioeconomic status. *American Journal of Physical Anthropology,* 143**,** 112-120.

OZENER, B., DUYAR, I. & ATAMTURK, D. (2007) Body composition of young laborers: the results of a bioelectrical impedance analysis. *Colegium Anthropologicum,* 31**,** 949-954.

ÖZENER, B. & FINK, B. (2010) Facial symmetry in young girls and boys from a slum and a control area of Ankara, Turkey. *Evolution and Human Behavior,* 31**,** 436-441.

OZENER, B. & ÖZENER (2010c) Brief Communication: Facial Fluctuating Asymmetry as a Marker of Sex Differences of the Response to Phenotypic Stresses. *American Journal of Physical Anthropology,* 143**,** 321-324.

OZENER, B. & OZENER, B. (2011) Relationship between shortness of final body height and fluctuating asymmetry in Turkish young males. *Annals of human biology,* 38**,** 34-38.

PALMER, A. (1993) Bilateral variation and the evolutionary origin of macroscopic asymmetries. *Genetica,* 89**,** 201-218.

PALMER, A. R. (1994) Fluctuating asymmetry analyses: primer in: developmental stability: its Origins and Evolutionary Implications (T. A. Markow, ed.). *Kluwer Academic Publishers, Dordrecht***,** 355-363.

PALMER, A. R. (1996a) From symmetry to asymmetry: Phylogenetic patterns of asymmetry variation in animals and their evolutionary significance. *Proceedings of the National Academy of Sciences of the United States of America,* 93**,** 14279-14286.

PALMER, A. R. (1996b) Waltzing with asymmetry. *BioScience***,** 518-532.

PALMER, A. R. (2004a) Selection for Asymmetry. *Science,* 306**,** 812-813.

PALMER, A. R. (2004b) Symmetry breaking and the evolution of development. *Science,* 306**,** 826-833.

PALMER, A. R. (2005) Antisymmetry. In: Variation (B. Hallgrimmson & B. K. Hall, eds). *Elsevier***,** 359-397.

PALMER, A. R. (2009a) Animal Asymmetry. *Current Biology,* 19: R473-R477.

PALMER, A. R. (2009b) Animal asymmetry. *Current Biology,* 19**,** R473-R477.

PALMER, A. R. (2012) Developmental origins of normal and anomalous random right-left asymmetry: lateral inhibition versus developmental error in a threshold trait. *Contributions to zoology,* 81**,** 111-124.

PALMER, A. R. & STROBECK, C. (1986) Fluctuating asymmetry: measurement analysis patterns. *Annal Review of Ecology and systematics***,** 391-421.
PALMER, A. R. & STROBECK, C. (1992) Fluctuating asymmetry as a measure of developmental stability: Implications of non-normal distributions and power of statistical tests. *Acta Zoologica Fennica,* 191**,** 57-72.
PALMER, A. R. & STROBECK, C. (1997) Fluctuating asymmetry and developmental stability: Heritability of observable variation vs. heritability of inferred cause. *Journal of Evolutionary Biology,* 10**,** 39-49.
PALMER, A. R. & STROBECK, C. (2003) Fluctuating asymmetry analysis revisited in Developmental instability (DI): causes and consequences (M. Polak, ed.). *Oxford University Press, Oxford, United Kindom***,** 279-319.
PALMER, A. R., STROBECK, C. & CHIPPINDALE, A. K. (1994) Bilateral variation and evolutionary origin of macroscopic asymmetries. In: Markow TA, ed. Developmental instability: its origins and evolutionary implications. *Dordrecht: Kluwer***,** 203-220.
PARSONS, P. A. (1990) Fluctuating asymmetry: an epigenetic measure of stress. *Biological Reviews***,** 131-145.
PARSONS, P. A. (1992) Fluctuating asymmetry: a biological monitor of environmental and genomic stress. *Heredity,* 68**,** 361-364.
PASCALIS, O., HAAN, M. & NELSON, C. A. (2002) Is face processing species-specific during the first year of life? *Science,* 296**,** 1321-1323.
PAWLOWSKI, B., DUNBAR, R. I. M. & LIPOWICZ, A. (2000) Tall men have more reproductive success. *Nature,* 403**,** 156.
PAWLOWSKI, B., LYNDA, G. B., PERRETT, D. I. & SYLWIA, K. (2008) Is Female Attractiveness Related to Final Reproductive Success? *Coll. Anthropol,* 32**,** 457-460.
PECCEI, J. S. (2001) Menopause: Adaptation or epiphenomenon? *Evol Anthropol,* 10**,** 43-57.
PECK, S., PECK, L. & KATAJA, M. (1991) Skeletal asymmetry in esthetically pleasing faces. *Angle Orthod***,** 43-48.
PELLOW, D. (1996) "Hausa" Encyclopedia of World Cultures. *Retrieved April 28, 2015 from Encyclopedia.com: http://www.encyclopedia.com/doc/IG2-3458001492*.
PENTON-VOAK, I. S. & CHEN, J. Y. (2004) High salivary testosterone is linked to masculine male facial appearance in humans. *Evol. Hum. Behav.,* 25**,** 229-241.
PENTON-VOAK, I. S., JACOBSON, A. & TRIVERS, R. (2004) Populational differences in attractiveness judgements of male and female faces: Comparing British and Jamaican samples. *Evol Hum Behav,* 25**,** 355-370.
PENTON-VOAK, I. S., LITTLE, A. C., JONES, B. C., BURT, D. M., TIDDEMAN, B. P. & PERRETT, D. I. (2003) Female condition influences preferences for sexual dimorphism in faces of male humans (Homo sapiens). *Journal of Comparative Psychology. http://dx.doi.org/10.1037/0735-7036.117.3.264 Medline:14498802,* 117**,** 264-271.
PENTON–VOAK, I. S. & SCOTT, I. (2010) Cross cultural studies of facial attractiveness and personality attribution. *Human behaviour and evolution society-22nd annual meeting; June 16-20, 2000; Eugene (OR): University of Oregon***,** 80.
PENTON VOAK, I. S., JONES, B. C., LITTLE, A. C., BAKER, S., TIDDEMAN, B. P., BURT, D. M. & PERRETT, D. I. (2001) Symmetry, sexual dimorphism

in facial proportions and male facial attractiveness. *Proceedings - Royal Society. Biological sciences,* 268**,** 1617-1621.

PERLOFF, D., GRIM, C., FLACK, J., FROHLICH, E. D., HILL, M., MCDONALD, M. & MORGENSTERN, B. Z. (1993) Human blood pressure determination by sphygmomanometry. *Circulation,* 88**,** 2460-2470.

PERRETT, D. I., BURT, D. M., PENTON-VOAK, I. S., LEE, K. J., ROWLAND, D. A. & EDWARDS, R. (1999) Symmetry and Human Facial Attractiveness. *Evolution and Human Behavior,* 20**,** 295-307.

PERRETT, D. I., LEE, K. J., PENTON-VOAK, I., ROWLAND, D., YOSHIKAWA, S., BURT, D. M., HENZI, S. P., CASTLES, D. L. & AKAMATSU, S. (1998) Effects of sexual dimorphism on facial attractiveness. *Nature,* 394**,** 884-887.

PERTOLDI, C., KRISTENSEN, T. N., ANDERSEN, D. H. & LOESCHCKE, V. (2006) Developmental instability as an estimator of genetic stress. *Heredity,* 96**,** 122-127.

PETER, H., TIM, J. H., JUDITH, E. A., LINDA, E. C., RAOUL, C. M. H., SEAN, H., MICHAEL, A. P., ADAM, S., TEMPLE, I. K., MATHEW, T., KIERAN, C. M., ROBIN, M. W. & (2004) 3D A analysis of Facial Morphology. *American Journal of Medical Genetics.,* 126A**,** 339-348.

PETERS, M., RHODES, G. & SIMMONS, L. W. (2007) Contributions of the face and body to overall attractiveness. *Animal Behaviour,* 73**,** 937-942.

PETERS, M., SIMMONS, L. W. & RHODES, G. (2008) Testosterone is associated with mating success but not attractiveness or masculinity in human males. *Anim Behav,* 76**,** 297–303.

PFLUGER, L. S., OBERZAUCHER, E., KATINA, S., HOLZLEITNER, I. J. & GRAMMER, K. (2012) Cues to fertility: perceived attractiveness and facial shape predict reproductive success. *Evolution and Human Behavior,* 33**,** 708-714.

PISANSKI, K. & FEINBERG, D. R. (2013) Cross-Cultural Variation in Mate Preferences for Averageness, Symmetry, Body Size, and Masculinity. *Cross-cultural research,* 47**,** 162-197.

POLAK, M. (2008) The developmental instability - Sexual selection hypothesis: A general evaluation and case study. *Evolutionary Biology,* 35**,** 208-230.

POLAK, M. & TRIVERS, R. (1994) The science of symmetry in biology. *Trends in Ecology and Evolution***,** 123-125.

POLAK, M. E. (2003) Developmental Instability. Causes and Consequencies. *New York: Oxford Univ. Press*.

POUND, N., LAWSON, D., TOMA, A., RICHMOND, S., ZHUROV, A. & PENTON-VOAK, I. S. (2014) Facial fluctuating asymmetry is not associated with childhood ill-health in a large British cohort study. *Proceedings - Royal Society. Biological sciences,* 281**,** 20141639-20141639.

POUND, N., PENTON-VOAK, I. S. & SURRIDGE, A. K. (2009) Testosterone responses to competition in men are related to facial masculinity. *Proceedings of the Royal Society B: Biological Sciences,* 276**,** 153-159.

PREVIC, F. (1991) A general theory concerning the prenatal origins of cerebral lateralization in humans. *Psychological review,* 98**,** 299.

PRICE, D. & FRIEDMAN, O. (2007) Facial asymmetry in maxillary sinus hypoplasia. *International Journal of Pediatric Otorhinolaryngology,* 71**,** 1627-1630.

PRIMOZIC, J., PERINETTI, G., ZHUROV, A., RICHMOND, S. & OVSENIK, M. (2012) Assessment of facial asymmetry in growing subjects with a three-dimensional laser scanning system. *Orthodontics & Craniofacial Research,* 15**,** 237-244.

PRIMOZIC, J., RICHMOND, S., KAU, C. H., ZHUROV, A. & OVSENIK, M. (2011) Three-dimensional evaluation of early crossbite correction: a longitudinal study. *The European Journal of Orthodontics*.

PROKOP, P. & FEDOR, P. (2011) Physical attractiveness influences reproductive success of modern men. *Journal of ethology,* 29**,** 453-458.

PURKAIT, R. (2004) A preliminary study on human facial asymmetry by photogrammetry method. *Ind. J. Phys. Anthrop. & Hum. Genet,* 23**,** 185-194.

PUTS, D. A. (2010) Beauty and the beast: mechanisms of sexual selection in humans. *Evolution and Human Behavior,* 31**,** 157-175.

QUIST, M. C., WATKINS, C. D., SMITH, F. G., DEBRUINE, L. M. & JONES, B. C. (2011) Facial masculinity is a cue to women's dominance. *Personality and Individual Differences,* 50**,** 1089-1093.

R CORE TEAM. (2014) R: A language and environment for statistical computing. . *R Foundation for Statistical Computing,Vienna, Austria. URL* http://www.R-project.org/*.*

RANTALA, M. J., COETZEE, V., MOORE, F. R., SKRINDA, I., KECKO, S., KRAMA, T., KIVLENIECE, I. & KRAMS, I. (2013) Adiposity, compared with masculinity, serves as a more valid cue to immunocompetence in human mate choice. *Proceedings of the Royal Society B: Biological Sciences,* 280.

RAS, F., HABETS, L., VANGINKEL, F. C. & PRAHLANDERSEN, B. (1995) METHOD FOR QUANTIFYING FACIAL ASYMMETRY IN 3 DIMENSIONS USING STEREOPHOTOGRAMMETRY. *The Angle orthodontist,* 65**,** 233-239.

RAS, F., HABETS, L. L. M. H., VAN GINKEL, F. C. & PRAHL-ANDERSEN, B. (1994) Three-Dimensional Evaluation of Facial Asymmetry in Cleft Lip and Palate. *The Cleft Palate-Craniofacial Journal,* 31**,** 116-121.

RASMUSON, M. (1960) Frequency of morphological deviations as criterion of developmental stability. *Hereditas,* 46**,** 511-535.

REINUIS, B., SAETRE, P., LEONARD, J. A., BLEKHMAN, R., MERINO-MARTINEZ, R., GILAD, Y. & JAZIN, E. (2008) An evolutionarily conserved sexual signature in the primate brain. *PLos Genetics,* 4.

RENNELS, J., BRONSTAD, P. M. & LANGLOIS, J. (2008) Are attractive men's faces masculine or feminine? The importance of type of facial stimuli. *Journal of experimental psychology. Human perception and performance,* 34**,** 884-893.

RHODES, G. (1998) Facial symmetry and the perception of beauty. *Psychonomic bulletin & review,* 5**,** 659-669.

RHODES, G. (2006) The Evolutionary psychology of facial beauty. *Annual review of psychology,* 57**,** 199-226.

RHODES, G., CHAN, J., ZEBROWITZ, L. A. & SIMMONS, L. W. (2003) Does sexual dimorphism in human faces signal health? *Proceedings of the Royal Society of London B,* 270**,** 593-595.

RHODES, G. & SIMMONS, L. W. (2007) Symmetry, attractiveness and sexual selection. *In the Oxford handbook of evolutionary psychology (eds R Dunbar, L. Barrett). Oxford, UK: Oxford University Press*, 333-364.

RHODES, G., SIMMONS, L. W. & PETERS, M. (2005) Attractiveness and sexual behavior: Does attractiveness enhance mating success? *Evolution and Human Behavior,* 26, 186-201.

RHODES, G., YOSHIKAWA, S., CLARK, A., LEE, K., MCKAY, R. & AKAMATSU, S. (2001a) Attractiveness of facial averageness and symmetry in non-Western populations: in search of biologically based standards of beauty. *Perception,* 30, 611-625.

RHODES, G., YOSHIKAWA, S., PALERMO, R., SIMMONS, L. W., PETERS, M., LEE, K., HALBERSTADT, J. & CRAWFORD, J. R. (2007) Perceived health contributes to the attractiveness of facial symmetry, averageness, and sexual dimorphism. *Perception,* 36, 1244-1252.

RHODES, G., ZEBROWITZ, L. A., CLARK, A., KALICK, S. M., HIGHTOWER, A. & MCKAY, R. (2001b) Do facial averageness and symmetry signal health? *Evolution and Human Behavior,* 22, 31-46.

RIGGIO, R. & WOLL, S. (1984) The role of non-verval and physical attractiveness in the selection of dating partners. *Soc. Pers. Relat.,* 1, 347-357.

RIKOWSKI, A. & GRAMMER, K. (1999) Human body odour, symmetry and attractiveness. *P Roy Soc Lond B Bio,* 266, 869-874.

ROBERTS, M. L., BUCHANNAN, K. L. & EVANS, M. R. (2004) Testing the immunocompetence handicap hypothesis: a review of the evidence. *Animal Behaviour,* 68, 227-239.

ROBERTS, S. C., LITTLE, A. C., GOSLING, L. M., PERRETT, D. I., CARTER, V., JONES, B. C., PENTON-VOAK, I. S. & PETRIE, M. (2005) MHC-Heterozygosity and human facial attractiveness. *Evol. Hum. Behav,* 26, 213-226.

ROFF, D. A. (1997) Evolutionary Quantitative Genetics. *New York: Chapman and Hall*.

RUFF, C. B. (2000) Biomechanical analyses of archeological human skeletons. In: Katzenberg MA, editor. *Biological anthropology of the human skeleton. New York: Wiley-Liss*.

SACKEIM, H. A. (1985) Morphologic asymmetries of the face: A review. *Brain and Cognition,* 4, 296-312.

SACKHEIM, H. A. (1985) Moephologic asymmetries of the face: A review. *Brain Cognition*, 296-312.

SADLER, T. W. (2006) *Langman's Medical Embryology.*, Lippincott Williams & Wilkins, Wolters Kluwer Health (India) pvt. Ltd., New Delhi.

SARAH, A. S. (2009) The Relevance of the Culture of Origin to Nation Building in Nigeria. *J Soc Sci,* 21, 185-189.

SARRINGHAUS, L. A., STOCK, J. T., MARCHANT, L. F. & MCGREW, W. C. (2005) Bilateral asymmetry in the limb bones of the chimpanzee (Pan troglodytes). *Am J Phys Anthropol,* 128, 840-845.

SCHALLER, M. & MURRAY, D. R. (2008) Pathogens, personality and culture: disease prevalence predicts worldwide variability in sociosexuality, extraversion and openness to experience. *J. Pers. Soc. Psychol.,* 95, 212-222.

SCHEIB, J. E., GANGESTAD, S. W. & THORNHILL, R. (1999) Facial Attractiveness, Symmetry and Cues of Good Genes. *Proceedings: Biological Sciences,* 266**,** 1913-1917.

SCHELL, L. M., JOHNSTON, F. E., SMITH, D. R. & PAOLONE, A. M. (1985) Directional asymmetry of body dimensions among white adolescents. *Am J Phys Anthropol,* 67**,** 317-322.

SCHEUER, L. & BLACK, S. (2000) *Developmental Juvenile Osteology*.

SCHILDKROUT, E. (1983) Dependency and Autonomy: The Economic Activities of Secluded in Kano. In: Female and Male in West Africa. *C. Oppong (ed.), Lnondon: George Allen and Unwin***,** 106-26.

SCHOENWOLF, SCHOENWOLF, G. C. & LARSEN, W. J. (2009) *Larsen's human embryology*.

SCHROEDER, S., ENDERLE, M. D., BAUMBACH, A., OSSEN, R., HERDEG, C., KUETTNER, A. & KARSCH, K. R. (2000) Influence of vessel size, age and body mass index on the flow-mediated dilatation (FMD%) of the brachial artery. *International Journal of Cardiology,* 76**,** 219-225.

SCHULTZ, A. H. (1923) Fetal growth in man. *American Journal of Physical Anthropology,* 6**,** 389-399.

SCHULTZ, A. H. (1926) Fetal Growth of Man and Other Primates. *The Quarterly Review of Biology,* 1**,** 465-521.

SCOTT, I., SWAMI, V., JOSEPHSON, S. C. & PENTON–VOAK, I. S. (2008) Context dependent preferences for facial dimorphism in a rural Malaysian population. *Evol Hum Behav,* 29**,** 289–296.

SCOTT, I. M., CLARK, A. P., JOSEPHSON, S. C., BOYETTE, A. H., CUTHILL, I. C., FRIED, R. L., GIBSON, M. A., HEWLETT, B. S., JAMIESON, M., JANKOWIAK, W., HONEY, P. L., HUANG, Z., LIEBERT, M. A., PURZYCKI, B. G., SHAVER, J. H., SNODGRASS, J. J., SOSIS, R., SUGIYAMA, L. S., SWAMI, V., YU, D. W., ZHAO, Y. & PENTON-VOAK, I. S. (2014) Human preferences for sexually dimorphic faces may be evolutionarily novel. *Proceedings of the National Academy of Sciences,* 111**,** 14388-14393.

SCOTT, I. M. L., CLARK, A. P., BOOTHROYD, L. G. & PENTON-VOAK, I. S. (2013) Do men's faces really signal heritable immunocompetence? *Behavioral Ecology,* 24**,** 579-589.

SCOTT, I. M. L., POUND, N., STEPHEN, I. D., CLARK, A. P. & PENTON-VOAK, I. S. (2010) Does Masculinity Matter? The Contribution of Masculine Face Shape to Male Attractiveness in Humans. *PLoS ONE,* 5**,** e13585.

SEAR, R. (2006) Height and reproductive success: how a Gambian population compares to the West. *Hum. Nat,* 17**,** 405-418.

SELANDER, R. K. (1972) In Sexual Selection and the Descent of Man (1871-1971). *Campbell, B. G., ed.)***,** 180-230.

SELL, A., COSMIDES, L., TOOBY, J., SZNYCER, D., VON RUEDEN, C. & GURVEN, M. (2009) Human adaptations for the visual assessment of strength and fighting ability from the body and face. *Proceedings of the Royal Society of London B: Biological Sciences,* 276**,** 575-584.

SENGUPTA, M. & KARMAKAR, B. (2007) Genetics of anthropometric asymmetry in an Indian endogamous population-Vaidyas. *Am J Hum Biol,* 19**,** 399-408.

SHACKELFORD, T. K. & LARSEN, R. J. (1997a) Facial asymmetry as an indicator of psychological, emotional, and physiological distress. *Journal of personality and social psychology,* 72**,** 456-66.

SHACKELFORD, T. K. & LARSEN, R. J. (1997b) Facial asymmetry as an indicator of psychological, emotional, and physiological distress. *J Pers Soc Psychol,* 72**,** 456-466.

SHACKELFORD, T. K. & LARSEN, R. J. (1999) Facial Attractiveness and Physical Health. *Evolution and Human Behavior,* 20**,** 71-76.

SHANER, D. J., PETERSON, A. E., BEATTIE, O. B. & BAMFORTH, J. S. (2000) Assessment of soft tissue facial asymmetry in medically normal and syndrome-affected individuals by analysis of landmarks and measurements. *Am J Med Genet,* 93**,** 143-154.

SHAW, C. N. & STOCK, J. T. (2009) Habitual throwing and swimming correspond with upper limb diaphyseal strength and shape in mordern human athletes. *Am J Phys Anthropol,* 140**,** 140-172.

SHI, B., SOMMERLAD, B., GRAYSON, B. & GARFINKLE, J. (2013) The Role of Nasoalveolar Molding in the Presurgical Management of Infants Born with Cleft Lip and Palate. *Cleft Lip and Palate Primary Repair.* Springer Berlin Heidelberg.

SHINE, R. (1989) Ecological Causes for the Evolution of Sexual Dimorphism: A Review of the Evidence. *The Quarterly Review of Biology,* 64**,** 419-461.

SIEBERT, J. W., ANSON, G. & LONGAKER, M. T. (1996) Microsurgical correction of facial asymmetry in 60 consecutive cases. *Plastic and reconstructive surgery,* 97**,** 354-363.

SILVA, A. S., LUMMAA, V., MULLER, U., RAYMOND, M. & ALVERGNE, A. (2012) Facial attractiveness and fertility in populations with low levels of modern birth control. *Evolution and Human Behavior,* 33**,** 491-498.

SIMMONS, L. W., RHODES, G., PETERS, M. & KOEHLER, N. (2004) Are human preferences for facial symmetry focused on signals of developmental instability? *Behavioral Ecology,* 15**,** 864-871.

SIMON, A. R., & & VASSAR, C. (1992) Ethnicity in Nigeria. *(English 32, Fall 1990) in the Postcolonial Literature in English, in the Postcolonial Web***,** 20-21.

SINGH, G. D., LEVY-BERCOWSKI, D., YÁÑEZ, M. A. & SANTIAGO, P. E. (2007) Three-dimensional facial morphology following surgical repair of unilateral cleft lip and palate in patients after nasoalveolar molding. *Orthodontics & Craniofacial Research,* 10**,** 161-166.

SINGH, I. & PAL, G. P. (2006) Human Embryology. *Macmillan India LTD,* 7th Edition**,** 139-143.

SINNATAMBY, C. S. (2011) *Lasts Anatomy: Regional and Applied,* New York, NY, [Elsevier Health Sciences.

SKVARILOVA, B. (1993) Facial asymmetry: type, extent and range of normal values. *ActaChirurgia Plastica,* 35**,** 173-180.

SLATKIN, M. (1984) Ecological Causes of Sexual Dimorphism. *Evolution,* 38**,** 622-630.

SMITH, K. (2011) *Nature of Mathematics*, Cengage Learning.

SMITH, W. M. (2010) Hemispheric and facial asymmetry: Gender differences. *Laterality,* 5**,** 251-258.

SOLER, C., KEKALAINEN, J., NUNEZ, M., SANCHO, M., ALVAREZ, J. G., NUNEZ, J., YABER, I. & GUTIERREZ, R. (2014) Male facial anthropometry and attractiveness and masculinity may provide sex and culture independent cues to semen quality. *Perception,* 41**,** 1234-1245.

SOLLARS, V., LU, X., XIAO, L., WANG, X., GARFINKEL, M. D. & RUDEN, D. M. (2003) Evidence for an epigenetic mechanism by which Hsp90 acts as a capacitor for morphological evolution. *Nature Genetics,* 33**,** 70-74.

STAUBER, I., VAIRAKTARIS, E., HOLST, A., SCHUSTER, M., HIRSCHFELDER, U. & NEUKAM, F. M. E. A. (2008) Three-dimensional analysis of facial symmetry in cleft lip and palate patients using optical surface data. *J Orofac Orthop,* 69**,** 268-.

STELLWAGEN, L., HUBBARD, E., CHAMBERS, C. & JONES, K. L. (2008) Torticollis, facial asymmetry and plagiocephaly in normal newborns. *Archives of Disease in Childhood,* 93**,** 827-831.

STEPHEN, I. D., SCOTT, I. M. L., COETZEE, V., POUND, N., PERRETT, D. I. & PENTON–VOAK, I. S. (2012) Cross-cultural effects of colour, but not morphological masculinity, on perceived attractiveness of men’s faces. *Evol Hum Behav* 33**,** 260–267.

STEWART, T. A. & ALBERTSON, R. C. (2010) Evolution of a unique predatory feeding apparatus: functional anatomy, development and a genetic locus for jaw laterality in Lake Tanganyika scale-eating chichlids. *BMC Biol,* 8**,** 8.

STYNE, D. M. & MCHENRY, H. (1993) The evolution of statture in humans. *Horm. Res,* 39**,** 3-6.

SULAIMAN, F. R. (2012) Internationalization in Education: The British Colonial Policies on Education in Nigeria 1882 - 1926. *Journal of Sociological Research,* 3.

SUTTON, J. E. G. (1979) Towards a Less Orthodox History of Hausaland. *The Journal of African History,* 20**,** 179-201.

SWADDLE, J. P. & CUTHILL, I. C. (1995) Asymmetry and Human Facial Attractiveness: Symmetry May not Always be Beautiful. *Proceedings: Biological Sciences,* 261**,** 111-116.

SWADDLE, J. P. & REIERSON, G. W. (2002) Testosteron increases percieved dominance but not attractiveness in human males. *Pro R Soc London B,* 269 (1507)**,** 2285-2289.

SWADDLE, J. P. & WITTER, M. S. (1997) On the ontogeny of developmental stability in a stabilized trait. Proceedings of the Royal Society of London, Biological Sciences. 264.

SWP (2000) The State of World Population, UNFPA. *NI World Guide 2001& 2002, Europa World Year Book 2001*.

TAKEUCHI, Y., HORI, M., MYINT, O. & KOHDA, M. (2010) Lateral bias of agonistic responses to mirror images and morphological asymmetry in the Siamese fighting fish (Betta splendens). *Behavioural Brain Research,* 208**,** 106-111.

TAMSIN, K. S., LISA, M. D., BENEDICT, C. J., ANTHONY, C. L. & CRAIG, R. C. (2011) A longitudinal study of of adolescents' judgement of facial symmetry, averageness, and sexual dimorphism. *Journal of Evolutionary Psychology: DOI: 10.1556/JEP.9.2011.22.1***,** 1-13.

THOMAS, A. F. (2005) The Evolutionary Genetics of Canalization. *The Quarterly Review of Biology,* 80**,** 287-316.

THOMPSON, A. E. & O'SULLIVAN, L. F. (2013) The relationship between men's facial masculinity and women's judgments of value as a potential romantic partner. *The Canadian Journal of Human Sexuality,* 22**,** 5-12.

THORNHILL, R. & GANGESTAD, S. W. (1993) Human facial beauty: averageness, symmetry, and parasite resistance. *Hum. Nat,* 4**,** 237-269.

THORNHILL, R. & GANGESTAD, S. W. (1994) Human Fluctuating Asymmetry and Sexual Behavior. *Psychological Science,* 5**,** 297-302.

THORNHILL, R. & GANGESTAD, S. W. (1996) The evolution of human sexuality. *Trends in Ecology and Evolution***,** 98-102.

THORNHILL, R. & GANGESTAD, S. W. (1999) Facial attractiveness. *Trends in Cognitive Sciences,* 3**,** 452-460.

THORNHILL, R. & GANGESTAD, S. W. (2006) Facial sexual dimorphism, developmental stability, and susceptibility to disease in men and women. *Evolution and Human Behavior,* 27**,** 131-144.

THORNHILL, R., GANGESTAD, S. W. & COMER, R. (1995) Human female orgasm and mate fluctuating asymmetry. *Animal Behaviour,* 50**,** 1601-1615.

THORNHILL, R. & MOLLER, A. P. (1997) Developmental stability, disease and medicine. *Biological Reviews,* 72**,** 497-548.

THORNHILL, R. & MOLLER, A. P. (1998) The relative importance of size and asymmetry in sexual selection. *Behavioral Ecology,* 9**,** 546-551.

THORNHILL, R. & THORNHILL, S. (2006) Facial sexual dimorphism, developmental stability, and susceptibility to disease in men and women. *Evolution and Human Behavior,* 27**,** 131-144.

TINUPER, P., PLAZZI, G., PROVINI, F., CERULLO, A., LEONARDI, M., AGATI, R., RIGHINI, A. & MONTAGNA, P. (1992) Facial Asymmetry in Partial Epilepsies. *Epilepsia,* 33**,** 1097-1100.

TOBO, S., TAKEUCHI, Y. & HORI, M. (2012) Morphological asymmetry and behavioral laterality in the crayfish, Procambarus clarkii.(Report). *Ecological research,* 27**,** 53.

TOMA, A. M., ZHUROV, A., PLAYLE, R., ONG, E. & RICHMOND, S. (2009) Reproducibility of facial soft tissue landmarks on 3D laser-scanned facial images. *Orthodontics & Craniofacial Research,* 12**,** 33-42.

TOMKINSON, G. R. & OLDS, T. S. (2000) Physiological correlates of bilateral symmetry in humans. *International journal of sports medicine,* 21**,** 545-550.

TORO-IBACACHE, V., CORTES ARAYA, J., DIAZ MUNOZ, A. & MANRIQUEZ SOTO, G. (2014) Morphologic variability of nonsyndromic operated patients affected by cleft lip and palate: A geometric morphometric study. *American Journal of Orthodontics and Dentofacial Orthopedics,* 146**,** 346-354.

TZIAVARAS, N., MIHAILIDIS, S., RAJION, Z., YUSOF, A., ANDERSON, P. J. & TOWNSEND, G. (2009) A Three-Dimensional Computed Tomography Analysis of Craniofacial Asymmetry in Malaysian Infants with Cleft Lip and Palate. *The Malaysian Journal of Medical Sciences : MJMS,* 17**,** 25-35.

UNDURRAGA, E. A., EISENBERG, D. T. A., MAGVANJAV, O., WANG, R., LEONARD, W. R., MCDADE, T. W., REYES-GARCIA, V., NYBERG, C., TANNER, S., HUANCA, T. S., TEAM, T. B. S. & GODOY, R. A. (2010) Human's Cognitive Ability to Assess Facial Cues from Photographs: A Study of Sexual Selection in the Bolivian Amazon. *PLoS ONE,* 5**,** e11027.

UNICEF (2007) Girls Education: Nigeria Country Office. http://www.unicef.org/wcaro/WCARO_Nigeria_Factsheets_GirlsEducation.pdf.

UYTTERSCHAUT, H. T. (1986) Sexual dimorphism in human skulls. A comparison of sexual dimorphism in different populations. *Hum Evol,* 1**,** 243-250.

UZEL, A. H. & ALPARSLAN, Z. N. (2011) Long-Term Effects of Presurgical Infant Orthopedics in Patients With Cleft Lip and Palate: A Systematic Review. *The Cleft Palate-Craniofacial Journal,* 48**,** 587-595.

UZOMA, A. O. (2013) Women Education in Nigeria: Problems and Implications for Family Role and Stability. *European Scientific Journal,* 9**,** ISSN: 1857-7881 (Print) e-ISSN 1857-7431.

VALEN, L. V. (1962) A Study of Fluctuating Asymmetry. *Evolution,* 16**,** 125-142.

VAN DONGEN, S. (2014) Associations among facial masculinity, physical strength, fluctuating asymmetry and attractiveness in young men and women. *Annals of human biology,* 41**,** 205-213.

VAN DONGEN, S., CORNILLE, R. & LENS, L. (2009) Sex and asymmetry in humans: what is the role of developmental instability? *Journal of Evolutionary Biology,* 22**,** 612-622.

VAN DONGEN, S. & GANGESTAD, S. W. (2011) Human fluctuating asymmetry in relation to health and quality: a meta-analysis. *Evolution and Human Behavior,* 32**,** 380-398.

VAN NUFFEL, A., VAN DONGEN, S., TALLOEN, W. & VAN POUCKE, E. (2007) Fluctuating asymmetry in broiler chickens: A decision protocol for trait selection in seven measuring methods. *Poultry Science,* 86**,** 2555-2568.

VAN VALEN, L. (1962) A study of fluctuating asymmetry. *Evolution.***,** 125-142.

VENNERS, S. A., LIU, X., PERRY, M. J., KORRICK, S. A. & LI, Z., ET AL. (2006) Urinary estrogen and progesterone metabolite concentrations in menstrual cucles of fertile women with non-contraception, early pregnancy loss or clinical pregnancy. *Hum Reprod,* 21**,** 2272–2280.

VERHOEVEN, T. J., COPPEN, C., BARKHUYSEN, R., BRONKHORST, E. M., MERKX, M. A. W., BERGE, S. J. & MAAL, T. J. J. (2013) Three dimensional evaluation of facial asymmetry after mandibular reconstruction: validation of a new method using stereophotogrammetry. *International Journal of Oral and Maxillofacial Surgery,* 42**,** 19-25.

WADDINGTON, C. H. (1942) Canalization of development and the inheritance of acquired characters. *Nature* 150**,** 563-565.

WADE, T. J. (2010) The Relationships between Symmetry and Attractiveness and Mating Relevant Decisions and Behavior: A Review. *Symmetry,* 2**,** 1081-1098.

WAGNER, G. P., BOOTH, G. & BAGHERI-CHAICHIAN, H. (1997) A population genetic theory of canalization. *Evolution,* 51**,** 329-347.

WALL, L. L. (1998) Dead Mothers and Injured Wives: The Social Context of Maternal Morbidity and Mortality among the Hausa of Northern Nigeria. *Studies in Family Planning,* 29**,** 341-359.

WATSON, P. J. & THORNHILL, R. (1994) Fluctuating asymmetry and sexual selection. *Trends in Ecology & Evolution,* 9**,** 21-25.

WAUTERS, L. A., DHONDT, A. A., KNOTHE, H. & PARKIN, D. T. (1996) Fluctuating Asymmetry and Body Size as Indicators of Stress in Red Squirrel Populations in Woodland Fragments. *Journal of Applied Ecology,* 33**,** 735-740.

WEEDEN, J. & SABINI, J. (2005) Physical Attractiveness and Health in Western Societies: A Review. *Psychological bulletin,* 131**,** 635-653.

WEINBERG, S. M., NAIDOO, S., GOVIER, D. P., MARTIN, R. A., KANE, A. A. & MARAZITA, M. L. (2006) Anthropometric Precision and Accuracy of Digital Three-Dimensional Photogrammetry: Comparing the Genex and 3dMD Imaging Systems with One Another and with Direct Anthropometry. *Journal of Craniofacial Surgery,* 17**,** 477-483.

WELLING, L. L. M., JOHNS, B. C., DEBRUINE, L. M., SMITH, F. G., FEINBERG, D. R., LITTLE, A. C. & AL-DUJAILI, E. A. (2008) Men report stronger attraction to femininity in women's faces when their testosteron levels are high. *Horm Behav,* 54**,** 703-708.

WESTON, E. M., FRIDAY, A. E. & LIO, P. (2007) Biometric evidence that sexual selection has shaped the hominin face. *PLoS ONE,* 2**,** e710.

WHITLOCK, M. (1996) The heritability of fluctuating asymmetry and the genetic control of developmental stability. *Proc. R. Soc. London. B,* 263**,** 849-853.

WHITLOCK, M. (1998) The repeatability of fluctuating asymmetry: a revision and extension. *Proceedings - Royal Society. Biological sciences,* 265**,** 1429-1431.

WHO (2008) Wold Health Organization. WHO Report Global TB control: Nigeria. In: WHO, editor. Geneva, Switzerland. *Available at:* http://www.who.int/globalatlas/predefinedReports/TB/PDF_Files/nga.pdf.

WIEDERMAN, M. W. & DUBOIS, S. L. (1998) Evolution and sex differences in preferences for short-term mates: results from a policy capturing study *Evol. Hum. Behav.,* 19**,** 153-170.

WILD, H. A., BARRETT, S. E., SPENCE, M. J., O' TOOLE, A. J., D, C. Y. & BROOK, J. (2000) Recognition and sex categorization of adults' and children's faces: Examining performance in the absence of sex-stereotyped cues. *Journal of Experimental Child Psychology.,* 77**,** 269-291.

WILLIAMS, A. C., BEARN, D., MILDINHALL, S., MURPHY, T., SELL, D., SHAW, W. C., MURRAY, J. J. & SANDY, J. R. (2001) Cleft Lip and Palate Care in the United Kingdomâ€"The Clinical Standards Advisory Group (CSAG) Study. Part 2: Dentofacial Outcomes and Patient Satisfaction. *The Cleft Palate-Craniofacial Journal,* 38**,** 24-29.

WILSON, J. M. & MANNING, J. T. (1996a) Fluctuating asymmetry and age in children: evolutionary implications for the control of developmental stability. *Journal of Human Evolution,* 30**,** 529-537.

WILSON, J. M. & MANNING, J. T. (1996b) Fluctuating asymmetry and age in children: Evolutionary implications for the control of developmental stability *Journal of human Evolution,* 30**,** 529-537.

WINNING, T., BROWN, T. & TOWNSEND, G. (1999) Quantifying asymmetry in the human facial skeleton.

WINTER, R. M. (1996) What's in a face? *Nature Genetics,* 12**,** 124-129.

WYNFORTH, D. (1998) Fluctuating asymmetry and human male life-history traits in rural Belize. *Proc R Soc Lond B Biol,* 1405**,** 1497-1501.

YAKUBU, Z. (2001) Enterpreneurs at Home: Secluded Muslim Women and Hidden Economic Activities in Northern Nigeria. *Nordic Journal of African Studies,* 10**,** 107-123.

YASUGI, M. & HORI, M. (2012) Lateralized behavior in the attacks of largemouth bass on Rhinogobius gobies corresponding to their morphological antisymmetry. *Journal of experimental biology,* 215**,** 2390-2398.

YNGVESSON, J. & KEELING, L. J. (2001) Body size and fluctuating asymmetry in relation to cannibalistic behaviour in laying hens. *Animal Behaviour,* 61**,** 609-615.

YOUNG, S. G., SACCO, D. F. & HUGENBERG, K. (2011) Vulnerability to disease is associated with a domain-specific preference for symmetrical faces relative to symmetrical non-face stimuli. *Eur. J.Soc. Psychol,* 41**,** 558-563.

YU, Z. H. (1998) Asymmetrical testicular weights in mammals, birds, reptiles and amphibians. *International Journal of Andrology,* 21**,** 53-55.

YUSOF, A. (2007) Craniofacial growth changes in Malaysian Malay children and young adults: A cross-sectional 3-dimensional CT study (dissertation). [Adelaide (AU)]: University of Adelaide.

ZAIDEL, D. M. & COHEN, J. A. (2005) The face, beauty, and symmetry: percieving asymmetry in beautiful faces. *Int J Neurosci,* 115**,** 1165-1173.

ZAIDEL, D. W. & HESSAMIAN, M. (2010) Asymmetry and Symmetry in the Beauty of Human Faces. *Symmetry,* 2**,** 136-149.

ZAKHAROV, V. M. (1989) Future prospects for population phenogenetics. *Sov Sci Rev F Physiol Gen Biol,* 4**,** 1-79.

ZAKHAROV, V. M. (1992) Population phenogenetics: Analysis of developmental stability in natural populations. *Acta Zoologica Fennica.,* 191**,** 7-30.

ZANKL, A., EBERLE, L., MOLINARI, L. & SCHINZEL, A. (2002) Growth charts for nose length, nasal protrusion and philtrum length from birth to 97 years. *Am. J. Med. Genet.,* 111**,** 388-391.

ZUPAN, J. & AAHMAN, E. (2005) Perinatal mortality for the year 2000: estimates developed by WHO. . *Geneva: World Health Organization*.

Chapter 12 : APPENDICES

Appendix 1: Information Sheet and Consent Form

Information Sheet for PARTICIPANTS in Research Studies
You will be given a copy of this information sheet.
Title of Project:
CORRELATES OF NON-CLINICAL FACIAL ASYMMETRY AND FACIAL SEXUAL DIMORPHISM IN A SUB-SAHARAN AFRICAN POPULATION
This study has been approved by the UCL Research Ethics Committee (Project ID Number): 3080/001

Name	ANAS IBRAHIM YAHAYA
Work Address	DEPARTMENT OF ANTHROPOLOGY, UNIVERSITY COLLEGE LONDON, GOWER STREET, WC1E 6BT/DEPARTMENT OF ANATOMY, FACULTY OF MEDICINE, BAYERO UNIVERSITY KANO, NIGERIA.
Contact Details	E-mail: anas.yahaya.10@ucl.ac.uk suhhis@yahoo.com.

We would like to invite you to participate in this research project.
Details of Study:
The aims of the research are:
To generate digital models of the faces of the Hausa individuals who will be involved in the study, using an ExaScan Surface Scanner.
To measure differences between the left and right hand sides of the face from the digital models.
To test whether bigger differences between the left and right hand sides in individuals are associated with a history of health problems and/or with a less privileged upbringing. This would indicate the degree to which health problems or a poorer upbringing can influence normal development.
To measure whether partners are more similar to each other than to the rest of the population in the shape of their face or in the level of symmetry. This would indicate that people prefer to choose partners that are more similar in looks to themselves than those that are less similar.
I am recruiting individuals between the ages of 18 to 25 years and if you agree to participate, I will book an appointment with you to meet at a local venue. The whole process poses no risk to your health, will take about one hour and I will provide drink and snacks for you.
You will be asked several questions about: your personal data, socioeconomic status and medical history. I will take biometric measurements consisting of weight, height, blood pressure and a facial scan using a surface scanner. The scanner uses a "Type II" laser, which is classified as "eye safe" by the manufacturer. You will be asked to keep your eyes closed during the scanning to avoid any discomfort caused by the bright light of the laser. I will also take a photograph of your face.
All information gathered will be used strictly for the purpose of research and will be kept

anonymous and confidential in compliance with the United Kingdom Data Protection act. None of the data and information supplied by you will be kept in association with your name.

If you feel uncomfortable or change your mind about participating in this research, you will be completely free to withdraw at any time during the data collection or interview. If you agree to participate, I will give you this information sheet to keep and you sign a consent form and complete the questionnaire in my presence. You may indicate your happiness for me to contact you in future studies.

Please discuss the information above with others if you wish or ask me if there is anything that is not clear or if you would like more information.

All data will be collected and stored in accordance with the United Kingdom Data Protection Act 1998 and the provision of the National Code for Health Research Ethics, Nigeria.

Informed Consent Form for participants in Research Studies

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Project:

CORRELATES OF NON-CLINICAL FACIAL ASYMMETRY AND FACIAL SEXUAL DIMORPHISM IN A SUB-SAHARAN AFRICAN POPULATION

Thank you for your interest in taking part in this research. Before you agree to take part, the person organising the research must explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement

I

Have read the notes written above and the Information Sheet, and understand what the study involves.

Understand that if I decide at any time that I no longer wish to take part in this project, I can notify the researchers involved and withdraw immediately.

Consent to the processing of my personal information for the purposes of this research study.

Understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the United Kingdom Data Protection Act 1998.

Agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.

I understand that the information I have submitted will be published as a report. Confidentiality and anonymity will be maintained and it will not be possible to identify me from any publications.

I agree that my non-personal research data may be used by others for future research. I am assured that the confidentiality of my personal data will be upheld through the removal of identifiers.

SIGNATURE--- Date:

NAME (OPTIONAL) ---

WITNESS' SIGNATURE (if applicable) --

WITNESS' NAME (If applicable) ---

NAME OF RESEARCHERS	CHRISTOPHE SOLIGO (PRINCIPAL RESEARCHER), ANAS IBRAHIM YAHAYA (STUDENT-RESEARCHER)
WORK ADDRESS	DEPARTMENT OF ANTHROPOLOGY, UNIVERSITY COLLEGE LONDON, GOWER STREET, WC1E 6BT/DEPARTMENT OF ANATOMY, FACULTY OF MEDICINE, BAYERO UNIVERSITY KANO, NIGERIA.
Contact Details	E-mails:anas.yahaya.10@ucl.ac.uk/c.soligo@ucl.ac.uk, suhhis@yahoo.com. Mobile: +447586758446/+2348023666048

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 3080/001 and the National Health Research Ethics Committee (NHREC) of Nigeria. If you have any questions regarding your rights as a research participant or have concern that your rights have been violated in the course of your participation in this study, please contact the ethics committees using the following:

UCL Research Ethics Committee``

2. Nigerian National Health Research Ethics Committee (NHREC)

3. Department of Health Planning, Research & Statistics

4. Federal Ministry of Health, Abuja

E-mail: chairman@nhrec.net, deskofficer@nhrec.net

Appendix 2: Demographic Questionnaire

Section A: Demographic/Personal data.

1. Age in years……………………….

2. Sex: a) Male b) Female

3. Religion: a) Islam b) Christianity d) Others

4. Tribe for:

   a) Self……………………………………………….

   b) Father…………………………………………….

   c) Mother……………………………………………

   d) Grandfathers……………………………………

   e) Grandmothers…………………………………..

5. Birth order:

   1) 1st child 2) 2nd child 3) 3rd child 4) others……….

6. Number of siblings (total)……………………………….

7. Marital status:

   a) Married b) Divorced c) Separated d) Widow e) Single

8. Partner identifier (if applicable): ………………

9. Relationship to the wife/husband:

   a) 1st cousin b) Distant cousin c) Related but not cousins

   d) Not related

Section B: Socioeconomic status:

1. Level of education:

A. Self:

a) Non-literate b) Primary education

c) Secondary education d) Post-secondary education

e) Others (please specify)……………………………

B. Mother:

a) Non-literate b) Primary education

c) Secondary education d) Post-secondary education

e) Others (please specify)……………………………

C. Father:

a) Non-literate b) Primary education

c) Secondary education d) Post-secondary education

e) Others (please specify)……………………………

2. Occupation:

a) Unemployed b) Farmer c) Trader d) Civil servant

e) House wife f) others (please specify)……………………

3. Assets ownership:

a) Land:

1) One 2) Two 3) Three and above 4) None

5) Estimate total acres……

b) House:

1) One 2) Two 3) Three and above 4) None

5) Total rooms………..

House built:

1) Mud 2) Blocks 3) Bricks 4) Thatches 5) Others

Livestock: How many?

1) Chickens……………………

2) Goats……………………

3) Sheep……………………

4) Cow……………………

5) Horses……………………

6) Camels……………………

Vehicles: How many?

1) Car………………………

2) Truck……………………

3) Bicycle…………………

4) Machine………………..

5) Others…………………..

6) Total income per month…………………

Section C: Past medical history, Mother (during pregnancy and breast feeding):

SNO	Disease	Yes	No	Time since conception	Treatment	No treatment
1.	High blood pressure					
2.	Diabetic mellitus					
3.	Sickle cell disease					
4.	Peptic ulcer disease					
5.	Severe malaria					
6.	Severe typhoid fever					
7.	Tuberculosis					
8.	Leprosy					
9.	HIV					
10.	AIDS					
11.	Others (specify)………………					

Smoking…………………..
Alcohol drinking……………

Self:

SNO	Disease	Yes	No	Age	Treatment	No treatment
1.	Malnutrition					
2.	Measles					
3.	Sickle cell disease					
4.	Meningitis					
5.	Severe malaria					
6.	Severe typhoid fever					
7.	Tuberculosis					
8.	Poliomyelitis					
9.	Diphtheria					
10.	Hepatitis					
11.	Others (specify)………………					

Smoking…………………..
Alcohol drinking…………

Section D: Basic somato-metric data:

1) Weight (Kg)……….

2) Height (m)…………

3) BP (mmHg)………..

Appendix 3: EXAscan 3D Laser Surface Scanner

Weight	1.25 kg (2.75lbs)
Dimensions (LxDxH)	172 x 260 x 216 mm (6.75 x 10.2 x 8.5 in)
Sampling Speed	25,000 measurements per second
Laser	Class Ⅱ (eye safe)
Resolution	0.04 mm (0.0016 in)
Accuracy	Up to 0.040 mm (0.0016 in)
Volumetric Accuracy	0.020 + 0.100 mm/m (0.0008 + 0.0012 in/ft)
Volumetric Accuracy(1) (with MaxSHOT 3D)	0.020 mm + 0.025 mm/m(0.0008 in. 0.0003 in./ft)
Stand Off Distance	300mm (12 in)
Depth of Field	± 150 mm (± 6 in)
Laser Cross Area	210 x 210 mm (8.2 x 8.2 in) Hi-res: 60 mm x 60 mm (2.4 in. x 2.4 in.)
Export File Formats	DAE, FBX, MA, OBJ,PLY, STL, TXT, WRL, X3D, X3DZ, ZPR
Regulatory Compliance	CE
Data transfer	FireWire
Included Accessories	VXelements software, FireWire™cable data transfer, calibration plate validation, carry-on case and ergonomic support

Appendix 4: Male rating questionnaire

The Questionnaire

Section A: Demographic/Personal data.

1. **Age** in years……………………….

2. **Sex**: a) Male b) Female

3. **Religion**: a) Islam b) Christianity d) Other (please specify):

4. **Tribe for**:

a) Self……………………………………………….

b) Father…………………………………………….

c) Mother……………………………………………

d) Grandfathers………………………………………

e) Grandmothers……………………………………..

5. **Marital status**:

a) Married b) Divorced c) Separated d) Widow e) Single

6. **How many children**?

a) One b) Two c) Three d) Four e) Five and above f) None

7. **Where did you grow up**?

a) Village (from age………..to age……….)
b) City (from age………..to age……….)

Section B: Socioeconomic status:

Level of education:

a) Non-literate b) Primary education

c) Secondary education d) Post-secondary education

e) Others (please specify)……………………………

Occupation:

a) Unemployed b) Farmer c) Trader d) Civil servant

e) House wife f) others (please specify)……………………

Assets ownership:

a) Plots of Land:

1) One 2) Two 3) Three and above 4) None

5) Estimate total acres……

House(s):

1) One 2) Two 3) Three and above 4) None 5) Total rooms…

6) If the house ownership is more than one:

How many do you and the family live in?

1) One 2) Two 3) Three and above 4) None
5) Total rooms………..

How many do you rent out?

1) One 2) Two 3) Three and above 4) None
5) Total rooms………..

House(s) built from:

1) Mud (specify how many house/s built from mud)……………
2) Blocks (specify how many house/s built from blocks)……….
3) Bricks (specify how many house/s built from bricks)………...
4) Thatches (specify how many house/s built from thatches)……
5) Others (specify how many house/s built from others)………...

Livestock: How many?

1) Chickens……………….

2) Goats……………………

3) Sheep……………………

4) Cow…………………….

5) Horses………………….

6) Camels…………………

Vehicles: How many?

i) Car………………………

ii) Truck……………………

iii) Bicycle…………………

iv) Motorbike………………..

v) Others…………………..

4) Total income per month…………………

5) Income source(s) (please circle all that apply):

a) My own business/employment

b) Marital partner's business/employment

c) Parents

d) Other (please describe): …………………

Section C: **Facial rating (please enter the selected scan number in the appropriate box)**

1) Of the two women in A),
   a) which do think is more attractive? Scan ☐
   b) which would you prefer as your wife? Scan ☐
   c) which do you think is more caring? Scan ☐
   d) which do you think is more aggressive? Scan ☐

2) Of the two women in B),
   a) which do you think is more attractive? Scan ☐
   b) which would you prefer as your wife? Scan ☐
   c) which do you think is more caring? Scan ☐
   d) which do you think is more aggressive? Scan ☐

3) Of the two women in C),
   a) which do you think is more attractive? Scan ☐
   b) which would you prefer as your wife? Scan ☐
   c) which do you think is more caring? Scan ☐
   d) which do you think is more aggressive? Scan ☐

4) There are six women in D), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1	**Most attractive**:	scan	☐
2	**Very attractive**:	scan	☐
3	**Attractive**:	scan	☐
4	**Unattractive**:	scan	☐
5	**Very unattractive**:	scan	☐
6	**Least attractive**:	scan	☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1	**Most likely**:	scan	☐
2	**Very likely**:	scan	☐
3	**Likely**:	scan	☐
4	**Unlikely**:	scan	☐
5	**Very unlikely**:	scan	☐
6	**Most unlikely**:	scan	☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

5) There are six women in E), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan
2 **Very caring**: scan
3 **Somewhat caring**: scan
4 **Uncaring**: scan
5 **Very uncaring**: scan
6 **Least caring**: scan

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan
2 **Very aggressive**: scan
3 **A bit aggressive**: scan
4 **Unaggressive**: scan
5 **Very unaggressive**: scan
6 **Least aggressive**: scan

6) There are six women in F), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan
2 **Very attractive**: scan
3 **Attractive**: scan
4 **Unattractive**: scan
5 **Very unattractive**: scan
6 **Least attractive**: scan

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan
2 **Very likely**: scan
3 **Likely**: scan
4 **Unlikely**: scan
5 **Very unlikely**: scan
6 **Most unlikely**: scan

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

7) There are six women in G), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

8) There are six women in H), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

9) There are six women in I), please give them a rank according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

THANK YOU VERY MUCH FOR YOU TIME!

Appendix 5: Female rating questionnaire

The Questionnaire

Section A: Demographic/Personal data.

1. **Age** in years……………………….

2. **Sex**: a) Male b) Female

3. **Religion**: a) Islam b) Christianity d) Other (please specify)…

4. **Tribe for**:

a) Self……………………………………………….

b) Father…………………………………………….

c) Mother……………………………………………

d) Grandfathers………………………………………

e) Grandmothers……………………………………..

5. **Marital status**:

a) Married b) Divorced c) Separated d) Widow e) Single

6. **How many children**?

a) One b) Two c) Three d) Four e) Five and above f) None

7. **Where did you grow up**?

3. Village (from age………..to age……….)
4. City (from age………..to age……….)

Section B: Socioeconomic status:

Level of education:

a) Non-literate b) Primary education

c) Secondary education d) Post-secondary education

e) Others (please specify)……………………………

Occupation:

a) Unemployed b) Farmer c) Trader d) Civil servant

e) House wife f) others (please specify)……………………

Assets ownership:

a) Plots of **Land**:

1) One 2) Two 3) Three and above 4) None 5) Estimate total acres……

House(s):

1) One 2) Two 3) Three and above 4) None 5) Total rooms………..

If the house ownership is more than one:

How many do you and the family live in?

1) One 2) Two 3) Three and above 4) None 5) Total rooms………..

How many do you rent out?

1) One 2) Two 3) Three and above 4) None 5) Total rooms………..

House(s) built from:

1) Mud (specify how many house/s built from mud)……………
2) Blocks (specify how many house/s built from blocks)……….
3) Bricks (specify how many house/s built from bricks)………..
4) Thatches (specify how many house/s built from thatches)……
5) Others (specify how many house/s built from others)…………

Livestock: How many?

1) Chickens……………….

2) Goats……………………

3) Sheep……………………

4) Cow…………………….

5) Horses……………………

6) Camels……………………

Vehicles: How many?

i) Car………………………

ii) Truck……………………

iii) Bicycle…………………

iv) Motorbike………………

v) Others…………………….

4) Total income per month: ………

5) Income source(s) (please circle all that apply):

a) My own business/employment

b) Marital partner's business/employment

c) Parents

d) Other (please describe): …………………

Section C: **Facial rating (please enter the selected scan number in the appropriate box)**

1) Of the two men in A),

a) which do think is more attractive? Scan ☐
b) which would you prefer as your husband? Scan ☐
c) which do you think is more caring? Scan ☐
d) which do you think is more aggressive? Scan ☐

2) Of the two men in B),

a) which do you think is more attractive? Scan ☐
b) which would you prefer as your husband? Scan ☐
c) which do you think is more caring? Scan ☐
d) which do you think is more aggressive? Scan ☐

3) Of the two men in C),

a) which do you think is more attractive? Scan ☐
b) which would you prefer as your husband? Scan ☐
c) which do you think is more caring? Scan ☐
d) which do you think is more aggressive? Scan ☐

4) There are six men in D), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

5) There are six men in E), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

6) There are six men in F), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

7) There are six men in G), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1	**Most likely**:	scan	☐
2	**Very likely**:	scan	☐
3	**Likely**:	scan	☐
4	**Unlikely**:	scan	☐
5	**Very unlikely**:	scan	☐
6	**Most unlikely**:	scan	☐

How ***CARING*** you think they are:

1	**Most caring**:	scan	☐
2	**Very caring**:	scan	☐
3	**Somewhat caring**:	scan	☐
4	**Uncaring**:	scan	☐
5	**Very uncaring**:	scan	☐
6	**Least caring**:	scan	☐

How ***AGGRESSIVE*** you think they are:

1	**Most aggressive**:	scan	☐
2	**Very aggressive**:	scan	☐
3	**A bit aggressive**:	scan	☐
4	**Unaggressive**:	scan	☐
5	**Very unaggressive**:	scan	☐
6	**Least aggressive**:	scan	☐

8) There are six men in H), please rank them by choosing each scan only once according to:

How ***ATTRACTIVE*** they are:

1	**Most attractive**:	scan	☐
2	**Very attractive**:	scan	☐
3	**Attractive**:	scan	☐
4	**Unattractive**:	scan	☐
5	**Very unattractive**:	scan	☐
6	**Least attractive**:	scan	☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

9) There are six men in l), please give them a rank according to:

How ***ATTRACTIVE*** they are:

1 **Most attractive**: scan ☐
2 **Very attractive**: scan ☐
3 **Attractive**: scan ☐
4 **Unattractive**: scan ☐
5 **Very unattractive**: scan ☐
6 **Least attractive**: scan ☐

How likely it is that you would choose them as your ***MARRIAGE PARTNER***:

1 **Most likely**: scan ☐
2 **Very likely**: scan ☐
3 **Likely**: scan ☐
4 **Unlikely**: scan ☐
5 **Very unlikely**: scan ☐
6 **Most unlikely**: scan ☐

How ***CARING*** you think they are:

1 **Most caring**: scan ☐
2 **Very caring**: scan ☐
3 **Somewhat caring**: scan ☐
4 **Uncaring**: scan ☐
5 **Very uncaring**: scan ☐
6 **Least caring**: scan ☐

How ***AGGRESSIVE*** you think they are:

1 **Most aggressive**: scan ☐
2 **Very aggressive**: scan ☐
3 **A bit aggressive**: scan ☐
4 **Unaggressive**: scan ☐
5 **Very unaggressive**: scan ☐
6 **Least aggressive**: scan ☐

THANK YOU VERY MUCH FOR YOU TIME!

Appendix 6: Socioeconomic classes of the Hausa ethnic group in Nigeria

Social classes	Land ownership	Livestock	Other assets	Type of housing	Educational level	Source of income/amount
SES 3	Have no land	May own few domestic animals such as ducks, chickens, goats, donkeys and sheep.	Possess an old bicycle, old motorbike, small radio, or even mobile phone.	Mud or grass thatch houses fairly maintained with a kitchen and latrine.	May or may not studied up to primary school.	Income comes from begging, borrowing, petty trading, casual labor, and sale of livestock and craft
SES 2	May own or inherit some few small lands	May possess Many domestic animals such as chickens, ducks, goats, sheep, cows or even horses.	May have bicycle, motorcycle, car, television grinding mill, radio cassette and a mobile phone.	Houses usually of blocks, roofed with iron sheets have kitchen and latrine.	May have gone through secondary and post-secondary schools but could be rich without modern education.	Income comes from sale of livestock, sale of agricultural products, wages or salary.
SES 1	Owns many large farmlands by lease, buying or as gift from local, state or national authority. May own several plots.	May have several types of domestic animals like chicken, turkeys, goats, sheep cows and horses.	May possess several bicycles, motorbikes, many cars, tractors, planes, televisions, radio cassette and mobile phones and other machines. Possess companies	Brick walled and iron roofed houses, kitchens and latrines, may have gardens, or swimming pools.	May have gone through university and post-doct studies. Could be rich without modern education.	Income is from big contracts, renting out their properties, selling livestock and investments. May come from salary, wages.

Appendix 7: Excel spread sheet for the facial symmetry data as the attractive for male scan D1 only.

ID	SNO	SEX	MS	INCOME	Scan number/ Questionnaire no	rating.rank	true.rank	WFACE
M1	1	M	S	60000	D1_368	1	6	0.274
M2	2	M	S	300000	D1_368	3	6	0.274
M3	3	M	S	100000	D1_368	6	6	0.274
M4	4	M	S	25000	D1_368	6	6	0.274
M5	5	M	S	180000	D1_368	1	6	0.274
M6	6	M	M	80000	D1_368	1	6	0.274
M7	7	M	S	75000	D1_368	6	6	0.274
M8	8	M	S	100000	D1_368	3	6	0.274
M9	9	M	S	100000	D1_368	3	6	0.274
M10	10	M	S	80000	D1_368	1	6	0.274
M11	11	M	S	500000	D1_368	1	6	0.274
M12	12	M	S	80000	D1_368	5	6	0.274
M13	13	M	S	50000	D1_368	6	6	0.274
M14	14	M	S	80000	D1_368	5	6	0.274
M15	15	M	S	50000	D1_368	6	6	0.274
M16	16	M	S	60000	D1_368	1	6	0.274
M17	17	M	S	276000	D1_368	4	6	0.274
M18	18	M	S	50000	D1_368	5	6	0.274
M19	19	M	S	1600000	D1_368	5	6	0.274
M20	20	M	S	80000	D1_368	6	6	0.274
M21	21	M	S	50000	D1_368	6	6	0.274
M22	22	M	S	150000	D1_368	3	6	0.274
M23	23	M	S	1500000	D1_368	1	6	0.274
M24	24	M	S	100000	D1_368	5	6	0.274
M25	25	M	S	1500000	D1_368	2	6	0.274
M26	26	M	S	100000	D1_368	6	6	0.274
M27	27	M	S	200000	D1_368	4	6	0.274
M28	28	M	S	200000	D1_368	3	6	0.274
M29	29	M	S	50000	D1_368	1	6	0.274
M30	30	M	S	300000	D1_368	3	6	0.274
M31	31	M	M	200000	D1_368	2	6	0.274
M32	32	M	S	300000	D1_368	1	6	0.274
M33	33	M	S	450000	D1_368	1	6	0.274
M34	34	M	S	270000	D1_368	1	6	0.274
M35	35	M	M	500000	D1_368	6	6	0.274
M36	36	M	S	50000	D1_368	2	6	0.274
M37	37	M	S	80000	D1_368	4	6	0.274
M38	38	M	S	200000	D1_368	2	6	0.274
M39	39	M	S	150000	D1_368	6	6	0.274
M40	40	M	S	450000	D1_368	6	6	0.274

M41	41	M	S	250000	D1_368	1	6	0.274
M42	42	M	S	180000	D1_368	5	6	0.274
M43	43	M	S	45000	D1_368	6	6	0.274
M44	44	M	S	700000	D1_368	6	6	0.274
M45	45	M	S	300000	D1_368	4	6	0.274
M46	46	M	S	250000	D1_368	5	6	0.274
M47	47	M	S	500000	D1_368	4	6	0.274
M48	48	M	S	270000	D1_368	6	6	0.274
M49	49	M	S	300000	D1_368	3	6	0.274
M50	50	M	S	420000	D1_368	1	6	0.274
M51	51	M	M	90000	D1_368	2	6	0.274
M52	52	M	S	50000	D1_368	4	6	0.274
M53	53	M	S	500000	D1_368	5	6	0.274
M54	54	M	S	215000	D1_368	6	6	0.274
M55	55	M	S	200000	D1_368	6	6	0.274
M56	56	M	S	150000	D1_368	6	6	0.274
M57	57	M	S	200000	D1_368	2	6	0.274
M58	58	M	S	500000	D1_368	4	6	0.274
M59	59	M	S	40000	D1_368	2	6	0.274
M60	60	M	S	250000	D1_368	6	6	0.274
M61	61	M	S	100000	D1_368	6	6	0.274
M62	62	M	S	200000	D1_368	6	6	0.274
M63	63	M	S	800000	D1_368	6	6	0.274
M64	64	M	S	90000	D1_368	5	6	0.274
M65	65	M	S	72000	D1_368	4	6	0.274
M66	66	M	S	180000	D1_368	5	6	0.274
M67	67	M	S	240000	D1_368	6	6	0.274
M68	68	M	S	700000	D1_368	5	6	0.274
M69	69	M	S	600000	D1_368	4	6	0.274
M70	70	M	S	500000	D1_368	5	6	0.274
M71	71	M	S	45000	D1_368	3	6	0.274
M72	72	M	S	450000	D1_368	5	6	0.274
M73	73	M	S	300000	D1_368	5	6	0.274
M74	74	M	S	500000	D1_368	6	6	0.274
M75	75	M	S	600000	D1_368	4	6	0.274
M76	76	M	S	270000	D1_368	4	6	0.274
M77	77	M	S	60000	D1_368	1	6	0.274
M78	78	M	S	150000	D1_368	6	6	0.274
M79	79	M	S	420000	D1_368	2	6	0.274
M80	80	M	S	150000	D1_368	5	6	0.274
M81	81	M	S	270000	D1_368	4	6	0.274
M82	82	M	S	250000	D1_368	4	6	0.274
M83	83	M	S	200000	D1_368	6	6	0.274
M84	84	M	S	50000	D1_368	5	6	0.274
M85	85	M	S	50000	D1_368	6	6	0.274
M86	86	M	S	162000	D1_368	4	6	0.274

M87	87	M	S	800000	D1_368	6	6	0.274
M88	88	M	S	700000	D1_368	1	6	0.274
M89	89	M	S	250000	D1_368	1	6	0.274
M90	90	M	S	350000	D1_368	5	6	0.274
M91	91	M	S	100000	D1_368	6	6	0.274
M92	92	M	S	500000	D1_368	5	6	0.274
M93	93	M	S	800000	D1_368	4	6	0.274
M94	94	M	S	150000	D1_368	4	6	0.274
M95	95	M	S	100000	D1_368	5	6	0.274
M96	96	M	S	85000	D1_368	2	6	0.274
M97	97	M	S	35000	D1_368	5	6	0.274
M98	98	M	S	150000	D1_368	4	6	0.274