In vivo facial tissue depth measurements of African Nova Scotian children for 3-D forensic facial reconstruction

by

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ABSTRACT

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Abstract: This study collaborated with the African Nova Scotian community to create the first African Canadian facial tissue depth database to help identify missing children of this descent. The relationships between tissue thickness, age, and sex were investigated, and comparisons were made with contemporary data for African Americans and White European Americans. Ultrasound technology was utilized to measure the facial tissue thickness of 54 living subadult African Nova Scotians between 3 and 18 years of age at 19 standardized points. Results revealed significant relationships between tissue thickness and age at some points. Sex was a strong determinant of tissue depth around puberty. African Nova Scotians had thicker tissues in the jaw and cheek regions than the American populations suggesting nutritional status is a strong factor. The topic of collapsing data is addressed and subadult facial tissue depth data is presented in several formats to assist in multiple forensic contexts.

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CHAPTER 1: INTRODUCTION

1.1 Objectives

Population specific facial tissue depth data helps increase the accuracy of three dimensional forensic facial reconstructions as well as the chance for establishing a positive identification for unknown individuals. Therefore, the purpose of this research is to expand the facial tissue depth data available in Canada to include African Canadians. Specifically, this study involves collaborating with the African Nova Scotian community to create the first African Canadian tissue depth database to help identify missing children of African Nova Scotian decent.

In 2008, a total of 56,102 children were reported missing Canada (R.C.M.P. National Missing Children Services). Since missing children organizations do not group missing children by ancestry, the exact number of missing African Nova Scotian children are unknown. However, even if only one missing child is of African Nova Scotian descent, this population-specific facial tissue depth data can be used to assist in the identification of the unknown child, and thus bring closure to families and friends.

The specific goals of this research are to 1) report standard summary statistics useful for forensic artists and researchers, including means, standard deviations, and ranges of tissue thicknesses for both sexes and varying subadult age groups; 2) determine if there is a relationship between age and tissue thickness for males and females; 3) determine if there are significant differences of facial tissue depths between and within the sexes of differing subadult age groups; and 4) compare the results of this study to contemporary data for African American and White European American children (Manhein et al. 2000).

Facial tissue depth reference data, for contemporary African Nova Scotian youth, will help forensic artists accurately create facial reconstructions of missing children. Consequently, a more accurate facial reconstruction will increase the likelihood of recognition and positive identification. As a result, this research will help alleviate the psychological, emotional, and physical suffering endured by relatives and friends of missing persons.

African Nova Scotian facial tissue depth measurements will be compared to African American data (Manhein et al. 2000) to assess the degree of diversity among similar ancestral populations living in different geographical locations. Comparative studies are important because they identify relationships between populations within the same ancestral group, but living in different geographical locations, thus validating the need for population-geographic specific facial tissue depth data.

1.2 'Race' in Biological Anthropology

1.2.1 *Concept of 'Race'*

'Race' is both a biological and social construct, depending on the context in which it is used. From a biological perspective, *'race'* is defined as "a subpopulation or variety of a species that differs somewhat in gene frequencies from other varieties of the species" (Ember and Ember 2003:471). Many biological anthropologists, however, feel that this definition is neither helpful nor appropriate for classifying humans; the term *'race'* is a social construction devised to explain human diversity.

Since the beginning of the 18th century, people have attempted to describe human variation by dividing humanity into various categories or *'races'*. The historical definition of *'race'* includes the following thoughts:

1. That humanity *can* be classified into groups using identifiable physical characteristics;
2. That these characteristics are transmitted 'through the blood';
3. That they are inherited together;
4. That physical features are linked to behaviour;
5. That these groups are by nature unequal and therefore can be ranked in order of intellectual, moral, and cultural superiority [Corcos 1997:1].

The first attempt at human classification was in 1735 by Linneaus, who divided humans into four groups based primarily on skin colour: American (Reddish), European (White), Asiatic (Yellow), and Negro (Black) (Corcos 1997:17). Overtime, the number and names of the categories changed, varying anywhere between three and thirty types of groups (Corcos 1997). Similarly, the criteria for determining the number of groups began to change with the emphasis slowly shifting from skin colour to the shape of the skull.

In the early 1800s, Darwin introduced craniometry which is based on the assumption that the shape of the skull is correlated to the shape of the brain and thus brain function. The belief that the shape of the skull dictates the intelligence of an individual eventually led to the creation of a hierarchy among categories with Caucasians superior and Ethiopians inferior (Corcos 1997:25). This assumption was later proven incorrect by Boas who showed that skull shape is not a permanent feature and it is influenced by environmental factors rather than genetics (Molnar 1983).

While some scientists continued to create new divisions resulting in negative connotations, others began to doubt the methods for organizing human diversity. Some anthropologists believe *'race'* is not a scientifically useful term for describing human variation. For example, Samuel Stanhope Smith wrote, "it is impossible to draw the line precisely between the various races of man" (Corcos 1997:18). Therefore, human variation could be considered a continuous spectrum and people cannot be divided into discrete groups based on the presence or absence of physical traits. Some anthropologists agree with this statement and further argue that the term "is an outdated creation of the human mind that attempts to simplify biological complexity by organizing it into categories" (Jurmain et al. 2004:306). As a result, new terms were created in place of the word *'race'* with the hopes of alleviating the negative undertones.

To eliminate the negative connotations, national origin and cultural affiliations are the basis for grouping individuals as opposed to physical traits. The term *ethnicity* is defined as "a group of people emphasizing common origins and language, shared history, and selected cultural differences such as a difference in religion" (Ember and Ember 2003:294). Therefore, ethnicity is a cultural term as opposed to a biological term. Since *culture* is defined as "a set of learned behaviours that is transmitted from one generation to the next by nonbiological means" (Jurmain et al. 2004:4), ethnicity groups individuals according to cultural linkages.

In contrast, the term *ancestry* refers to the geographical origin of an individual's biological ancestors (Jorde and Wooding 2004:S29). *Ancestry* has also been identified as "a more subtle and complex description of an individual's genetic makeup than is race" (Jorde and Wooding 2004:S30). Since the word *ancestry* is a biological construction

with a genetic linkage, this term better suits the objective of describing human variation for use in this research. Furthermore, with respect to forensic facial reconstruction, "if a system for predicting the likeness of an individual is to be effective it should be developed from genetically related people" (Aulsebrook et al. 1996:84). Since the term *ancestry* denotes ancestral linkages and thus genetic relationships, as opposed to *'race'* which has no genetic connections, using this term ensures that the appropriate groups of individuals are being included in this study. As a result, *ancestry* will be used in this research to describe the diverse groups of humanity.

Even though anthropologists are not in complete agreement on the concept of *'race'*, the grouping of human diversity still assists forensic anthropologists in the identification of unknown human skeletal remains. Brace (1995:172) notes that "skeletal analysis provides no direct evidence for skin color for example, but it does allow an accurate estimate of original geographical origins." With the specialized knowledge of particular features and their occurrences, forensic anthropologists are able to estimate the ancestry of human skeletal remains.

In the past, the three traditionally cited human classifications were Caucasoid, Negroid, and Mongoloid (Taylor 2001:60). Over time, new groups were created and the terms European, African, and Asian became preferred by many anthropologists (Taylor 2001:60). However, more recent technology has incorporated a more diverse compilation of human populations. For example, the Forensic Data Bank FORDISC 3.0 uses the following groups for estimating ancestry from cranial measurements: White, Black, American Indian, Japanese, Guatemalan males, Vietnamese males, Hispanic males, and Chinese males (Jantz & Ousley 2005). One must keep in mind that the

description of human variation is based on social, legal, and political criteria. Therefore, the forensic anthropologist must be able to effectively communicate the ancestry of an individual to the police, coroner/medical examiner, and ultimately the general public.

1.2.2 Nonmetric Analysis of Ancestry

A biological profile, which includes information for age, sex, and ancestry, must be determined prior to beginning the forensic facial reconstruction since this information dictates which tissue depth data will be utilized. As part of establishing a biological profile, forensic anthropologists must estimate the ancestry of the unidentified individual. Nonmetric and metric techniques can be used to assess the ancestral background of skeletal remains.

Metric analysis of ancestral origin involves measuring the distance between various craniometric points and inputting them into discriminant function formulas generated by computer software such as FORDISC 3.0. In contrast, nonmetric analyses require visual assessment of the morphological features of particular skeletal elements that are known to exhibit variation based on ancestral origin. While nonmetric methods are more commonly used, they are also very subjective in nature. Furthermore, ancestral traits are expressed on a continuous spectrum, however, nonmetric analyses require the division of this spectrum into discrete categories. Therefore, it is up to the discretion of the observer which category each characteristic will fall into (Byers 2008:154). As a result, it can be expected that the inter-observer error would be greater for these types of analyses despite their common use.

Although nonmetric analyses are subjective, they are the most useful methods for assessing the ancestry of adults. In particular, most of the morphological traits for

estimating ancestry are located in the cranial skeleton (Byers 2008:154). It has been suggested that ancestry can be determined from the skull with an accuracy rate of 77-95% (Wilkinson 2004:84). An analysis of ancestry depends on the examination of "traits known to vary among different human populations in different parts of the world" (White 2000:374). Therefore, specific characteristics of the skull are observed, and these features help determine the ancestral group.

A compilation of the main cranial features that help distinguish Europeans (Whites), Africans (Blacks), and Asians is best described by Byers (2008). The basic features analyzed are the facial profile, overall facial shape, shape of the eye orbits, lower eye border, browridges, muscle markings, cranial sutures, postbregma form, nasal root, nasal bridge, nasal spine, nasal width, lower border, overall jaw shape, palatal form, and the shape of the upper incisors. Of these traits, the most reliable feature used to assess ancestry is the shape of the nose (Byers 2008:156) (Appendix A1).

The process of estimating ancestry in juvenile individuals is very difficult since the skulls of subadults have not reached full biological maturity. For example, younger children tend to have very similar facial characteristics, such as chubby cheeks and upturned noses, making it difficult to differentiate children into ancestral groups (Wilkinson 2004:231). Furthermore, characteristics that indicate ancestry, such as mid-facial projection and the development of the nasal root, occur after hormone levels have increased and puberty has been reached (Lewis and Rutty 2003:202). Despite these problems, however, the morphological analysis of ancestry, for juvenile remains, is sometimes possible by examining deciduous and permanent dentition. For instance, the presence of shovel-shaped incisors is more common in Asian, Native American, and

Canadian Aboriginal populations while Carabelli's cusps occur at a greater frequency in White Europeans (Lewis and Rutty 2003:202). As the child reaches adolescence, ancestral features become clearer and the assessment of ancestry can be performed with a higher success rate.

1.3 Construction of Identity

1.3.1 Definition of African Nova Scotian

Attempts were made to define *African Nova Scotian* in order to develop the parameters of the volunteer group. After meetings with professors and African Nova Scotian organizations, it was determined that self–identification, within certain boundaries, was most appropriate for this research.

The first meeting was with Dr. Cecil Foster, an author and Associate Professor at the University of Guelph. His research area focused on identity construction and *race.* According to Foster, since all identities are constructive, and there is no real definition for "who is African Nova Scotian", the definition is very subjective. As a result, the basis for the definition should be either 1) as an object of history and how it was defined historically, or 2) how organizations and the community members currently define themselves (Foster, personal communication, September 30, 2008). It was decided that defining African Nova Scotian according to the mandate of organizations and community members was the most appropriate method.

Various African Nova Scotian organizations were contacted by phone and/or e-mail. Communications with the following organizations occurred: Office of African Nova Scotian Affairs, Black Educators Association, Black Cultural Centre, Black

Loyalist Heritage Society, African Canadian Services Division, Department of Education, and Black Business Initiative (Appendix A2). Only two of the organizations replied to my correspondence.

The Office of African Nova Scotian Affairs (ANSA) is the only organization that has a definition for African Nova Scotian. It states that African Nova Scotian "includes all individuals from first migrants to this province (Matthew Da Costa circa 1604) to recent newcomers from the African Diaspora" (Office of African Nova Scotian Affairs 2008). Wayn Hamilton, CEO of ANSA, stated that there are no restrictions for the amount of time an individual must be in Nova Scotia for them to 'qualify' as an African Nova Scotian. He also noted that there is "no law that requires somebody to carry a certain identification marker" (Hamilton, personal communication, October 27, 2008). Furthermore, he stated that identity is a personal choice and whatever identity people want to carry with them in life is "entirely up to them" (Hamilton, personal communication, October 27, 2008).

The second organization, with which I spoke, was the Black Educators Association. Halifax Regional Educator, Roger Johnson, noted that a precise definition of African Nova Scotian does not exist (Johnson, personal communication, October 28, 2008) which confirms conversations with Dr. Cecil Foster. This further supports the idea that identity is a personal construct and does not have a specific definition.

Lastly, I decided that it would be appropriate to see how researchers have defined other African populations with which they collaborated. I contacted Dr. Ginesse Listi, co-author of the facial tissue depth study conducted with African American children and adults utilizing ultrasound technology (Manhein et al. 2000). According to Listi, the

African American volunteers in her project "self–identified as 'Black' which was understood to mean African-American" (Listi, personal communication, October 13, 2008). The review of the current views of professors, community leaders, organizations, community members, and fellow researchers, suggested that the appropriate criteria for identifying an individual as African Nova Scotian is self-identification within the parameters of the general definition created by the Office of African Nova Scotian Affairs. This means that as long as volunteers have an ancestral link to individuals that came from Africa, and are now living in Nova Scotia, they are eligible to participate in this study.

Although one study (Klimentidis 2009) has revealed inconsistencies between self-identified ethnicity, self-estimated admixture, and genetic ancestral markers, their methodology is questionable. While this research examines individuals of Hispanic, Native American, and mixed ethnicity, only one ancestral group (Hispanics) was statistically large enough to generate inferences about self-identification versus genetic testing.

Most importantly, however, the researchers compared genetic ancestry and self-identified ethnicity. As previously defined, *ancestry* refers to genetic linkages while *ethnicity* is based on cultural affiliations. Therefore, labels associated with *ancestry* and *ethnicity* can be different for a single individual. For example, genetically, the present author's ancestry includes Ukrainian and Jamaican, however she lives her life culturally as a Canadian. Since the questionnaire used in Klimentidis (2009) asked for the participants to cite their *ethnicity*, rather than *ancestry*, there is a possibility that they were identifying themselves based on cultural affiliations and not biological linkages.

Therefore, comparisons between genetic *ancestry* and self-identified *ethnicity* may not be accurate because the terms are defined differently.

CHAPTER 2: HISTORICAL BACKGROUND

2.1 History of Forensic Facial Reconstruction

The earliest reconstructions of modelling a face onto a skull can be found in the Neolithic Period. The 7000 BC facial reconstructions from Jericho in the Jordon valley were created with local plaster and shells for the eyes (Prag and Neave 1999:13). At this time, it is believed that the artist's primary purpose was to create a symbolic representation as opposed to an accurate representation of the physical features (Prag and Neave 1999:13). It was not until the production of death masks that reconstructions were created with the intent of accurately representing a deceased person. The first attempt recorded in history was found in an Egyptian grave dated to 1370 BC (Wilkinson 2004:41-42). Additional methods generated at a later date, such as wax reconstructions, were used to create models to facilitate teaching medical procedures.

The earliest recorded attempt at a scientific facial reconstruction for identification purposes was in 1895 by the anatomist His. His is recognized for identifying human remains, found in a Leipzig grave, as Johann Sebastian Bach by rebuilding the face onto the skull (Prag and Neave 1999:14). This practice aided in the authentication and identification of famous individuals such as the German poet Schiller and Italian painter Raphael (Prage and Neave 1999:15). These methods were then used by anthropologists to make portraits of early humans, the most famous being the Neanderthal found in 1908 at La Chapelle-aux-Saints in France (Prag and Neave 1999:16). It was not until the early 20th century, in Europe, that the first facial reconstruction, for a medicolegal investigation, was documented.

Forensic art is a multidisciplinary field, which utilizes knowledge gathered from forensic science, art, anthropology, and human anatomy. It consists of any type of art form that helps to identify, capture, or convict criminal offenders or that aids in finding missing persons or identifying unknown deceased individuals (Taylor 2001:3). Creating the most accurate representation possible increases the likelihood of recognition and positive identification, thus providing closure for relatives and friends of missing persons. Forensic art is divided into four main categories:

1. Composite Imagery: graphic images made up from the combination of individually described component parts.
2. Image Modification and Image Identification: methods of manipulation, enhancement, comparison, and categorization of photographic images.
3. Demonstrative Evidence: visual information for case presentation in court as trial displays.
4. Reconstruction and Postmortem Identification Aids: methods to aid in the identification of human physical remains in various conditions. [Taylor 2001:4]

Category 4 is further divided into three subcategories, which include: (A) 2-dimensional drawings performed over a photograph of a skull; (B) 3-dimensional reconstructions involving clay sculptures, and; (C) 3-dimensional reconstruction using computer software (Wilkinson 2004:39). This thesis concentrates on Category 4(B): the 3-dimensional method of forensic facial reconstruction which utilizes clay and sculpting techniques to rebuild a face onto a skull.

The first forensic 3-dimensional reconstruction method was developed in the 1920s by the Russian anthropologist Mikhail Gerasimov. This technique is known today as the Russian or Anatomical Method. It involves rebuilding the muscles, cartilage, and glands onto the skull with clay and then placing a thin layer of clay over them to represent the skin (Taylor 2001:341). This method is both time consuming and very expensive, therefore, some forensic artists use the American Method or Tissue Depth Method.

Around 1898, Kollman and Buchly developed the American Method utilizing His' foundation of tissue depth research. Tissue depths are measurements of the distance between the surface of the underlying bone and the surface of the skin. Tissue thickness varies within an individual's face and between persons of different ages, sexes, and ancestries. As a result, average facial tissue depths are collected from various points on the face and used to guide the reconstruction. The American Method involves filling in the gaps with clay to the height of tissue depth markers; selected according to the determined age, sex, and ancestry of the individual's skull (Taylor 2001:342-343).

The American Method is the most commonly employed technique by forensic artists because it is fast and less expensive than the Russian Method. Furthermore, this tissue depth technique does not require extensive anatomical knowledge of the human face. Some forensic artists, however, believe that the most accurate method incorporates both musculature anatomy and tissue depth markers in the facial reconstruction. Richard Neave is credited with the creation of the Manchester Method, whereby the muscles of the face and neck are individually modelled and then 'skin' is applied over them (Wilkinson 2004:60).

Before the reconstruction can begin, the sex, age, and ancestry of the skeletal remains must be established. This will determine the specific tissue depth markers to be used for the 3-dimensional facial reconstruction. Once a cast of the skull is made, the mandible and cranium are attached and oriented in the Frankfurt Horizontal Plane. This standardized reference plane orients the skull in its natural position in real life; the lower margin of the orbit is positioned in line with the top margin of the external auditory meatus and this plane is parallel to the ground (Figure 2.01).

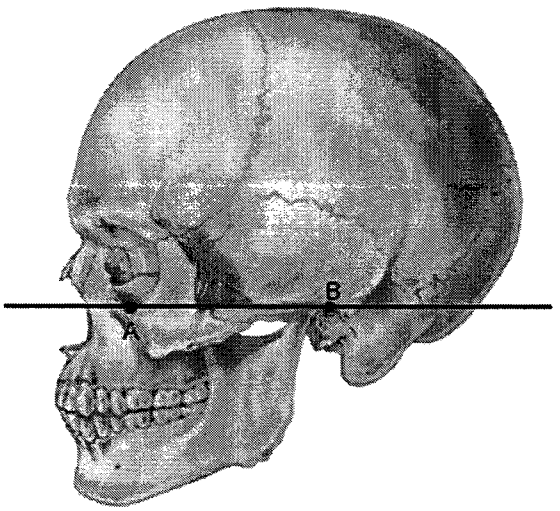

Figure 2.01 Frankfurt Horizontal Plane. The line represents the plane where Point A is the lower margin of the orbit and Point B is the top margin of the external auditory meatus (modified from Burns 1999:248).

Tissue depth markers are then placed on anatomical landmarks of the face; various researchers have cited landmarks between 15 and 34 points (Wilkinson 2004:124). Prosthetic eyes are positioned in the eye sockets and clay is used to rebuild

the contours of the face. The mouth, nose, and ears are then shaped, and final accessories such as texturing, colouration, wigs, and clothing are added for realism (Taylor 2001).

Once the facial reconstruction is complete, photographs are taken and the images are disseminated through various networks. Such networks include television, newspapers, magazines, internet websites, and posters. The publication and distribution of these images assists with reaching as many people as possible, in particular, the family and friends of the missing person. Ultimately, it is a combination of creating the most accurate 3-D forensic facial reconstruction possible and the dissemination of the images that aids in the recognition and identification of the missing person.

2.2 History of Facial Tissue Depth Studies

2.2.1 Cadaveric Studies

The earliest methods employed to measure facial tissue thickness involved the use of human cadavers. The first record of tissue depth data research was performed by Welcker in 1883. He measured the facial soft tissue depth of 13 White European male cadavers by inserting a double-edged knife blade into the flesh at nine midline points and measuring its displacement (Wilkinson 2004:126). Twelve years later, His developed a similar technique using four female and 15 male White European cadavers. The method involved inserting a sewing needle, collared with a rubber stopper, into the skin at nine midline points and six lateral points on the face. The motion of the skin, beneath the rubber disc, pushed the disc upwards until the needle came into contact with the bone. The tissue thickness could then be determined by measuring how far the rubber stopper moved (Wilkinson 2004:126).

A few years later, Kollman and Buchly developed a method based on His' research. In 1898, they created a technique that penetrated the flesh with a soot-covered needle and the tissue depth represented the clean region upon removal. Kollman and Buchly gathered data from four female and 21 male White European cadavers; they measured three extra anatomical points in addition to the 15 points recommended by His (Wilkinson 2004:126).

While these techniques were innovative and successfully employed, the use of cadavers these methods did have limitations. This is attributed to soft tissue deformation after death which can be due to shrinkage of soft tissue, dehydration, loss of muscle mass and elasticity, bloating, as well as embalming (Wilkinson 2004:129). Recent research by Simpson and Henneberg (2002) examined the effects of the embalming process. Results showed that recent embalming significantly increased the facial tissue depth at most of the points on the face. However, Simpson and Henneberg (2002) argued that the tissue depth of cadavers embalmed for more than six months is equivalent to normal body hydration thickness. In addition, the position of the body during data collection affects the alignment of the soft tissues over the bony landmarks. The horizontal position allows the force of gravity to act on the tissues, thus causing soft tissue distortion and realignment of the tissue over the bone (Wilkinson 2004:129). Therefore, depending on the state of preservation and positioning of the body, cadaveric studies can result in underestimating or overestimating the thickness of facial soft tissues.

Despite the limitations associated with using deceased individuals for facial tissue depth studies, many of these methods persisted for decades and used successfully by forensic artists. Over time, researchers attempted to improve the technique conducted on

cadavers. Rhine and Campbell (1980) modified His' technique to collect data for adult African Americans. After gently levelling the skin by hand, the rubber stopper was pushed down to meet the skin instead of allowing the skin to displace the stopper. This technique was used to measure the facial tissue depths of 59 unembalmed African American cadavers from New Mexico. The most recent cadaveric study was performed on 33 embalmed adult Australian cadavers using Kollman and Buchly's soot covered needle puncture method on 13 anatomical points (Domaracki and Stephan 2006).

Since the introduction of tissue depth data, researchers have been challenged with the unavoidable task of having to select, and correctly locate, anatomical points with the tissue overlying the bone. The number of facial tissue depth points chosen for a study depends on the researcher. Welker collected measurements from nine midline points while Kollman and Buchly gathered data from 18 points (Wilkinson 2004:126). Researchers have not reached a consensus about the number of points that should be examined, however, the importance of standardizing the location of the landmarks has been stressed in the literature (Brown et al. 2004). The difficult task of trying to correctly locate and identify landmarks persists today, despite the introduction of *in vivo* techniques utilized on living individuals.

2.2.2 In Vivo Studies

While some researchers continued their studies on cadavers, others believed data collected from the living was much more valuable. To overcome the distortion of soft tissues, researchers took advantage of medical imaging technologies which permitted studies to be safely conducted on living individuals. George (1987) is credited with the creation of the lateral craniographic method for 2-D facial reconstruction. The technique

involved tracing the skull and soft tissues over radiographs obtained from orthodontic procedures and then measuring the distance between the anatomical landmark and the surface of the skin.

Radiographic imaging has been utilized in many studies to collect midline facial tissue depths. A study performed on a subadult White European population in Burlington, Ontario, collected midline tissue depth data from lateral tracings of radiographs (Garlie and Saunders 1999). Additional studies collected data for the midfacial region from African American children (Williamson et al. 2002) and Japanese children (Utsuno et al. 2005; Utsuno et al. 2007). Some researchers have combined medical imaging techniques to create new methods for collecting tissue depth data. For example, the radiographic method has been combined with the ultrasound technique to collect data for Zulu males in South Africa (Aulsebrook et al. 1996).

Despite the high accuracy associated with this method, the radiographic technique restricts the researcher to a limited number of views, thus making it difficult to locate and measure landmarks (Nelson and Michael 1998:172). Radiographic imaging also emits radiation that could be harmful to the health of the participants (Wilkinson 2004:132). Furthermore, radiography is expensive, non-portable, and not readily available to researchers (Phillips and Smuts 1996:52). As a result, researchers have investigated the use of other medical imaging techniques for measuring facial tissue thicknesses.

With the advent of new medical imaging technology, some researchers turned to computerized tomography (CT) and magnetic resonance imaging (MRI) to collect tissue depth data from living persons. Phillips and Smuts collected tissue depth data from a South African 'Coloured' population, which is "a mixture of Caucasian, Negro, Khoi and

San" (Phillips and Smuts 1996:52). They utilized CT scans from patients with facial sinus diseases. A few years later, researchers used MRI scans from a Northwest Indian population to collect tissue depth measurements (Sahni et al. 2002). Even though these imaging technologies allowed data collection to be conducted on living people, the techniques yield orientation, health, and availability problems.

Computerized tomography and magnetic resonance imaging scans restrict individuals to the horizontal position subjecting the facial tissues to the forces of gravity (Wilkinson 2004:129). Since 3-D facial reconstructions are created to resemble the individual in the upright position, collecting tissue depth data in the horizontal orientation causes the forces of gravity to distort the soft tissues, thus leading to the underestimation or overestimation of the depth. Similar to the radiographic imaging, CT and MRI scans emit radiation that could affect the health of volunteers (Wilkinson 2004:132). Finally, these techniques are expensive, non-portable, and not readily available to researchers (Phillips and Smuts 1996:52). As a result, ultrasound technology was introduced to forensic facial reconstruction to resolve these issues.

The application of ultrasound technology for forensic facial reconstruction has many advantages – most importantly data is collected on living individuals. It is cited as currently the "most accurate method" (Wilkinson 2004:135) for collecting facial tissue depth data since problems associated with cadavers are eliminated using this technique. One issue commonly encountered during cadaveric studies is soft tissue distortion associated with body orientation. The ultrasound method permits the participant to be in the vertical position, therefore allowing gravity to act on the soft tissues, as it would

normally. Furthermore, it has been found that needle penetration methods create wider tissue depth ranges than the ultrasound method (Simpson and Henneberg 2002:130).

The ultrasound machine has also been identified in literature as "a safe, effective diagnostic tool" (Manhein et al. 2000:49) exposing participants to no immediate or long-term side effects. Due to its non-invasive nature and child-friendly application, the ultrasound method has also allowed for the creation of reference tables for children so that juvenile remains can also be positively identified (Hodson et al. 1985). Ultrasonic imaging is also more readily available than CT scans, MRI scans, and radiology, since the equipment is portable and less expensive (Phillips and Smuts 1996:52).

In 1979, Lebedinskaya and colleagues were the first researchers to utilize ultrasound technology to collect facial tissue depth measurements for forensic facial reconstruction. Additional research, conducted in 1993, collected one of the largest reference datasets for ten ancestral groups from the former USSR totalling approximately 17 thousand adults (Lebedinskaya et al. 1993).

Hodson and colleagues (1985) are credited as the first researchers to utilize ultrasound technology to gather facial tissue depth data for an American population. Although this was the first study that allowed for facial reconstructions of White European American children, the accuracy of the data is questionable due to positional problems. The participants were lying on their backs during the measurement process, causing improper alignment of the bony landmark and soft tissues (Hodson et al. 1985).

Since the introduction of the ultrasound technique, researchers have expanded tissue depth data to include various ancestral populations. Aulsebrook and colleagues (1996) utilized ultrasound technology and radiographic imaging to collect the first tissue

depth data for Zulu male adult populations. El-Mehallawi and Soliman (2001) collected facial tissue depth measurements for adult Egyptians. While both studies added to the tissue depth data for individuals of underrepresented populations, the age range was restricted to individuals between 20 and 35 years old.

Manhein and colleagues (2000) collected tissue depth data for 515 children and 197 adults of various ancestral origins, including White European American, African American, and Hispanic individuals. In addition, a procedural guide was developed to correctly locate 19 anatomical bony landmarks on living individuals (Manhein et al. 2000:51). Their research was used as a comparative template for other studies employing the ultrasound methodology. For example, Wilkinson (2002) is credited with being the first researcher to collect facial tissue depth data for White European children. She gathered data from 200 White British children between 11 and 18 years old and found that White European American children have thicker facial tissues at the mouth and chin areas and concluded that it was due to an overweight population.

While some researchers have used the ultrasound technique to update tissue depth data, others have continued to increase the range of ancestral groups being scanned to better understand human variation. De Greef and colleagues (2006) gathered data from 510 White European females and 457 White European males with the primary goal of updating facial thickness measurements for forensic facial reconstruction. The most recent research utilizing ultrasound technology collected data for male and female adult Chinese American individuals (Chan 2007).

2.2.3 Factors Affecting Facial Tissue Depth

Nutritional status, sex, age, and ancestry are primary factors that affect the thickness of facial soft tissues. Relationships between nutritional status and facial tissue depth have been recognized since the work of His (1895) and Kollman and Buchly (1899) (Wilkinson 2004:141). They identified that well-nourished individuals have greater facial tissue depths at most points, except the nasal bridge, than those who are emaciated. The most significant differences were found in the chin, lower jaw, and cheek regions (Wilkinson 2004:141). Furthermore, researchers have found that an individual's weight at death is an important factor for positive identification (Starbuck and Ward 2007:134). While statistically there may not be a significant difference between facial reconstructions of individuals of varying weights, tests revealed that visual comparisons of the facial reconstructions are significantly different (Starbuck and Ward 2007:134).

Similar to nutritional status, a common pattern arises when the affects of sex, on facial tissue thickness, are examined. In general, results show that adult women have thinner facial tissues at most points than men since women are much more gracile. Adult women do have thicker tissues at the cheeks, while adult men have thicker tissues at the mouth, jaw, and brow region (Wilkinson 2004:142).

Even though the robust skeletal structure of males and gracile structure of females tends to result in varying tissue depths between the sexes, a significant amount of overlap exists (Simpson and Henneberg 2002:125). Stephan and colleagues (2005) examined research from Wilkinson (2002), Manhein et al. (2000), and Simpson and Henneberg (2002) and found equivalent tissue depths for males and females at some points while others differed by only a couple of millimetres. Therefore, their study demonstrates that

the differences in facial tissue depth measurements, between males and females, are on a continuous spectrum.

It is also important to remember that the factors affecting facial tissue depths are intertwined. For example, adult Egyptian females demonstrate thicker facial tissues than males (El-Mehallawi and Soliman 2001:106). Therefore, this study demonstrates how trends in facial tissue depths are not always consistent when other variables are considered. Similarly, tissue thickness is affected by the relationship between sex and age. An examination of subadult males and females reveals a similar trend as seen in adults – the tissue is thicker at the lip and brow region in males and in the cheeks for females (Wilkinson 2002:460). However, Garlie and Saunders (1999) have shown that males have greater tissue thickness than females but significant differences are only present after 14 years of age.

The thickness of soft tissues on the face is also affected by the age of the individual though the changes are extremely variable. For example, a study with Japanese female children revealed that Japanese girls exhibit thicker facial tissues than the adult women, suggesting that tissue depth decreases with increasing age at most points (Utsuno et al. 2005). In contrast, results from a study with White European British children found that as age increased the tissue thickness increased at the midline and jaw for males and at all points, except the jaw, for females. This observation was attributed to the development of a robust jaw in males (Wilkinson 2002:460). Since children grow at varying rates, there are no universal formulae or standardized techniques that can predict the pattern of growth of a child's face (Feik and Glover 1998). As a result,

researchers have been unable to identify a definite relationship between age and changes in tissue thickness for juvenile individuals.

2.3 African Facial Tissue Depth Data

2.3.1 African Population Studies

Researchers have collected facial tissue depth measurements for various ancestral groups utilizing either cadaveric or *in vivo* methods. Studies with adults have included the following ancestral populations: White European Americans (Lebedinskaya et al 1993; Manhein et al. 2000; Rhine and Moore 1982), Chinese Americans (Chan 2007), Japanese (Suzuki 1948), Egyptians (El-Mehallawi and Soliman 2001), Indians (Sahni et al. 2002), African Americans (Rhine and Campbell 1980; Manhein et al. 2000), South African Zulus (Aulsebrook et al. 1996), and South African 'Coloured' populations (Phillips and Smuts 1996).

Studies with children have gathered data for White European Americans (Hodson et al. 1985; Manhein et al. 2000), White European Canadians (Garlie and Saunders 1999), French Canadians (Smith and Buschang 2001), White European British (Wilkinson 2002), Japanese (Utsuno et al. 2005, Utsuno et al. 2007), Hispanic (Manhein et al. 2000), African Americans (Williamson et al. 2002; Manhein et al. 2000) and South African 'Coloured' children (Phillips and Smuts 1996).

A review of the literature reveals a large amount of American data and only two published Canadian studies. The first study employed a French Canadian population in Montreal (Smith and Buschang 2001). Lateral craniographs of females and males, between the ages of 6 and 19 years old, were examined. Results revealed significant

differences between the sexes at the time of adolescence as well as minute and slow changes during growth and development. However, the authors noted that more accurate reconstructions require going "beyond the two dimensional view of standard radiographs and beyond other measurement techniques that measure depth at a limited series of landmarks" (Smith and Buschang 2001:1300).

The second Canadian study, conducted by Garlie and Saunders (1999), measured 14 midline points from profile radiographs of northwestern White European Canadian subadults from Burlington, Ontario. Results reveal clear sexual dimorphism and a weak correlation between tissue depth and age (Garlie and Saunders 1999). This analysis, however, is confined to the mid-facial region and provides data that is only useful for the profile plane. Therefore, an analysis of previous studies indicates a lack of Canadian data for many ancestral populations.

The absence of African Canadian data, for both children and adults, is quite apparent. It has been further noted that "children of non-European ancestry are also underrepresented in the anthropometric literature" (Williamson et al. 2002:25). Therefore, when remains of an African Canadian child are discovered, and a forensic facial reconstruction is required, African tissue depth data from another geographic population, i.e. African American, is utilized.

This is applicable to the reconstruction of adult African Canadians as well. For example, the facial reconstruction of an unidentified male of mixed ancestry (African and White European Canadian), found deceased near the Halifax International Airport in October 2004, utilized African American tissue depth data (Peckmann, personal communication, January 24, 2009). This individual has yet to be identified. It is

important to gather population specific data to ensure the most accurate representation possible.

The accuracy of current tissue depth data depends on the method utilized, total sample size, and date when the study was performed. The first record of facial tissue depth measurements, for an African population, was created by Von Eggeling in 1909. The study included three male cadavers of African ancestry – 18 anatomical points were measured using the calibrated needle technique (Von Eggeling 1909). Soon after, using the same method, Stadtmuller (1923-25) measured 20 anatomical points on 18 cadavers, two of whom were of African ancestry. Due to the utilization of cadavers and an insufficient sample size for statistical analyses, the results may not accurately reflect the true tissue depths for this population. Furthermore, the data is not viable for contemporary populations because it was collected from an historical population.

Rhine and Campbell (1980) modified His' technique of inserting a needle collared with a rubber stopper. Tissue depth measurements were collected from 59 African American unembalmed cadavers from New Mexico. Results revealed that African Americans have greater facial tissue depths overall than other ancestral populations. Furthermore, African American females have facial tissue depths that are almost equivalent in thickness to the African American males. Although attempts were made to minimize tissue deformation associated with using cadavers, including levelling the rubber stopper to the surface of the skin by hand and using refrigerated unembalmed individuals that have been deceased no longer than 12 hours, soft tissue distortion could not be completely avoided (Rhine and Campbell 1980).

The most recent study conducted on cadavers of African ancestry was published in 1981. Moore (1981) utilized the same technique employed by Rhine and Campbell (1980). The modified version of the rubber stopper-collared needle was used to measure the tissue thickness at 21 points on the face. A reference chart was constructed, totalling 41 male and 17 female adult cadavers of African American ancestry between the ages of 2 and 100 years old. Since Moore's facial tissue depth reference table is not divided into age categories, it becomes difficult to know the exact age group(s) that could be reconstructed using this data. The cadavers were unembalmed, deceased no longer than 12 hours, or refrigerated no more than 24 hours, to minimize tissue distortion due to postmortem changes. Similar to Rhine and Campbell (1980), results revealed that African Americans have thicker facial tissues at most points than Asians and White European Americans (Moore 1981). While measures were taken to minimize soft tissue distortion associated with using cadavers, postmortem changes to facial tissues could not be completely avoided.

After the integration of medical imaging technology to the field of forensic facial reconstruction, researchers began to collect more accurate data from living African populations. Phillips and Smuts (1996) were the first to collect tissue depth measurements for 'Coloured' adults and children in South Africa – individuals of mixed ancestries. The sample consisted of 32 participants, 16 males and 16 females, between the ages of 12 and 71 years old. A total of 21 anatomical points were measured using computerized tomography (CT) scans derived from patients who had sinus disorders. While results revealed differences between African populations located in different geographical regions, this study suffers from positional problems (Phillips and Smuts

1996). The horizontal orientation of the body during a CT scan allows gravity to misalign the soft tissues in relation to the bony landmarks.

In 1996, Aulsebrook and colleagues collected the first tissue depth data for Zulu populations; the volunteers were "African Negroid[s] who [have] remained relatively free from genetic admixture with other populations" (83). This study combined ultrasound and radiographic techniques to collect data from 55 adult males between the ages of 20 and 35 years old. Not only is this sample restricted to a small age range, it is also limited to only male volunteers.

It was not until the beginning of the 21st century that ultrasound technology was used to collect tissue depth data from living children of African ancestry. The first record of African American juvenile facial tissue depth data is attributed to Altemus in 1963 (Wilkinson 2004:231-233). The study was conducted on children between the ages of 12 and 16 years old, however, the data is restricted to the mid-facial region.

Manhein et al. (2000) utilized the ultrasound technique to measure facial tissue depths, at 19 points, for individuals of various ancestries including African American children and adults. A total of 111 male and 136 female African American children between the ages of 3 and 18 years were measured. A total of 44 African American female adults between the ages of 19 and 55 years and 22 African American male adults between 19 and 45 years old were also measured. This study is very useful for providing accurate tissue depth data for African American facial reconstructions. However, data must be gathered for other populations of African ancestry to account for the genetic admixture of individuals from various geographical regions.

The most recent tissue depth study for an African population recruited volunteers from living African American children. Williamson et al. (2002) included 224 lateral craniographs of the midfacial region from 77 males and 147 females between the ages of 7 and 12 years. This data is not only restricted to the reconstruction of profile images but is also limited to the African American population. Therefore, it is important to collect population specific data that takes into consideration the genetic admixture of the contemporary population. Such geographic specific data will help increase the accuracy of reconstructions of missing persons of African descent from different countries or regions of the world.

2.3.2 Facial Tissue Depth Differences Between African Populations

Differences in facial tissue depth not only exist *between* ancestral groups but also *within* ancestral populations. After comparing craniofacial measurements of northern White European Americans and southern White European Americans, Richardson (1980) found that "the differences in means *within* ethnic or racial groups are often greater than the differences in means *among* ethnic or racial groups" (309). This study supports the fact that statistically significant variation exists between geographically isolated populations of the same ancestral background. Stephan and Simpson (2008a) also found that the variation between studies of identical population groups and different population groups are very similar (1264). As a recommendation for future studies, Moore (1981) proposed the following research question, "What effect does climate and geographical area have on facial tissue thicknesses?" (129).

Although researchers are aware of the "high levels of genetic diversity in African populations" (Tishkoff and Williams 2002:611), few studies have examined its

significance with respect to facial tissue thickness. Williamson et al. (2002) were the first researchers to directly compare African ancestral populations from different geographical regions. They collected mid-facial tissue depth data using lateral craniographs of African American children between the ages of 7 and 12 years. Differences between African American populations were investigated by comparing females from Indiana with females from Georgia and South Carolina. Results revealed that overall there is no significant difference in facial tissue depth between the two African American populations (Williamson et al. 2002:30). While the results indicate that regional variation does not exist between these two populations, the data could be inaccurate due to the restricted nature of the methodology – their method only compared females and the midline points of the face. Furthermore, it is also possible that the geographical separation of the two African American populations was not great enough, as they were both from the same country. Therefore further investigation is needed to verify the significance of these findings.

Additional studies have led some researchers to make invalid comparisons between African populations located in different geographical regions. For example, Phillips and Smuts (1996) collected data on a South African 'Coloured' population with computerized tomography technology. They compared their results to Rhine and Campbell (1980), who utilized the calibrated needle technique with African American cadavers. Phillips and Smuts (1996) concluded that African Americans have thicker facial tissues at the upper and lower regions of the face than South African 'Coloured' individuals. The presence of these differences could be a result of making comparisons between studies that utilized different methodologies thus, resulting in inaccurate

conclusions. Another possibility is that Phillips and Smuts' populations could have contained more genetic admixture than the individuals in Rhine and Campbell's study.

Collecting the most accurate facial tissue depth data is imperative for creating the most accurate forensic facial reconstruction of a missing or unknown individual. Accurate data results in an increased likelihood of the reconstruction being recognized and a positive identification. While facial tissue depth data is limited for individuals of some ancestries, "comparisons of facial tissue thickness between groups of similar predominant ancestry but from different geographic locations are even more scarce" (Williamson et al. 2002:25). Furthermore, there is only a small amount of facial tissue depth data for African ancestral populations especially children (Williamson et al. 2002:25).

Although two Canadian facial tissue depth studies exist, neither included African Canadian populations. The absence of facial tissue depth data for African Canadians is apparent. Since African populations vary genetically, it is important to collect facial tissue depth data for specific geographical populations to account for any differences in facial tissue depths. This will help create more accurate forensic facial reconstructions of missing or unidentified African Canadians.

CHAPTER 3: METHODOLOGY

Although various techniques for measuring facial tissue depth data have been employed in the past, this study utilized ultrasound technology to collect the facial tissue depth measurements. Currently, "ultrasound is considered to be the most accurate method" (Wilkinson 2004:135), as well as the most ideal procedure, for measuring facial tissue thickness when compared to cadaveric and other *in vivo* techniques. Ultrasonic imaging permits the measurements to be taken with the body in the vertical position. This prevents the realignment of soft tissues over bony landmarks, which is a problem commonly associated with the horizontal positioning of the body during cadaveric studies and methods involving CT and MRI scanning technology.

Ultrasonic imaging "has experienced unprecedented growth in terms of refinement of the equipment, portability, and increased use in the medical field as a safe, effective diagnostic tool" (Manhein et al. 2000:49). For instance, the portable ultrasound machine is more readily available than CT scans, MRI scans, and radiology (Phillips and Smuts 1996:52). Cranial radiographs also produce a limited number of views available to researchers, thus making landmarks difficult to measure and restricting the applicability of the data to two-dimensional reconstructions (Nelson and Michael 1998:172). Furthermore, CT scans, MRI scans, and radiology emit radiation that could affect the health of volunteers (Wilkinson 2004:132). Finally, due to its non-invasive nature and child-friendly application, the ultrasound method has allowed for the creation of reference tables for children so that juvenile remains can also be positively identified (Hodson et al. 1985).

While there are many advantages for utilizing the ultrasound technique, a few limitations do exist. The primary difficulty is accuracy in locating the bony anatomical points while soft tissue is present (Wilkinson 2004:135). Some researchers have also noted that the process of identifying landmarks is subjective and requires standardization (Brown et al. 2004; Nelson and Michael 1998). Manhein et al. (2000) have addressed this issue by creating a procedural guide describing how to locate 19 anatomical points on living individuals. Their protocol was followed for this study to ensure that the data was collected in a standardized manner, thus permitting comparisons between studies.

The methodology implemented for this study also followed the guidelines proposed by Aulsebrook et al. (1996). In requirements stated that the measurement sites should be similar to those selected in other studies thus permitting valid comparisons, the same for all participants, located over flat bone if possible, and measured on the prominences or depressions (91). The selection of anatomical points was similar to ensure valid comparisons. In addition, to maintain consistency during the measurement process, the same protocol was used on each participant and the landmarks were located over bony prominences, flat regions, prominences, or depressions (Aulsebrook et al. 1996:91).

3.1 Ultrasound Principles & Instruments

Ultrasound technology involves the conversion of sound waves into visual images. Sound waves that travel at a frequency greater than 20 kilocycles per second are considered ultrasonic because they exceed the limits of human hearing (Whittingham 1962:1121). When ultrasound is combined with medical imaging the result is sonography (Kremkau 2006). Sonography is based on a pulse-echo technique involving

the conversion of sound waves into visual images. Electric pulses are emitted from the transducer in the form of high frequency vibrations. When the pulses encounter a medium that conducts sound differently, e.g. bone, some of the pulses are reflected or echoed. These echoes return back to the transducer and are converted into an image on the monitor (Kremkau 2006).

The information delivered from the transducer can be displayed on the monitor in three ways: A-mode, B-mode, or M-mode. The A-mode image display is most commonly used in ophthalmologic sonography or surgeries related to visual pathways which illustrate amplitudes of echoes for purposes of depth calculation (Kremkau 2006). This mode, however, does not provide contextual information such as the location of the surrounding anatomical structures. The M-mode is frequently used for visualizing the motion of cardiac structures. The B-mode is the most commonly used image display since it shows an anatomical cross-section of the scanning plane in gray scale (Kremkau 2006). Since this research required a stationary cross-sectional image of known origin to calculate the distance between two points, the B-mode was utilized.

There are three main components of an ultrasound machine: transducer, monitor, and computer. For this study, an ultrasound machine was loaned from a private medical clinic in Nova Scotia. Training in sonography was obtained from an ultrasound technician at the medical clinic. As per their request, the clinic and associated personnel will remain anonymous. The make and model was the Aloka SSD-500 OB/GYN system (black & white monitor) with an Aloka UST-5521-7.5 Mhz transducer. A Sony Video graphic thermal printer, which uses Sony thermal paper, was used to print the sonographic images in hardcopy. Manhein et al. (2000) used a very similar machine and

transducer as was employed for this project. Utilizing similar instruments to collect tissue depth measurements allowed results that were valid for comparison.

The date, time, patient identification number, and the ultrasound image of a specific point is displayed on the monitor. Calipers within the machine, controlled by a track ball, measure the distance between designated points (from the surface of the skin to the bone) directly from the image displayed on the monitor (Figure 3.01). The calipers measure to an accuracy of one-tenth of a centimeter (0.1 centimeters).

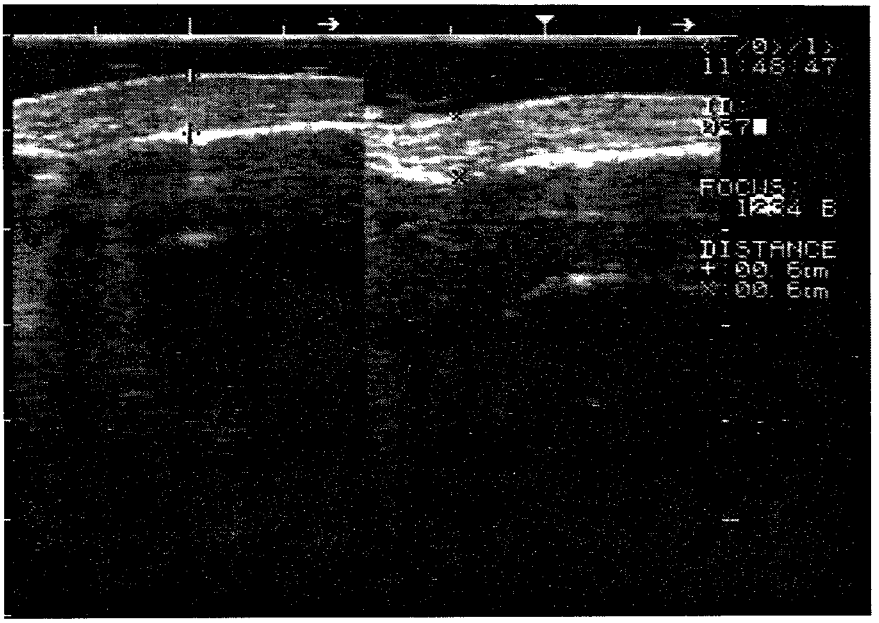

Figure 3.01 Printout of ultrasound measurements for glabella (left) and nasion (right).

According to the medical clinic, the ultrasound machine is calibrated every 12 months by an ultrasound technician. In addition, prior to the collection of data, the author measured an anatomical landmark on a colleague multiple times to test the precision of the instrument. The result was the same distance each time the measurement was taken, indicating the high precision rate of the instrument.

3.2 Participants

Tissue depth measurements were collected from living children of African Nova Scotian descent. Participants included males and females between 3 and 18 years of age. Volunteers were recruited from March Break Camps and Summer Camps organized by the Black Business Initiative in Halifax. Information Workshops, about the purpose and benefits of the research, were presented to all volunteers. Ethics approval was obtained from Saint Mary's University Research Ethics Board (Appendix B1) as well as African Nova Scotian community leaders.

A mandatory consent form (Appendix B2) was signed and a biographical data sheet (Appendix B3) completed by the parent or legal guardian of each volunteer. A three-digit identification number was assigned to each participant to maintain confidentiality and anonymity. The biographical datasheets and signed consent forms were scanned and saved electronically to a computer disc and the originals were shredded. Information obtained from the biographical datasheets, except for the participants' names, was entered into an Excel spreadsheet which is stored in a locked filing cabinet in Dr. Tanya Peckmann's office at Saint Mary's University along with the computer disc. The spreadsheet, containing the biographical data, will only be available upon request from law enforcement for use by a forensic artist, if the skeletal remains of an African Nova Scotian child are found and a facial reconstruction is necessary for identification purposes.

3.3 Technique

The height and weight of each participant was measured and recorded on the biographical data sheet. This information was used to divide the data into weight categories according to Body Mass Index-for-age (BMI-for-age). BMI-for-age is a reliable indicator of body fatness for children and teens as it takes into account the sex and age of the individual. It identifies weights that are considered to be healthy and unhealthy for youths (Centers for Disease Control and Prevention 2009). However, selecting facial tissue depth measurements for youths of strictly 'normal' weight was not useful for purposes of this study.

The objective of this research was to obtain facial tissue depth measurements that are representative of the 'standard' weight for African Nova Scotian subadults. This is because the goal of collecting facial tissue depth data is to help forensic artists reconstruct the face of an individual using data that is typical for that population. Therefore, it is imperative to measure participants with a weight that is representative for children of certain age ranges in the African Nova Scotian community.

According to registered nurses at the Community Health and Wellness Center in North Preston, a location highly populated by African Nova Scotians and one of the regions from where participants were recruited, African Nova Scotian youth "tend to fall 50/50 into the normal weight (BMI) and overweight/obese category" (Roode, personal communication, February 3, 2010). As a result, facial tissue depths of participants that fell within the normal and overweight/obese BMI-for-age were used to construct the facial tissue depth tables. This ensured that the facial tissue depth measurements accurately reflected the standard weight of African Nova Scotian subadults.

Manhein et al. (2000) performed statistical analyses on participants that were "placed into a normal weight category if the visual assessment concluded that [the volunteers] were not severely under or overweight" (49). A visual assessment is not a quantitative measurement as is a BMI-for-age calculation. Therefore, if the volunteers in the Manhein et al. (2000) study were assessed based on the BMI-for-age calculation, many may have been classified as normal, overweight, or obese. Hence, the volunteers in Manhein et al. (2000) study were most likely not restricted to the normal weight BMI category. As a result, the data collected in the current study, with African Nova Scotian children, is comparable to the Manhein et al. (2000) study.

The volunteer was photographed from the anterior and right lateral views with neutral relaxed facial expressions. Photographs of each participant are important for future reference and comparison. The combination of tissue depth data and photographic data increases the accuracy of 3-D facial reconstructions produced by the forensic artist. The use of tissue depth data and photographs provides information as to the exact shape of cartilaginous features that are difficult to reconstruct accurately, such as the ears and nose.

To maintain consistencies in locating anatomical landmarks when overlying tissues are present, the protocol developed by Manhein et al. (2000) was followed (Table 3.01). A total of 19 anatomical facial points were measured (Figure 3.02; Table 3.01). Digital metal calipers were used to measure the greatest lip height, to the nearest one-hundredth of a millimeter (0.01 millimeters), and was recorded on the biographical data sheet. This feature was measured to help forensic artists reconstruct lips for missing African Nova Scotian subadults. Anatomical landmarks were then assigned to six

regions of the face (eyebrow, nose, mouth, chin, jaw, and cheek) to aid in the description of trends for the thickness of facial tissues. The points were assigned based on their exact location upon overlying tissues (Table 3.02).

Table 3.01 Facial anatomical points and descriptions (modified from Manhein et al. 2000:51).

1 Glabella	approx. 1 cm above and directly between the subject's eyebrows
2 Nasion	directly between eyes
3 End of nasals	palpating to determine where bone ends and cartilage begins
4 Lateral nostril	approximately 0.5 cm to the right of the nostril
5 Mid-philtrum	centered between nose and mouth
6 Chin-lip fold	centered in fold of chin, below lips
7 Mental eminence	centered on forward-most projecting point of chin
8 Beneath chin	centered on inferior surface of mandible
9 Superior eye orbit	centered on eye, at level of eyebrow
10 Inferior eye orbit	centered on eye, where inferior bony margin lies
11 Supra canine	upper lip, lined up superiorly/inferiorly with lateral edge of nostril
12 Sub canine	lower lip, lined up superiorly/inferiorly with lateral edge of nostril
13 Supra M2	cheek region, lateral: lined up with bottom of nose; vertical: center of transducer lined up beneath lateral border of eye, measurement taken 0.5 cm to the left of center mark
14 Lower cheek	cheek region, lateral: lined up with mouth; vertical; same as 13
15 Mid mandible	inferior border of mandible, vertically lined up same as 13
16 Lateral eye orbit	lined up laterally with corner of the eye, on the bone
17 Zygomatic	lined up with the lateral border of the eye, on the zygomatic process
18 Gonion	found by palpating
19 Root of zygoma	anterior to and 0.5 cm superior to tragus
Greatest lip height	Measured from superior most point of the upper lip to the inferior-most part of the lower lip.

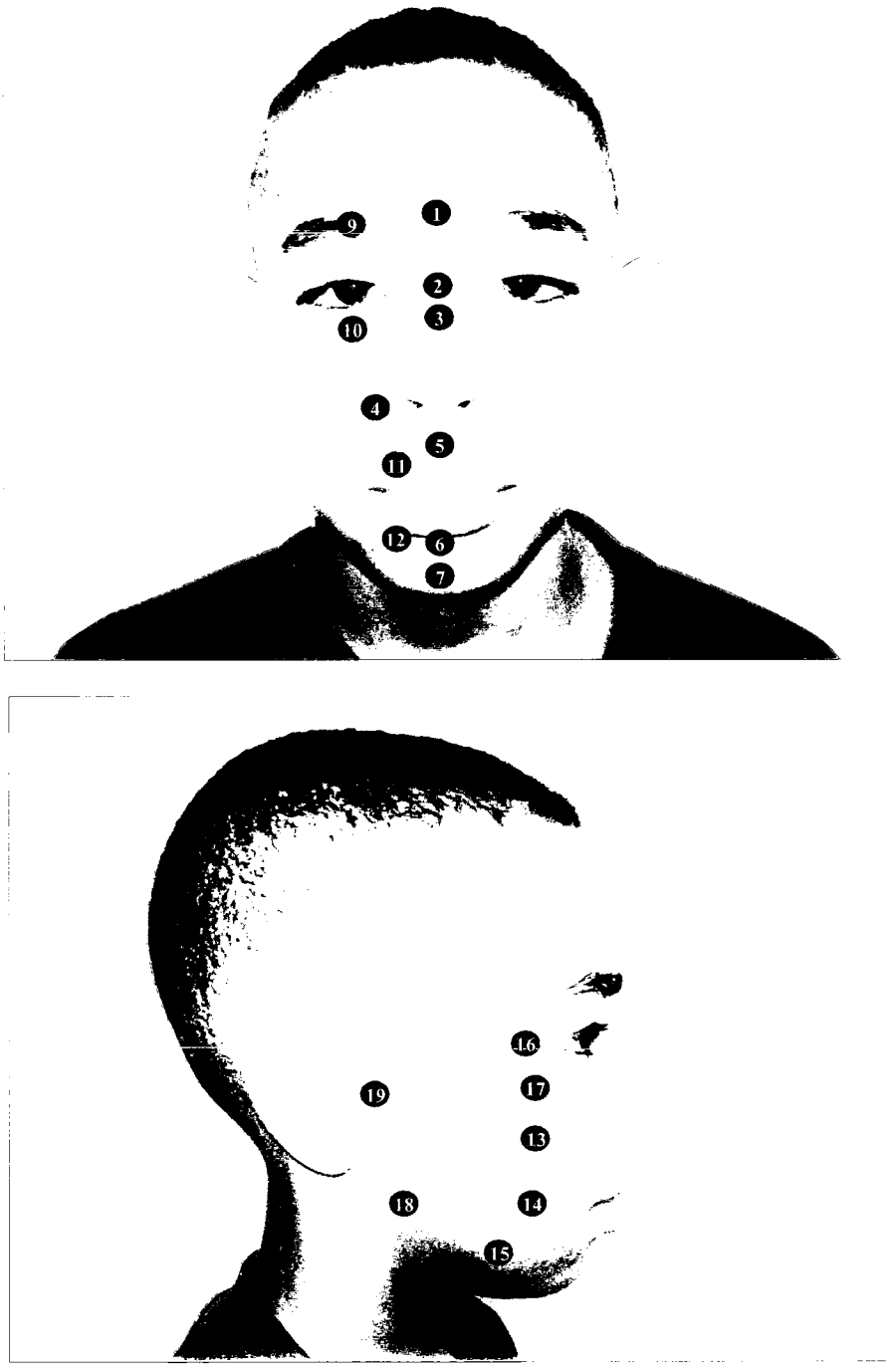

Figure 3.02 Frontal and right lateral views of a 12-year old male volunteer illustrating the measurement sites on the face. (Displayed with permission from legal guardian).

Table 3.02 Anatomical landmarks corresponding to the regions on the face.

Anatomical Landmark	Region of Face
1 Glabella 9 Superior eye orbit	Eyebrow
2 Nasion 3 End of Nasals	Nose
5 Mid-philtrum 6 Chin-lip fold 11 Supracanine 12 Subcanine Greatest lip height	Mouth
7 Mental eminence 8 Beneath chin	Chin
15 Mid mandible 18 Gonion 19 Root of zygoma	Jaw
4 Lateral nostril 10 Inferior eye orbit 13 Supra M2 14 Lower cheek 16 Lateral eye orbit 17 Zygomatic	Cheek

The participant was seated in the upright position, facing forward to maintain the Frankfurt Horizontal position, with facial muscles and jaw relaxed. The transducer was coated with a non–allergenic gel and lightly applied to the skin at a 90° angle to the underlying bony landmark. To prevent depression of the soft tissues, the gel was the only substance in contact with the skin (Figure 3.03).

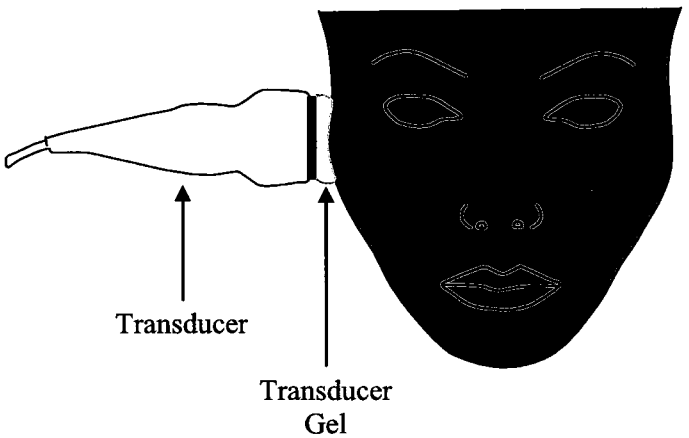

Figure 3.03 The placement of the ultrasound transducer on the face. The gel occupies the space between the surface of the skin and the transducer to prevent depression of the soft tissues. (Figure created by M. Huculak).

The participant remained still while the measurement was taken to ensure accuracies in sonographic measurements. Once the coated transducer was in the correct position, the image was frozen on the monitor and the participant was able to relax for a few moments prior to the next measurement. An ultrasound output was generated and the depth of the soft tissue was measured using calipers built into the computer system. This process was then repeated for all 19 anatomical points. Measurements were only taken of the right side of the face – slight asymmetry does occur in humans but the differences are negligible with respect to cranio-facial reconstruction (De Greef et al.

2006:S126). Furthermore, measuring one side of the face allowed the data to be collected in a timely manner and as a result, this method worked well with children who could only remain still for short periods of time during the measuring process. Two landmark measurements were saved on one screen, therefore a total of ten screen images were printed per individual case file.

3.4 Statistical Analyses

The measurements were entered into a Microsoft Excel spreadsheet and MINITAB Release 14.20 statistical software package for statistical analysis. The tissue depths were divided into male and female categories and then into specific age categories (3-8 years, 9-13 years, and 14-18 years). This allowed for comparisons with previous research conducted with children using sonographic technology. Microsoft Excel was used to calculate the mean, standard deviation, and range of the tissue depths for each anatomical landmark, and the greatest lip height, in each age category.

The mean averages of the greatest lip height, for males and females in each age category, were calculated and included in the final tissue depth tables. However, statistical tests were not performed for this site because greatest lip height is not a measurement of tissue thickness. Furthermore, no statistical analyses have ever been conducted on the greatest lip height (Manhein et al. 2000). Therefore, following similar protocol as Manhein et al. (2000) for comparative purposes, statistical analyses were only performed on the landmarks numbered one through 19 in Table 3.01.

Pearson's Correlations (McClave and Sincich 2006) were calculated to determine if there was a relationship between age and tissue thickness for males and females independently. This test was utilized because the data exhibited a linear relationship after

constructing scatterplots of age versus tissue depth at each landmark. Two-Sample (Independent Sample) T-Tests (McClave and Sincich 2006) were used to determine if there were significant differences between sex and tissue thickness. In addition, Two-Sample T-Tests were used to investigate whether the differences in facial tissue depths were statistically significant between the sexes of differing subadult age groups. The Two-Sample T-Tests were selected as the appropriate statistical test because the sample was randomly and independently selected, the variances were similar for the majority of the measurements, and the majority of the data exhibited an approximately normal distribution based on Ryan-Joiner Normality Tests (Normal Probability Plots) generated by MINITAB.

During the analysis of the probability plots, a couple of the landmarks exhibited p-values less than 0.05 suggesting that the data are not normally distributed. For example, the probability plot of landmark 10 for females (Figure 3.04) shows columns of points at tissue depths of 5 mm, 6 mm, 8 mm, and 10 mm with a p-value of 0.031. The rejection of normality is a product of the discrete nature of the data and the precision of the measurements (Meek, personal communication, February 9, 2010). The facial tissue thickness measurements are continuous values, however the data appears discrete due to precision limitations of the equipment. The normality tests suggest that the data for some points are not normal, but it is believed that this is an artefact of the way the data were measured. In addition, it is also possible that the normal distribution is not evident because of the small sample size.

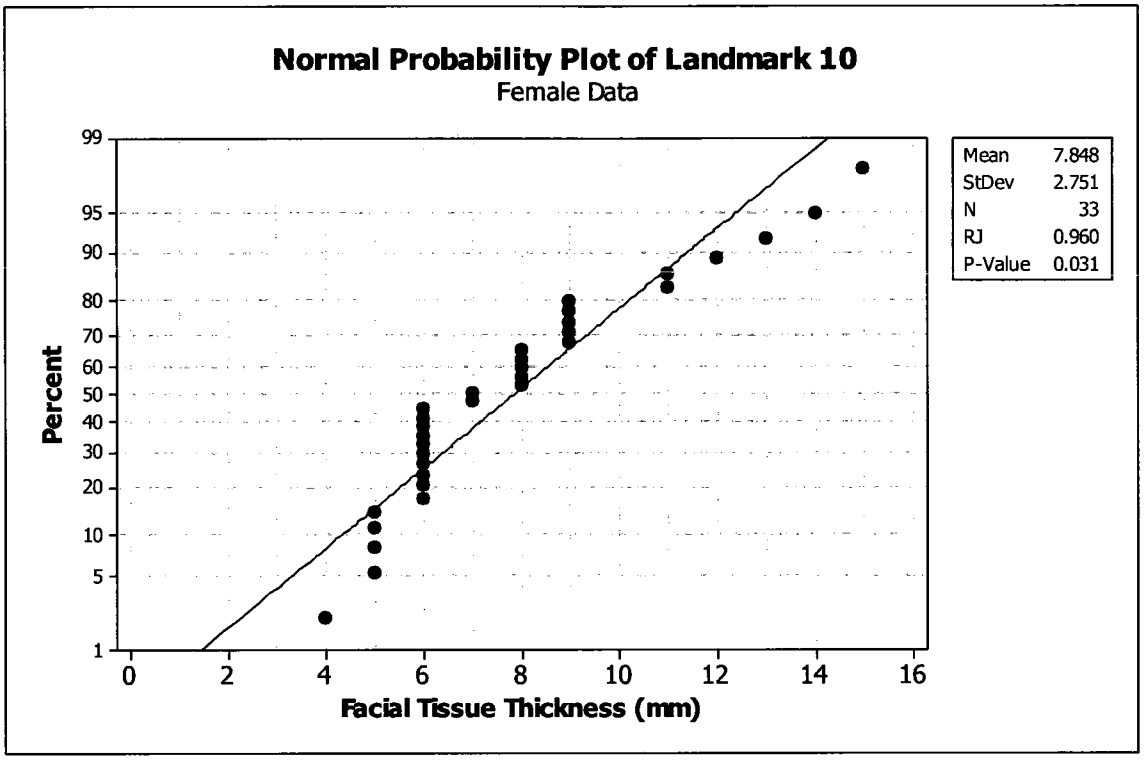

Figure 3.04 Ryan-Joiner Normal Probability Plot of landmark 10 for females displaying the discrete nature of the data as columns of points. (Generated by MINITAB)

A One-Way Analysis of Variance (ANOVA) was calculated to determine if there were significant differences within the sexes of differing subadult age groups for males and females independently (McClave and Sincich 2006). The ANOVA test was appropriate since the samples were randomly and independently selected, they exhibited an approximately normal distribution, and the population variances were similar. A Paired Difference T-Test (McClave and Sincich 2006) was used to calculate the intra-observer error of each anatomical landmark since the sample distribution was approximately normal and the selection was random. Six participants were measured twice for this error test. The critical value for statistical significance of the above tests was $\alpha = 0.05$.

To assess variation within African ancestral populations from different geographical regions, differences in facial tissue depths of African Nova Scotians and African Americans (Manhein et al. 2000) were calculated using Microsoft Excel. Similarly, to evaluate variation between ancestries, differences in facial tissue depths of African Nova Scotians and White European Americans (Manhein et al. 2000) were calculated as well. Due to the inability of accessing raw data for the African American and White European American populations, statistical analyses could not be performed to evaluate the significance of these differences.

CHAPTER 4: RESULTS

4.1 Participants

Volunteers were recruited from the Dartmouth, Cole Harbour, and Halifax area of Nova Scotia during the March Break Camps and Summer Camps organized by the Black Business Initiative of Nova Scotia. Facial tissue depth measurements were collected from 54 participants, including 33 females and 21 males. An even distribution of females and males within each age category was attempted, however, it was difficult to recruit an adequate number of males 14 to 18 years old, and both females and males 3 to 8 years old.

All of the participants accurately reflected the standard weight (Roode, personal communication, February 3, 2010) of African Nova Scotian subadults, and were thus a representative sample of the population. A total of 26 volunteers fell within the normal BMI-for-age category while 28 participants fell in the overweight/obese BMI-for-age category.

4.2 Subadult African Nova Scotian Data

Tables 4.01 and 4.02 illustrate the means, standard deviations, and ranges of the facial tissue depths at each anatomical landmark for females and males in three standardized subadult age categories, (3-8 year olds, 9-13 year olds, 14-18 year olds). All raw data can be viewed in Appendices C1-C10.

Table 4.01 Descriptive statistics of facial tissue depths (mm) of subadult African Nova Scotian females.

Anatomical Landmarks	Females aged 3-8 Years Old (N = 5)			Females aged 9-13 Years Old (N = 15)			Females aged 14-18 Years Old (N = 13)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	5.0	0.71	4-6	5.8	0.68	5-7	5.0	1.00	3-7
2 Nasion	6.0	0.00	0	6.3	0.96	5-8	5.6	0.96	4-7
3 End of nasals	4.2	1.30	3-6	5.0	1.85	2-7	3.5	1.27	2-5
4 Lateral nostril	17.8	2.28	14-20	20.9	3.38	15-29	19.6	2.26	16-24
5 Mid-philtrum	10.6	1.52	9-12	10.3	1.68	7-13	10.5	1.85	8-15
6 Chin-lip fold	8.6	1.52	7-11	11.0	1.36	9-14	11.8	2.19	8-16
7 Mental eminence	9.8	1.64	8-12	13.3	1.80	0-16	11.8	2.92	6-16
8 Beneath chin	6.4	0.89	5-7	8.9	2.63	6-14	7.8	2.42	5-13
9 Superior eye orbit	6.2	1.79	4-8	8.0	1.00	7-11	6.1	1.04	4-8
10 Inferior eye orbit	7.2	4.44	4-15	7.6	1.76	5-12	8.4	3.07	5-14
11 Supracanine	11.8	4.15	7-17	14.3	3.84	8-22	12.1	2.02	9-16
12 Subcanine	11.2	0.84	10-12	12.5	2.20	10-15	12.7	2.50	9-19
13 Supra M2	22.8	5.02	15-27	23.3	7.99	12-38	25.5	3.38	20-31
14 Lower cheek	21.0	1.58	19-23	22.3	4.64	13-30	21.4	2.96	19-28
15 Mid mandible	9.6	2.61	7-14	10.9	2.58	6-14	9.2	2.82	6-14
16 Lateral eye orbit	4.4	1.14	3-6	4.9	0.80	4-6	4.2	1.01	3-6
17 Zygomatic	6.8	1.92	5-10	8.7	2.55	5-13	7.8	2.38	5-12
18 Gonion	6.2	1.64	5-9	9.6	5.26	4-22	6.6	3.25	4-14
19 Root of zygoma	3.8	0.45	3-4	4.7	1.05	3-7	4.2	1.10	3-6
Greatest lip height	14.512	1.46	12.46-16.38	20.066	4.52	15.46-28.68	21.688	3.14	14.39-25.43

Table 4.02 Descriptive statistics of facial tissue depths (mm) of subadult African Nova Scotian males.

Anatomical Landmarks	Males aged 3-8 Years Old (N = 3)			Males aged 9-13 Years Old (N = 14)			Males aged 14-18 Years Old (N = 4)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	5.0	0.00	0	5.6	1.22	4-9	5.8	0.50	5-6
2 Nasion	5.0	1.00	4-6	6.2	1.12	5-9	7.5	0.58	7-8
3 End of nasals	4.7	1.15	4-6	4.7	0.99	3-7	4.0	1.41	3-6
4 Lateral nostril	18.3	4.16	15-23	19.1	5.33	7-28	19.3	4.79	15-26
5 Mid-philtrum	10.0	1.73	8-11	11.4	1.65	9-14	12.3	0.96	11-13
6 Chin-lip fold	9.7	1.53	8-11	11.2	1.72	9-15	13.0	2.45	11-16
7 Mental eminence	8.0	1.00	7-9	12.8*	3.03	7-18	14.0	1.83	12-16
8 Beneath chin	5.7	1.15	5-7	8.1	3.18	5-18	8.7†	1.53	7-10
9 Superior eye orbit	6.0	0.00	0	6.9	1.46	4-9	8.0	0.82	7-9
10 Inferior eye orbit	11.3	5.13	7-17	8.9	3.45	5-15	7.5	1.29	6-9
11 Supracanine	11.7	2.52	9-14	13.4	3.32	10-22	12.3	1.71	10-14
12 Subcanine	9.7	1.53	8-11	12.8	1.89	9-16	12.5	0.58	12-13
13 Supra M2	24.0	2.00	22-26	22.6	3.95	13-26	24.5	4.65	20-29
14 Lower cheek	24.7	2.52	22-27	21.7	3.22	15-27	23.5	7.42	17-34
15 Mid mandible	7.0	0	0	9.7	3.20	6-14	10.8	2.50	8-14
16 Lateral eye orbit	3.7	1.15	3-5	4.5	1.09	3-6	4.8	1.89	2-6
17 Zygomatic	5.7	0.58	5-6	7.1	2.46	4-14	5.8	0.96	5-7
18 Gonion	4.7	1.53	3-6	7.6	3.99	3-17	13.0	1.41	11-14
19 Root of zygoma	3.0	0	0	4.4	2.10	2-10	3.5	1.00	3-5
Greatest lip height	16.403	1.15	15.28-17.57	20.381	2.84	15.00-24.90	26.353	2.27	23.95-28.74

*Indicates $N = 13$, one individual had a dimple.

†Indicates $N = 3$, one individual had facial hair at this location.

Subadult African Nova Scotian females and males, between 9 and 13 years old, exhibit the greatest amount of tissue thickness variation based on the large standard deviation values (Tables 4.01 and 4.02). These values are large at measurement sites 4, 11, 13, 14, and 18 for both females and males. There is also an overlap in all 19 measurements when the range for both sexes is compared within their corresponding age categories.

4.2.1 Female Facial Tissue Depths & Age

Table 4.02 displays the facial tissue thickness of females for each age group. Facial tissue depths increase from the 3-8 year old age category to the 9-13 year old age category at all points except mid-philtrum. In contrast, facial tissue depth decreases from the 9-13 year old age category to the 14-18 year old age category at most sites, with the exception of points 5, 6, 10, 12 and 13 (Figure 4.01). A reference of corresponding locations for each landmark can be found in Table 3.01.

Therefore, facial tissue depth for females increases early in life, specifically from the 3-8 year old age category to the 9-13 year old age category, at all regions of the face (eyebrow, nose, mouth, chin, jaw, and cheek). In contrast, facial tissue depth decreases from the transition into adolescent years for females, specifically from the 9-13 year old age category to the 14-18 year old age category, at the eyebrow, nose, chin, and jaw regions. From the 9-13 year old age category to the 14-18 year old age category, tissue depth increases at the majority of the points at the mouth region while the cheek region illustrates both an increase (points 10 and 13) and a decrease (points 4, 14, 16, and 17) (Figure 4.01).

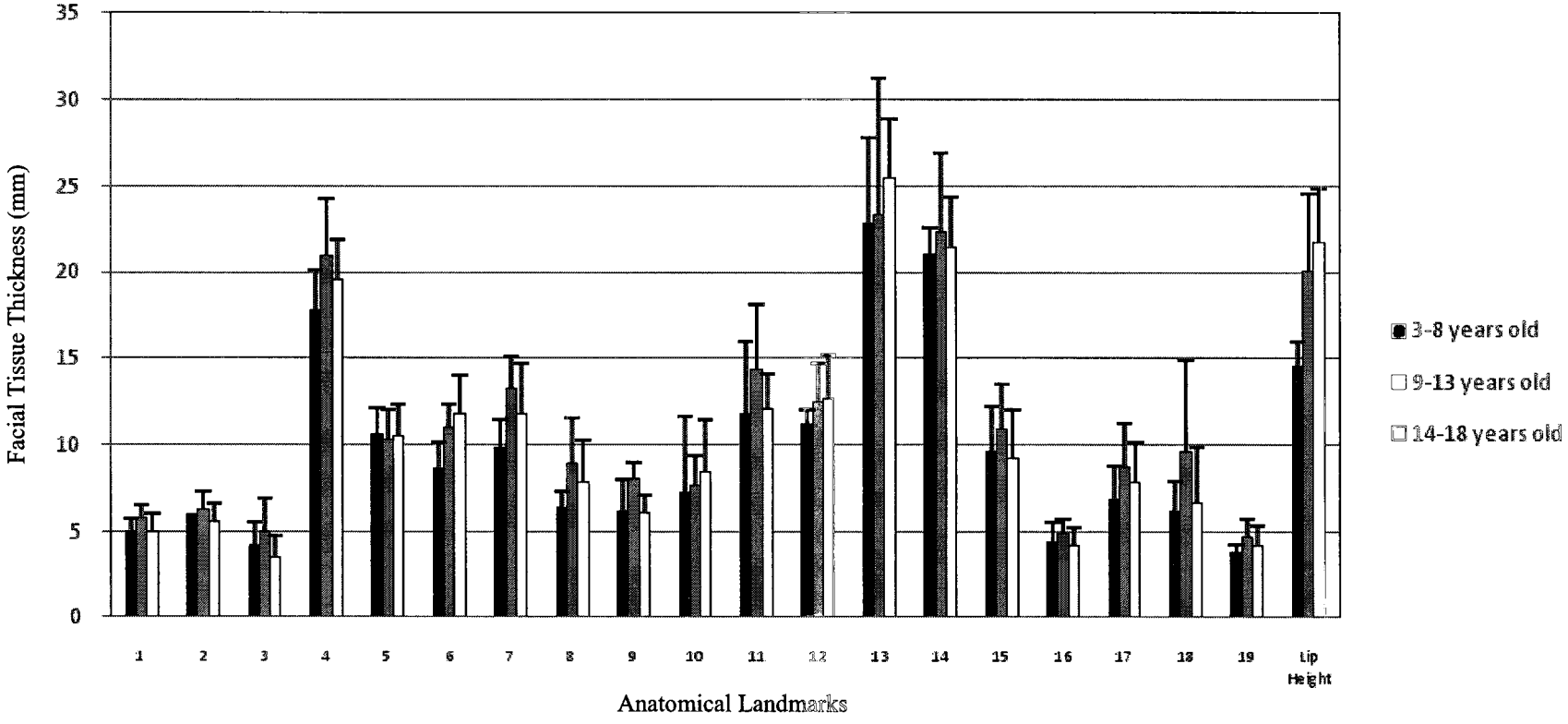

Figure 4.01 Comparison of facial tissue depth means and standard deviation bars of African Nova Scotian females between three subadult age categories.

Table 4.03 illustrates the Pearson's correlations between age and tissue thickness for females. Results reveal a significant relationship between age and tissue thickness at point 6, however, it is not a strong linear correlation. In contrast, age has no significant influence on the remainder of the 18 landmark sites.

Table 4.04 summarizes a One-way ANOVA that tested for significant differences of facial tissue thickness within females when all three age categories were compared to one another. At points 6, 7, and 9 significant differences in tissue depth were evident between the 3-8 year old age category and 9-13 year old age category, suggesting these measurement sites exhibit changes early in life (Figure 4.02). In contrast, points 1, 3, and 9 demonstrate significant differences in tissue depth between the 9-13 year old age category and 14-18 year old age category, suggesting these measurement sites undergo changes later in life (Figure 4.03). The remainder of the 19 points exhibited no significant differences in tissue depth between age categories for females.

Overall, observations of the results suggest a trend of increasing facial tissue thickness for subadult female African Nova Scotians into early childhood and a decrease in facial tissue thickness into adolescence. Statistical tests revealed that one point demonstrated a significant correlation between age and tissue depth in females and a few points showed significant differences between tissue thicknesses when comparisons were made between age categories.

Table 4.03 Pearson's Correlations between tissue thickness and age for subadult African Nova Scotian females ($N = 33$).

Anatomical Landmarks	Pearson's Correlation	P-value
1 Glabella	-0.075	0.679
2 Nasion	-0.117	0.517
3 End of nasals	-0.240	0.179
4 Lateral nostril	0.151	0.402
5 Mid-philtrum	0.009	0.962
6 Chin-lip fold	0.478†	0.005
7 Mental eminence	0.101	0.575
8 Beneath chin	0.036	0.844
9 Superior eye orbit	-0.153	0.396
10 Inferior eye orbit	0.228	0.203
11 Supracanine	-0.031	0.863
12 Subcanine	0.131	0.466
13 Supra M2	0.198	0.269
14 Lower cheek	-0.013	0.943
15 Mid mandible	-0.099	0.583
16 Lateral eye orbit	-0.089	0.624
17 Zygomatic	0.082	0.651
18 Gonion	-0.076	0.675
19 Root of zygoma	0.042	0.816

† Correlation is significant at the 0.05 level.

Table 4.04 Summary of a One-way ANOVA showing the significant differences of tissue thickness within African Nova Scotian females for differing subadult age groups.

	Anatomical Landmarks																		
Age Groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
3-8 years (A)	–	–	–	–	–	B,C	B	–	B	–	–	–	–	–	–	–	–	–	–
9-13 years (B)	C	–	C	–	–	A	A	–	A,C	–	–	–	–	–	–	–	–	–	–
14-18 years (C)	B	–	B	–	–	A	–	–	B	–	–	–	–	–	–	–	–	–	–

Note: Different letters indicate a significant difference at the landmark among the age groups ($p = 0.05$).

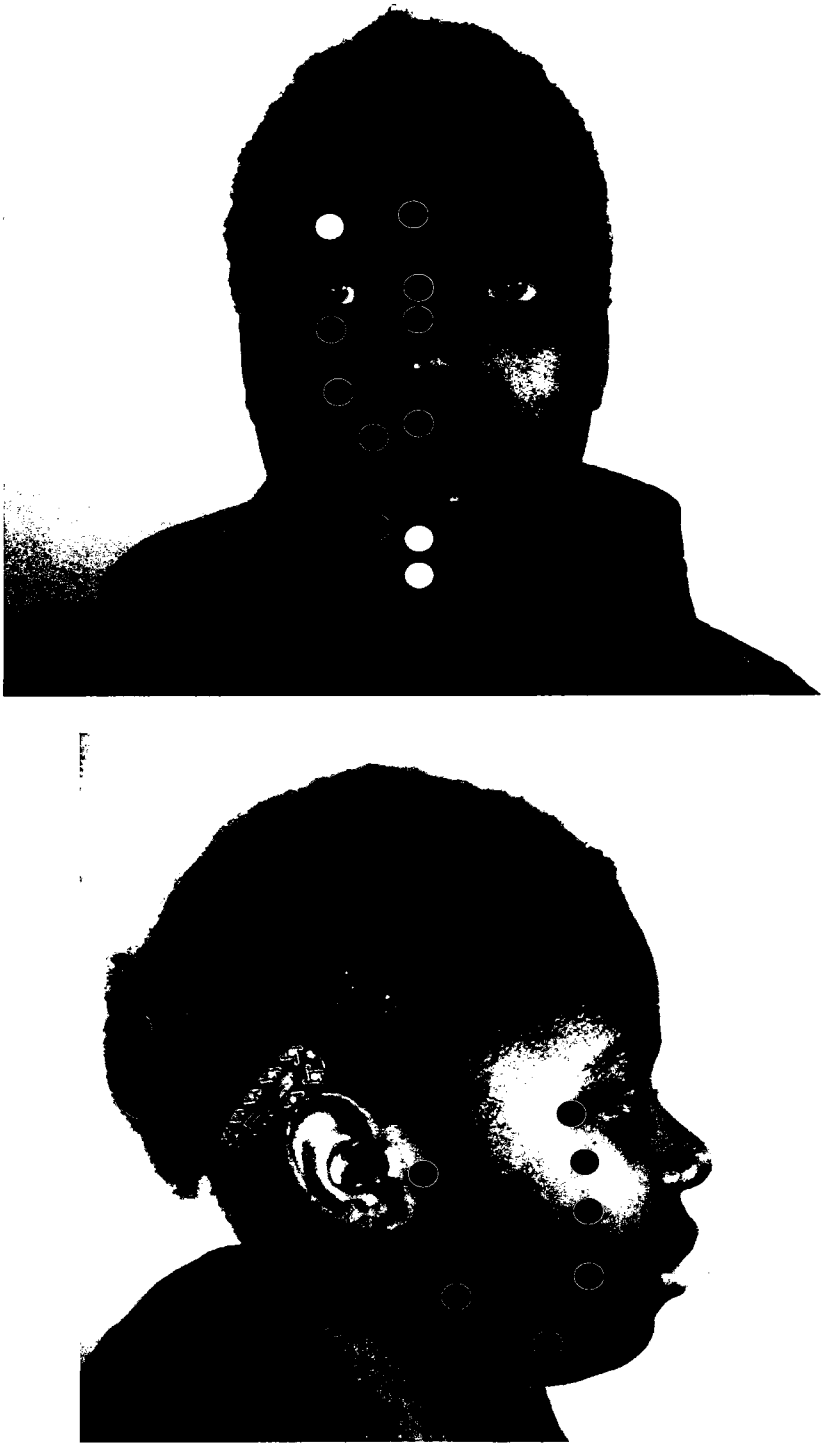

Figure 4.02 Frontal and right lateral views of a 12-year old female volunteer illustrating the measurement sites (black dots) and those that were significantly different (yellow dots) when comparing the first age category (3-8 years old) to the second (9-13 years old). (Displayed with permission from legal gaurdian).

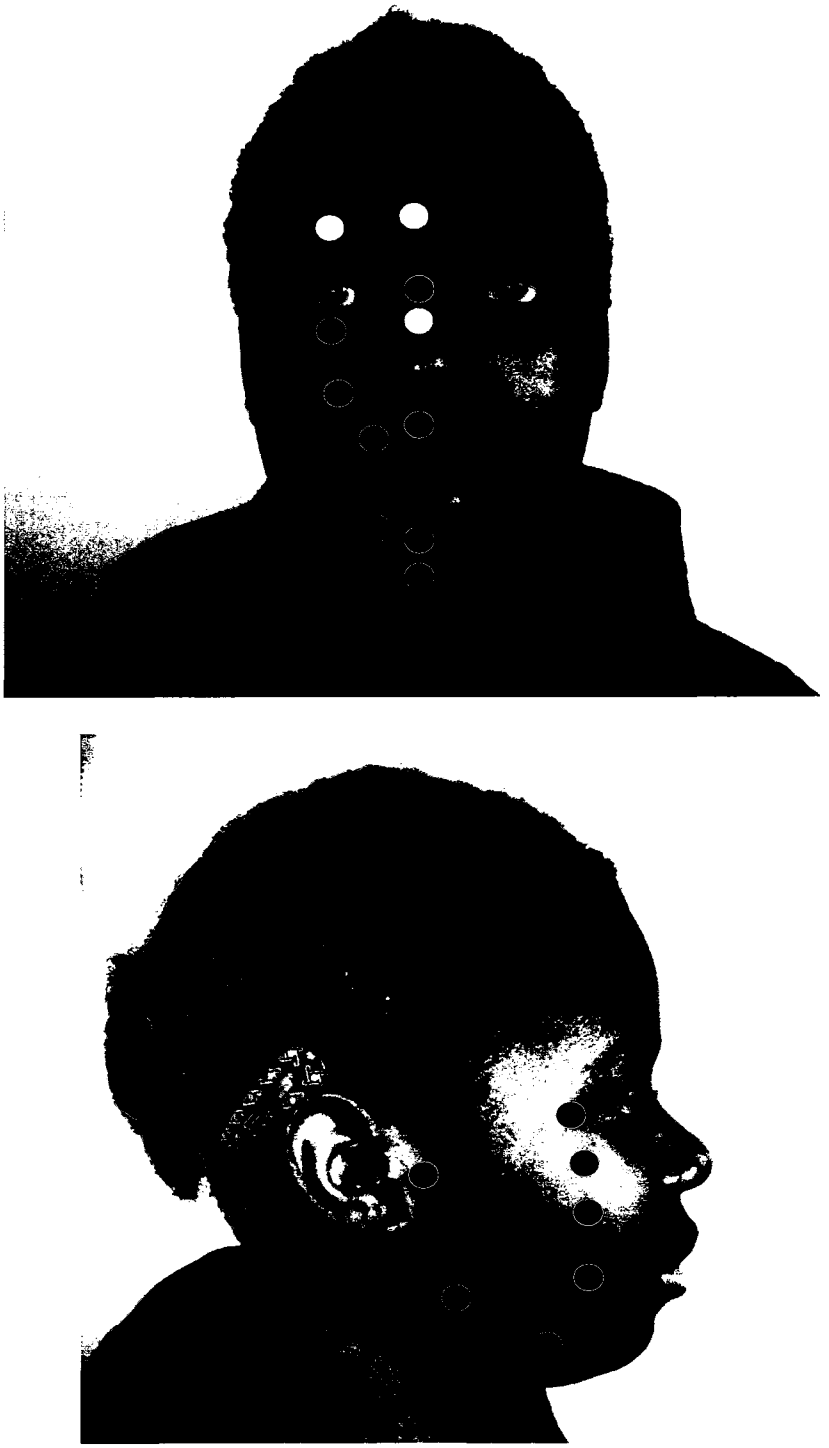

Figure 4.03 Frontal and right lateral views of a 12-year old female volunteer illustrating the measurement sites (black dots) and those that were significantly different (yellow dots) when comparing the second age category (9-13 years old) to the third (14-18 years old). (Displayed with permission from legal gaurdian).

4.2.2 Male Facial Tissue Depths & Age

Table 4.02 displays the facial tissue thickness of males for each age group. Facial tissue depth increases from the 3-8 year old age category to the 9-13 year old age category at the majority of the sites, except for points 3, 10, 13 and 14. Facial tissue depth increases from the 9-13- year old age category to the 14-18 year old age category at most landmarks, with the exception of points 3, 10, 11, 12, 17, and 19 (Figure 4.04).

Therefore, facial tissue depth for males increases early in life, specifically from the 3-8 year old age category to the 9-13 year old age category, at most regions of the face (eyebrow, mouth, chin, and jaw). This is similar to the results for females. Unlike females, facial tissue depth for males increases from the transition into adolescent years. From the 9-13 year old age category to the 14-18 year old age category, depth increases at the eyebrow, chin, and jaw regions. From the 9-13 year old age category to the 14-18 year old age category, tissue depth increases at the midline points of the mouth (points 5 and 6) while the lateral points decrease in tissue depth (points 11 and 12). The cheek region illustrates both an increase (points 4, 16, 17) and a decrease (points 10, 13, 14) of tissue depth from the 3-8 year old age category to the 9-13 year old age category. During the transition into the teenage years, depth increases at points 4, 13, 14, and 16, and decreases at points 10 and 17. These results reveal no definitive trend at the cheek region in males.

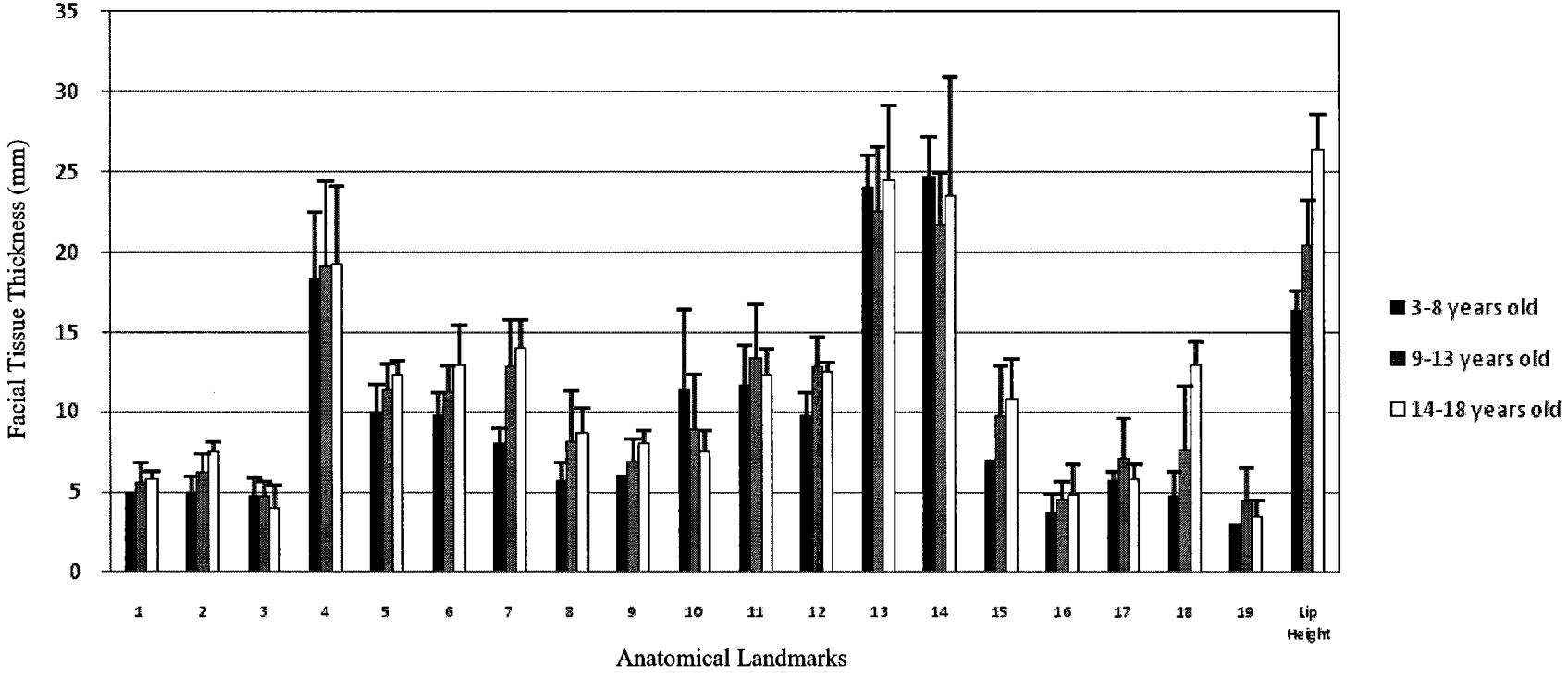

Figure 4.04 Comparison of facial tissue depth means and standard deviation bars of African Nova Scotian males between three subadult age categories.

Table 4.05 illustrates the Pearson's correlations between age and facial tissue thickness for males. Results reveal significant relationships between age and tissue thickness at points 2, 5, 6, 7, 10, and 18. Measurement sites 2 and 18 show relatively strong positive linear correlations, while points 5, 6, 7, and 10 exhibit weak linear correlations. In contrast, age has no significant influence on the remainder of the 12 landmark sites.

Table 4.06 summarizes a One-way ANOVA that tested for significant differences for facial tissue thickness within males when all three age categories were compared to one another. Points 7 and 12 demonstrate significant differences in tissue depth between the 3-8 year old age category and the 9-13 year old age category, suggesting that these measurement landmarks undergo changes early in life (Figure 4.05). In contrast, point 18 showed significant differences in tissue depth between the 9-13 year old age category and the 14-19 year old age category, suggesting that this measurement site exhibits changes later in the subadult years (Figure 4.06). The remainder of the 18 points exhibited no significant differences in tissue depth between age categories for males.

Overall, observations of the results suggest a trend of increasing facial tissue thickness as age increases for subadult African Nova Scotian males. Statistical tests revealed that six points demonstrated significant correlations between age and tissue depth in females and a couple of points showed significant differences between tissue thicknesses when comparisons were made between age categories.

Table 4.05 Pearson's Correlations between tissue thickness and age for subadult African Nova Scotian males ($N = 21$).

Anatomical Landmarks	Pearson's Correlation	P-value
1 Glabella	0.083	0.720
2 Nasion	0.602†	0.004
3 End of nasals	-0.220	0.338
4 Lateral nostril	0.097	0.677
5 Mid-philtrum	0.488†	0.025
6 Chin-lip fold	0.459†	0.037
7 Mental eminence	0.533†*	0.016
8 Beneath chin	0.189*	0.424
9 Superior eye orbit	0.365	0.104
10 Inferior eye orbit	-0.543†	0.011
11 Supracanine	-0.007	0.974
12 Subcanine	0.285	0.210
13 Supra M2	0.003	0.988
14 Lower cheek	-0.145	0.531
15 Mid mandible	0.200	0.384
16 Lateral eye orbit	0.079	0.733
17 Zygomatic	-0.084	0.716
18 Gonion	0.661†	0.001
19 Root of zygoma	0.157	0.497

† Correlation is significant at the 0.05 level.
* $N = 20$.

Table 4.06 Summary of a One-way ANOVA showing the significant differences of tissue thickness within African Nova Scotian males for differing subadult age groups.

	Anatomical Landmarks																		
Age Groups	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
3-8 years (A)	–	C	–	–	–	–	B,C	–	–	–	–	B	–	–	–	–	–	C	–
9-13 years (B)	–	–	–	–	–	–	A	–	–	–	–	A	–	–	–	–	–	C	–
14-18 years (C)	–	A	–	–	–	–	A	–	–	–	–	–	–	–	–	–	–	A,B	–

Note: Different letters indicate a significant difference at the landmark among the age groups ($p = 0.05$).

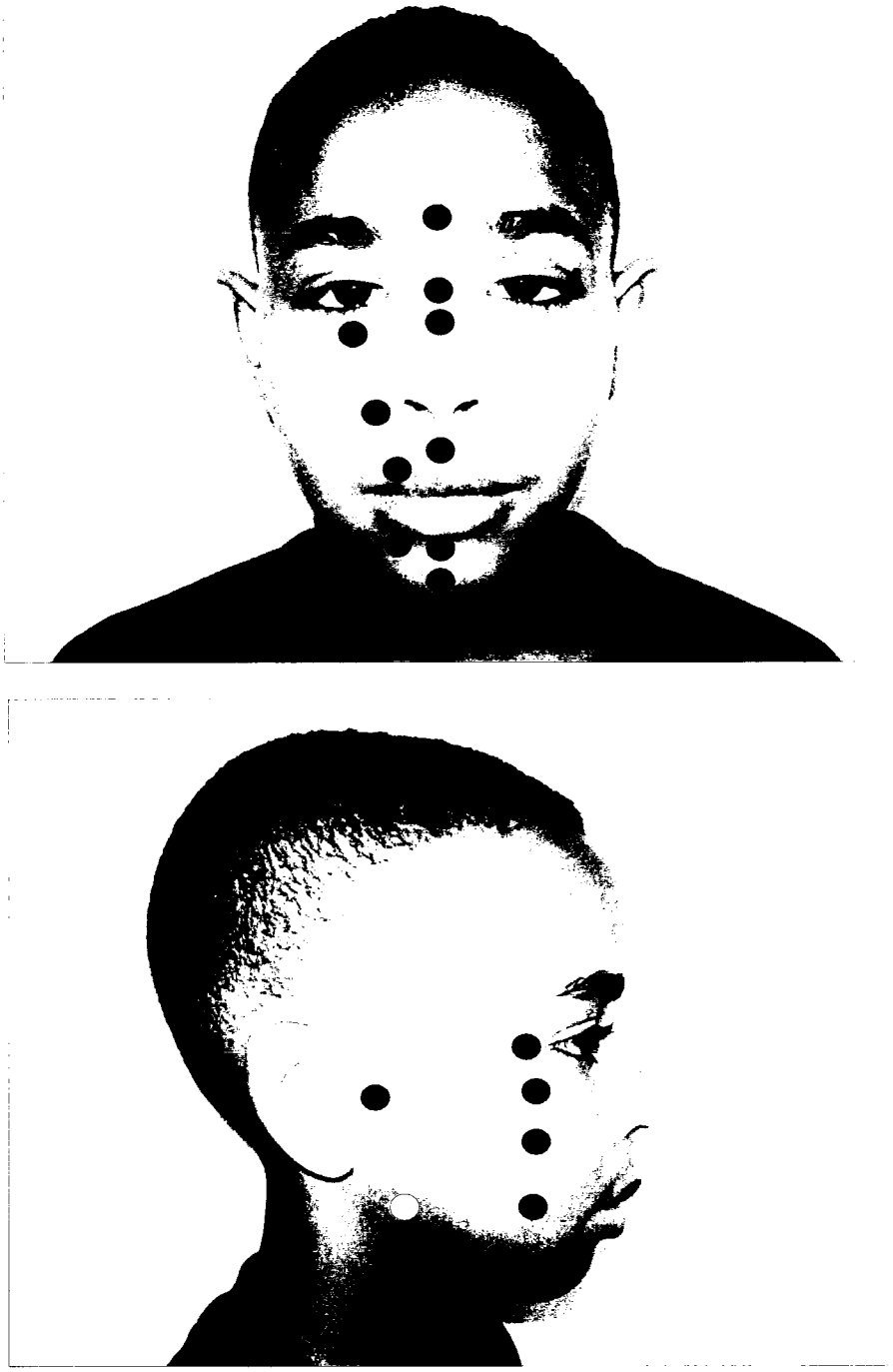

Figure 4.05 Frontal and right lateral views of a 12-year old male volunteer illustrating the measurement sites (black dots) and those that were significantly different (yellow dots) when comparing the first age category (3-8 years old) to the second (9-13 years old). (Displayed with permission from legal guardian).

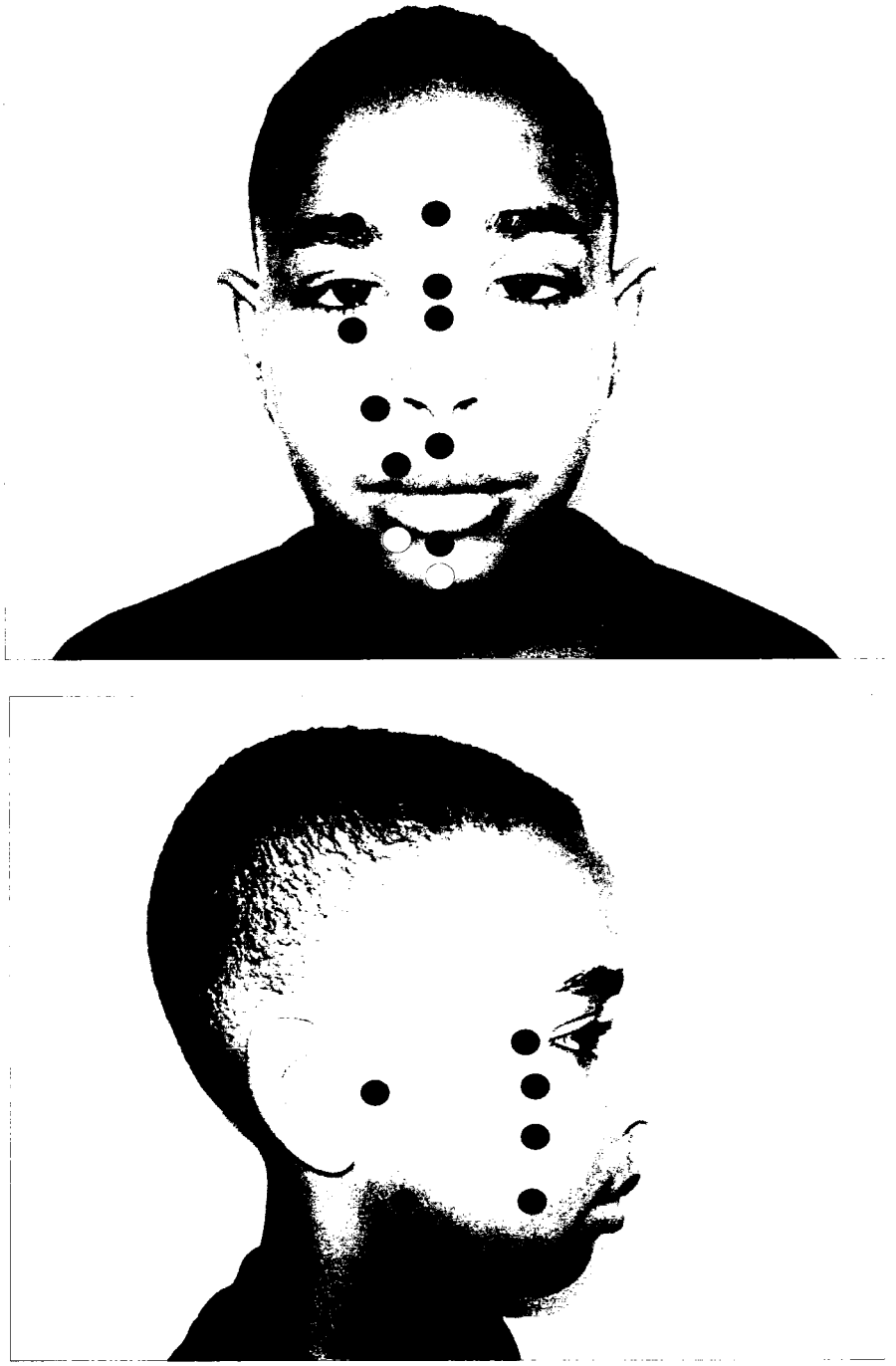

Figure 4.06 Frontal and right lateral views of a 12-year old male volunteer illustrating the measurement sites (black dots) and those that were significantly different (yellow dots) when comparing the second age category (9-13 years old) to the third (14-18 years old). (Displayed with permission from legal guardian).

4.2.3 Facial Tissue Depths Between Sexes Aged 3-8 Years

A comparison of male and female facial tissue depth means for the 3-8 year old age category reveals that females have thicker facial tissue depths than males at most landmarks, with the exception of points 3, 4, 6, 10, 13, and 14. With regards to the nasal region, point 3 is thicker in males and point 2 is thicker in males. Females, however, illustrate thicker facial tissue depth at the eyebrow (point 9) except for glabella which shows the same depth for both sexes. Females exhibit thicker facial tissue depths at the chin (points 7 and 8) and jaw (points 15, 18, and 19). Females also have thicker facial tissue depths at more points of the mouth (points 5, 11, and 12) than males (point 6). Lastly, males have thicker facial tissue depths at the majority of the points at the cheek (points 4, 10, 13, and 14) than females (points 16 and 17).

Table 4.07 summarizes the results of the Two-Sample T-Tests comparing females and males at each measurement site for ages 3-8 years old. Results reveal no significant differences in facial tissue depth between males and females at any of the locations for this age category. This suggests that sex does not significantly influence the facial tissue thickness of African Nova Scotian children between 3 and 8 years of age, thus supporting the collapse of data for female and male means for this age group.

Table 4.07 Comparisons of the tissue thickness between African Nova Scotian females (N = 5) and males (N = 3) for ages 3-8 years old using Two-Sample (Independent Sample) T-Tests.

Anatomical Landmarks	T-value	P-value
1 Glabella	**	**
2 Nasion	**	**
3 End of nasals	-0.53	0.626
4 Lateral nostril	-0.20	0.857
5 Mid-philtrum	0.50	0.654
6 Chin-lip fold	-0.96	0.392
7 Mental eminence	1.93	0.112
8 Beneath chin	0.94	0.415
9 Superior eye orbit	**	**
10 Inferior eye orbit	-0.16	0.330
11 Supracanine	0.06	0.957
12 Subcanine	1.60	0.251
13 Supra M2	-0.48	0.655
14 Lower cheek	-2.27	0.151
15 Mid mandible	**	**
16 Lateral eye orbit	0.87	0.432
17 Zygomatic	1.23	0.274
18 Gonion	1.34	0.253
19 Root of zygoma	**	**

** unable to calculate due to identical measurements.

4.2.4 Facial Tissue Depths Between Sexes Aged 9-13 Years

A comparison of male and female facial tissue depth means in the 9-13 year old age category reveals that females have thicker facial tissue depths than males at the majority of the landmarks with the exception of points 5, 6, 10, and 12. Females exhibit thicker tissue depths at the nose (points 2 and 3) than males. Females also have thicker facial tissue depths at the chin (points 7 and 8) and jaw (points 15, 18, and 19). This is similar to the results for females in the 3-8 years old age category. In contrast, males exhibit thicker facial tissue depths at all of the points of the mouth (points 5, 6, 12) except point 11 when compared to females. Females have thicker facial tissue depths at the eyebrow (points 1 and 9) and at all points of the cheek (points 4, 13, 14, 16, and 17) except point 10 when compared to males of the same age category.

Table 4.08 summarizes the results of the Two-Sample T-Tests comparing females and males at each measurement site for ages 9-13 years old. Significant differences in facial tissue depth between males and females for this age category were observed at one location only, point 9 (Figure 4.07). This suggests that sex does not significantly influence the facial tissue thickness of African Nova Scotian children between 9 and 13 years of age, thus supporting the collapse of data for female and male means for this age group.

Table 4.08 Comparisons of the tissue thickness between African Nova Scotian females (N = 15) and males (N = 14) for ages 9-13 years old using Two-Sample (Independent Sample) T-Tests.

Anatomical Landmarks	T-value	P-value
1 Glabella	0.43	0.675
2 Nasion	0.13	0.894
3 End of nasals	0.52	0.607
4 Lateral nostril	0.95	0.351
5 Mid-philtrum	-1.77	0.088
6 Chin-lip fold	-0.37	0.714
7 Mental eminence	0.59*	0.564
8 Beneath chin	0.73	0.475
9 Superior eye orbit	2.44†	0.023
10 Inferior eye orbit	-1.29	0.212
11 Supracanine	0.68	0.501
12 Subcanine	-0.33	0.742
13 Supra M2	0.38	0.705
14 Lower cheek	0.42	0.678
15 Mid mandible	1.13	0.271
16 Lateral eye orbit	1.21	0.238
17 Zygomatic	1.79	0.086
18 Gonion	1.13	0.268
19 Root of zygoma	0.38	0.707

† Significant difference between males and females (p = 0.05).
* $N = 13$ males.

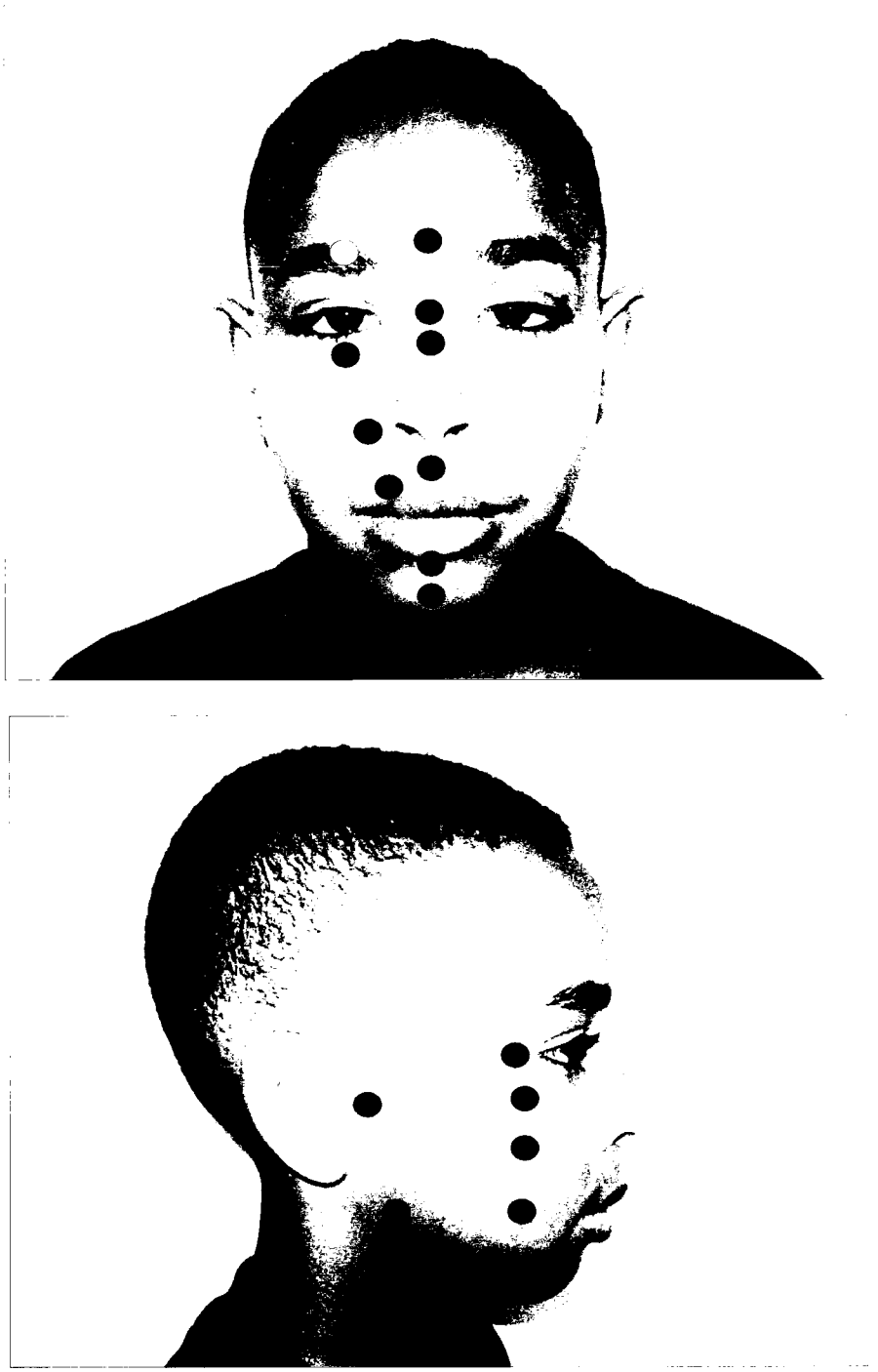

Figure 4.07 Frontal and right lateral views of a 12-year old male volunteer illustrating the measurement sites (black dots) and those that were significantly different (yellow dots) when comparing females and males in the second age category (9-13 years old). (Displayed with permission from legal guardian).

4.2.5 Facial Tissue Depths Between Sexes Aged 14-18 Years

A comparison of female and male facial tissue depth means for the 14-18 year old age category reveals that males have thicker facial tissue depths than females at most landmarks with the exception of points 4, 10, 12, 13, 17, and 19. The nasal points (points 2 and 3) are thicker in males in this age category. Males also have thicker facial tissue depths at the eyebrow (points 1 and 9) and chin (points 7 and 8) when compared to females. In contrast to the 9-13 year old age category, males exhibit thicker facial tissue depths at the majority of the points of the jaw (points 15 and 18), except point 19. Males have thicker facial tissue depths at all points of the mouth (points 5, 6, and 11) except point 12. Females, however, have thicker facial tissue depths at the majority of the cheek points (points 4, 10, 13 and 17) except points 14 and 16.

Table 4.09 summarizes the results of the Two-Sample T-Tests comparing females and males at each measurement site for ages 14-18 years old. Significant differences in facial tissue depth between males and females were observed at five locations, including points 2, 5, 9, 17, and 18 (Figure 4.08). This suggests that adolescence, in males and females, begins to influence the facial tissue thickness of African Nova Scotian children, thus supporting the separation of female and male means for this age group.

Table 4.09 Comparisons of the tissue thickness between African Nova Scotian females (N = 13) and males (N = 4) for ages 14-18 years old using Two-Sample (Independent Sample) T-Tests.

Anatomical Landmarks	T-value	P-value
1 Glabella	-2.01	0.072
2 Nasion	-4.80†	0.001
3 End of nasals	-0.68	0.533
4 Lateral nostril	0.15	0.892
5 Mid-philtrum	-2.44†	0.035
6 Chin-lip fold	-0.84	0.446
7 Mental eminence	-1.83	0.105
8 Beneath chin	-0.81*	0.464
9 Superior eye orbit	-3.85†	0.008
10 Inferior eye orbit	0.83	0.424
11 Supracanine	-0.17	0.872
12 Subcanine	0.26	0.801
13 Supra M2	0.41	0.700
14 Lower cheek	-0.56	0.616
15 Mid mandible	-1.08	0.329
16 Lateral eye orbit	-0.53	0.635
17 Zygomatic	2.57†	0.023
18 Gonion	-5.57†	<0.001
19 Root of zygoma	1.25	0.267

† Significant difference between males and females (p = 0.05).
* $N = 3$ males.

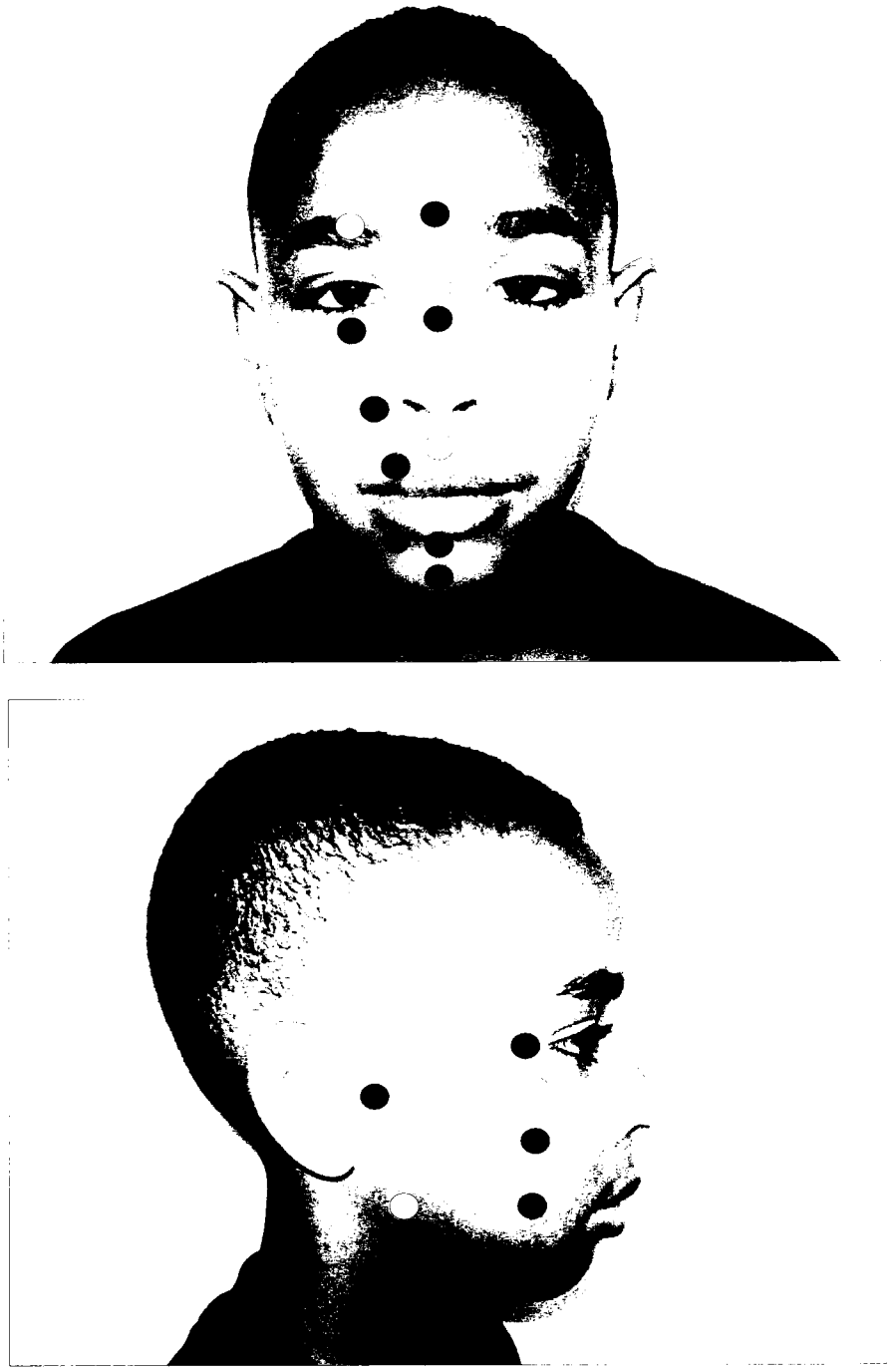

Figure 4.08 Frontal and right lateral views of a 12-year old male volunteer illustrating the measurement sites (black dots) and those that were significantly different (yellow dots) when comparing females and males in the third age category (14-18 years old). (Displayed with permission from legal guardian).

4.2.6 Combined Sexes & Ages

In summary, facial tissue depths at most of the points in the nasal region are thicker in females during late childhood, while males exhibit thicker nasal tissue depths during adolescence. Females exhibit thicker facial tissue depths at the eyebrow, chin, and jaw regions throughout early and late childhood, however, tissue depths at these regions are greater in males once they reach adolescence. At the mouth region, females have thicker tissue depths in early childhood. Males have greater tissue depths than females at the mouth region in late childhood and adolescence. The cheek region is thicker in males, at the majority of the points in early childhood. Females have thicker tissue depths than males at the cheek region in late childhood and adolescence. Note that the majority of the differences described in this summary are not statistically significant. Table 4.10 shows the sex that illustrated the thickest facial tissue depth mean within each age category. For example, males have thicker tissue depths at the cheek region than females during early childhood, however, females have thicker tissue depths at this region than males during late childhood and adolescence.

Table 4.10 Facial tissue depth mean comparisons of subadult African Nova Scotian females and males for different facial regions and age groups.*

Facial Region	**Early Childhood** (3-8 yrs. old)	**Late Childhood** (9-13 yrs. old)	**Adolescence** (14-18 yrs. old)
Nose	Neither	Females	Males
Eyebrow	Females	Females	Males
Chin	Females	Females	Males
Jaw	Females	Females	Males
Mouth	Females	Males	Males
Cheek	Males	Females	Females

*The sex with the thickest facial tissue depth means in the specified region is shown in this table

4.3 Subadult African Nova Scotian Females vs. Subadult African American & White European American Females

Tables 4.11 and 4.12 show the results of comparing tissue depth means for subadult African Nova Scotian females to subadult African American females and White European American females, respectively. African Nova Scotian females have thicker facial tissue depths, at the majority of the points, than subadult African American females and White European American females. The results for both ancestral population comparisons are identical and illustrated in Figure 4.09. African Nova Scotian females have thicker facial tissue depths than African American and White European American females at points 1 through 12 (the eyebrow, nose, mouth, and chin regions) consistently across all three age categories. African Nova Scotian females have thinner facial tissue depths than African American females and White European American females at the majority of points 13 through 19 (jaw and cheek regions with the exception of point 4) throughout all three age categories.

4.4 Subadult African Nova Scotian Males vs. Subadult African American & White European American Males

Tables 4.13 and 4.14 display the results of comparing tissue depth means for subadult African Nova Scotian males to subadult African American males and White European American males, respectively. Subadult African Nova Scotian males have thicker facial tissue depths at the majority of the points than subadult African American males and subadult White European American males. Small differences were observed in the results and are illustrated in Figures 4.10 and 4.11.

Table 4.11 Comparison of facial tissue depth means (mm) of subadult African Nova Scotian females to subadult African American females (Manhein et al. 2000).

	3-8 Years Old			9-13 Years Old			14-18 Years Old		
Anatomical Landmarks	African Nova Scotian (N = 3)	African American (N = 52)	Difference	African Nova Scotian (N = 14)	African American (N = 59)	Difference	African Nova Scotian (N = 14)	African American (N = 25)	Difference
1 Glabella	5.0	4.0	+1.0	5.8	4.3	+1.5	5.0	4.7	+0.3
2 Nasion	6.0	4.9	+1.1	6.3	5.4	+0.9	5.6	5.3	+0.3
3 End of nasals	4.2	1.7	+2.5	5.0	1.7	+3.3	3.5	1.7	+1.8
4 Lateral nostril	17.8	7.0	+10.8	20.9	7.6*	+13.3	19.6	8.1	+11.5
5 Mid-philtrum	10.6	8.9	+1.7	10.3	9.6	+0.7	10.5	9.9	+0.6
6 Chin-lip fold	8.6	8.2	+0.4	11.0	10.3	+0.7	11.8	10.1	+1.7
7 Mental eminence	9.8	8.3	+1.5	13.3	10.0	+3.3	11.8	10.0	+1.8
8 Beneath chin	6.4	4.8	+1.6	8.9	5.8	+3.1	7.8	5.6	+2.2
9 Superior eye orbit	6.2	4.5	+1.7	8.0	5.3	+2.7	6.1	5.7	+0.4
10 Inferior eye orbit	7.2	5.6	+1.6	7.6	6.1	+1.5	8.4	6.4	+2.0
11 Supracanine	11.8	8.8	+3.0	14.3	10.0	+4.3	12.1	10.6	+1.5
12 Subcanine	11.2	9.0	+2.2	12.5	10.2	+2.3	12.7	11.0	+1.7
13 Supra M2	22.8	23.0	-0.2	23.3	24.5	-1.2	25.5	27.6	-2.1
14 Lower cheek	21.0	18.0	+3.0	22.3	20.0	+2.3	21.4	23.2	-1.8
15 Mid mandible	9.6	9.8	-2.0	10.9	10.8	+0.1	9.2	12.0	-2.8
16 Lateral eye orbit	4.4	3.9	+0.5	4.9	4.4	+0.5	4.2	4.6	-0.4
17 Zygomatic	6.8	8.3	-1.5	8.7	8.9	-0.2	7.8	9.2	-1.4
18 Gonion	6.2	13.5	-7.3	9.6	14.6	-5.0	6.6	16.2	-9.6
19 Root of zygoma	3.8	4.7	-0.9	4.7	4.8*	-0.1	4.2	6.2	-2.0

*Indicates $N = 58$.

Table 4.12 Comparison of facial tissue depth means (mm) of subadult African Nova Scotian females to subadult White European American females (Manhein et al. 2000).

	3-8 Years Old			9-13 Years Old			14-18 Years Old		
Anatomical Landmarks	African Nova Scotian (N = 3)	European American (N = 43)	Difference	African Nova Scotian (N = 14)	European American (N = 51)	Difference	African Nova Scotian (N = 14)	European American (N = 35)	Difference
1 Glabella	5.0	3.9	+1.1	5.8	4.4	+1.4	5.0	4.6	+0.4
2 Nasion	6.0	5.0	+1.0	6.3	5.5	+0.8	5.6	5.4	+0.2
3 End of nasals	4.2	1.7	+2.5	5.0	1.5	+3.5	3.5	1.8	+1.7
4 Lateral nostril	17.8	7.0	+10.8	20.9	7.7	+13.2	19.6	7.7	+11.9
5 Mid-philtrum	10.6	8.3	+2.3	10.3	9.4	+0.9	10.5	9.4	+1.1
6 Chin-lip fold	8.6	7.6	+1.0	11.0	9.0	+2.0	11.8	9.7	+2.1
7 Mental eminence	9.8	7.4	+2.4	13.3	8.8	+4.5	11.8	8.7	+3.1
8 Beneath chin	6.4	4.2	+2.2	8.9	5.5	+3.4	7.8	5.5	+2.3
9 Superior eye orbit	6.2	4.4	+1.8	8.0	5.1	+2.9	6.1	5.7	+0.4
10 Inferior eye orbit	7.2	5.6	+1.6	7.6	5.6	+2.0	8.4	6.0	+2.4
11 Supracanine	11.8	8.4	+3.4	14.3	9.8	+4.5	12.1	10.3	+1.8
12 Subcanine	11.2	7.9	+4.4	12.5	9.2	+3.3	12.7	9.8	+2.9
13 Supra M2	22.8	22.7	+0.1	23.3	24.3	-1.0	25.5	26.8	-1.3
14 Lower cheek	21.0	18.9	+2.1	22.3	20.8	+1.5	21.4	23.2	-1.8
15 Mid mandible	9.6	10.5	-0.9	10.9	11.7	-0.8	9.2	13.4	-4.2
16 Lateral eye orbit	4.4	4.0	+0.4	4.9	4.6	+0.3	4.2	4.5	-0.3
17 Zygomatic	6.8	8.4	-1.6	8.7	9.5	-0.8	7.8	9.5	-1.7
18 Gonion	6.2	13.9	-7.7	9.6	14.4	-4.8	6.6	17.0	-10.4
19 Root of zygoma	3.8	4.6	-0.8	4.7	5.2	-0.5	4.2	6.8	-2.6

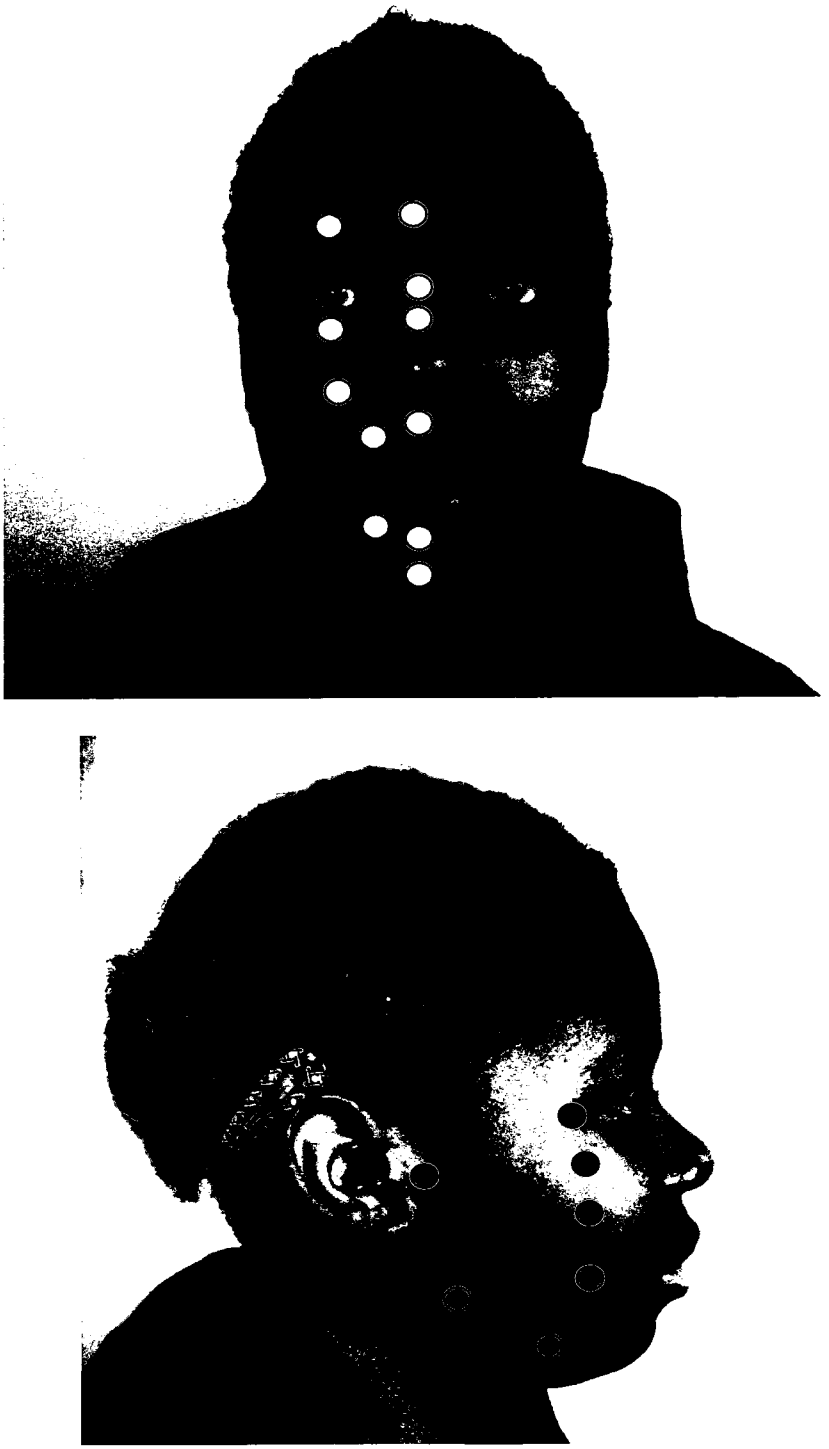

Figure 4.09 Frontal and right lateral views of a 12-year old female volunteer illustrating the facial tissue depths that were thicker (yellow dots) and thinner (red dots) in African Nova Scotian females than African American and White European American females. (Displayed with permission from legal guardian).

Table 4.13 Comparison of facial tissue depth means (mm) of subadult African Nova Scotian males to subadult African American males (Manhein et al. 2000).

	3-8 Years Old			9-13 Years Old			14-18 Years Old		
Anatomical Landmarks	African Nova Scotian (N = 3)	African American (N = 37)	Difference	African Nova Scotian (N = 14)	African American (N = 62)	Difference	African Nova Scotian (N = 4)	African American (N = 12)	Difference
1 Glabella	5.0	4.1	+0.9	5.6	4.5	+1.1	5.8	5.3	+0.5
2 Nasion	5.0	5.4	-0.4	6.2	5.4	+0.8	7.5	6.1	+1.4
3 End of nasals	4.7	1.8	+2.9	4.7	1.9	+2.8	4.0	2.1	+1.9
4 Lateral nostril	18.3	7.3	+11.0	19.1	7.4	+11.7	19.3	7.9	+11.4
5 Mid-philtrum	10.0	9.0	+1.0	11.4	10.0	+1.4	12.3	12.1	+0.2
6 Chin-lip fold	9.7	8.6	+1.1	11.2	9.8	+1.4	13.0	12.6	+0.4
7 Mental eminence	8.0	8.3	-0.3	12.8*	9.9	+2.9	14.0	9.5	+4.5
8 Beneath chin	5.7	4.5	+1.2	8.1	5.5	+2.6	8.7†	6.3	+2.4
9 Superior eye orbit	6.0	4.5	+1.5	6.9	5.2	+1.7	8.0	5.8	+2.2
10 Inferior eye orbit	11.3	5.6	+5.7	8.9	5.8	+3.1	7.5	6.0	+1.5
11 Supracanine	11.7	8.9	+2.8	13.4	10.7	+2.7	12.3	12.3	0.0
12 Subcanine	9.7	8.5	+1.2	12.8	11.0	+1.8	12.5	12.8	-0.3
13 Supra M2	24.0	22.1	+1.9	22.6	23.6	-1.0	24.5	26.0	-1.5
14 Lower cheek	24.7	17.4	+7.3	21.7	20.1	+1.6	23.5	21.9	+1.6
15 Mid mandible	7.0	8.7	-1.7	9.7	10.3	-0.6	10.8	11.2	-0.4
16 Lateral eye orbit	3.7	4.1	-0.4	4.5	4.4	+0.1	4.8	4.4	+0.4
17 Zygomatic	5.7	7.8	-2.1	7.1	8.3	-1.2	5.8	7.3	-1.5
18 Gonion	4.7	12.8	-8.1	7.6	14.7	-7.1	13.0	17.9	-4.9
19 Root of zygoma	3.0	4.2	-1.2	4.4	5.0‡	-0.6	3.5	6.0	-2.5

*Indicates $N = 13$, one individual had a dimple.
†Indicates $N = 3$, one individual had facial hair at this location.
‡Indicates $N = 61$.

Table 4.14 Comparison of facial tissue depth means (mm) of subadult African Nova Scotian males to subadult White European American males (Manhein et al. 2000).

	3-8 Years Old			9-13 Years Old			14-18 Years Old		
Anatomical Landmarks	African Nova Scotian (N = 3)	European American (N = 36)	Difference	African Nova Scotian (N = 14)	European American (N = 45)	Difference	African Nova Scotian (N = 4)	European American (N = 27)	Difference
1 Glabella	5.0	4.0	+1.0	5.6	4.6*	+1.0	5.8	5.0	+0.8
2 Nasion	5.0	5.7	-0.7	6.2	5.7*	+0.5	7.5	6.3	+1.2
3 End of nasals	4.7	1.8	+2.9	4.7	1.6	+3.1	4.0	2.0	+2.0
4 Lateral nostril	18.3	7.2	+11.1	19.1	7.4	+11.7	19.3	7.8	+11.5
5 Mid-philtrum	10.0	9.0	+1.0	11.4	9.7	+1.7	12.3	11.2	+1.1
6 Chin-lip fold	9.7	8.1	+1.6	11.2	9.6	+1.6	13.0	10.4	+2.6
7 Mental eminence	8.0	8.3	-0.3	12.8†	8.7	+4.1	14.0	9.3	+4.7
8 Beneath chin	5.7	4.6	+1.1	8.1	5.5	+2.6	8.7‡	6.0	+2.7
9 Superior eye orbit	6.0	4.6	+1.4	6.9	5.2	+1.7	8.0	5.7	+2.3
10 Inferior eye orbit	11.3	5.5	+5.8	8.9	5.9	+3.0	7.5	5.3	+2.2
11 Supracanine	11.7	9.4	+2.3	13.4	10.0	+3.4	12.3	11.7	+0.6
12 Subcanine	9.7	8.4	+1.3	12.8	9.6	+3.2	12.5	10.6	+1.9
13 Supra M2	24.0	23.3	+0.7	22.6	24.7	-2.1	24.5	27.4	-2.9
14 Lower cheek	24.7	20.7	+4.0	21.7	21.6	+0.1	23.5	23.2	+0.3
15 Mid mandible	7.0	10.4	-3.4	9.7	12.1	-2.4	10.8	12.3	-1.5
16 Lateral eye orbit	3.7	4.1	-0.4	4.5	4.4	+0.1	4.8	4.3	+0.5
17 Zygomatic	5.7	8.4	-2.7	7.1	9.1	-2.0	5.8	8.0	-2.2
18 Gonion	4.7	13.7	-9.0	7.6	15.4	-7.8	13.0	18.1	-5.1
19 Root of zygoma	3.0	4.8	-1.8	4.4	5.4	-1.0	3.5	6.0	-2.5

* Indicates $N = 44$.

† Indicates $N = 13$, one individual had a dimple.

‡ Indicates $N = 3$, one individual had facial hair at this location.

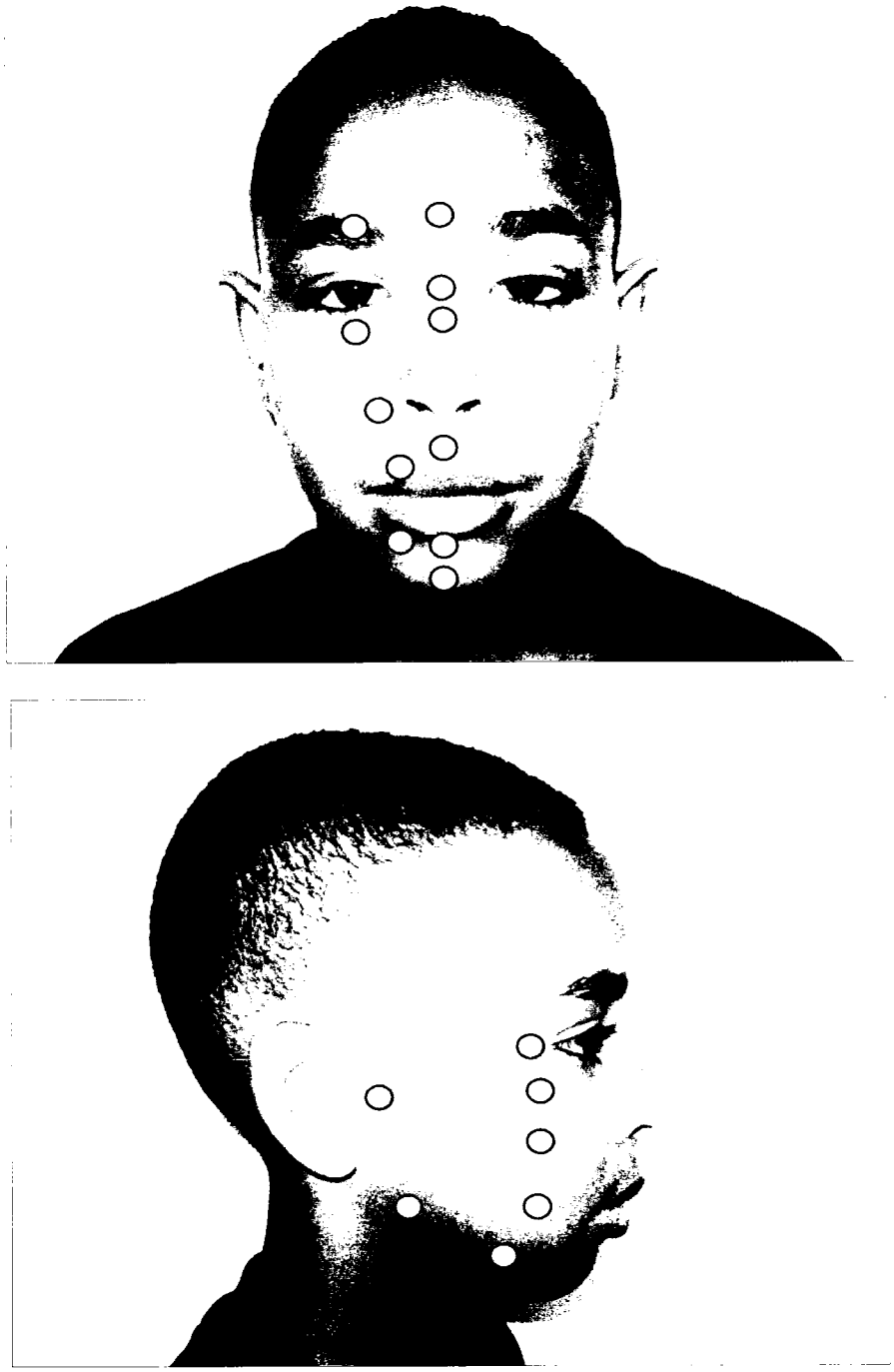

Figure 4.10 Frontal and right lateral views of a 12-year old male volunteer illustrating the dominant trend of facial tissue depths that were thicker (yellow dots) and thinner (red dots) in African Nova Scotian males than African American males. (Displayed with permission from legal guardian).

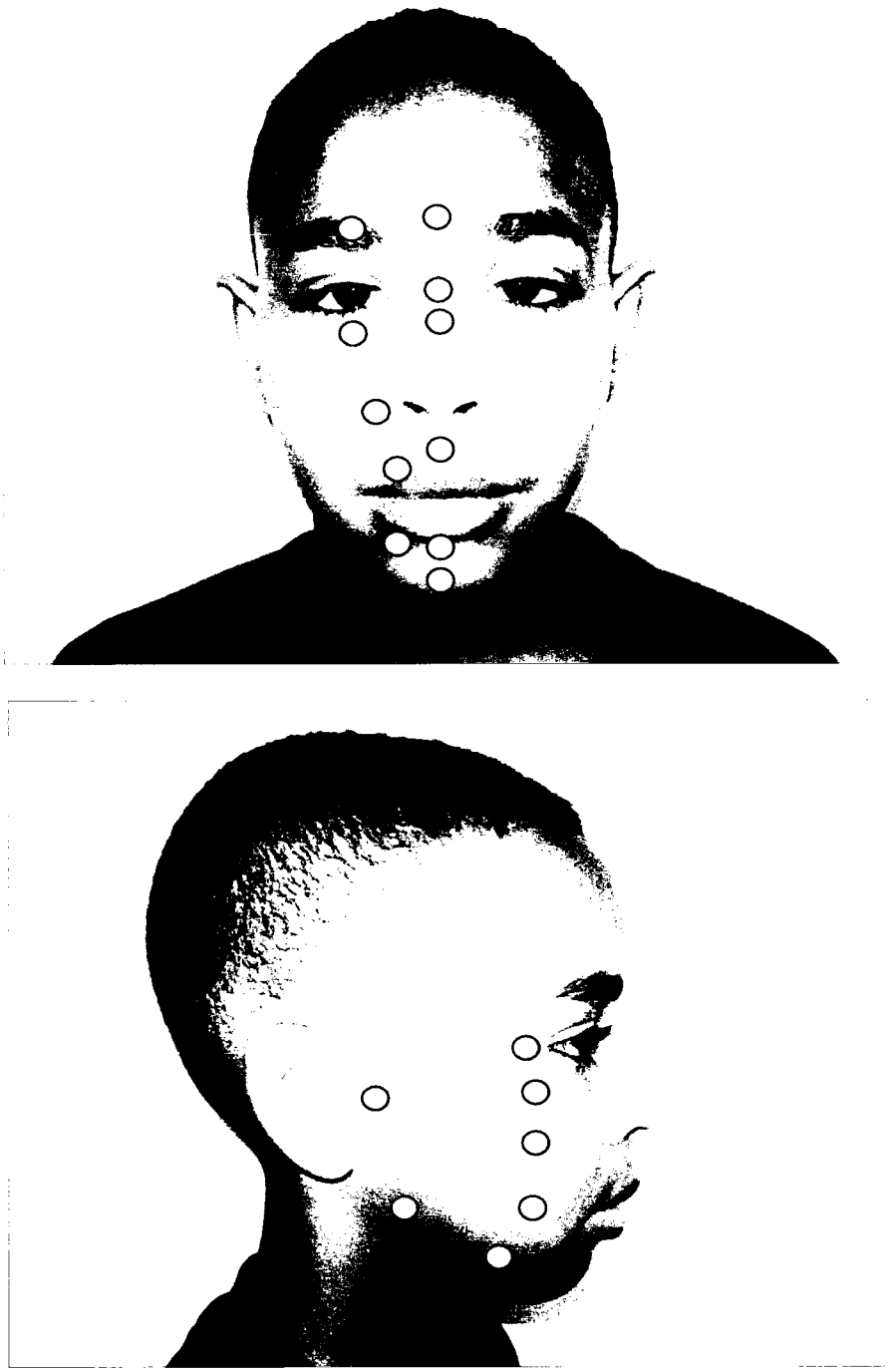

Figure 4.11 Frontal and right lateral views of a 12-year old male volunteer illustrating the dominant trend of facial tissue depths that were thicker (yellow dots) and thinner (red dots) in African Nova Scotian males than White European American males. (Displayed with permission from legal guardian).

Specifically, points 1 through 11 and 14 are thicker in African Nova Scotian males when compared to African American males, while points 1 through 12 and 14 are thicker in African Nova Scotian males when compared to White European American males. This trend is observed at the eyebrow, nose, mouth, and chin regions and is consistent across all three age categories with the exception of points 2 and 7 for both ancestral population comparisons. In addition, African Nova Scotian males have thinner facial tissue depths at points 12 though 19 when compared to African American males, while points 13 through 19 are thinner in African Nova Scotian males when compared to White European American males. With the exception of point 4, these points correspond to the jaw and cheek regions, and the results are consistent across all three age categories.

A relatively large difference in tissue depth is evident at two landmarks when comparing African Nova Scotian females and males to African American and White European American females and males: lateral nostril (point 4) and gonion (point 18). This large variation in the measurement of the lateral nostril could be attributed to the incorrect placement of the transducer over the bony landmark. This site is one of the most difficult landmarks to measure due to the shape and size of the contact surface area of the transducer. The long rectangular shape of the probe is difficult to position beside the nostril and at a 90° angle to the bony landmark. As a result, it is possible that this site was measured slightly more than 0.5 cm from the lateral edge of the nostril as described in Manhein et al. (2000) protocol (Table 3.01).

In contrast, the tissue depth measurements of gonion for African Nova Scotian females and males are very small when compared to African American and White European American females and males. This could be an accurate representation of the

facial tissue thickness for subadult African Nova Scotians in this region, but it is also possible that it is a result of measurement error either in the form of ultrasonic image interpretation or transducer placement.

4.5 Intra-Observer Error

Table 4.15 illustrates the results of the intra-observer error test conducted on six participants by measuring each volunteer twice. The Paired Difference T-Tests revealed significant differences in repeated measurements at points 1, 2, 3, and 6. Since these four measurement sites exhibit small depths, and the calipers measure to an accuracy of one-tenth of a centimeter (0.1 centimeters), minute differences may not be accurately reflected in the measurement. For example, a point measured twice may reveal 0.5 cm and 0.6 cm, with a difference of 0.1 cm, which appears to be significantly different from a statistical standpoint. However, if the precision was greater, the measurements may in fact be 0.59 cm and 0.60 cm. Therefore, the differences observed at these locations are identified as artefacts of measurement precision (Meek, personal communication, December 15, 2009).

Table 4.15 Intra-observer error of measuring the facial tissue depths of participants (N = 6) twice using Paired Difference T-Tests.

Anatomical Landmarks	T-value	P-value
1 Glabella	-5.00†	0.004
2 Nasion	-3.16†	0.025
3 End of nasals	-2.70†	0.043
4 Lateral nostril	1.29	0.253
5 Mid-philtrum	-1.17	0.296
6 Chin-lip fold	2.73†	0.041
7 Mental eminence	-0.54	0.611
8 Beneath chin	-0.00	1.000
9 Superior eye orbit	-1.00	0.363
10 Inferior eye orbit	1.75	0.140
11 Supracanine	-1.17	0.296
12 Subcanine	-1.17	0.296
13 Supra M2	-0.19	0.856
14 Lower cheek	1.08	0.328
15 Mid mandible	1.20	0.286
16 Lateral eye orbit	-1.58	0.175
17 Zygomatic	0.70	0.516
18 Gonion	-0.42	0.695
19 Root of zygoma	0.35	0.741

† Significant difference between first and second measurements (p = 0.05).

CHAPTER 5: DISCUSSION

Since the late 1800s, facial tissue depth data have been collected for populations in Europe and the United States of America. Researchers have started to expand the database to include other ancestral groups, however, African populations remain underrepresented. As a result, the objectives of this study were to expand the facial tissue depth data available in Canada to include African Canadians. By collaborating with the African Nova Scotian community, the first facial tissue depth measurements of African Canadian subadults were collected. Such population specific data will help increase the accuracy of forensic facial reconstructions, thus aiding in the positive identification of missing children of African Nova Scotian decent.

5.1 Variation in Facial Tissue Depths of Subadult African Nova Scotians

The primary goal of this study was to report standard descriptive statistics of subadult African Nova Scotian facial tissue depth measurements, including means, ranges, and standard deviations. The greatest amount of tissue depth variation was evident in the 9-13 year old age category, which is consistent with the onset of puberty for females (as early as 10 years of age) and males (as early as 12 years of age) (Farkas et al. 1992:308; Wilkinson, personal communication, January 13, 2010). Some of the cheek and jaw points showed large variations in tissue depth, which are the locations that exhibit the most change during puberty for females and males, respectively (Wilkinson 2004:246-247). Females, however, exhibited the largest amount of variation in the tissue

thickness in this age category, particularly in the cheek region, which could have been due to the earlier onset of puberty for this sex.

5.2 Relationship Between Facial Tissue Depth & Age

Results indicate that, during the early years of childhood, facial tissue thickness increases for both females and males. This trend, however, does not continue into adolescence for females. Separate analyses revealed age and tissue thickness are significantly related at one landmark in females and six landmarks in males, with the majority of these sites showing weak linear correlations. This means that age influences the depth of soft tissues at some of the landmarks in African Nova Scotian children, while the remainder of the landmarks show no significant relationships.

These results are consistent with the findings of some other studies conducted with children (Garlie and Saunders 1999; Manhein et al. 2000; Smith and Buschang 2001), as they have shown significant relationships at some sites but very weak linear correlations. For example, research by Manhein et al. (2000) shows statistically significant relationships at the majority of the measurement sites for White European American, African American, and Hispanic American children, however, all of the Pearson's correlations (r) are small and therefore show weak relationships. This supports the statement that there is no universal formula that can calculate the growth pattern of facial soft tissues for children (Feik and Glover 1998).

Some studies, however, have observed significant relationships between facial tissue thickness and the age of children (Wilkinson 2002; Williamson et al. 2002). The absence of a definitive relationship between age and tissue thickness observed in the African Nova Scotian study could be due to small sample sizes in the 3-8 year age

category and 14-18 year age category for females and males. As a result, it is possible that this study may not have accurately represented the full range of the variability of facial soft tissue thickness in African Nova Scotian children.

5.3 Differences Within the Sexes of Differing Subadult Age Groups

The second question of this study was two-fold. The first question addressed whether significant differences in facial tissue depth were evident within the sexes of differing subadult age groups. Points that exhibited significant differences between the 3-8 year old age category and the 9-13 year old age category suggest these sites undergo early development in life. Females showed early changes in facial tissue thickness at the eyebrow, mouth, and chin regions (chin-lip fold, mental eminence, and superior eye orbit), while males showed significant differences in facial tissue thickness at the mouth and chin regions (mental eminence and sub canine). These findings were consistent with the study conducted by Williamson et al. (2002) involving the collection of mid-facial tissue depths of African American children. They found that the mouth and eye tissues exhibited a rapid development at 13 years of age, while the chin region showed a significant increase in tissue depth at around nine years of age (Williamson et al. 2002:29-30). These results show that the growth of facial tissue depth at certain points occurs in spurts rather than at a slow and gradual pace.

Measurement sites that showed significant differences between the 9-13 year old age category and the 14-18 year old age category are likely the product of the onset of puberty. African Nova Scotian females displayed a significant decrease in tissue depth at the eyebrow and nose regions (glabella, superior eye orbit, and end of nasals), while African Nova Scotian males showed a significant increase at a landmark located in the

jaw region (gonion). The significant decrease at the superior eye orbit of females between these two age categories contradicts the former comparison between the first age category and the second. One possible explanation is that the tissues at the superior eye orbit may undergo further changes as a result of craniofacial growth of the face. The frontal sinuses grow at a faster rate after puberty and are not fully developed until 20 years of age (Quatrehomme et al. 1996:150-151). Since the enlargement of the frontal sinuses affects the supraorbital region and its protrusion into adulthood (Wilkinson 2008:222-223), the significant differences observed at this location, in African Nova Scotian females, may be a result of the later development of the sinus region. In contrast, the significantly thicker facial tissue depths at the jaw region, of African Nova Scotian males, are consistent with the skeletal development and enlargement of the masticatory complex observed in males (Wilkinson 2008:247). Overall, there are minimal significant differences within subadult African Nova Scotian females and males when age categories within each sex are compared to one another.

5.4 Differences Between the Sexes of Differing Subadult Age Groups

The second question was to examine if significant differences in facial tissue thickness occurred between females and males of differing subadult age groups. During early childhood, puberty has yet to commence and the development of sexually dimorphic traits has yet to occur. However, late childhood is a time when youth may experience changes related to the early onset of puberty. Therefore, comparisons between females and males of the early and late stages of childhood would be expected to show minimal significant differences in facial tissue thickness. This trend is consistent with what is observed in this study and suggests prepubescent subadult male and female

facial tissue depth data can be collapsed into one category, i.e. 3-8 year old age category and 9-13 year old age category can be represented as 3-13 year old age category.

The onset of male puberty may begin as early as 12 years of age (Farkas et al. 1992:308; Wilkinson, personal communication, January 13, 2010). Therefore, an increased number of sites exhibiting significant differences in facial tissue depth, between females and males, once adolescence has been reached, would be expected. The results from the current research indicate the need to separate subadult female and male facial tissue depth data once puberty has commenced and sexual dimorphic features have developed. As a result, the significant differences observed between males and females, around the onset of puberty, suggest that sex is a major factor affecting the thickness of facial soft tissues at five anatomical landmark locations.

5.5 Comparisons Within African Ancestral Populations & Between Ancestral Groups

This research also investigated the differences in facial tissue thickness between two geographically distant populations of the same ancestry as well as between two populations of differing ancestral backgrounds. The first study that examined differences between two regionally separated populations of the same ancestry was conducted by Williamson et al. (2002). This study compared subadult African American females from Georgia and South Carolina to subadult African American females from Indiana. They found that only one point, the nasal tip angle, was significantly different (Williamson et al. 2002:30). While statistical tests could be conducted in the Williamson et al. (2002) study, statistical comparisons of facial tissue depths between African Nova Scotian children and contemporary data for African American and White European American

children could not be conducted because the raw data from the Manhein et al. (2000) research was unavailable. As a result, it could not be determined if the facial tissue depths at any of the 19 anatomical landmarks, collected from the current research, were significantly different from Manhein's volunteers.

When the facial tissue depth means of the current project were compared to subadult data collected from Manhein et al. (2000), the results revealed that African Nova Scotians had thicker facial tissue depths at the eyebrow, nose, mouth, and chin regions. However, the jaw and cheek areas were thinner compared to the African American and White European American populations. This trend may be attributed to one of the factors that affect facial tissue thickness: nutritional status.

According to Statistics Canada, American children are more overweight and obese than Canadian children (Shields 2006:31). Therefore, it is reasonable to suggest that subadult African and White European Americans are typically more overweight than subadult African Nova Scotians. It is also known that the most variation in facial tissue thickness between emaciated and overweight individuals is observed in the cheek, jaw, and chin regions (Wilkinson 2004:141). This current study shows that African Americans and White European Americans have thicker facial tissue depths at the cheek and jaw regions than African Nova Scotians, suggesting that the two former populations are more overweight than the latter.

There are many factors that affect the depth of soft tissues on the face therefore, it is also possible that the patterns observed during population comparisons could be a product of other factors such as genetics. Theories based on genetic linkages, however, cannot be definitively made since genetic samples were not taken from the participants in

this study. To address this topic, future research must be conducted on a genetic level in conjunction with the collection and statistical analyses of facial soft tissue depth data.

5.6 Presentation of Future Subadult Facial Tissue Depth Data

While future studies should consider the impact of genetics, researchers must also take into account the manner in which facial tissue depth data is presented. A few studies in the current literature have addressed the impact of puberty on facial tissue thickness. Garlie and Saunders (1999) have noted a distinct divergence in facial tissue depth at various locations after puberty and have suggested that the separation of young female and male data may not be required. They have also suggested that "it may be necessary to apply separate standards for older children, a time when skeletal indicators of sex become more reliable" (Garlie and Saunders 1999:66). A recent review of published subadult facial tissue depth data (Stephan and Simpson 2008b) concurs that there is no need to separate subadult data into more than two age categories. Specifically, Stephan and Simpson (2008b) believe that facial tissue depth data should be divided into the age categories of 0-11 years of age and 12-17 years of age. The age of division was based on the age at which the densest portion of plotted data was evenly divided (Stephan and Simpson 2008b:1275) however, this age also corresponds to the earliest time period when males begin to enter puberty. While their reasoning is different, the conclusion is ultimately the same: facial tissue depth data should be collapsed before 12 years of age.

Current researchers have continuously discussed the effects of puberty and facial tissue depths and suggested the need to collapse facial tissue depth data for younger females and males. However, there are no publications citing discussions with forensic artists about determining the most effective way of presenting facial tissue depth data for

their needs. The current author met with Sergeant Michel Fournier, R.C.M.P., Forensic Facial Identification Specialist, Atlantic Region, Canada, to determine the most useful formats, for forensic artists, to present the facial tissue depth means and to address the influence of BMI-for-age on facial tissue depths for subadults.

Sgt. Fournier (personal communication, December 1, 2009) suggested that the data be presented in multiple ways so that it can be useful in different contexts. For example, if a prepubescent skull was found with female clothing, Sgt. Fournier would create two reconstructions: one female reconstruction using the data subcategorized into three age categories and the other as a generic reconstruction using the collapsed data. Although it has been shown that a measurement of "body weight cannot yet be determined accurately from skeletal remains so weight-categorized data are typically of limited value" (Stephan and Simpson 2008a:1259), it can sometimes be inferred by the undergarments of the individual if clothing is still present (Fournier, personal communication, December 1, 2009). For instance, if underwear was found with the skeletal remains of an African Nova Scotian child, the approximate weight of the child may be inferred from the clothing. As a result, Sgt. Fournier requested that the tissue depth data be summarized into three age categories, collapsed into two age categories, and then divided according to BMI-for-age to aid in the construction of 3-D forensic facial reconstructions and ultimately the identification of missing children.

The age at which the data should be collapsed should correspond to when females and males show significant differences in facial tissue depths at multiple sites and sex can be reliably determined from the skeleton. Support for the collapse of data, in this study, was based on the results of the statistical analyses. Out of the 19 measurement sites,

significant differences within females and males of differing subadult age groups were observed at no more than 16% of the landmarks. Therefore, this suggests that the subadult facial tissue depth measurements, for each age category, could be collapsed for males and females separately. Additional tests revealed that a greater amount of landmarks (~26%) exhibited significant differences in facial tissue depths between males and females around the time of puberty, while prepubescent comparisons showed little to no differences (<0.06%). These tests suggest that subadult female and male data should remain collapsed until the onset of puberty.

The age at which data should be collapsed is also affected by the inability to determine the sex of a child prior to the onset of puberty. Sexual dimorphism does not become apparent until puberty has commenced, therefore, prior to the onset of this developmental stage, juvenile skulls tend to appear female. For example, if a 13 year old subadult skull exhibits male traits then it is most likely male, however if the skull appears female then the remains could be that of a female or pre-pubescent male (Wilkinson, personal communication, January 13, 2010). In general, puberty can commence at 12 years of age for males while females can begin two years earlier (Farkas et al. 1992:308; Wilkinson, personal communication, January 13, 2010). Since "sexual dimorphism exhibited by the skull is mainly dependent on changes that occur in male at puberty ... whereas the female skull tends to retain pedomorphic features" (Scheuer 2002:300), it was decided to collapse the prepubescent African Nova Scotian data prior to 12 years of age.

Statistical analyses in this study support the collapse of early and late childhood facial tissue depth data for females and males, and furthermore, researchers as well as

forensic artists concur that there is a need to present the data in a new way. This study has generated additional tables for the forensic artists to aid in the identification of missing children in different contexts (Appendix D1-D6). These tables collapse female and male tissue depths thus producing two age categories: 3-11 years of age and 12-18 years of age.

While separating and collapsing the subadult facial tissue depth data is beneficial for forensic artists, it is important to remember that the division of data into discrete categories (for example BMI) decreases the sample size. The results of statistical tests performed in this study, utilizing early childhood facial tissue depth data (i.e. 3-8 year old age category), should be interpreted with caution since the number of participants in this age category was very small (n=5 females, n=3 males). Although the results appear to be consistent with current literature, future studies should increase the number of participants for each sex and the assigned age categories to increase the likelihood of depicting the variation in the population studied.

With only sample size as a limitation, this study did fulfill the majority of the criteria necessary for facial tissue depth data to be considered useful as suggested by Stephan and Simpson (2008b:1278). According to this publication, facial tissue depth data is more useful if it:

(i) is not biased toward people of ''normal'' weight;

(ii) reports a complete set of descriptive statistics rather than means alone;

(iii) minimizes and measures its respective measurement errors;

(iv) uses a minimum set of standardized measurement sites;

(v) makes use of a number of measurement methods so data can be pooled across measurement methods to reduce method bias; and

(vi) longitudinally tracks individuals across the sub-adult/adult divide [Stephan and Simpson 2008:1278].

The current researcher did not restrict the study to participants of 'normal' weight. Facial tissue depth measurements were utilized only if they were representative of the population being measured. Since the majority of the subadult African Nova Scotians fell into the normal and overweight/obese BMI-for-age, data was collected for these weight categories. In addition, a complete facial tissue depth table was generated including all of the descriptive statistics for each of the anatomical landmarks. Intra-observer error was also measured to minimize the errors associated with the utilization of ultrasound technology for measuring the depth of soft tissues. Furthermore, to ensure the anatomical landmarks were measured in a standardized manner, the protocol developed by Manhein et al. (2000) was followed. Lastly, the final two criteria, as suggested by Stephan and Simpson (2008), were not applicable to this study due to the methodology utilized and the limited time frame of the research project.

CHAPTER 6: CONCLUSION

Prior to this study, no African Canadian facial tissue depth data existed to help identify missing children of this ancestry using 3-D forensic facial reconstruction. This research collaborated with the African Nova Scotian community to expand the facial tissue depth data to include African Canadians. The objectives of this research included generating a set of descriptive statistics of facial tissue depth measurements for subadult African Nova Scotians; investigating the relationships between facial tissue thickness, age and sex; and comparing facial tissue depths of this study to contemporary data for African Americans and White European Americans.

By utilizing ultrasound technology and following a standardized protocol developed by Manhein et al. (2000), 19 anatomical landmarks were accurately located and measured on a total of 54 subadult African Nova Scotians between the ages of three and 18 years. Facial tissue depth tables were successfully generated for females and males separately. Significant relationships were found between age and facial tissue thickness at one anatomical site for females and six for males, however, the linear correlations were weak at the majority of these sites. Significant differences in facial tissue thickness between differing age groups for females and males were minimal, however, significant differences in facial tissue thickness between females and males within each age group revealed expected results. Little to no differences were observed between the sexes during early and late childhood, suggesting that female and male facial tissue depth data should be combined (or collapsed). In contrast, five anatomical landmarks exhibited significant differences during adolescence, suggesting a need to separate data around puberty. Lastly, comparisons between African Nova Scotians with

African Americans and White European Americans yielded similar results. Subadult African Nova Scotian females and males tended to have thinner tissue depths at the cheek and jaw regions while the other facial areas were thicker than the comparative populations.

This study has provided additional ways to summarize and ultimately present subadult facial tissue depth data. Currently, researchers have subdivided subadult facial tissue depth data into more than two age categories. With the support of statistical analyses, some researchers have acknowledged significant differences between females and males around the time of puberty and others have suggested that the data should be collapsed prior to the onset of puberty. This study not only recognized the effects of puberty on facial tissue thickness and the need to combine female and male data before puberty, but it also addressed the views of both the researcher and the forensic artist. The author has taken into consideration both perspectives and generated multiple tables in several formats to address different forensic contexts. By doing so, this will help identify missing children of African Nova Scotian ancestry by providing more accurate data to guide the 3-D forensic facial reconstruction for many different circumstances.

The only limitation of this study was the difficulty in recruiting a sufficient number of volunteers. The division of the data by sex and the further subdivision into age categories further decreased the sample sizes. Future researchers must increase the number of participants to allow for a more accurate representation of the variation in facial tissue depths observed in a population. In addition, future studies should investigate whether there are significant differences in facial tissue thickness between

geographically distant populations of the same ancestry to help determine if researchers should start collecting population specific data.

The only way to know if the differences observed between studies are significant is if raw data is available to all researchers. Therefore, it is also recommended that whenever possible, raw data be inputted into appropriate databases so that it will be accessible to the scientific community. Lastly, the data should be available, if possible, to outside researchers for future studies.

Finally, future researchers should continue to expand the *in vivo* facial tissue depth data available in Canada by collecting data across the country. The database should include more ancestral groups for both children and adults. Such studies will help forensic artists create more accurate 3-D forensic facial reconstructions of missing persons. Ultimately, the generation of the reconstructions and dissemination of the images will help identify missing individuals.

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APPENDIX A: ANCESTRY & CONSTRUCTION OF IDENTITY

APPENDIX A1. Nonmetric ancestral characteristics of the skull for White Europeans, Black Africans, and Asians

Structure	White Europeans	Black Africans	Asians
Face			
Profile	Straight	Projecting	Intermediate
Shape	Narrow	Narrow	Wide
Eye orbits	Angular	Rectangular	Rounded
Lower eye border	Receding	Receding	Projecting
Vault			
Browridges	Heavy	Small	Small
Muscle marks	Rugged	Smooth	Smooth
Vault sutures	Simple	Simple	Complex
Postbregma	Straight/convex	Depressed/concave	Straight/convex
Nose			
Root	High, 'pinched'	Low, rounded	Low, 'tented'
Bridge	High,	Low	Low
Spine	Pronounced	Small	Small
Width	Narrow	Wide	Flat, sharp
Lower border	Sharp (sill)	Guttered	Medium
Jaws and teeth			
Jaws	Small	Large	Large
Palatal shape	Parabolic	Hyperbolic	Elliptical
Upper incisors	Spatulate	Spatulate	Shovelled

(modified from Krogman (1962), Brues (1977), and Rhine (1990) as cited in Byers 2008:156)

APPENDIX A2. Record of personal communications with organizations regarding definition for African Nova Scotian

Organization	Contact	Date(s)	Outcome
Office of African Nova Scotian Affairs	Wayn Hamilton	24/10/08 27/10/08	Definition on website does not have a time limit & can be self-identification
Black Educators Association	Roger Johnson	15/10/08 24/10/08 28/10/08	No precise definition exists
Black Cultural Centre	Dr. Henry Bishop	01/10/08 24/10/08	No response
Black Loyalist Heritage Society	Beverly Cox	01/24/08 24/10/08	Stated she was going to "formulate her response" but did not send it
African Canadian Services Division	Calvin Gough	24/10/08	Definition not provided in conversation
Department of Education	Patrick	24/10/08	No response
Black Business Initiative	Roselyn Orengo	01/10/08	No response

APPENDIX B: ETHICS, BIOGRAPHICAL DATA SHEET, & CONSENT FORM

APPENDIX B1. Ethics approval certificate.

Saint Mary's University

Certificate of Ethical Acceptability of Research Involving Human Subjects

This is to certify that the Research Ethics Board has examined the research proposal or other type of study submitted by:

Principal Investigator:	**HUCULAK, Meaghan**
Faculty Supervisor:	**PECKMANN, Tanya**
Name of Research Project:	**In vivo facial tissue depth measurements of African Nova Scotians to aid in 3-D forensic facial reconstruction**
REB File Number:	**08-168**

and concludes that in all respects the proposed project meets appropriate standards of ethical acceptability and is in accordance with the Tri-Council Policy Statement on the Conduct of Research Involving Humans.

Please note that approval is only effective for one year from the date approved. If your research project takes longer than one year to complete, submit Form #3 (Annual Report) to the REB at the end of the year and request an extension. You are also required to submit Form #5 (Completion of Research) upon completion of your research.

Date: 21 November 2008

APPENDIX B2. Participant biographical data sheet.

SAINT MARY'S UNIVERSITY & AFRICAN NOVA SCOTIAN COMMUNITY

3-D FORENSIC FACIAL RECONSTRUCTION RESEARCH

PARTICIPANT BIOGRAPHICAL DATA SHEET

*ID NUMBER _____

Please provide **ALL** of the information requested below. The data collected on each participant will be kept confidential.

PLEASE PRINT CLEARLY

NAME _____
LAST FIRST MIDDLE

BIRTH DATE _____
DAY MONTH YEAR

SEX ☐ MALE ☐ FEMALE

AGE _____
(MUST BE 3-18 YRS)

*HEIGHT _____

*WEIGHT _____

*LIP WIDTH _____

*will be filled out at the time of measuring

PHONE NUMBER _____
(To enter for grand prize draw at the end of the summer)

PARTICIPANT'S ANCESTRY
- ☐ WHITE EUROPEAN
- ☐ AFRICAN NOVA SCOTIAN
- ☐ ASIAN
- ☐ FIRST NATIONS
- ☐ OTHER _____

FATHER'S ANCESTRY
- ☐ WHITE EUROPEAN
- ☐ AFRICAN NOVA SCOTIAN
- ☐ ASIAN
- ☐ FIRST NATIONS
- ☐ OTHER _____

MOTHER'S ANCESTRY
- ☐ WHITE EUROPEAN
- ☐ AFRICAN NOVA SCOTIAN
- ☐ ASIAN
- ☐ FIRST NATIONS
- ☐ OTHER _____

PLEASE CHECK ONE OR MORE OF THE FOLLOWING CATEGORIES THAT DESCRIBES YOUR (PARTICIPANT'S) ANCESTRY.

- ☐ FIRST NATIONS (NORTH AMERICAN) 01
- ☐ INDIGENOUS (SOUTH AMERICAN) 02
- ☐ WHITE EUROPEAN 03
- ☐ VIETNAMESE 04
- ☐ CHINESE 05
- ☐ JAPANESE 06
- ☐ KOREAN 07
- ☐ AFRICAN NOVA SCOTIAN 08
- ☐ MEXICAN 09
- ☐ CUBAN 10
- ☐ PUERTO RICAN 11
- ☐ HISPANIC (S. AMERICA) 12
- ☐ EASTERN INDIAN 13
- ☐ OTHER (PLEASE SPECIFY) _____

APPENDIX B3. Consent form.

SAINT MARY'S UNIVERSITY & AFRICAN NOVA SCOTIAN COMMUNITY

CONSENT FORM

1. PROJECT TITLE: In vivo facial tissue depth measurements of African Nova Scotian children to aid in 3-D forensic facial reconstruction

2. PROJECT LOCATION: T.B.A.

3. NAMES AND TELEPHONE NUMBERS OF RESEARCHERS:

Meaghan Huculak
Department of Anthropology
Saint Mary's University
McNally South 208
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Halifax, Nova Scotia
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Dr. Tanya Peckmann, Supervisor
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4. PURPOSE OF THE STUDY:
   A. This is a research study.
   B. Participants, of African Nova Scotian ancestry, of both sexes, between the ages of 3 and 18 years, who are capable of remaining in a motionless position for a period of 3 to 5 seconds can volunteer
   C. This study is designed to collect depth measurements of soft tissues on particular areas of the face of African Nova Scotian children to create population specific data for 3-D facial reconstruction.

5. WHO CAN PARTICIPATE IN THIS PROJECT? Males and females, between the ages of 3 and 18 years, of African Nova Scotian ancestry, that have the ability to remain in a motionless position for a period of 3 to 5 seconds, and completed a written consent form (**signed by a parent or legal guardian**), can participate in this study.

6. WHO CAN NOT PARTICIPATE IN THIS PROJECT? An individual will be excluded from this study only if he/she is not of African Nova Scotian ancestry, and does not have the capacity to remain motionless for a period of 3 to 5 seconds.

7. DESCRIPTION OF THE STUDY: The study will involve at least 50 participants and will measure skin and muscle depth from 19 points on the faces of children. Measurements will be taken using an ultrasound machine. Ultrasound is completely painless and has no immediate or long term side effects. A small amount of non-allergenic gel will be applied to the ultrasound transducer and lightly placed on the 19 points of the face. While the transducer touches the face, it will be necessary for the participant to stay motionless. Once the transducer is removed, the volunteer may relax and the gel will be removed with a sanitary wipe. The entire procedure will take 20 minutes per person.

   To document this research procedure, still or video pictures may be taken while measurements are in progress. All participants will be photographed before ultrasound measurements are obtained – frontal and side views. Additional still or video pictures may be taken while measurements are in progress. This is important for future reference and comparison. Some cases may require the forensic artist to use comparative photos as questions relating to soft tissue facial structure may arise, e.g. exact shape of the nose, ears, or chin.

   Any participant wishing to view pictures or video tape may contact Meaghan Huculak or Tanya Peckmann. Any pictures or video taken will **NOT** be used either in future research projects having to do with facial growth patterns, the aging face, or in publishing the results of this research, unless otherwise indicated by the participant or guardian. Publication of the results will be in scientific journals and lectures.

APPENDIX B3. Consent form (con't).

8. BENEFITS TO COMMUNITY: This project will aid in positive identifications for missing children of African Nova Scotian ancestry. For the police, who are searching for a missing child, employing this new data may help provide closure for the individual's family and friends. The project will also provide a workshop for African Nova Scotians who are interested in learning how to use the ultrasound machine.

9. RISKS TO PARTICIPANTS: None. The ultrasound method of measuring presents no harm, present or long-term, to the participant.

10. INDIVIDUAL'S RIGHT TO REFUSE TO PARTICIPATE OR WITHDRAW: Study participants may refuse to participate or withdraw from the study at any time. This includes, but not solely limited to, withdrawing from the study prior to commencement, the termination of the photograph or ultrasound session, and the removal of personal data from the archive at any time.

11. PARTICIPANT'S RIGHT TO PRIVACY: The results of the study may be released to the funding agency. The results of the study may be published. The privacy of participants will be protected and they will not be identified in any way. The files will be stored in a locked cabinet in the office of Dr. Tanya Peckmann at Saint Mary's University. Names of participants will not be identified on any reports, publications, presentations, or summaries produced for this project. Names of participants will only appear on the consent form which will be sealed in an envelope and stored separately from the photographs and data.

12. RELEASE OF INFORMATION: The personal data, except for the volunteer's name, related to the study are available only to researchers and forensic artists. The forensic artist would have access to all of the data on Page 1 of the "Participant Data Sheet" but **NOT** the individual's name. The information from these sheets will be entered into an Excel spreadsheet with each volunteer being identified by an "ID Number" as indicated on the top right corner of Page 1. The forensic artists will **ONLY** have access to the Excel spreadsheets and photographs but not the original data sheets with the participant's name. The participant may request to view their own personal data but not the data of any other individual participating in the study.

13. OTHER INFORMATION
    A. The costs of any study related and unforeseen complications must be met by the participant
    B. Individuals will not be paid for participation, but will receive a small "thank you" gift.

14. SIGNATURES: The study has been discussed with me and my questions have been answered. I understand that additional questions regarding the study should be directed to investigators listed on Page 1 of this consent form. I agree with the terms above.

☐ The study participant is a child and I certify that I am his/her legal guardian.

Legal Guardian Name	Legal Guardian Signature	Date
Child's Name & Age	Child's Signature	Date
Signature of Witness		Date

☐ I give permission for my photograph(s) to be used in publications & conference presentations to illustrate the method.
☐ I give permission for my measuring session to be videotaped to illustrate the method.

APPENDIX C: RAW DATA

APPENDIX C1. Legend of anatomical landmarks on the skull.

Point	Anatomical Landmark
1	Glabella
2	Nasion
3	End of nasals
4	Lateral nostril
5	Mid-philtrum
6	Chin-lip fold
7	Mental eminence
8	Beneath chin
9	Superior eye orbit
10	Inferior eye orbit
11	Supra canine
12	Sub canine
13	Supra M2
14	Lower cheek
15	Mid mandible
16	Lateral eye orbit
17	Zygomatic
18	Gonion
19	Root of zygoma

APPENDIX C2. Facial tissue depth measurements (mm) of points 1-11 for participants 001-020.

ID	Sex	Age	1	2	3	4	5	6	7	8	9	10	11
001	M	10	5.0	6.0	5.0	7.0	10.0	12.0	7.0	8.0	4.0	7.0	13.0
002	F	12	5.0	6.0	7.0	29.0	13.0	12.0	13.0	6.0	9.0	5.0	13.0
003	M	13	6.0	6.0	4.0	19.0	12.0	10.0	(dimple)	6.0	7.0	5.0	10.0
004	F	5	5.0	6.0	4.0	19.0	9.0	7.0	9.0	6.0	8.0	6.0	7.0
005	F	12	7.0	8.0	3.0	22.0	10.0	11.0	15.0	9.0	8.0	9.0	8.0
006	F	12	5.0	6.0	4.0	20.0	10.0	10.0	10.0	7.0	8.0	7.0	11.0
007	F	12	5.0	6.0	6.0	21.0	8.0	11.0	13.0	7.0	8.0	7.0	14.0
008	F	12	7.0	8.0	6.0	22.0	11.0	12.0	12.0	7.0	11.0	12.0	20.0
009	M	13	5.0	8.0	5.0	20.0	14.0	13.0	16.0	9.0	9.0	6.0	13.0
010*	–	–	–	–	–	–	–	–	–	–	–	–	–
011*	–	–	–	–	–	–	–	–	–	–	–	–	–
012	M	16	6.0	8.0	3.0	26.0	13.0	16.0	16.0	7.0	7.0	9.0	13.0
013	F	9	6.0	5.0	2.0	17.0	10.0	9.0	13.0	6.0	7.0	6.0	13.0
014	F	3	4.0	6.0	3.0	18.0	12.0	8.0	9.0	5.0	8.0	5.0	11.0
015	M	9	6.0	6.0	4.0	22.0	12.0	15.0	15.0	18.0	8.0	15.0	13.0
016	F	10	6.0	6.0	5.0	18.0	12.0	14.0	15.0	14.0	8.0	9.0	12.0
017	F	12	5.0	6.0	2.0	15.0	11.0	9.0	14.0	7.0	8.0	6.0	15.0
018	M	15	6.0	7.0	6.0	17.0	12.0	11.0	13.0	(facial hair)	8.0	6.0	12.0
019	F	14	4.0	6.0	5.0	23.0	11.0	11.0	13.0	7.0	6.0	9.0	13.0
020	M	10	5.0	5.0	4.0	17.0	9.0	11.0	12.0	6.0	6.0	5.0	22.0

*omitted because adult, i.e. over 18 years of age.

APPENDIX C3. Facial tissue depth measurements (mm) of points 12-19 and greatest lip height for participants 001-020.

ID	Sex	Age	12	13	14	15	16	17	18	19	Greatest Lip Height
001	M	10	11.0	19.0	18.0	8.0	5.0	4.0	4.0	4.0	24.90
002	F	12	12.0	18.0	19.0	6.0	6.0	8.0	10.0	5.0	27.19
003	M	13	12.0	21.0	21.0	6.0	4.0	8.0	11.0	10.0	19.84
004	F	5	10.0	15.0	23.0	7.0	6.0	7.0	6.0	4.0	15.25
005	F	12	14.0	15.0	24.0	12.0	4.0	7.0	6.0	5.0	19.96
006	F	12	10.0	12.0	30.0	10.0	5.0	8.0	11.0	4.0	24.03
007	F	12	15.0	29.0	21.0	13.0	4.0	11.0	12.0	3.0	28.68
008	F	12	10.0	25.0	20.0	12.0	4.0	12.0	22.0	5.0	25.23
009	M	13	12.0	24.0	22.0	13.0	5.0	8.0	17.0	3.0	22.30
010*	–	–	–	–	–	–	–	–	–	–	–
011*	–	–	–	–	–	–	–	–	–	–	–
012	M	16	13.0	29.0	34.0	14.0	6.0	7.0	13.0	5.0	27.78
013	F	9	10.0	15.0	23.0	12.0	4.0	13.0	12.0	6.0	19.10
014	F	3	11.0	21.0	21.0	9.0	4.0	6.0	9.0	4.0	16.38
015	M	9	12.0	26.0	27.0	13.0	5.0	14.0	5.0	5.0	15.00
016	F	10	10.0	16.0	28.0	14.0	5.0	9.0	20.0	4.0	16.00
017	F	12	11.0	38.0	16.0	7.0	6.0	7.0	4.0	4.0	20.55
018	M	15	12.0	20.0	17.0	8.0	5.0	6.0	14.0	3.0	24.94
019	F	14	19.0	23.0	21.0	6.0	4.0	10.0	4.0	4.0	21.81
020	M	10	14.0	24.0	20.0	6.0	4.0	5.0	4.0	3.0	16.68

*omitted because adult, i.e. over 18 years of age.

APPENDIX C4. Facial tissue depth measurements (mm) of points 1-11 for participants 021-040.

ID	Sex	Age	1	2	3	4	5	6	7	8	9	10	11
021	F	10	6.0	6.0	6.0	20.0	7.0	12.0	15.0	12.0	7.0	8.0	19.0
022	F	13	6.0	7.0	6.0	19.0	11.0	10.0	14.0	11.0	8.0	8.0	22.0
023	F	17	6.0	5.0	2.0	21.0	10.0	12.0	14.0	9.0	7.0	5.0	10.0
024	F	17	5.0	7.0	2.0	20.0	12.0	13.0	13.0	8.0	4.0	9.0	12.0
025	F	16	5.0	6.0	5.0	19.0	10.0	13.0	16.0	13.0	7.0	6.0	10.0
026	M	11	5.0	6.0	4.0	16.0	10.0	10.0	12.0	8.0	5.0	6.0	15.0
027	M	15	6.0	8.0	4.0	15.0	11.0	11.0	12.0	9.0	9.0	7.0	10.0
028	M	12	6.0	6.0	3.0	14.0	11.0	11.0	10.0	8.0	6.0	9.0	10.0
029	F	10	6.0	5.0	4.0	23.0	9.0	10.0	10.0	7.0	8.0	6.0	10.0
030	F	12	6.0	7.0	7.0	19.0	13.0	11.0	13.0	11.0	8.0	6.0	11.0
031	F	10	6.0	6.0	7.0	20.0	10.0	12.0	16.0	11.0	8.0	8.0	15.0
032	M	10	9.0	9.0	6.0	25.0	14.0	10.0	18.0	9.0	9.0	12.0	18.0
033	F	13	6.0	7.0	7.0	21.0	11.0	10.0	12.0	7.0	7.0	9.0	15.0
034	F	15	5.0	5.0	5.0	19.0	15.0	12.0	14.0	11.0	6.0	8.0	16.0
035	M	11	7.0	6.0	7.0	23.0	12.0	12.0	15.0	10.0	7.0	8.0	12.0
036	M	11	6.0	6.0	5.0	17.0	9.0	9.0	11.0	6.0	8.0	13.0	11.0
037	F	17	7.0	7.0	5.0	19.0	8.0	11.0	12.0	8.0	5.0	11.0	11.0
038	F	18	5.0	6.0	3.0	20.0	9.0	8.0	10.0	7.0	6.0	6.0	13.0
039	F	18	4.0	5.0	2.0	20.0	11.0	9.0	9.0	6.0	7.0	11.0	14.0
040	F	18	6.0	7.0	3.0	24.0	10.0	15.0	13.0	10.0	6.0	14.0	14.0

APPENDIX C5. Facial tissue depth measurements (mm) of points 12-19 and greatest lip height for participants 021-040.

ID	Sex	Age	12	13	14	15	16	17	18	19	Greatest Lip Height
021	F	10	15.0	16.0	23.0	10.0	6.0	8.0	6.0	5.0	15.46
022	F	13	15.0	26.0	22.0	9.0	5.0	13.0	7.0	7.0	20.06
023	F	17	14.0	26.0	24.0	7.0	3.0	7.0	5.0	3.0	19.82
024	F	17	12.0	29.0	25.0	14.0	4.0	12.0	6.0	6.0	14.39
025	F	16	11.0	31.0	28.0	14.0	5.0	7.0	14.0	4.0	24.00
026	M	11	15.0	21.0	21.0	12.0	3.0	5.0	13.0	3.0	22.68
027	M	15	12.0	28.0	23.0	10.0	6.0	5.0	11.0	3.0	23.95
028	M	12	14.0	23.0	15.0	7.0	6.0	6.0	9.0	2.0	23.13
029	F	10	11.0	23.0	13.0	9.0	4.0	5.0	7.0	5.0	16.82
030	F	12	14.0	28.0	21.0	9.0	5.0	6.0	7.0	5.0	19.93
031	F	10	15.0	26.0	22.0	13.0	5.0	8.0	6.0	5.0	12.43
032	M	10	13.0	29.0	24.0	15.0	6.0	8.0	9.0	5.0	19.51
033	F	13	11.0	30.0	23.0	14.0	6.0	6.0	5.0	3.0	17.92
034	F	15	14.0	25.0	18.0	7.0	4.0	5.0	5.0	5.0	18.85
035	M	11	13.0	13.0	25.0	11.0	4.0	5.0	6.0	4.0	20.43
036	M	11	12.0	26.0	21.0	9.0	3.0	6.0	6.0	3.0	17.68
037	F	17	12.0	30.0	21.0	8.0	5.0	10.0	6.0	6.0	23.54
038	F	18	11.0	25.0	24.0	9.0	5.0	7.0	12.0	5.0	21.22
039	F	18	9.0	21.0	20.0	11.0	3.0	6.0	4.0	3.0	24.67
040	F	18	14.0	29.0	19.0	12.0	6.0	8.0	6.0	4.0	25.43

APPENDIX C6. Facial tissue depth measurements (mm) of points 1-11 for participants 041-056.

ID	Sex	Age	1	2	3	4	5	6	7	8	9	10	11
041	F	6	5.0	6.0	3.0	20.0	12.0	9.0	12.0	7.0	4.0	15.0	17.0
042	F	17	5.0	5.0	3.0	20.0	10.0	12.0	7.0	5.0	6.0	13.0	13.0
043	M	11	5.0	7.0	5.0	23.0	10.0	12.0	11.0	7.0	7.0	11.0	11.0
044	M	12	4.0	6.0	4.0	28.0	12.0	13.0	10.0	8.0	6.0	8.0	15.0
045	F	17	3.0	5.0	2.0	16.0	11.0	10.0	6.0	5.0	5.0	6.0	10.0
046	M	18	5.0	7.0	3.0	19.0	13.0	14.0	15.0	10.0	8.0	8.0	14.0
047	F	18	5.0	4.0	4.0	17.0	12.0	16.0	13.0	6.0	8.0	6.0	12.0
048	F	10	5.0	5.0	3.0	25.0	9.0	12.0	15.0	12.0	7.0	8.0	16.0
049	M	13	5.0	5.0	5.0	15.0	12.0	9.0	15.0	6.0	6.0	6.0	13.0
050	M	9	5.0	5.0	5.0	22.0	13.0	10.0	14.0	5.0	8.0	14.0	11.0
051	F	17	5.0	5.0	4.0	17.0	8.0	12.0	13.0	6.0	6.0	5.0	9.0
052	F	4	6.0	6.0	5.0	18.0	9.0	8.0	11.0	7.0	6.0	6.0	9.0
053	F	3	5.0	6.0	6.0	14.0	11.0	11.0	8.0	7.0	5.0	4.0	15.0
054	M	4	5.0	4.0	4.0	15.0	8.0	10.0	7.0	5.0	6.0	17.0	12.0
055	M	6	5.0	5.0	4.0	17.0	11.0	8.0	8.0	5.0	6.0	10.0	9.0
056	M	8	5.0	6.0	6.0	23.0	11.0	11.0	9.0	7.0	6.0	7.0	14.0

APPENDIX C7. Facial tissue depth measurements (mm) of points 12-19 and greatest lip height for participants 041-056.

ID	Sex	Age	12	13	14	15	16	17	18	19	Greatest Lip Height
041	F	6	12.0	24.0	22.0	14.0	4.0	10.0	5.0	4.0	14.01
042	F	17	14.0	24.0	20.0	8.0	5.0	12.0	5.0	3.0	24.75
043	M	11	9.0	25.0	20.0	8.0	3.0	6.0	4.0	3.0	20.03
044	M	12	15.0	25.0	25.0	8.0	5.0	8.0	9.0	6.0	18.43
045	F	17	10.0	20.0	19.0	6.0	5.0	6.0	10.0	3.0	19.75
046	M	18	13.0	21.0	20.0	11.0	2.0	5.0	14.0	3.0	28.74
047	F	18	13.0	24.0	19.0	10.0	3.0	6.0	5.0	4.0	23.90
048	F	10	15.0	36.0	30.0	14.0	5.0	10.0	9.0	4.0	17.63
049	M	13	11.0	19.0	20.0	6.0	4.0	8.0	3.0	7.0	23.98
050	M	9	16.0	22.0	25.0	14.0	6.0	8.0	7.0	4.0	20.75
051	F	17	12.0	25.0	20.0	7.0	3.0	6.0	4.0	5.0	19.82
052	F	4	11.0	27.0	20.0	9.0	5.0	6.0	6.0	3.0	14.46
053	F	3	12.0	27.0	19.0	9.0	3.0	5.0	5.0	4.0	12.46
054	M	4	11.0	22.0	27.0	7.0	3.0	6.0	6.0	3.0	16.36
055	M	6	8.0	24.0	22.0	7.0	5.0	6.0	3.0	3.0	15.28
056	M	8	10.0	26.0	25.0	7.0	3.0	5.0	5.0	3.0	17.57

APPENDIX C8. Facial tissue depth measurements (mm) of six participants, measured twice, for intra-observer error test.

	ID #023		ID #024		ID #051		ID #054		ID #055		ID #056	
Anatomical Landmarks	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1 Glabella	6.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0	5.0	6.0	5.0	5.0
2 Nasion	5.0	6.0	7.0	7.0	5.0	6.0	4.0	5.0	5.0	6.0	6.0	6.0
3 End of nasals	2.0	5.0	2.0	4.0	4.0	4.0	4.0	6.0	4.0	5.0	6.0	6.0
4 Lateral nostril	21.0	21.0	20.0	19.0	17.0	14.0	15.0	17.0	17.0	16.0	23.0	20.0
5 Mid-philtrum	10.0	12.0	12.0	12.0	8.0	8.0	8.0	9.0	11.0	10.0	11.0	12.0
6 Chin-lip fold	12.0	11.0	13.0	8.0	12.0	8.0	10.0	8.0	8.0	8.0	11.0	10.0
7 Mental eminence	14.0	13.0	13.0	14.0	13.0	13.0	7.0	8.0	8.0	8.0	9.0	9.0
8 Beneath chin	9.0	9.0	8.0	7.0	6.0	6.0	5.0	6.0	5.0	6.0	7.0	6.0
9 Superior eye orbit	7.0	7.0	4.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
10 Inferior eye orbit	5.0	5.0	9.0	8.0	5.0	4.0	17.0	14.0	10.0	6.0	7.0	8.0
11 Supracanine	10.0	10.0	12.0	13.0	9.0	9.0	12.0	11.0	9.0	10.0	14.0	16.0
12 Subcanine	14.0	15.0	12.0	14.0	12.0	11.0	11.0	11.0	8.0	9.0	10.0	10.0
13 Supra M2	26.0	25.0	29.0	33.0	25.0	26.0	22.0	22.0	24.0	23.0	26.0	24.0
14 Lower cheek	24.0	21.0	25.0	28.0	20.0	19.0	27.0	21.0	22.0	21.0	25.0	25.0
15 Mid mandible	7.0	7.0	14.0	11.0	7.0	6.0	7.0	6.0	7.0	7.0	7.0	8.0
16 Lateral eye orbit	3.0	5.0	4.0	3.0	3.0	4.0	3.0	3.0	5.0	6.0	3.0	4.0
17 Zygomatic	7.0	6.0	12.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0	5.0	7.0
18 Gonion	5.0	6.0	6.0	7.0	4.0	5.0	6.0	5.0	3.0	3.0	5.0	4.0
19 Root of zygoma	3.0	3.0	6.0	4.0	5.0	4.0	3.0	3.0	3.0	4.0	3.0	4.0

APPENDIX C9. Height, weight, and BMI-for-age of participants 001-031.

ID	Height (cm)	Weight (lbs)	BMI-for-age	BMI-for-age Percentile**
001	136	81	19.9	86.4
002	154	106	20.3	75.5
003	149	89	18.2	35.9
004	113	51	18.1	93.7
005	147.5	128	26.7	96.3
006	150	119	24.0	90.5
007	154	140	26.8	97.3
008	152.5	154	30.0	98.7
009	156	151	28.1	97.1
010*	–	–	–	–
011*	–	–	–	–
012	171	250	38.8	99.6
013	138	110	26.2	98.6
014	104	35	14.7	27.3
015	145	118	25.5	98.1
016	140	120	27.8	98.5
017	160	123	21.8	81.9
018	168	132	21.2	63.3
019	150	135	27.2	94.4
020	148	90	18.6	73.7
021	158	119	21.6	89.3
022	167.5	223	36.1	99.2
023	164.5	137	23.0	70.2
024	166	145	23.9	77.4
025	162.5	117	20.1	43.7
026	147	105	22.0	90.1
027	170	178	27.9	96.0
028	151	92	18.3	56.0
029	153.5	121	23.3	93.6
030	159	118	21.2	76.6
031	151	106	21.1	86.3

*omitted because adult, i.e. over 18 years of age.
** BMI-for-age percentiles are as follows:
Underweight (< 5th %ile)
Normal (5th - 85th %ile)
Overweight/obese (≥ 85th %ile)
Obese (≥ 95th %ile)

APPENDIX C10. Height, weight, and BMI-for-age of participants 032-056.

ID	Height (cm)	Weight (lbs)	BMI-for-age	BMI-for-age Percentile**
032	164	175	29.5	98.9
033	167.5	106	17.1	21.8
034	166.5	130	21.3	62.4
035	148	119	24.6	96.5
036	148	133	27.5	97.9
037	151	174	34.6	97.7
038	149.5	101	20.5	37.5
039	160	120	21.3	48.6
040	157.5	142	26.0	85.0
041	118	52	16.9	82.9
042	157	133	24.5	79.7
043	145	79	17.0	43.9
044	152.5	80	15.4	6.6
045	161	120	21.0	49.4
046	182	154	21.1	34.5
047	164.5	162	27.2	89.2
048	145	120	25.9	97.1
049	175	125	18.5	47.7
050	139	108	25.4	98.3
051	165.5	144	23.8	77.7
052	112	61	22.1	99.5
053	95	38	19.1	98.1
054	108	38	14.8	21.8
055	131	60	15.9	61.5
056	140	70	16.2	52.3

** BMI-for-age percentiles are as follows:
Underweight (< 5th %ile)
Normal (5th - 85th %ile)
Overweight/obese (≥ 85th %ile)
Obese (≥ 95th %ile)

APPENDIX D: ADDITIONAL TABLES FOR FORENSIC ARTISTS

APPENDIX D1. Facial tissue depth means (mm) of subadult African Nova Scotian females and males with data collapsed prior to the onset of male puberty (12 years of age).

	Females & Males 3-11 Years Old (N = 23)			Females aged 12-18 Years Old (N = 22)			Males aged 12-18 Years Old (N = 9)		
Anatomical Landmarks	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	5.6	0.99	4-9	5.3	0.99	3-7	5.4	0.73	4-6
2 Nasion	5.8	0.94	4-9	6.1	1.07	4-8	6.8	1.09	5-8
3 End of nasals	4.7	1.30	2-7	4.2	1.77	2-7	4.1	1.05	3-6
4 Lateral nostril	19.1	4.10	7-25	20.1	2.93	15-29	19.2	4.89	14-28
5 Mid-philtrum	10.4	1.70	7-14	10.7	1.70	8-15	12.2	0.97	11-14
6 Chin-lip fold	10.5	1.97	7-15	11.4	1.87	8-16	12.0	2.18	9-16
7 Mental eminence	11.8	3.14	7-18	12.2	2.45	6-16	13.4*	2.50	10-16
8 Beneath chin	8.2	3.30	5-18	7.9	2.17	5-13	7.9*	1.46	6-10
9 Superior eye orbit	6.8	1.38	4-9	7.0	1.54	4-11	7.3	1.22	6-9
10 Inferior eye orbit	9.0	3.72	4-17	8.1	2.69	5-14	7.1	1.45	5-9
11 Supracanine	13.3	3.53	7-22	13.0	3.32	8-22	12.2	1.86	10-15
12 Subcanine	12.0	2.17	8-16	12.6	2.28	9-19	12.7	1.22	11-15
13 Supra M2	22.7	5.35	13-36	25.1	5.68	15-31	23.3	3.50	19-29
14 Lower cheek	22.6	3.68	13-30	21.5	3.28	16-30	21.9	5.44	15-34
15 Mid mandible	10.3	2.85	6-15	9.6	2.77	6-14	9.2	2.95	6-14
16 Lateral eye orbit	4.4	1.08	3-6	4.5	1.01	3-6	4.8	1.30	2-6
17 Zygomatic	7.2	2.61	4-14	8.2	2.46	5-12	6.8	1.30	5-8
18 Gonion	7.1	3.74	3-20	7.7	4.40	4-22	11.2	4.02	3-17
19 Root of zygoma	4.0	0.88	3-5	4.4	1.14	3-7	4.7	2.60	2-10
Greatest lip height	17.26	3.10	15.00-24.90	22.10	3.36	14.39-28.68	23.68	3.33	18.43-28.74

APPENDIX D2. Facial tissue depth means (mm) of subadult African Nova Scotian females for normal BMI-for-age.

Anatomical Landmarks	Females Aged 3-8 Years Old (N = 2)			Females Aged 9-13 Years Old (N = 4)			Females Aged 14-18 Years Old (N = 9)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	4.5	0.71	4-5	5.5	0.58	5-6	4.8	0.83	3-6
2 Nasion	6.0	0.00	0	6.5	0.58	6-7	5.4	0.73	5-7
3 End of nasals	3.0	0.00	0	5.8	2.50	2-7	3.1	1.27	2-5
4 Lateral nostril	19.0	1.40	18-20	21.0	5.89	15-29	19.1	1.62	16-21
5 Mid-philtrum	12.0	0.00	0	12.0	1.15	11-13	10.7	2.00	8-12
6 Chin-lip fold	8.5	0.70	8-9	10.5	1.29	9-12	11.2	1.79	8-13
7 Mental eminence	10.5	2.10	9-12	13.0	0.82	12-14	11.3	3.46	6-16
8 Beneath chin	6.0	1.40	5-7	7.8	2.22	6-11	7.8	2.77	5-13
9 Superior eye orbit	6.0	2.80	4-8	8.0	0.82	7-9	6.0	1.00	4-7
10 Inferior eye orbit	10.0	7.10	5-15	6.5	1.73	5-9	7.7	2.83	5-13
11 Supracanine	14.0	4.20	11-17	13.5	1.91	11-15	11.9	2.32	9-16
12 Subcanine	11.5	0.70	11-12	12.0	1.41	11-14	11.9	1.83	9-14
13 Supra M2	22.5	2.10	21-24	28.5	8.23	18-30	25.1	3.44	20-31
14 Lower cheek	21.5	0.70	21-22	19.8	2.99	16-23	22.0	3.35	18-25
15 Mid mandible	11.5	3.50	9-14	9.0	3.56	6-14	9.2	3.07	6-14
16 Lateral eye orbit	4.0	0.00	0	5.8	0.50	5-6	4.1	0.93	3-5
17 Zygomatic	8.0	2.80	6-10	6.8	0.96	6-8	7.6	2.60	5-12
18 Gonion	7.0	2.80	5-9	6.5	2.65	4-10	7.2	3.77	4-14
19 Root of zygoma	4.0	0.00	0	4.3	0.96	3-5	4.1	1.17	3-6
Greatest lip height	15.195	1.68	14.01 - 16.38	21.398	4.02	17.92 - 27.19	20.81	3.33	14.39 - 24.75

APPENDIX D3. Facial tissue depth means (mm) of subadult African Nova Scotian males for normal BMI-for-age.

Anatomical Landmarks	Males Aged 3-8 Years Old (N = 3)			Males Aged 9-13 Years Old (N = 6)			Males Aged 14-18 Years Old (N = 2)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	5.0	0.00	0	5.2	0.75	4-6	5.5	0.71	5-6
2 Nasion	5.0	1.00	4-6	5.8	0.75	5-7	7.0	0.00	0
3 End of nasals	4.7	1.15	4-6	4.2	0.75	3-5	4.5	2.12	3-6
4 Lateral nostril	18.3	4.16	15-23	19.3	5.32	14-28	18.0	1.41	17-19
5 Mid-philtrum	10.0	1.73	8-11	11.0	1.26	9-12	12.5	0.71	12-13
6 Chin-lip fold	9.7	1.53	8-11	11.0	1.41	9-13	12.5	2.12	11-14
7 Mental eminence	8.0	1.00	7-9	11.6	2.07	10-15	14.0	1.41	13-15
8 Beneath chin	5.7	1.15	5-7	6.8	0.98	6-8	10.0*	--	--
9 Superior eye orbit	6.0	0.00	0	6.3	0.52	6-7	8.0	0.00	0
10 Inferior eye orbit	11.3	5.13	7-17	7.3	2.42	5-11	7.0	1.41	6-8
11 Supracanine	11.7	2.52	9-14	13.5	4.59	10-22	16.0	1.41	12-14
12 Subcanine	9.7	1.53	8-11	12.5	2.26	9-15	12.5	0.71	12-13
13 Supra M2	24.0	2.00	22-26	22.8	2.40	19-25	20.5	0.71	20-21
14 Lower cheek	24.7	2.52	22-27	20.2	3.19	15-25	18.5	2.12	17-20
15 Mid mandible	7.0	0.00	0	6.8	0.98	6-8	9.5	2.12	8-11
16 Lateral eye orbit	3.7	1.15	3-5	4.3	1.03	3-6	3.5	2.12	2-5
17 Zygomatic	5.7	0.58	5-6	6.8	1.33	5-8	5.5	0.71	5-6
18 Gonion	4.7	1.53	3-6	6.7	3.39	3-11	14.0	0.00	0
19 Root of zygoma	3.0	0.00	0	5.2	3.06	2-10	3.0	0.00	0
Greatest lip height	16.40	1.15	15.28 - 17.57	20.35	2.77	16.68 - 23.98	26.84	2.69	24.94 - 28.74

* Indicates $N = 1$.

APPENDIX D4. Collapsed facial tissue depth means (mm) of subadult African Nova Scotians for normal BMI-for-age.

Anatomical Landmarks	Females & Males Aged 3-11 Years (N = 7)			Females Aged 12-18 Years Old (N = 13)			Males Aged 12-18 Years Old (N = 6)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	4.9	0.38	4-5	5.0	0.82	3-6	5.3	0.82	4-6
2 Nasion	5.6	0.98	4-7	5.8	0.83	5-7	6.2	0.75	5-7
3 End of nasals	4.1	1.07	3-6	3.9	2.06	2-7	4.2	1.17	3-6
4 Lateral nostril	19.0	3.11	15-23	19.7	3.35	15-29	18.7	5.01	15-28
5 Mid-philtrum	10.4	1.51	8-12	11.1	1.85	8-15	12.0	0.63	11-13
6 Chin-lip fold	9.9	1.57	8-12	11.0	1.63	8-13	11.3	1.86	9-14
7 Mental eminence	9.7	1.98	7-12	11.8	2.97	6-16	12.6*	2.51	10-15
8 Beneath chin	6.0	1.00	5-7	7.8	2.52	5-13	7.6*	1.67	6-10
9 Superior eye orbit	6.1	1.21	4-8	6.6	1.33	4-9	6.8	0.98	6-8
10 Inferior eye orbit	10.0	4.73	5-17	7.3	2.53	5-13	7.0	1.55	5-9
11 Supracanine	13.7	4.46	9-22	12.4	2.26	9-16	12.3	2.07	10-15
12 Subcanine	10.7	1.98	9-14	11.9	1.66	9-14	12.8	1.47	11-14
13 Supra M2	23.7	1.70	21-26	26.2	5.24	18-31	21.5	2.17	19-25
14 Lower cheek	22.4	2.64	20-27	21.3	3.30	16-25	19.7	3.44	15-25
15 Mid mandible	8.3	0.269	6-14	9.2	3.08	6-14	7.7	1.86	6-11
16 Lateral eye orbit	3.7	0.76	3-5	4.6	1.12	3-6	4.3	1.37	2-6
17 Zygomatic	6.3	1.70	5-10	7.3	2.21	6-12	6.8	1.33	5-8
18 Gonion	5.1	1.95	3-9	7.0	3.37	4-14	10.0	4.10	3-14
19 Root of zygoma	3.3	0.49	3-4	4.2	1.07	3-5	5.2	3.06	2-10
Greatest lip height	16.62	1.88	14.01-20.03	20.99	3.40	14.39-27.19	23.18	3.70	18.43-28.74

*Indicates $N = 5$.

APPENDIX D5. Facial tissue depth means (mm) of subadult African Nova Scotian females for overweight and obese BMI-for-age.

Anatomical Landmarks	Females Aged 3-8 Years Old (N = 3)			Females Aged 9-13 Years Old (N = 11)			Females Aged 14-18 Years Old (N = 4)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	5.3	0.58	5-6	5.9	0.70	5-7	5.5	1.29	4-7
2 Nasion	6.0	0.00	0	6.2	1.08	5-8	6.0	1.41	6-7
3 End of nasals	5.0	1.00	4-6	4.7	1.62	2-7	4.3	0.96	3-5
4 Lateral nostril	17.0	2.65	14-19	20.9	2.23	17-25	20.8	3.30	17-24
5 Mid-philtrum	9.7	1.15	9-11	9.7	1.42	7-12	10.3	1.71	8-12
6 Chin-lip fold	8.7	2.08	8-11	11.2	1.40	9-14	13.3	2.63	11-16
7 Mental eminence	9.3	1.53	8-11	13.5	2.07	10-16	12.8	0.50	12-13
8 Beneath chin	6.7	0.58	6-7	9.4	2.73	6-14	7.8	1.71	6-10
9 Superior eye orbit	6.3	1.53	5-8	8.0	1.10	7-11	6.3	1.26	5-8
10 Inferior eye orbit	5.3	1.15	4-6	8.0	1.67	6-12	10.0	3.37	6-14
11 Supracanine	10.3	4.16	7-15	14.5	4.39	8-22	12.5	1.29	11-14
12 Subcanine	11.0	1.00	10-12	12.7	2.45	10-15	14.5	3.11	12-19
13 Supra M2	23.0	6.93	15-27	21.7	7.46	12-36	26.5	3.51	23-30
14 Lower cheek	20.7	2.08	19-23	23.3	4.88	13-30	20.0	1.15	19-21
15 Mid mandible	8.3	1.15	7-9	11.6	1.86	9-14	9.0	2.58	6-12
16 Lateral eye orbit	4.7	1.53	3-6	4.6	0.67	4-6	4.5	1.29	3-5
17 Zygomatic	6.0	1.00	5-7	9.5	2.58	7-13	8.5	1.91	6-10
18 Gonion	5.7	0.58	5-6	10.7	5.61	6-22	5.3	0.96	4-6
19 Root of zygoma	3.7	0.58	3-4	4.8	1.08	3-7	4.5	1.00	4-6
Greatest lip height	14.057	1.44	12.46-15.25	19.582	4.77	12.43 - 28.68	23.67	1.49	21.81 - 25.43

APPENDIX D6. Facial tissue depth means (mm) of subadult African Nova Scotian males for overweight and obese BMI-for-age.

Anatomical Landmarks	Males Aged 3-8 Years Old (N = 0)			Males Aged 9-13 Years Old (N = 8)			Males Aged 14-18 Years Old (N = 2)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	–	–	–	6.0	1.41	5-9	6.0	0.00	0
2 Nasion	–	–	–	6.5	1.31	5-9	8.0	0.00	0
3 End of nasals	–	–	–	5.1	0.99	4-7	3.5	0.71	3-4
4 Lateral nostril	–	–	–	19.0	5.71	7-25	20.5	7.78	15-26
5 Mid-philtrum	–	–	–	11.8	1.91	9-14	12.0	1.41	11-13
6 Chin-lip fold	–	–	–	11.4	2.00	9-15	13.5	3.54	11-16
7 Mental eminence	–	–	–	13.5	3.42	7-18	14.0	2.83	12-16
8 Beneath chin	–	–	–	9.1	3.94	5-18	8.0	1.41	7-9
9 Superior eye orbit	–	–	–	7.3	1.83	4-9	8.0	1.41	7-9
10 Inferior eye orbit	–	–	–	10.1	3.76	6-15	8.0	1.41	7-9
11 Supracanine	–	–	–	13.3	2.31	11-18	11.5	2.12	10-13
12 Subcanine	–	–	–	13.0	1.69	11-16	12.5	0.71	12-13
13 Supra M2	–	–	–	22.5	4.99	13-29	28.5	0.71	28-29
14 Lower cheek	–	–	–	22.9	2.90	18-27	28.5	7.78	23-34
15 Mid mandible	–	–	–	11.9	2.42	8-15	12.0	2.83	10-14
16 Lateral eye orbit	–	–	–	4.6	1.19	3-6	6.0	0.00	0
17 Zygomatic	–	–	–	7.3	3.15	4-14	6.0	1.41	5-7
18 Gonion	–	–	–	8.4	4.47	4-13	12.0	1.41	11-13
19 Root of zygoma	–	–	–	3.9	0.83	3-5	4.0	1.41	3-5
Greatest lip height	–	–	–	20.41	3.08	17.68 - 24.90	25.87	2.71	23.95 - 27.78

APPENDIX D7. Collapsed facial tissue depth means (mm) of subadult African Nova Scotians for overweight/obese BMI-for-age.

Anatomical Landmarks	Females & Males Aged 3-11 Years (N = 16)			Females Aged 12-18 Years Old (N = 9)			Males Aged 12-18 Years Old (N = 3)		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
1 Glabella	5.9	1.02	5-9	5.8	1.09	4-7	5.7	0.58	5-6
2 Nasion	5.9	0.93	5-9	6.6	1.24	6-8	8.0*	--*	--*
3 End of nasals	4.9	1.36	2-7	4.7	1.22	3-6	4.0	1.00	3-5
4 Lateral nostril	19.1	4.56	7-25	20.8	2.22	17-24	20.3	5.51	15-26
5 Mid-philtrum	10.4	1.82	7-14	10.1	1.36	8-12	12.7	1.53	11-14
6 Chin-lip fold	10.8	2.10	7-15	11.9	2.15	10-16	13.3	2.52	11-16
7 Mental eminence	12.8	3.15	7-18	12.8	1.39	10-14	14.7	2.31	12-16
8 Beneath chin	9.1	3.52	5-18	8.0	1.66	6-11	8.3	1.15	7-9
9 Superior eye orbit	7.1	1.39	4-9	7.6	1.74	5-11	8.3	1.15	7-9
10 Inferior eye orbit	8.5	3.27	4-15	9.2	2.64	6-14	7.3	1.53	6-9
11 Supracanine	13.1	3.19	7-19	13.9	4.46	8-22	12.0	1.73	10-13
12 Subcanine	12.6	2.06	10-16	13.6	2.79	10-19	12.3	0.58	12-13
13 Supra M2	22.3	6.34	13-36	23.7	6.28	12-30	27.0	2.65	24-29
14 Lower cheek	22.6	4.13	13-30	21.9	3.41	19-30	26.3	6.66	22-34
15 Mid mandible	11.2	2.51	7-15	10.2	2.28	6-13	12.3	2.08	10-14
16 Lateral eye orbit	4.7	1.08	3-6	4.4	0.88	3-6	5.7	0.58	5-6
17 Zygomatic	7.6	2.87	4-14	9.4	2.35	6-13	6.7	1.53	5-8
18 Gonion	7.9	4.06	4-13	8.8	5.63	4-22	13.7	3.06	11-17
19 Root of zygoma	4.3	0.86	3-6	4.7	1.22	3-7	3.7	1.15	3-5
Greatest lip height	17.54	3.52	12.43-22.68	23.63	2.76	19.96-28.68	24.70	2.81	22.30-27.78