THE EFFICACY OF TRADITIONAL AND DIGITALLY-DERIVED ANTHROPOMETRY AMONG BLACK WOMEN

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A PROJECT IN LIEU OF THESIS PRESENTED TO THE COLLOEGE OF FINE ARTS OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
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To my intellectual grandmother, who worked from the intersection of anthropology and the fine arts, and was unafraid to stand on a street corner in Harlem, take a pair of calipers, and measure anyone who passed by. With her pencil and caliper, she fought against pseudoscientific racism. Zora Neale Hurston, I dedicate this project to you.

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By

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May 2013

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Member: Ben DeVane
Major: Digital Arts and Sciences

This project tests the efficacy of handheld technology against traditional direct methods to inexpensively gather anthropometric data from African American and Afro-Caribbean women living in Florida, and to help create an ethnic-specific digital database for future anthropometric survey use. Results demonstrate that indirect anthropometry that uses handheld technology has a shorter examination period, but provides less precision. This proposed project also explores the benefits and drawbacks of replacing 2D body image charts in clinical research and practice with charts derived from anthropometry that uses handheld 3D technology. How participants interact with and experience handheld technology, while undergoing anthropometric examinations, are also reported.

Based on methodological validity, direct anthropometry is more effective. More participants also prefer the direct anthropometric exam as opposed to the indirect methods derived from digital technology. However, although in its prototypical phase,

the technology used during this project presents unique opportunities to compare individual body shape and size, which may serve as a powerful medical screening tool in the future.

BACKGROUND

The Early (Mis)use of Anthropometry

The development of efficacious methods to measure the human body influences how we conceptualize physical health and disease risk, and create human compatible technologies in contemporary society. Such measurements of the human body, skull, and face are collectively referred to as anthropometry (Relethford 2010: 364). In the United States, anthropometry was central to the historical advancement of the sociopolitical and scientific belief, held by early anthropologists and eugenicists, that human behavior was contingent on biologically predetermined race rather than the social environment (Ulijasjek and Komlos 2009, Baker 1998). Racial taxonomies were initially introduced by Carl Linnaus, and according to the article, “From a History of Anthropometry to Anthropometric History,” anthropometry was the locus of this endeavor, because it helped to form, “the basis of scientific racism and eugenics in the late nineteenth century” (Ulijasjek and Komlos 2009: 185). However, in the second half of the twentieth century, the Boasian anthropological school, among others, challenged the Social Darwinist notion that behavior was determined by biological race rather than the social and material world. Anthropometric surveys were conducted by twentieth century anthropologists, such as Franz Boas and Melville Herskovits, to prove that race was not biologically-derived but socially constructed, and that the environment—in the case of the US, an environment that privileged some groups while disenfranchising others—determined behavior and altered phenotype (Gershenhorn 2004: 29).

Widely known as the father of American anthropology, Franz Boas would conduct craniofacial and full body anthropometric measurements on the Shoshonean people in North America, and would later train other anthropologists such as—Abram Harris, Zora Neale Hurston, Louis King, Melville Herskovits, and Greene Maxwell—to perform similar anthropometric measures on European immigrants, African Americans, and other ethnic groups in the United States in the early twentieth century (Ulijasjek and Komlos 2009, Gershenhorn 2004, Boas 1899, Herskovits 1932). These early twentieth century anthropometric surveys initiated by Boas would help debunk the racial ideology surrounding human typology, and facilitate a greater understanding for how morphological plasticity enables humans to adapt to their environments (Ulijasjek and Komlos 2009: 185). This early anthropometric data would also help pave the way for contemporary research that studies how racially hegemonic environments that socially include and exclude others would lead to a divided populace—where some physically embody social privilege (i.e. healthy bodies) while others embody social inequality (i.e. bodies afflicted by health disparities) (Farmer 2001, Krieger 1999, Gravlee 2009, Gulbas 2012). Contemporary research also draws upon The Human Adaptability section of the International Biological Programme (HAIBP) of the 1960s, which employed an "explanatory framework" to further the understanding of human adaptation using anthropometric data; in particular, HAIBP studies conducted in "ninety-three nations between 1964 and 1974" would be used to chart and recreate human growth patterns across global populations over long periods of time (Ulijasjek and Komlos 2009 185-6, Collins and Weiner 1977, and Eveleth and Tanner 1976). The HAIBP's *Worldwide Variation in Human Growth of 1976 and 1990*, which primarily used weight, height, and skinfold thickness, would serve as a foundational anthropometric publication that would influence the use of anthropometry in today's public health, epidemiology, medical anthropology, and other health social science fields (Ulijasjek and Komlos 2009: 187). It also would reinforce the current standpoint that variation in human growth patterns and morphology is not the result of intrinsic racial difference, but rather, stems from the need for humans to increase their survival fitness through physical adaptation to a constantly changing social and natural environment. Consequently, since the environment continues to change—either through global migration, geological change, technological innovation etc.—anthropometry remains a vital tool to document how humans effectively or ineffectively respond to that change.

Current Anthropometry in Measuring Body Size and Shape

Despite its early racial beginnings, anthropometry has become the most universal method to non-invasively and inexpensively assess the size, proportion, and composition of the human body (WHO 1995). Today, a qualified anthropometrist will employ several methodological measures—height, weight, fat skinfolds, bone breadths, and girths among others—to calculate the fat free mass (FFM), such as muscle, bone, and fluid, and fat composition of the body (Macfarlene 2007, ISAK 2001). Within medical anthropology, as well as neighboring fields such as public health and medicine, anthropometric data continues to elicit information about nutrition, exercise inactivity, fat distribution, and disease risk in individuals and populations (Hussain 2011). Two of the most common anthropometric measurements, height and weight, continue to serve as the primary measures for calculating the Body Mass Index (BMI), which is considered “the most well-known indicator of body fatness” (NHANES 1-1). However, just as environments change, the anthropometric methods used to measure physical response to that change must also adapt. Although the BMI continues to serve as a universal index for weight classification, it has several limitations. By measuring total body mass, the BMI is unable to distinguish between FFM and body fat (Daniels 2009, Burkhauser and Cawley 2008). Moreover, it does not distinguish between abdominal visceral fat and total adiposity; such a distinction is essential, because visceral fat, research suggests, is what directly increases a person's cardiovascular risk (Hamdy et al 2006).

Anthropometric measures that help to shape the BMI are not only used to classify body weight, but they are also used to help categorize body shape and fat distribution. The Ashwell Shape Chart, among other body image charts, rely on anthropometric measures such as height and waist circumference (WC) to calculate a waist-to-height ratio (WHtR) (Ashwell 2011). The Ashwell Shape chart distinguishes between four classic body types—(1) banana (or chili pepper shaped), (2) pear, (3) pear-apple (or boxed shape), and (4) apple—and serves as a screening tool for clinicians and their patients to rapidly assess their central obesity risk (Ashwell 2011: 87). Although a useful tool, body shape charts alone are poor proxies for anthropometric measures that directly measure the various types of FFM, and distinguish between subcutaneous and visceral fat. Moreover, in order for anthropometry to truly adapt in a way that effectively measures body composition, it had to draw upon a sociocultural environment that was increasingly relying on technology.

Digital Technology and Indirect Anthropometric Methods

Much of the measurements explained in the earlier sections are referred to as *direct anthropometry*. This form of anthropometry has become standardized by the International Society for the Advancement of Kinanthropometry (ISAK), and is considered to be the traditional standard for collecting anthropometric data (ISAK 2001).

With this method, measurements are obtained in areas of the body that are obscured by hair, and anthropometrists are able to directly assess depth of certain phenotypic attributes (Farkas and Deutsch 1996). However, direct methods are also associated with prolonged examinations, examiner skill variation and inconsistency, and unpredictable examinee behavioral response to measurements; such variables often dissuade clinicians and health researchers from using direct anthropometric methods for screening, which contributes to a greater dependence on body weight and body shape charts, notwithstanding their glaring limitations (Farkas and Deutsch 1996: 2, Park et al. 2012). Moreover, such a methodological approach also requires training on live human subjects, which can elevate the discomfort and anxiety of both examiner and examinee (Fourie 2011: 127). In contrast, *indirect anthropometry* involves collecting anthropometric data indirectly from the examinee using some form of technology. Four ubiquitous indirect methods are photogrammetry, cephalometry, bioelectrical impedance analysis (BIA), and laser surface scans (Farkas and Deutsch 1996: 2). Photogrammetry is an anthropometric method derived from 2D images, although emergent 3D photogrammetry is now being used to collect anthropometric data using 3D images (Wong et al 2008, Weingberg et al 2006). Cephalometry is another indirect method, specifically used to gather craniofacial measurements; this method is normally performed using radiographs (or x-ray photographs), and is frequently employed by orthodontists and other clinicians (Farkas and Deutsch 1996). BIA calculates body composition, particularly body fat, by "sending a low level of electric current through the body and measuring the impedance (*Z*) of conducting tissues" (Haroun et al 2010: 1253). 3D digital surface scans can either be performed using stereophotogrammetry, which is digital 3D photogrammetry, or surface laser scanning (Fourie et al 2011). Also medical imaging equipment, such as the dual x-ray absorptiometry (DXA), computed axial tomography (CAT), and magnetic resonance imaging (MRI), are commonly used in indirect anthropometry (Karisson et al 2012).

Like direct methods, indirect anthropometry has its advantages. This methodological approach requires a shorter examination time, is less dependent on the examinee's behavior, and is accomplished using a simple measuring technique (Farkas and Deutsch 1996: 2, Haroun et al 2010). Moreover, whereas children tend to become impatient when undergoing traditional direct examinations, the rapid assessment achieved via some forms of indirect anthropometry become more effective among the youth and those subjects with disabilities (Weinberg et al 2006: 478). Indirect methods are also noninvasive, and their reliance on digital technology allows for images containing anthropometric measures to be digitally archived. Most importantly, the use of digital technology is considered an effective way to obtain precise and reliable measures, whereas measures obtained by anthropometrists, who practice direct methodology, may be subject to greater inconsistencies and measurement error (Wong et al 2008: 233).

However, although there are advantages to using indirect anthropometry, there are also drawbacks. Its reliance on technology inhibits its use in regions where electricity is highly volatile. This becomes problematic for health researchers such as medical anthropologists who study diverse populations, some of which come from developing nations or highly rural areas that may suffer from periodic electrical outages. Moreover, some indirect methods, such as cephalometry, emit radiation that may be deleterious to examinees, which make multiple screenings that need to be conducted infeasible (Wong et al 2008, Park et al 2006). Also, despite the fact that BIA is inexpensive, the standard prediction equations derived from this method have not been rigorously validated on non-white ethnic groups (Haroun et al 2010: 1253). In addition, although laser scanning has great precision, image capture is time-consuming; this may not be an issue for an anthropometrist working with skeletal human remains; however, living subjects, particularly children and the disabled, may find it difficult to maintain the same stance for an extended period of time (Wong et al 2008: 233). Also, some indirect anthropometric methods, particularly those that use medical imaging equipment, can be very expensive to implement (Wong et al 2008). Furthermore, many indirect methods do not capture hair, which may be an important physical landmark in body image research, particularly when hair grooming, texure and styling is central to overall body satisfaction. Moreover, very few methods have utilized handheld technology, and those that do, are primarily used to measure craniofacial morphology, rather than the whole body (Park et al 2006). This too can prove limiting for health researchers who must have mobility in order to conduct their work in various sociocultural contexts.

Since many indirect methods were not initially created to measure the full body, particularly body composition, *The Body Benchmark Study* was a global collaborative study launched in 2007 to investigate if three-dimensional body scanners were more effective as screening tools than the BMI in biomedical weight assessment (Hussain 2011). In particular, the scanners would calculate an individual's total body volume and segmental volume, and this would help establish the Body Volume Index (BVI), which has, "the potential to be used as a long-term computer based anthropometric measurement for health care" (Hussain 2011: 10). The BVI was officially launched in 2010 as an improved anthropometric measurement for healthcare and obesity predictability; in particular, it would use, "a 3D scanner as opposed to manual measurement…to calculate risk factors associated with a person's body shape and type, through analysis of weight and body fat distribution" (bodyvolume.com). The BVI has emerged in response to a global technological culture, and is designed to eventually replace the BMI. However, it too has a drawback. Although the BMI has glaring limitations, it is an anthropometric method that can be performed using either direct or indirect methods, which allows it to be performed anywhere, and under various environmental conditions.

In contrast, BVI scanners are full-bodied and incapable of being portable. Unfortunately, this presents a dilemma for health researchers and clinicians who would like to integrate this more precise and accurate index into their work. Even though it arose out of a global technical culture, its very design makes it inaccessible to certain regions, countries, and demographics. Although it has come a far way from the racial anthropometry of the nineteenth century, if it supplants the BMI in its current state, the BVI will disenfranchise certain people from efficacious health care and obesity screenings, while privileging others—namely those in developed nations that have regular access to health services, and reliable electricity that can sustain a BVI scanning facility.

Indirect Anthropometry Using Handheld Technology

Within health research and clinical practice, there is a need for more anthropometric studies that integrate handheld technology. Reason being, although technology is as a powerful tool in anthropometric research, most indirect innovations, like the Body Volume Index, requires expensive full-bodied scanning technology. This thesis project aims to help address the lack of handheld technology in indirect anthropometry used for body image and obesity research and in clinical practice. In particular, this project tests the efficacy of traditional direct methods and indirect methods using handheld technology on ten African American and Afro-Caribbean women living in Florida. This demographic was purposively chosen, because obesity is prevalent among black women, and their ethnic-specific body ideals are not fully captured by 2D shape charts (Ogden et al 2006). The following section provides an overview of the methodology used during this project.

METHODOLOGY

To test direct anthropometry against indirect methods using handheld technology, the study primarily took place in Central Florida among ten African American (6) and Afro-Caribbean women (4). The project was informed by a research design and methodology commonly used within the field of medical anthropology. The study is broken down into three major stages.

STAGE I: Participant Recruitment and Ethnographic Interviews

The first stage involved recruiting a purposive sample of black women of various body sizes and shapes from local churches, universities, family, friends, and online social networking sites (SNSs) (Table 1).

EXAMINEE DEMOGRAPHICS					
ID	Age	Ethnicity	Occupation	Married	Children
DH0218	28	African American	Lab Technician	No	0
MB0814	27	Jamaican	Self-Employed	Yes	0
MN1129	18	Bahamian	College Student	No	0
VO0720	50	Bahamian	Medical Assistant	Yes	1
SS1111	26	Jamaican	Medical Student	No	0
YG1026	34	African American	Teacher	No	0
EH0124	48	African American	Material Handler	Yes	1
BE0306	60	African American	Certified Nurse Assistant	No	2
RV0212	42	African American	Registered Nurse	Yes	2
CM0703	36	African American	Attorney	No	0

Table 1. Ethnographic observation, interviews, and anthropometric exams were conducted among ten women of African Descent living in Central Florida.

Purposive sampling, as opposed to random sampling, was a more appropriate method for recruiting participants, because such samples are widely used in: "(1) pilot studies, (2) intensive case studies, (3) critical case studies, and (4) studies of hard-to-find populations" (Bernard 2011: 145). This project is an intensive case qualitative study that is not making generalizations across populations, but rather is rigorously testing and comparing multiple anthropometric measures on each examinee, which makes this form of sampling methodologically appropriate. Moreover, the small sample size is appropriate, because anthropological research indicates that 10-20, and even a sample size as small as 6, can be enough to, "uncover and understand the core categories in any well-defined cultural domain or study of lived experience" (Bernard 2011: 154). It is important to note that this research project is not only relying on the raw anthropometric data to determine which method is most effective; rather, as the abovementioned section indicates, any method used must take into consideration the examinee's behavioral response to that method in order to gauge its effectiveness. This small sample was appropriate, because it allowed the researcher to conduct not only multiple anthropometric examinations across methods, but it allowed for in-depth participant observation and interviews with examinees to capture their phenomenological experience during the examination. The phenomenological component of the project is critical, because much of the research on indirect methodological efficacy is focused on ways to improve the technology and limit human interaction rather than improve the human *experience* with the technology that is being used.

During examinations, unstructured interviews were conducted to learn how examinees perceived their bodies and overall health. Participants were also asked to openly share with the researcher their feelings about the current examination they were undergoing that involved both indirect and direct anthropometry. Preceding the examination, a survey was administered to participants, which lasted between 15-20 minutes. Each woman was asked to provide demographical information, along with their current lifestyle and exercise habits, and any weight-related medical conditions they may have (e.g. high blood pressure, diabetes, body image disorders, or any other health conditions related to body shape and weight). This survey was administered to help socioculturally situate the anthropometric data, and to determine whether body type or size (i.e. apples and hourglass versus obese or normal weight) is considered a more accurate measure for disease risk predictability. Responses to the survey and unstructured interview were partially recorded in an excel spreadsheet, and all files were assigned a code number and were password-protected for security purposes.

STAGE II: Traditional Direct Anthropometry Measures

Seventeen measures were collected from each examinee. These measurements included: (1) body mass (kg), (2) stretch stature (cm), (3) triceps (mm), (4) subscapular (mm), (5) biceps (mm), (6) iliac crest (mm), (7) supraspinale (mm), (8) abdominal (mm), (9) front thigh (mm), (10) medial calf (mm), (11) arm girth relaxed (cm), (12) arm girth flexed and tensed (cm), (13) waist girth (min.)(cm), (14) gluteal girth (max.)(cm), (15) calf girth (max.)(cm), (16) biepicondylar humerus (cm), and (17) biepicondylar femur (cm) (Figure 1).

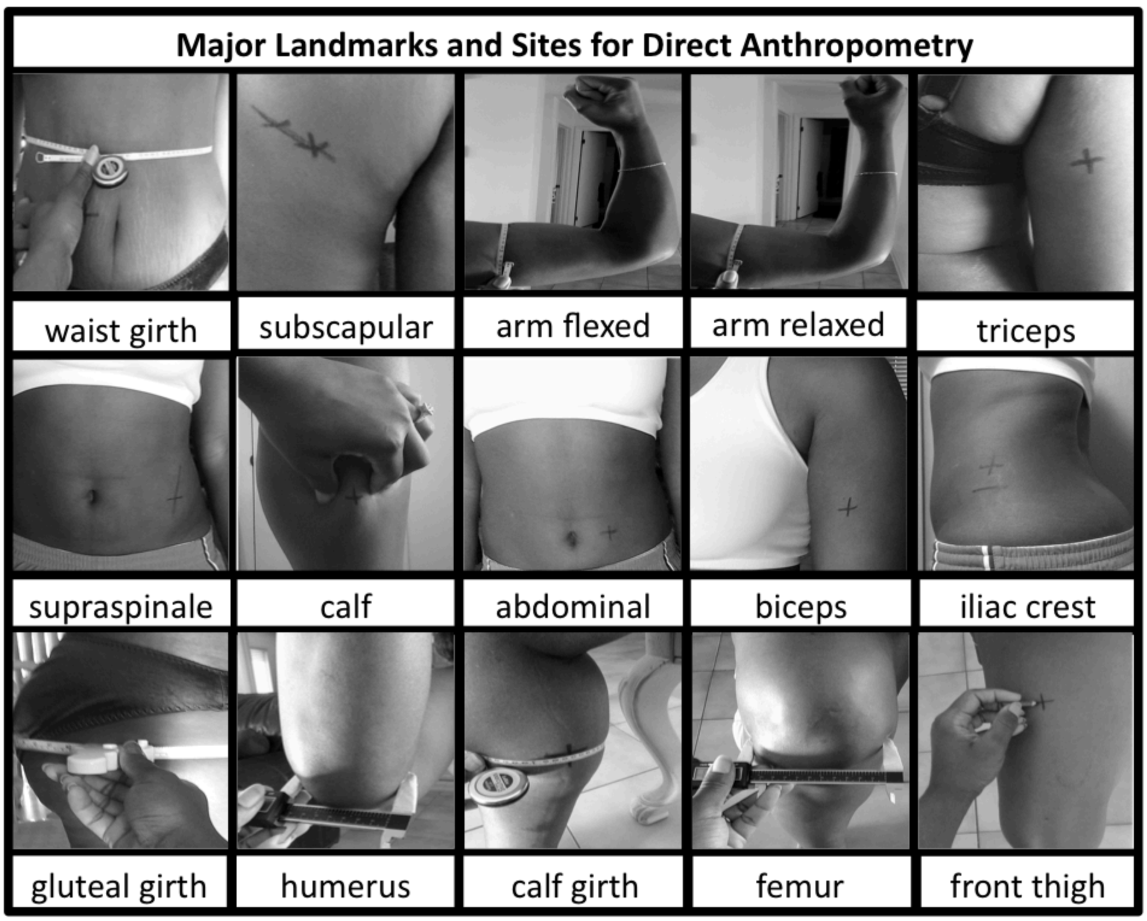


Figure 1. These are the major landmarks and sites used in direct anthropometry for the body. Note: body mass and stature are not included.

This collection of direct measures was broken down into 2 basic measures (*weight and stature*) 8 skinfolds (*triceps, subscapular, biceps, iliac crest, supraspinale, abdominal,* *front thigh, and calf*), 2 bone breadths (*humerus and femur*), and 5 girths (*arm relaxed & flexed, waist, gluteal, and calf*) (ISAK 2001). All sites were measured twice on one side of the body, excluding weight and stature, so as not to exceed 5% technical error of measurement (TEM) (ISAK 2001, Nevill 2006). Since measurements were taken twice, less stature and body mass, direct measures totaled 320. The percentage of body fat (%BF) was then calculated using the ISAK recommended Yuhasz Method, which is *%BF = (.1548 x sum of all skinfolds (minus biceps and iliac crest) + 3.580)* (Yuhasz 1974). This %BF derived from direct methods was then compared to each participant's BMI and waist-to-height ratio (WHtR), or waist girth divided by stature. Body size and body shape categories were derived from each measure, and any discrepancies were recorded (see Table 6). Slim Guide skinfold calipers were used to measure skinfolds, a Lufkin measuring tape was used for stature, a home scale measured body mass, Lufkin W606PM tape and MyoTapes measured girths, and a small sliding caliper was used for bone breadths; all equipment was properly calibrated prior to examinations.

Direct anthropometric data was collected using the standardization methods created by the International Society for the Advancement of Kinanthropometry (ISAK 2001). The researcher underwent ISAK anthropometric training in the Summer of 2012. All participants were asked to disrobe down to their undergarments; however, sports bras and shorts were also permitted. All measurements for each participant were recorded using an excel spreadsheet.

STAGE III: Indirect Anthropometric Measurements

After participants have been measured using direct anthropometry, their bodies were scanned using a Microsoft Kinect SDK. Microsoft Kinect is an active depth-sensing camera, which allows 3D body shape reconstructions to be obtained, “by combining multiple monocular views of a person moving in front of the sensor” (Weiss et al 2013: 99). To conduct indirect anthropometry using the Microsoft Kinect, a customized Kinesthetic Three-Dimensional toolset (K3D) was used to generate 3D avatars for each participant (Barmpoutis 2013). Body scans were digitally archived, and accompanied measurements were later exported into Microsoft Excel. To perform the body scan, participants were asked to stand in front of the Microsoft Kinect until they saw their 3D image from the neck down on the computer screen. To activate the camera, participants raised their left hands. Participants moved their bodies slightly in front of the camera to fill out their avatars, and they then raised their right hands to deactivate the Kinect. Each avatar was saved in a folder as a .wrl file. The shape of each avatar was captured in wireframe mode, and a screenshot was taken of each examinee (Figure 2).

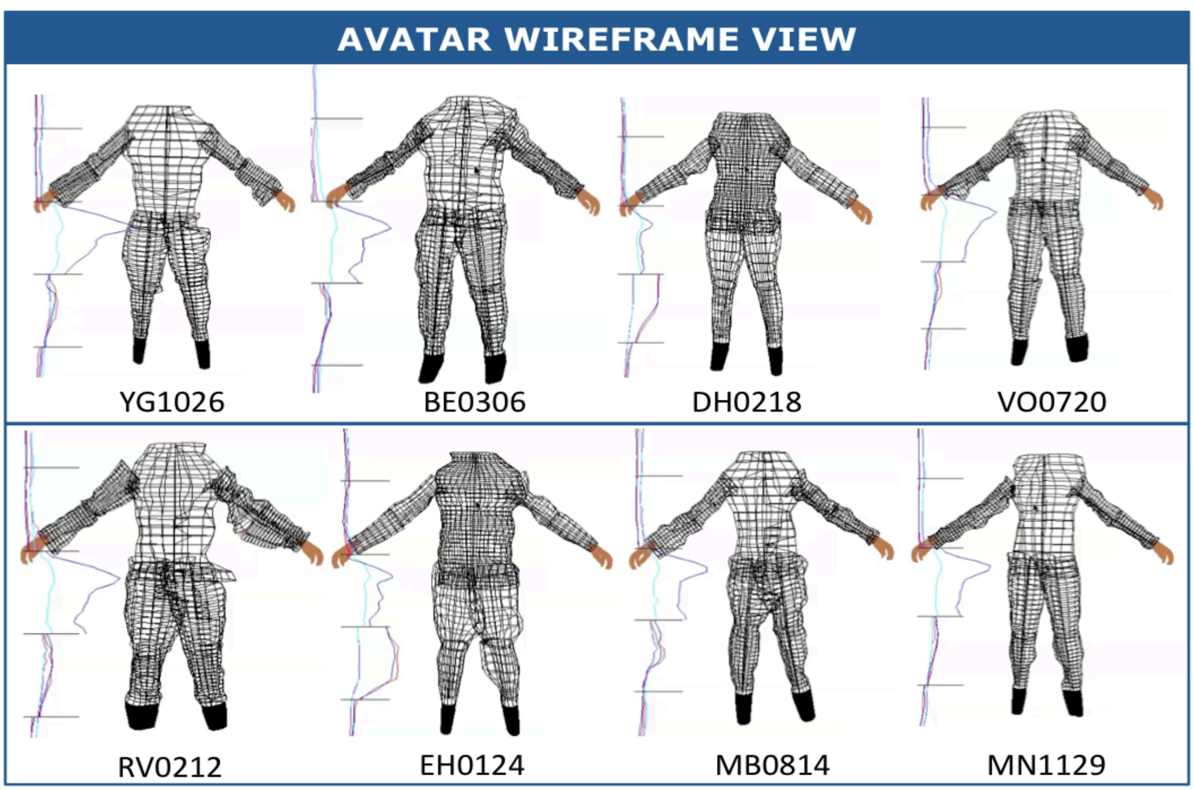


Figure 2. Body scans were created with Kinect and K3D software. Each edge loop corresponds with a perimeter value. Volume is calculated for the area between edge loops. Note: some avatars have more edge loops than others.

The perimeter and volume for each body scan was saved as .txt files. For each .txt file, nine measurements were automatically generated: (1) torso, (2) left arm, (3) left forearm, (4) right arm, (5) right forearm, (6) left thigh, (7) left leg, (8) right thigh, and (9) right leg. This totaled 18 indirect measurement groups for each participant. All perimeter measures were in meters, and all volume measurements were in liters. Although ten women were scanned, two wished to withdraw their scanned images, and only have their direct measures included in the study. Consequently, a total of ten women were measured using direct methods, and eight of their indirect measures are analyzed in this study.

RESULTS

Direct Measurements

On average, each examination took thirty-five minutes to complete. In particular, the marking of sites took approximately six to ten minutes; the first examination took roughly twelve minutes, and then the second examination took an additional ten to twelve minutes. The amount of time it took to complete a direct anthropometric exam correctly was very time consuming, comparable to the indirect method that followed. This time constraint became even more pronounced among older participants who suffered from arthritic pain. The following tables provide the average of the two examinations.

Table 2. **Direct Anthropometric Measures** Sites 1 – 5					
ID	**Body Mass** (lb)	**Height** (in)	**Triceps** (mm)	**Subscapular** (mm)	**Biceps** (mm)
DH0218	140	65.25	20.5	23	12.5
MB0814	168	68	26	23.5	8.5
MN1129	150	67.75	27	19	12
VO0720	179	67	23	21	16
SS1111	119	63	23	22	9.5
YG1026	174	60.75	32	37.5	22.5
EH0124	231	69.75	42.5	47.5	38.5
BE0306	173	63.5	34	50.5	29
RV0212	205	64.75	39	37.5	43
CM0703	287	64.38	43	52	31

Table 3. **Direct Anthropometric Measures** Sites 6 – 11						
ID	**Iliac Crest** (mm)	**Supraspinale** (mm)	**Abdominal** (mm)	**Front Thigh** (mm)	**Medial Calf** (mm)	**Arm Girth relaxed** (cm)
DH0218	27	13	30.5	37	23.5	27
MB0814	24.5	11	26	40	22	32
MN1129	20.5	19.5	23.5	44.5	27	33.5
VO0720	31	16	28.5	48.5	28	33.5
SS1111	24	20	25	35	19	30
YG1026	41.5	33.5	36.5	37	33.5	33.5
EH0124	48	27.5	37	37.5	40	39
BE0306	32	28	38	61	31	35.5
RV0212	44	27	24	75	27.5	34
CM0703	52	35.5	52.5	79	52	44

Table 4. **Direct Anthropometric Measures** (Sites 12-17)						
ID	**Arm Girth** Flexed (cm)	**Waist Girth** (min)(cm)	**Gluteal Girth** (max)(cm)	**Calf Girth** (max)(cm)	**Biepicondylar** Humerus (cm)	**Biepicondylar** Femur (cm)
DH0218	28	74.5	96.5	34.5	6.3	8.2
MB0814	33	75.5	101.5	40	6.3	9.3
MN1129	34.4	78	86	40	6.2	9.6
VO0720	34	82	110.5	44.5	7.8	10.9
SS1111	30.5	76.6	89.5	37.5	5.8	8.3
YG1026	34.5	84.5	110	38.5	6.4	10.2
EH0124	39.5	100	123	39.5	7.6	10.7
BE0306	37.5	101	105.4	38.5	7.5	8.5
RV0212	35	98.5	123.5	39.5	6.9	10
CM0703	45	111	134	51.5	7.2	11.4

Although the direct method was very time consuming, it produced information that the indirect method using the Kinect simply could not do. For example, to measure bone breadth, an anthropometrist must feel for certain indentations between and or on bone before positioning the sliding caliper. Moreover, skinfolds require that the examiner pinch the skin and subcutaneous fat using a caliper. 3D technology that only scans the surface of the body cannot perform this. Consequently, such human-to-human contact is an essential prerequisite for an accurate bone breadth or skinfold measurement to be obtained. Moreover, although a second examination prolongs the anthropometric screening, it increases the precision of measurements by accounting for the technical error of measurement.

Indirect Measurements

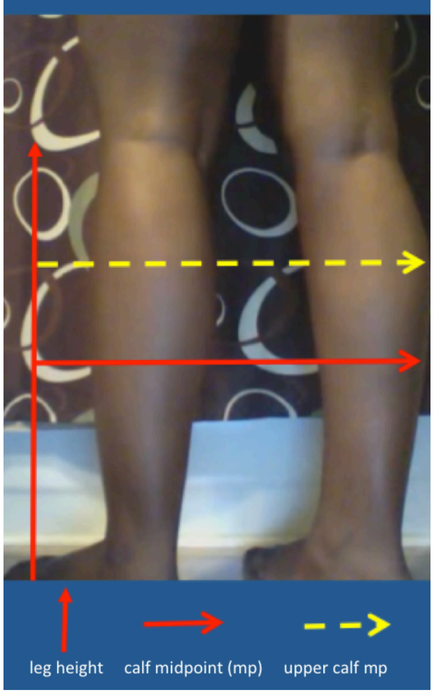
In contrast, whereas the direct methods took on average thirty-five minutes to complete, once the Microsoft Kinect was properly setup, the body scan took anywhere between a few seconds to five minutes. The reason why some indirect sessions took five minutes was because some participants were scanned as much as four or five times before a suitable avatar was generated. The brief time duration associated with this method was not surprising, since much of the literature substantiates that indirect anthropometric methods have a shorter duration than direct anthropometric examinations. The following table provides the actual measurements derived from this method:

Indirect Anthropometric Measures					
ID	**Avatar Volume** (L)	**Torso Volume** (L)	**Calf Girth** (m)	**Arm Girth (relaxed)** (m)	**Waist Girth** (m)
DH0218	38.22	33.72	0.35	0.26	0.80
MB0814	18.42	8.06	0.44	0.29	0.79
MN1129	16.68	8.20	0.38	0.23	0.84
RV0212	19.6	9.04	0.46	0.30	0.94
YG1026	18.26	9.48	0.33	0.27	0.97
VO0720	9.30	9.2	0.41	0.32	0.96
BE0306	15.54	7.86	0.36	0.28	0.87
EH0124	50.68	45.06	0.35	0.24	0.101

Table 5. These measures were directly derived from the volume.txt and perimeter.txt files for each avatar. Volumes were calculated by adding all area slices between edge loops together. Girths were approximated by taking the mode edge loop value of specific body areas.

It is important to note that the .txt files only provide values for the front half of the body, because K3D only scans the front of the body. Multiplying the anterior values by two approximates values for the posterior side of the body. After this was done, all volume values were derived by adding all of the numbers in the volume.txt file (for avatar volume), and the torso row (for torso volume). Girths used the perimeter.txt files. Within the .txt file, a number represents ½ the perimeter of each edge loop, and edge loops are arranged in rows from left to right; the left number represents the top of the body segment, and the number furthest to the right represents the number for the bottom of the segment. For example, for BE0306, the top of her left leg is the edge loop value furthest to the left in the .txt file (.22 m * 2 = .44m) and the bottom of her leg, near the ankle, is the value the furthest to the right (.15 m * 2 = .30m). An anatomical assessment of the human body confirms that the upper leg is wider than the lower leg.

Fig 3. Approximating Calf Girth (max)

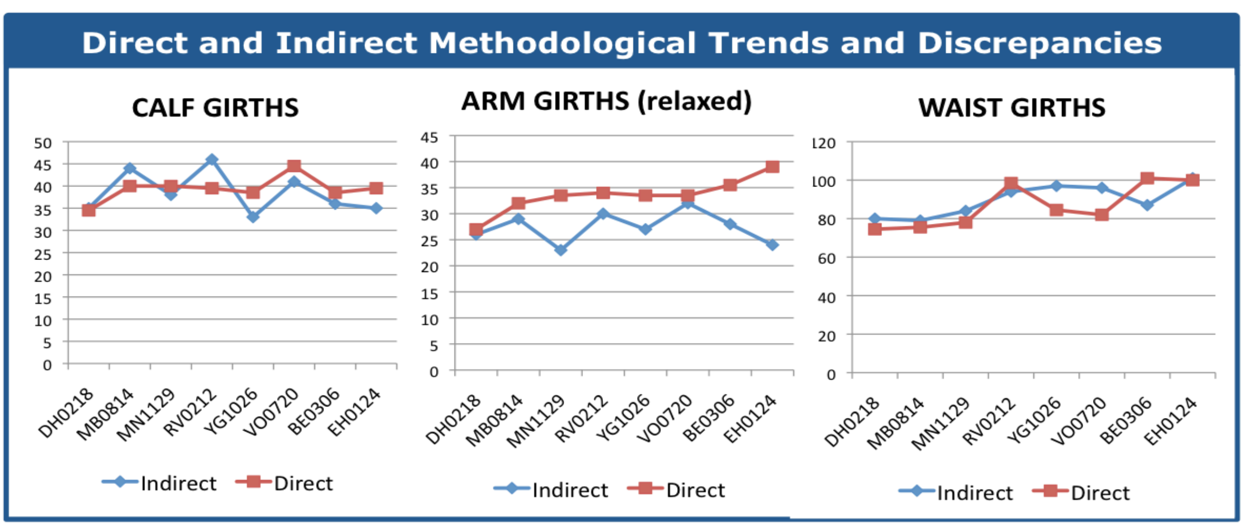


All girth measurements were calculated using the corrected perimenter.txt files for the legs (for calf girth), arms (arm girth relaxed), and torso (for waist girth). Since calf girth is taken at the maximum width of the calf, the following equation was used: calf girth = (Right Leg Q1)/2. Q1 represents the median of the first quadrant, or the midpoint (mp) of the upper calf. The values for edge loops are illustrated by a relative line and are not actually shown on the scanned image; instead, they are exported as .txt files. One can either manually count each individual loop (which is not very feasible), or approximate by exporting the .txt file into an excel spreadsheet, and multiplying all values by two to represent the fully body, rather than the anterior side only. Consequently, the Q1 of the right leg was the desired number, because the widest part of the calf is approximately located in the upper half of the leg (Figure 3).

Arm girth (relaxed) was calculated by taking the average of both the right and left arm median. The median (or middle number) rather than Q1 was the preferred measure, because the direct measure of the arm girth is taken at the midpoint of the superior part of the acromion border, to the proximal and lateral point of the radial head (ISAK 2001). In other words, arm girths are taken at the midpoint of the arm. The waist girth is taken at the most narrow point of the waist, and the median edge loop of the torso was the approximate measure used.

Comparing Direct and Indirect Measures

Indirect measures could not be generated for skinfolds or bone breadths, so waist, arm, and calf circumferences were the only measures that could be compared for each examinee (Graph 1).



Graph 1. Indirect measures were first converted to cm in order to compare girths. Notice how some indirect and direct values match, or have low TEM, while others diverge.

There was a huge technical error of measurement (TEM) between the indirect and direct methods used. As already mentioned, a good %TEM should be no greater than 5%; however, this general rule applies to checking the accuracy of the *intra-tester*; this is when one person performs both examinations. In this study's case, we take the average of the examiner's direct measurements and compare them to the indirect measures derived from the K3D body scans to calculate the *inter-tester %TEM*, or the error of measurement between exams performed by two separate examiners. A good inter-tester %TEM is 7.5%. However, both 5% and 7.5% is the maximum TEM allowed for skin folds. Other anthropometrical measures, like girths, require an inter-tester %TEM of 1.5% or less (ISAK 2001, Sicotte 2005: 3). %TEM was calculated by (1) finding the deviation (d) between the indirect and direct measures for a site on each individual, (2) taking the square root of the deviation (d^2), (3) summing all squared deviations ($\sum d^2$), and applying them to this equation: $\sqrt{}(\sum d^2 / 2n)$, where (n) equals the total number of examinees measured (Perini 2005, ISAK 2001). This results in the absolute TEM. To find the relative or %TEM, the variable average value (VAV or the *mean*) is first calculated by finding the average of the indirect and direct measures for the given site on each woman. Add the measurement averages for all women (8 total), and divide by 8. This final equation is used to find %TEM: [(absolute TEM/VAV)*100] (Perini et al 2005, ISAK 2001).

The calculated %TEM for calf girths, arm girths (relaxed), and waist girths was 7.4%, 17.7%, and 7.2% respectively. The corresponding absolute TEMs are 2.9 cm, 5.4 cm, and 6.4 cm. Based on these results, there was a greater relative technical error of measurement found among arm girths (relaxed), and waist girths had the least %TEM.

This major %TEM may signify that there are shortcomings in either one or both methods. Such a drastic discrepancy can either result from the examiner's inaccuracy during direct anthropometric exams, or the result of the Kinect and K3D software not fully or accurately capturing the examinee's body during the surface scan.

As already mentioned, the Kinect using the K3D toolset only captures the front of the person, while digitally approximating the posterior. Perimeter and volume files derived only account for the front of the scanned body, and are doubled to achieve an approximate 3D representation. However, this half-capture approach the K3D uses does not take into consideration that the front of the body is morphologically different than the back. This is why anthropometrists who use direct methods, when measuring the arm for example, take skin fold measures at the tricep and bicep sites. The half-capture approach also ignores morphological nuances that play a major role in accurately measuring girth. For example, when taking the direct measure of waist girth, a trained anthropometrist will be cognizant of the natural sloping of the back (Figure 4).

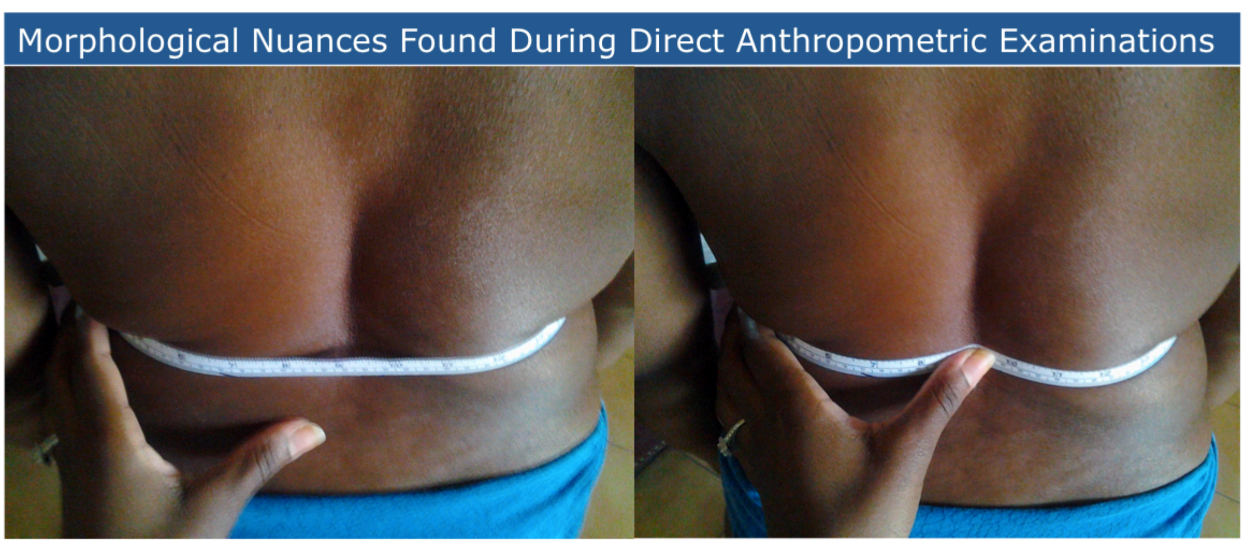


Figure 4. Anthropometrists who measure waist girth must account for the natural concaving of the lower back, normally by a placement of the thumb. Without this placement, waist circumferences will appear larger than they really are.

This half-capture approach also proves to be problematic, because body scans do not reflect body shape variation of examinees, particularly those who are well endowed in the gluteofemoral region of their bodies. Using this technique, women with well-endowed posteriors will intrinsically not have an accurate 3D representation of their bodies (Figure 5).

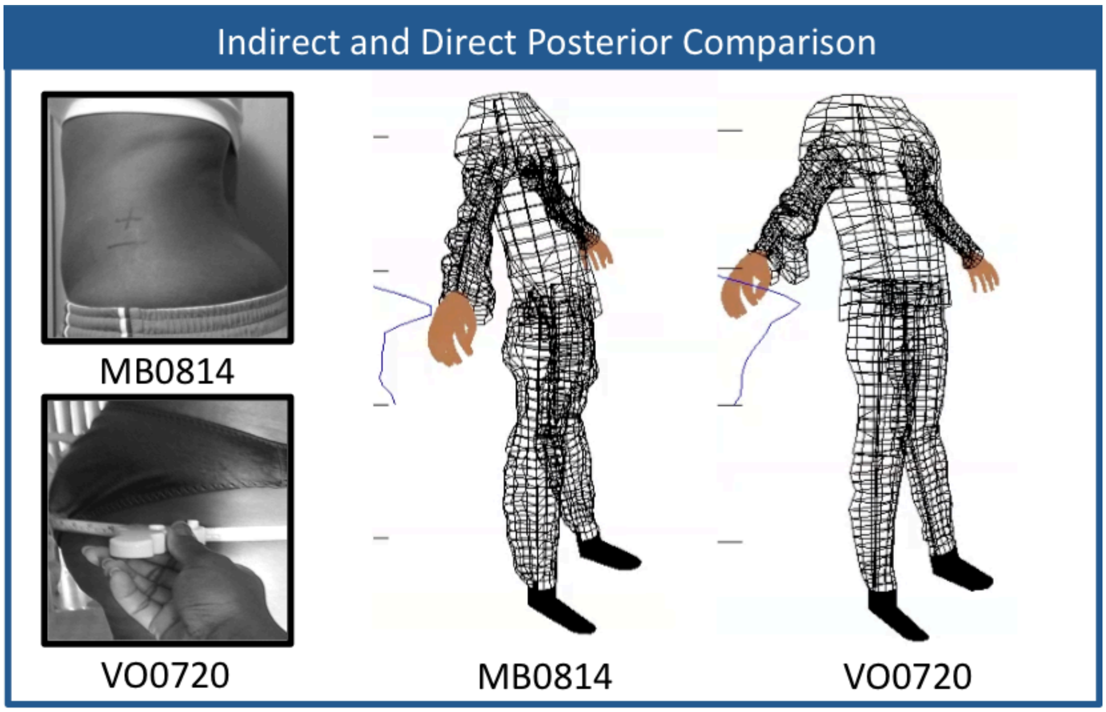


Figure 5. Direct measures provide a more accurate representation of the gluteofemoral region. This body area is critical when using anthropometry as a body image screening tool among individuals who come from cultures that prefer well-endowed posteriors.

However, the girths compared in Graph 1 do provide a unique opportunity to assess trends between methods, and point out possible outlier direct or indirect measurements within methods that would need to be measured again for increased validity. This would prove useful for anthropometrists who recognize the limitations of the current K3D software, but would like to perform a visual assessment of those measurements they knew were less than precise during examinations.

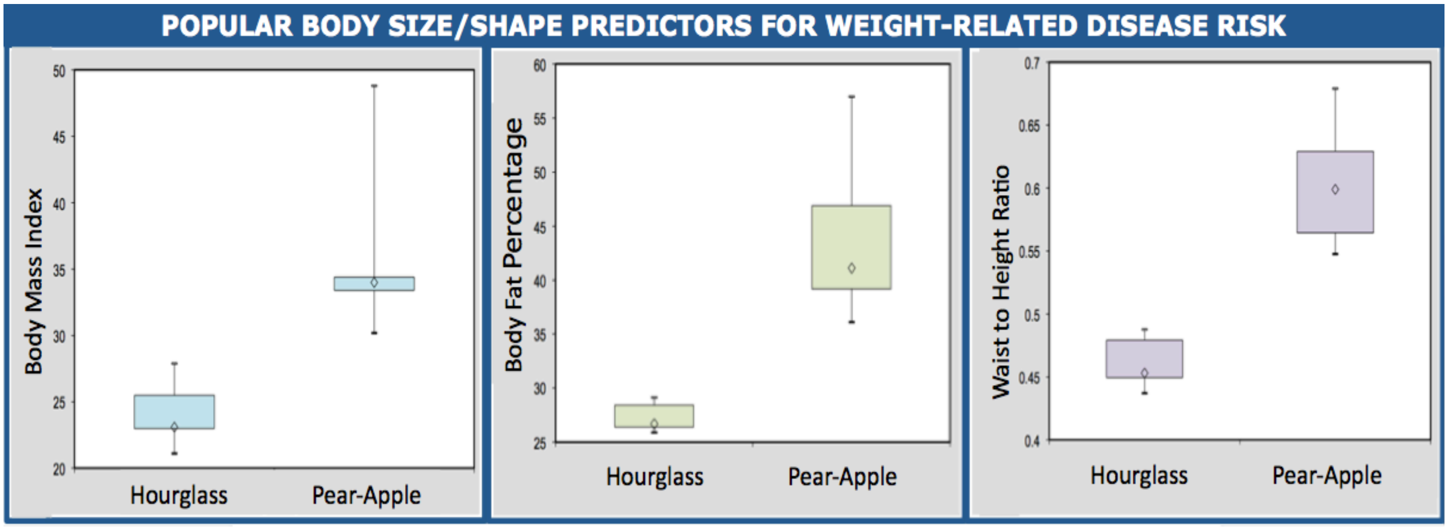
Determining Body Shape Using Indirect and Direct Anthropometry

Part of this research project aimed to evaluate which method would better inform body image charts and predict disease risk. To do this, the BMI, WHtR, and %BF were calculated from direct measures (Table 6). As already noted, the body mass index is not an accurate estimate for body shape or fat, because it only determines total body mass, and does not distinguish between total adiposity and fat free mass. The percentage of body fat (%BF) could not be used for comparison purposes, because skinfolds could not be obtained using indirect anthropometric measures. The WHtR was the only measure that could be used, because waist girths could be obtained using both methods. Graphs 2-4 illustrate how these predictors determine body shape and disease risk derived from direct measures. To compare WHtRs across methods, the direct measure for stature was used for both the body scan and actual examinee, because avatar height does not include the head (Figure 6).

Disease Risk across Body Size and Shape

ID	Shape	WHtR Category	WHtR	BMI Category	BMI	%BF Category	%BF	Exercise	HBP	Diabetes
DH0218	hourglass	healthy	0.4495	normal	23.1	acceptable	26.4	no	no	no
MB0814	hourglass	healthy	0.4371	overweight	25.5	acceptable	26.7	seldom	no	no
MN1129	hourglass	healthy	0.4532	normal	23	acceptable	28.4	yes	no	no
VO0720	hourglass	healthy	0.4877	overweight	27.9	acceptable	29.1	yes	yes	no
SS1111	hourglass	healthy	0.4793	normal	21.1	acceptable	25.9	yes	no	no
YG1026	pear	seriously overweight	0.5476	obese	34	obese	36.1	no	no	no
EH0124	pear	seriously overweight	0.5644	obese	33.4	obese	46.9	seldom	no	no
BE0306	apple	highly obese	0.629	obese	30.2	obese	41.1	no	yes	no
RV0212	apple	highly obese	0.5989	obese	34.4	obese	39.2	yes	no	no
CM0703	apple	highly obese	0.6789	obese	48.8	obese	57.0	yes	no	no

Table 6. WHtR, BMI, and %BF were calculated for each examinee. Level of activity was also documented, and common medical conditions associated with body weight and shape were reported.



Graphs 2-4. These boxplots illustrate the minimum, q1, medium, q3, and maximum values of the BMI, %BF, and WHtR for examinees distinguished by their body shapes. BMI between 18.5-24.9 is healthy, %BF between 25-31 is acceptable, and WHtR between .4-.5 is healthy. WHtR between .54 and .58 is considered seriously overweight. Values greater than these ranges are considered obese for their respective predictors.

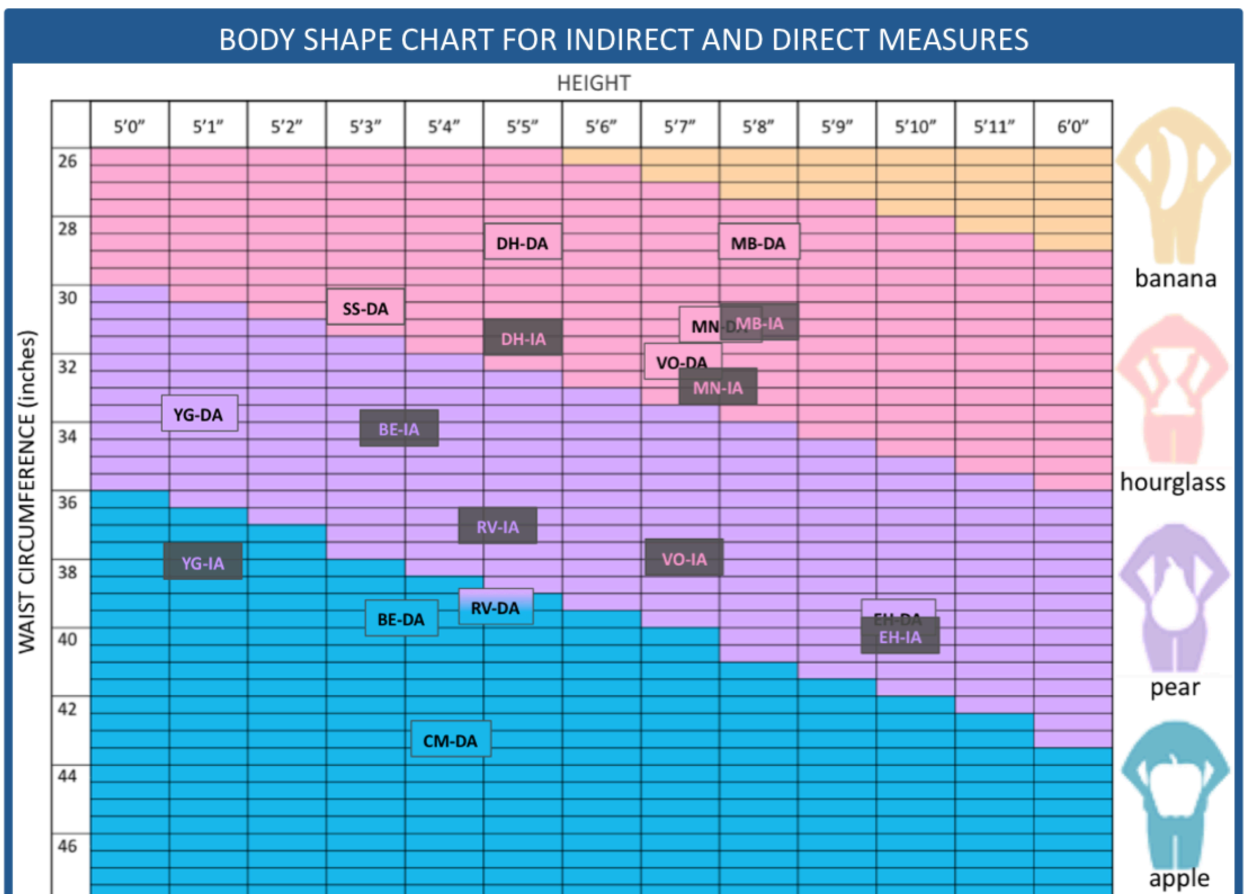


Figure 6: This body shape chart approximates body type and risk of weight-related illnesses by calculating the waist-to-height ratio (WHtR). WHtRs between .4 and .5 are normally within healthy range. Note: XX-DA/XX-IA are WHtRs derived from direct/indirect methods. Illustrations are adapted and taken from webmd.com.

As Table 6 shows, eight participants, including some who were obese, did not suffer from any weight-related medical conditions. Most women self-reported that they exercised regularly and led healthy lifestyles, which may indicate that their body shape/size and associated disease risk is predicated on genetics or some other extrinsic sociocultural factors. Based on Table 6, most women were classified as having an hourglass shape, including those who may be considered overweight by BMI standards. In contrast, women with pear shapes were generally considered to be either seriously overweight or obese. However, when viewing Figure 6, it can be noted that their WHtR scores from direct measuring fell below the median value associated with their height, which according to the Ashwell Shape Chart, would place them in the pear-apple range (Ashwell 87: 2011). There was an obesity classification consensus found across all predictors for women with apple shapes.

Moreover, although WHtR was the only predictor compared across methods, there was a strong correlation between it and BMI and %BF, particularly for obese women. When compared across methods, there was 50% consensus in WHtR ratios and body shape classifications. Of those women who were scanned, direct anthropometry classified four of them as hourglasses, but only three were classified as such using indirect methods. Also, direct measures categorized only two women as pears, whereas four were classified as pears with indirect methods. Finally whereas direct measures classifed only two scanned women as apples, only one is classified as an apple using indirect measures. In sum, four women (EH0124, MB0814, DH0218, and MN1129) had the same body shape classifications across methods. However, the other four (VO0720, YG1026, BE0306, and RV0212) had body shape discrepancies across anthropometric methods. Althogh VO0720’s discrepancy was quite significant, both methods placed here within the hourglass-pear range, which is considered a healthy body type. However, RV0212, has a pear-apply body type with direct measures, but a very distinct pear shape using indirect anthropometry. In contrast, YG1026 is classified as a medial pear using direct methods, and a marginal apple with indirect methods. Such discrepancies could be contingent on the high %TEM between both methods, or it could result from having a body shape chart that narrowly classifies the female body, by viewing body shape in mutually exclusive, rather than overlapping and highly diverse categories.

Indirect Anthropometric Rapid Assessment of Abdominal Obesity

The K3D software includes a useful difference-mapping tool that allows avatars to be compared to each other. This enables anthropometrists to metaphorically compare apples to oranges, or in this case, women with diverse body shapes. Much of the body image research indicates that apple body types generally deposit fat in their abdomens, which can lead to central (or abdominal) obesity and increased risk of metabolic syndrome (Shearer 2013). In contrast, women with pear shapes tend to accumulate fat deposits in the gluteofemoral region (e.g. the buttocks, hips, and thighs); research indicates that the latter fat distribution is indicative of greater fertility, fitness, and overall healthy (Cashda 2008). The hourglass is the only body shape, however, that tends to have an equal distribution of fat. Below are the results from the difference maps that compare apple, pear, and hourglass body types.

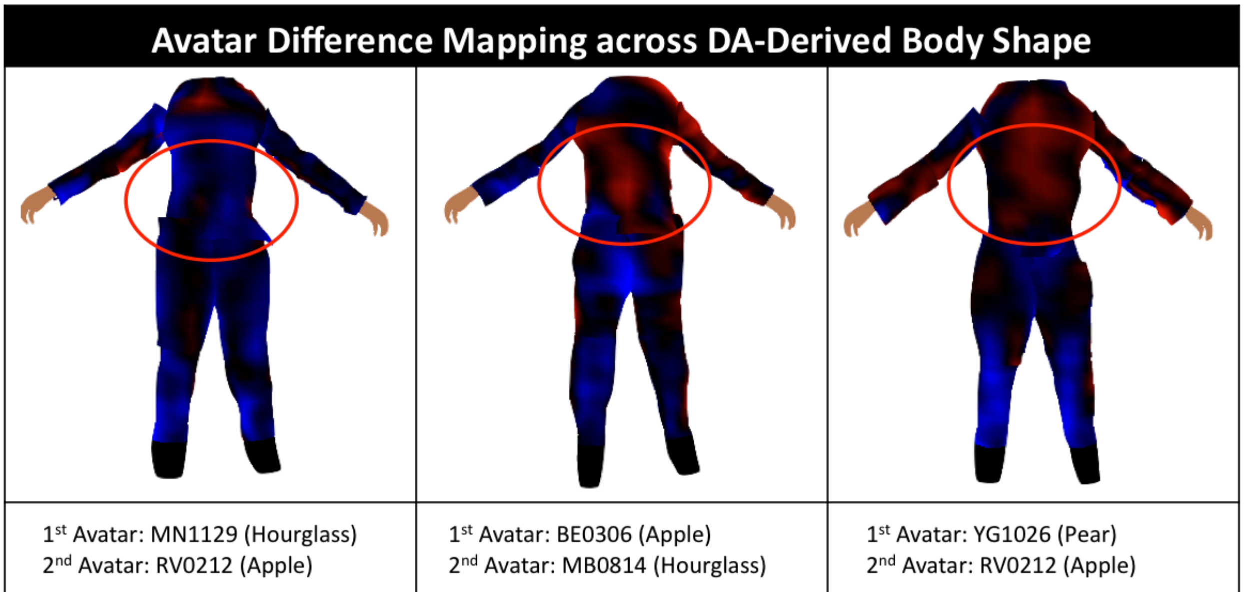


Figure 7. K3D software allows avatars to be compared. When difference texture mapping is shaded red, the first avatar is larger in that area. In contrast, when it is shaded blue, this signifies that the second avatar is larger.

The first two avatars illustrate that indeed women classified as having apple bodies have more central fat deposition than women with hourglass body types. Keep in mind, that RV0212 and BE0306 had body shape discrepancies across methods. However, by using the difference mapping there may be a stronger argument made for direct anthropometry, which classified both women as apple shaped. In contrast, the last avatar indicates that RV0212 has less abdominal adipose fat than pear shaped YG1026. This may be an indication that indirect methods were more precise with these measures. However, when viewing Table 5, YG1026 is classified as either being seriously overweight or obese, and RV0212 is classified as being obese across predictors. In Figure 6, there is a distinct classification shift for YG1026, whereas the discrepancy in RV0212 is smaller and takes place at the intersection of pear and apple classifications. It is important to note that when RV0212 is compared with a true hourglass, she is considered an apple; however, when she is compared with someone who also has a body shape discrepancy, she becomes a pear. Such discrepancies could have resulted from posterior-less body scans, or examiner inconsistency during direct screening. As previously mentioned, the body shape chart itself could have intrinsic flaws, or WHtR may not be a good tool for comparing women who are either seriously overweight or obese. There are many reasons for why this discrepancy may exist.

Notwithstanding, these three difference maps are a great way to assess and compare body shape and size. If the K3D software was further tweaked, it could capture more precise full-bodied scans. This would allow women of various body weights—who were directly measured and found to be true pear, hourglass, or apple body types—to become standardized avatars in clinical screenings. Clinicians trained in these indirect scanning methods could rapidly assess what body type range their patient falls within, and how close or far they deviate from the ideal range of fat distribution.

Participant Anthropometric Methodological Preferences

Based on the current indirect and direct anthropometric methods used, traditional direct anthropometry is a more effective tool than indirect anthropometry that uses handheld digital technology. Methodologically, this is primarily due to the fact that the K3D software only captures the anterior angle of the body, while digitally reconstructing the posterior. This skews findings, and make any measurements derived from such body scans questionable. However, in addition to method precision, it is important to understand the phenomenological experience of participants during anthropometric examinations in order to determine which method they preferred (Table 7).

EXAMINEE Preferred Methods			
ID	Age	Preferred Method	Examinee Thoughts
DH0218	28	Indirect	The body scan was way better because it only took a couple of seconds.
MB0814	27	Direct	The hands is what got me. I mean come on. I'm a brown-skinned sister, so why are my hands beige? Last time I checked, I am not white.
MN1129	18	Indirect	Getting scanned was a lot of fun, and it didn't take that long.
VO0720	50	Direct	I liked when you marked me. The image on the computer screen just didn't look like me. It made me look masculine, like a quarter back, a football player. It didn't make me look or feel like a woman.
SS1111	26	Direct	If I didn't see the scan, it'd be no big deal. But of course I want to see it. It's like taking a picture on facebook, you know? I wanna see what I look like before it goes out into the world.
YG1026	34	Direct	I prefer the body measurements for the sake of accuracy. It took longer, but the measurements are more precise because of that.
EH0124	48	none	It doesn't really matter. I was fine with either method.
BE0306	60	Direct	Working in the medical field made me appreciate the hands-on method. It's a lot of work, but it wasn't that bad, because we had good conversation.
RV0212	42	Indirect	I was kind of pissed that my avatar butt was flat. Look at me. You can see I'm a curvy woman. But having my fat pulled and pinched was the worst thing.
CM0703	36	Direct	It's all about being comfortable, and frankly I don't want my body saved and shown to God knows who. Even from the neck down, it's still my body.

Table 7. Participants had very diverse views about the indirect and direct anthropometric methods used. Most preferred traditional direct anthropometry as opposed to the indirect methods.

As Table 7 shows, 60% of participants preferred the traditional direct method. 30% preferred the indirect method, and 10% did not care. It is important to note that 2 of those who preferred the indirect method were younger than most women in the study. Although research purports that younger children are impatient with direct anthropometry, young adults may share this feeling. Those who preferred the direct method, however, crosscut all ages. Some women preferred the latter method because they believed it was a more accurate way of measuring the body. The oldest of the participants, BE0306, was not perturbed by the long duration, because she used the time to engage in conversation with the examiner. Lack of privacy was another reason for why some women preferred one method over the other. CM0703, for example, was uncomfortable with her body scan being archived indefinitely by the examiner. Even if it was a headless 3D representation of her actual self, she still claimed ownership of the image as her own body. In contrast, RV0212 felt like the direct examination intruded upon her personal space. The pulling and pinching of her body made her metaware of her “fat,” which made her extremely uncomfortable.

Many of the women who chose direct anthropometry as their preferred method did so because they were dissatisfied with the way they were portrayed using 3D technology. Some women felt that their body scans were not accurate representations of who they really were. MB0814 felt that the use of beige hands were not racially ambiguous, but showed preference for individuals with lighter skin. Similarly, VO0720 and RV0212 believed that their body scans stripped them of their curves and femininity. Finally, SS1111 compared her body scan experience to having a picture taken and uploaded to a social networking site (SNS). She wanted to share authority with the examiner in determining which scan, if any, is shown.

LIMITATIONS

Initially, this project intended to use the Artec Studio scanner, which has greater precision. However, the scanner was appropriate for only medium objects, which would have worked well for specific body areas, rather than full-body scans. Due to this limitation, the Kinect scanner was used as a substitute. However, the per-pixel depth resolution of the Kinect camera is one centimeter when the camera is positioned approximately 2 meters away (Wilson 2010). Moreover, the depth precision of the camera decreases as the examinee’s distance from the camera increases. This limitation in the camera’s depth precision may also play a role in the low level of precision of the indirect methods used.

During the conceptual phase of this project, body scans were going to be exported as .obj files to Maya, a 3D modeling software. The purpose of this exportation was to indirectly measure avatars using 3D modeling tools, and “tweak” them to have a more accurate representation of the participant. However, the researcher opted instead to use the K3D software’s built-in measurement tools that automatically assess the perimeter and volumes of each avatar; however, such actual measurements were only viewable by .txt file export, and were only represented as relative lines within the actual software. Moreover, Maya was not used to “tweak” avatars, because such remodeling would be contingent on the researcher’s artistic discretion and expertise. Remodeling avatars would have only resulted in a realistic vision, not replica, of actual participants and it would not have allowed for a direct comparison between indirect and direct methods.

The K3D software and Microsoft Kinect camera used to compare, measure, and archive the digital scans had several limitations. As already mentioned, the posterior side of participants could not be captured using this technology. Rather, the examiner had to rely on the software’s reconstruction of these areas. Consequently, most women with well-endowed buttocks had flatter posteriors in the accompanying scan. Moreover, the use of beige hands made the examination experience uncomfortable for some women. Many of the women who agreed to participate in the study had skin color that ranged in various shades of brown, and the lack of race-neutral colors to them was an indication that the technology had inherent bias.

As far as direct anthropometric methods, examinations were very time-consuming, and some of the equipment used, although ISAK approved, was not the most ideal instruments for measurement. For example, although ISAK has designated Slim Guide calipers as a tool to accurately measure skinfolds, the gold standard for skinfold measuring is the Harpenden caliper (ISAK 2001). This caliper was not used because it was too expensive and was outside of the examiner's budget. Although a trained anthropometrist can serve as both examiner and data recorder, having two anthropometrists, one examiner and one recorder, helps to increase precision and validity. Reason being, the recorder's role is, "to 'assist' the examiner in obtaining correct measurements" (NHANES 2007: 1-4). The recorder not only records the actual measurements as they are taken, but he or she helps position instruments on the examinee, and quickly identifies errors in measurement at sites that need to be measured again. In the case of this study, the researcher acted as both examiner and recorder. Moreover, although this project did not need a large sample size, more participants could have enriched the data collected. In future research, a larger sample could be used to make generalizations, some thing this study could not do.

DISCUSSION

From its early use within the United States, anthropometry has been both praised and contested as a tool for measuring body composition. In anthropometry's developmental phase, anthropologists both thwarted and furthered the ideological belief that race was biological, rather than constructed by one's own material and social environment. However, more anthropometric research reinforces the reality that race is a social construct and our physical difference is more indicative of our body's response to environmental change. Physical difference is not only found between socially constructed races or ethnicities, but as this study has shown, it is found within them.

Morphological variation does not only happen on a population level, but it occurs between individuals. Such individual difference provides the opportunity to understand how different people experience and interact with different anthropometric methods. For example, how efficacious are direct or indirect anthropometric methods that are precise, but leave individuals feeling invisible, unfeminine, or “fat”? What criterion do we as anthropometrists use to determine methodological efficacy—the method, the person, or both?

Certainly, methods can be determined to be effective based on precision and validity, but if integrated into clinical settings, will it cultivate or exacerbate the clinician-patient relationship? Will patients be more or less compliant with follow-up examinations or receptive to advice, given their initial experience? Perhaps some individuals like YG1026 are most concerned with their examination’s accuracy, which could provide them with deeper insight into their bodily health. Indeed, greater precision leads to a more accurate virtual representation of the body. This reality resonated with most participants, and is why direct anthropometry is considered their preferred form of examination, and is considered a more effective tool of measurement. Consequently, this study argues that both the person and technology are fundamental to assessing the efficacy of direct and indirect anthropometric methods.

Even though the indirect method used in this study was not as effective as the direct anthropometric methods, due to its half-capture approach, there is room for improvement and future application. Capturing a full 3D representation of the body would allow body scans to be measured against measures derived from direct anthropometry, because it would take into consideration morphological nuances and diversity. It would also make the difference-mapping feature in the K3D software a powerful tool in clinical practice, research, and education. Anthropometric exam simulations could be conducted on interactive 3D avatars as opposed to real humans. Students within the health field who use anthropometry could identify major landmark sites, and perform various direct measures indirectly. If avatars can be animated, students could also be tested on their cultural competency and interaction with the examinee. Furthermore, proponents of 3D body image charts, that assess body shape, size, and disease risk, would have a stronger platform to argue against 2D charts that fail to capture fat depositions in healthy areas (i.e. the gluteofemoral region). If the K3D software can capture the posterior angle of individuals, and take into consideration the individual’s phenomenological experience, it could become a very powerful anthropometric screening tool that could be just as effective, if not more so, than direct anthropometry.

BIBLIOGRAPHY

Ashwell, Margaret.
2011 "Shape: The Waist-to-Height Ratio is a Good, Simple Screening Tool for Cardiometabolic Risk." *Nutrition Today* 46(2): 85-89.

Baker, Lee.
1998 *From Savage to Negro*. Berkeley: University of California Press.

Barmpoutis, Angelos.
2013 "Automated Human Avatar Synthesis for Obesity Control using Low-Cost Depth Cameras." *Stud. Health Technol. Inform.* 184: 36-42.

Bernard, Russell H.
2011 *Research Methods in Anthropology: Qualitative and Quantitative Approaches 5th Edition*. Lanham: AltaMira Press.

Boas, Franz.
1899 "Anthropometry of Shoshonean Tribes." *American Anthropologist, New Series* 1(4): 751-758.

BodyVolume.com
2013 "Body Volume Index." *Bodyvolume.com*. website.

Burkhauser, Richard and John Cawley.
2008 "Beyond BMI: The value of more accurate measures of fatness and obesity in social science research." *Journal of Health Economics* 27: 519-529.

Cashda, Elizabeth.
2008 "Waist-to-Hip Ratio across Cultures: Trade-Offs between Androgen- and Estrogen-Dependent Traits." *Current Anthropology* 49(6): 1099-1107.

Collins, K.J. and J.S. Weiner.
1977 *Human Adaptability: A History and Compendium of Research*. London: Taylor and Francis.

Daniels, Stephen.
2009 "The Use of BMI in the Clinical Setting." *Pediatrics* 124(1): S35-S41.

Eveleth, P.B. and J.M. Tanner.
1990 *Worldwide Variation in Human Growth. 2nd Ed*. Cambridge: Cambridge University Press.

Farkas, Leslie and Curtis Deutsch.
1996 "Anthropometric Determination of Craniofacial Morphology."

American Journal of Medical Genetics 65:1-4.

Farmer, Paul.
2001 *Infections and Inequalities: The Modern Plagues*. Berkeley: University of California Press.

Fourie, Zacharias et al.
2011 "Evaluation of anthropometric accuracy and reliability using different three-dimensional scanning systems." *Forensic Science International* 207(1-3): 127-134.

Gershenhorn, Jerry.
2004 *Melville J Herskovits: And the Racial Politics of Knowledge.* Lincoln: U of Nebraska Press.

Gravlee, Clarence.
2009 "How Race Becomes Biology: Embodiment of Social Inequality*." American Journal of Physical Anthropology* 139: 47-57.

Gulbas, Lauren.
2012 "Embodying Racism: Race, Rhinoplasty, and Self-Esteem in Venezuela." *Qualitative Health Research* 1-10.

Hamdy, Osama, Sriurai Porramatikul, and Ebaa Al-Ozairi.
2006 "Metabolic Obesity: The Paradox Between Visceral and Subcutaneous Fat." *Current Diabetes Review* 2(4): 1 – 7.

Haroun, Dalia et al.
2010 "Validation of Bioelectrical Impedance Analysis in Adolescents Across Different Ethnic Groups." *Obesity* 18(6): 1252-1259.

Herskovits, Melville.
1932 "Negro Year Book: An Annual Encyclopedia of the Negro, 1931-1932." American Anthropologist, New Series 34(3): 528-530.

Hussain, Tahir.
2011 *Anthropometry in Physical Education and Sports*. New Delhi: Sports Publication.

International Society for the Advancement of Kinanthropometry (ISAK).
2001 *International Standards for Anthropometric Assessment*. Australia: ISAK

Karisson, Ann-Katrine et al.
2012 "Measurements of total and regional body composition in preschool children: a comparison of MRI, DXA, and anthropometric data." *Obesity*. Accepted Article: 1-26.

Krieger, Nancy.
1999 "Embodying Inequality: A Review of Concepts, Measures, and Methods for Studying Health Consequences of Discrimination." *International Journal of Health Services* 29(2): 295-352.

Macfarlane, Duncan.
2007 "Can bioelectrical impedance monitors be used to accurately estimate body fat in Chinese adults?" *Asia Pac J Clin Nutr* 16(1): 66-73.

National Health and Nutrition Examination Survey (NHANES)
2007 "Anthropometry Procedures Manual." Center for Disease Control.

Nevill, Alan, Arthur Steward, Tim Olds, and Roger Holder.
2005 "Relationship Between Adiposity and Body Size Reveal Limitations of BMI." *American Journal of Physical Anthropology* 129: 151-156.

Ogden, Cynthia et al.
2006 "Prevalence of Overweight and Obesity in the United States, 1999-2004." *The Journal of the American Medical Association* 295(13): 1549-1555.

Park, Hyun Jae.
2012 "Correlation between Direct Anthropometry and Di3D Camera System." *Journal of Hard Tissue Biology* 21(1): 87-92.

Park, Hee-Kyung et al.
2006 "Use of hand-held laser scanning in the assessment of craniometry." *Forensic Science International* 160: 200-206.

Perini, Talita et al.
2005 "Technical error of measurement in anthropometry." *Rev Bras Med Esporte* 11(1): 81-85.

Relethford, John.
2010 *The Human Species: An Introduction to Biological Anthropology.* New York: McGraw Hill.

Shearer, E.S.
2013 "Obesity anesthesia: the angers of being an apple." *British Journal of Anesthesia* 110(2): 172-174.

Sicotte, Maryline et al.
2010 "Reliability of anthropometric measures in a longitudinal cohort of patients initiating ART in West Africa." *Medical Research Methodology* 10(102): 1-9.

Ulijaszek, Stanley and John Komlos.
2010 "From a History of Anthropometry to Anthropometric History." *Human Variation: From the Laboratory to the Field*. CG Nicholas Mascie-Taylor, Akira Yasukouchi, Stanley Ulijaszek Eds. Boca Rotan: CRC Press. Pgs 183-198.

Weinberg et al.
2006 "Anthropometric Precision and Accuracy of Digital Three-Dimensional Photogrammetry: Comparing the Genex and 3dMD Imaging Systems with One Another and with Direct Anthropometry." *The Journal of Craniofacial Surgery* 17(3): 477-483.

Weiss, Alexander et al.
2013 "Home 3D Body Scans from a Single Kinect." *Consumer Depth Cameras for Computer Vision*. A. Foassati et al. eds pgs 99-117.

Wilson, Andrew.
2010 "Using a Depth Camera as a Touch Sensor." *Devices and Algorithms*. 69-72.

World Health Organization (WHO).
1995 *Physical Status: The Use and Interpretation of Anthropometry.* Report of a WHO Expert Committee Technical Report Series. Geneva: WHO.

Wong et al.
2008 "Validity and Reliability of Craniofacial Anthropometric Measurement of 3D Digital Photogrammetric Images." *Cleft-Palate-Craniofacial Journal* 45(3): 232-239.

Yuhasz, M.S.
1974 *Physical Fitness Manual*. London and Ontario: University of West Ontario.

BIOGRAPHICAL SKETCH

Brittany Osbourne is a PhD candidate specializing in medical anthropology at the University of Florida. She holds bachelor degrees in English and anthropology, and earned a Masters of Fine Arts in Creative Writing from the University of Central Florida. Her academic passions for anthropology and the arts have led her to study abroad in Ghana and Cambridge University, and present on her research at national academic and nonacademic conferences, as well as an international conference at the University of Lisbon in Portugal.

Since pursuing her PhD, Brittany has conducted workshops on body image and undergone rigorous ISAK anthropometric training at Princeton University. She has also served as a biometric screener in the Shands Employer Survey. Currently, she works as the assistant web editor for QualQuant.org, a site dedicated to social research methods funded by the National Science Foundation. When she finds time away from her studies, Brittany enjoys revising her MFA masters thesis novel, v/blogging about body image topics prevalent in the African Diaspora, participating in local and online community activism, spending quality time with her fiancé, family, and friends, and planning the day she jumps the broom with her future husband!