Determination Of Standard Reference Body Indices For Clinical Application In Ghana.

Issahaku Shirazu, Y. B Mensah, Cyril Schandorf, S. Y. Mensah

ABSTRACT: The study is tailored to measure body height and weight in order to estimate local base standard reference body surface area, body surface index and body mass index (BSA, BSI and BMI) in Ghana for clinical application. The data were collected based on age and gender variation of patients and compare the established standard reference body indices with international established estimates. The weight and BMI measuring machine together with tape measure were the measuring tools used. The procedure involve using BMI calculator with DuBois formula to estimate local standard reference values of BMI, BSI and BSA in Ghana. The height and weight of male were 178.6cm and 80.8kg, while female height and weight were 167.1cm and 61.9kg respectively. The determined Ghanaian standard reference estimated BMI, BSI and BSA were: 25.19kg/m^2 39.81 kg/m^2 and 2.02m^2 for male and 21.91kg/m^2 36.58kg/m^2 and 1.69m^2 for female respectively. Model relationship between these parameters has been designed to enable prediction of any unknown parameters if at least one is known. The reference height, weight, BMI, BSI and BSA are recommended to be used in Ghana for clinical application.

Key words: Body mass Index, Body surface area, Body surface index, Body height and body weight

OBJECTIVES

The aims of the study is to:

- Estimate local standard reference body height, body weight, body mass index, body surface index and body surface area for clinical application in Ghana.
- Compare the established body parameters with international recommendations and reference values and make appropriate recommendations.

1.0 INTRODUCTION

Body height and weight are the most common body indices that are measured during clinical body checkup together blood pressure (BP). These are done regularly to estimate human body condition in relation to adipose tissue deposit in the body. With these measurements the commonest indicator is the use of these two body parameters to estimate body mass index (BMI). A BMI scale provides information about whether an individual body weight is appropriate for the individual body height. These was first estimated by Belgian polymath **Adolphe Quetelet,** between **1796 and 1874** who devise a method to measure the body index during the course of developing social physics [1]. It was known as the Quetelet Index until it was termed the Body Mass Index in 1972 by Ancel Keys (1904–2004) [1].

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Since this development two other parameter has been developed to determine the relationship between body height and weight. The second measured relationship between height and weight is described as the surface area of human body. It is an estimated value that define the relationship between the average body size to the height and normal increases with increasing age. It has been define by various scientist, amount the definitions is the general accepted **Du Bois formula** which is generally used for clinical application [2]**.** However, the more theoretical general accepted formula is define as the sum of the square root of the height and weight divide by **sixty.** In addition, another important parameter describe as the body surface index, which is estimated by dividing the weight of the body by the body surface area. This second index is describe as a more precise indicator of body weight in relation to body surface area. One simple way by which the relationship between height and weight can be estimated is by the use of major axis regression analysis. In clinical application, the results of these analysis are modeled and coded in GUI that enable prediction of body height by using the measured weight on the patient couch without physically measuring the patient height. Establishing this relationship is important in the case of children and extremely sick patients, whose height cannot be determine directly by measurements. Additionally, the surface area of human body described the relationship between the average body size to the height and normal increases with increasing age. The estimated body surface area of human body is a measured total surface area of human body [6].

2.0 BASIC LITERATURE

A number of researchers have established a relationship between body height and weight. One such work is the research publication by Dorothy W. Sargent [3]. She devise a relationship between weight and height in American population, which she stated as:

$$\mathbf{W = 12.1e^{0.01H}} \qquad \mathbf{2.1}$$

For men

$$\mathbf{W = 9.5e^{0.0108H}} \qquad \mathbf{2.2}$$

For women
Where W is the weight in kg and H is the height in cm. Universally, a number of publications has agreed that, the body mass index measured in kg/m^2, best represent height and weight, which describe the estimate of a human body fat between ages 18 and 65 years [4]. Available publications shows that, the average Ghanaian adult BMI is 25.7kg/m^2 for male and 21.65kg/m^2 for female [5]. Several scientific authors have designed formulae to determine the body surface area. Notable among these include: Boyd E, 1935; Dubois and Dubois, 1916; Haycock et al., 1978; Sadinha et al, Current JD et al, Gehan EA et al, Verbraecken et al, Mosteller et al, Fujimoto S, Shutter B. and George, 1970. [6-16].All of these are generally expressed in the form:

$$\mathbf{BSA} = \alpha_0\, \mathbf{H}^{\alpha_1} + \mathbf{M}^{\alpha_2} \qquad \mathbf{2.3}$$

Where, M is mass (kg), H is height (cm). All parameter values derived from various studies gave reasonably similar results. Generally, the average BSA estimated value for adult male is 1.9 m^2, while the average body surface area for adult female is approximately 1.6 m^2. Furthermore, the average body surface area for younger children largely varied with age in the range of 1.07 m^2 and 1.14 m^2.between the age of 10 to age 16 years [2]. Furthermore, another important parameter describe as Body Shape Index (aBSI) describe the relationship between the body height, weight and waist circumference. It is of interest to know that the inclusion of the waist circumference is believed to make the Body Shape Index a better indicator of the health risks from excess weight than the standard Body Mass and surface Index [17, 18].

$$\mathbf{aBSI} = \frac{\mathbf{WC}}{\mathbf{BMI}^{\frac{2}{3}}\mathbf{+Height}^{\frac{1}{2}}} \qquad \mathbf{2.4}$$

Where WC is Waist circumference and Height are measured in meters. Various body dimensions and other body descriptions has been done by a number of regional organisations including IAEA, ICRP, EC, Asian Center for Reference Man Studies and AAMP as reference man in various sub-regions in the world [19, 20]. A summary of these reference bodies are shown in Table 2.4.

Table 2.1: *Asian and ICRP Reference Male/Female models*

Parameter	Asian (1998)	ICRP RM (1975)	ICRP RM (1995)
Male			
Age	35 (20-50)	20-30	35(20-50)
Race	Caucasoid	Caucasoid	Caucasoid
Sex	Male	Male	Male
Body weight (kg)	60	70	73
Height (cm)	170	170	176
BMI	22	24	24
BSA	1.78	1.8	1.9
Female			
Age	35(20-50)	20-30	35(20-50)
Race	Caucasoid	Caucasoid	Caucasoid
Sex	Female	Female	Female
Body weight	51	60	60
Body height	160	161	163
BMI	22	22	23
BSA	1.55	1.66	1.66

3.1 MATERIALS

The material used include the following equipment and tools: Weighing Machine, Automatic BMI Calculator/Machine. The BMI machine (**figure 3.1**) was used to estimate the BMI of the patients while the weighing scale (**Figure 3.2)** was used to measure the patient weight. The BMI was also calculated using an excel sheet.

Figure 3.1: *BMI Calculator/Machine*

Figure 3.2: *Weighing Machine*

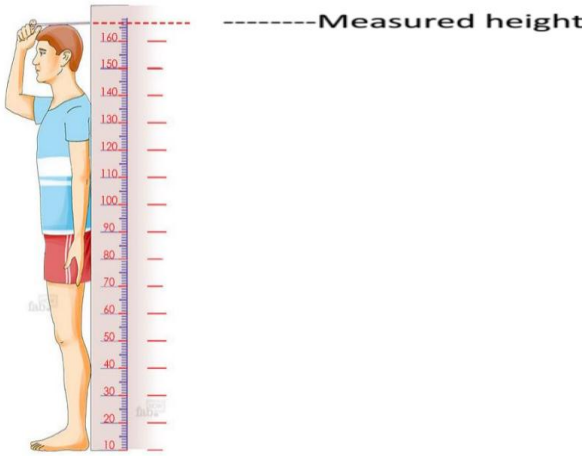

Figure 3.3: *Measurement of height*

3.2 METHODOLOGY

3.2.1 MEASUREMENTS OF HEIGHT, WEIGHT, BMI, BSI AND BSA

This were part of pre-image data collection process, where weight and height were measured as part of the regular physical check-up before imaging. The height was measured with a meter rule placed on a wall as shown in **figure 3.3.** Two different methods were used to estimate the BMI: By either direct registration with the BMI automatic measuring system (**figure 3.2**) or by calculation from separated measurement of height and weight as defined by **equation 2.5**. Whilst BSA was estimated indirectly using Du Bois formula shown as in **equation 2.6**. In addition, BSI was estimated by dividing measured body weight by BSA. Furthermore, the relationship between renal volume and BMI, BSA and BSI was established by using Minitab statistical software. The major regression analysis produce a modeled relationship between the body parameters and the renal volume.

Mathematically BMI is expressed as:

$$\mathbf{BMI} = \frac{\mathbf{W}}{\mathbf{H^2}} \qquad \mathbf{2.5}$$

Where **w** and **h** are weight and height respectively The most widely used BSA calculated formulae is the DuBois and DuBois formula expressed as:

$$\mathbf{BSA(m^2)} = \mathbf{w^{0.425} * h^{0.725} * 0.007184} \qquad \mathbf{2.6}$$

Where **w** and **h** are weight and height respectively. The relationship between body weight and body surface area has been establish and described as the body surface index (BSI) [15, 16]. Which is estimated by dividing the weight of the body by the body surface area.

$$\mathbf{BSI} = \frac{\mathbf{Weight}}{\sqrt{\mathbf{BSA}}} \qquad \mathbf{2.7}$$

4.0 RESULTS, DISCUSSION AND ANALYSIS

The basic framework of this section describe the pictorial view of the relationship between the various parameters in tables and graphical representation. It provide a space platform to answer all the pictorial questions by presenting the data in a pictorial format. It also help to describe the relationship between the various measurable quantities and the estimated parameters in order to draw a reasonable conclusions. Finally, the analysis of the presented data using various practical and theoretical tools based on the study objectives are also captured.

4.1 RESULTS: SUMMARRY OF DATA

TABLE 4.1 *ESTIMATED HEIGHT, WEIGHT, BMI, BSI AND BSA*

STATISTICS	AGE	WEIGHT	HEIGHT	BMI	BSA	BSI
MALE	years	Kg	cm	kg/m²	m²	kg/m²
20-40						
MEAN	33	81.05	177.93	25.48	2.02	39.93
MAX	40	105.3	189	33.99	2.25	47.65
MIN	20	56.5	162	18.97	1.75	27.16
MAX/MIN	2			1.79	1.29	1.75
41-60						
MEAN	52	83.40	181	25.36	2.06	40.21
MAX	60	110	195	31.47	2.40	46.23
MIN	41	55.8	167	18.64	1.78	26.20
MAX/MIN	1.46			1.69	1.35	1.77
61-80						
MEAN	68	68	63.86	22.23	1.77	36.15
MAX	80	80	73.8	24.1	2.01	39.05
MIN	62	62	55.7	21.26	1.56	33.88
MAX/MIN	1.29			1.13	1.29	1.18
20-80						
MEAN	45	80.83	178.64	25.19	2.02	39.81
MAX	80	110	195	33.99	2.4	47.65
MIN	20	52.1	156	18.64	1.5	26.20
MAX/MIN	4	2.11	1.25	1.82	1.6	1.82
FEMALE						
20-40						
MEAN	31	63.25	168.95	22.04	1.71	37.09
MAX	40	76.4	189	26.08	2.02	44.94
MIN	20	48.6	158	19.22	1.47	30.45
MAX/MIN	2			1.36	1.37	1.48
41-60						
MEAN	51	63.86	168.70	22.18	1.74	36.88
MAX	59	81.9	187	25.38	2.14	52.84
MIN	42	50.6	155	18.85	1.5	30.75
MAX/MIN	1.41			1.35	1.43	1.72
61-80						
MEAN	68	53.38	158.58	20.93	1.53	34.81
MAX	80	59	165	22.35	1.62	38.82
MIN	61	43.7	146	18.19	1.39	31.44
MAX/MIN	1.36			1.23	1.17	1.24
20-80						
MEAN	46	61.87	167.11	21.91	1.69	36.58

4.2 GRAPHICAL REPRESENTATION

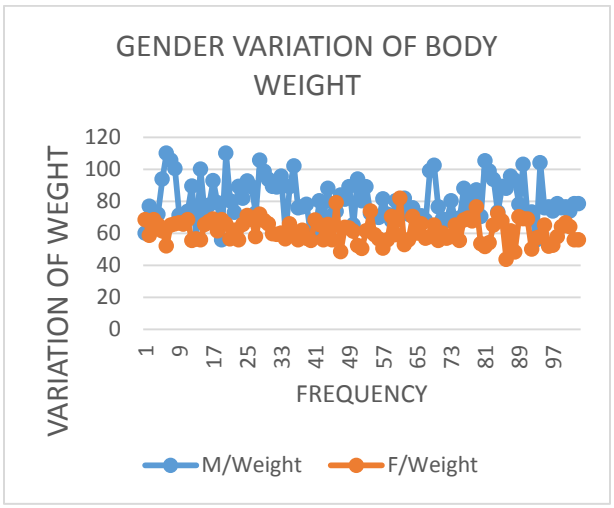

FIGURE 4.1 *Age and gender variation of weight*

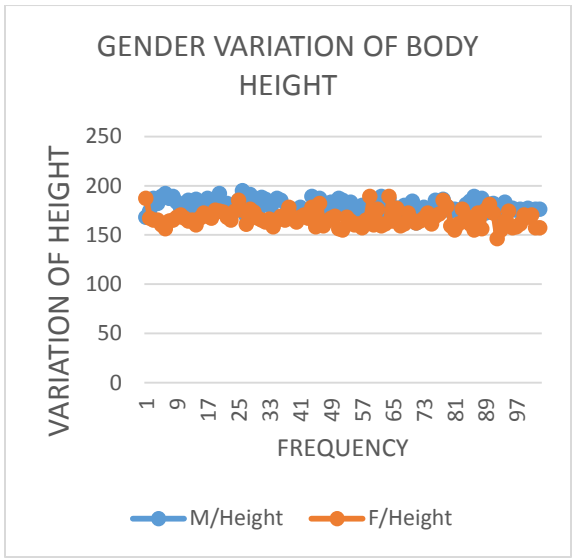

FIGURE 4.2 *Age and gender variation of height*

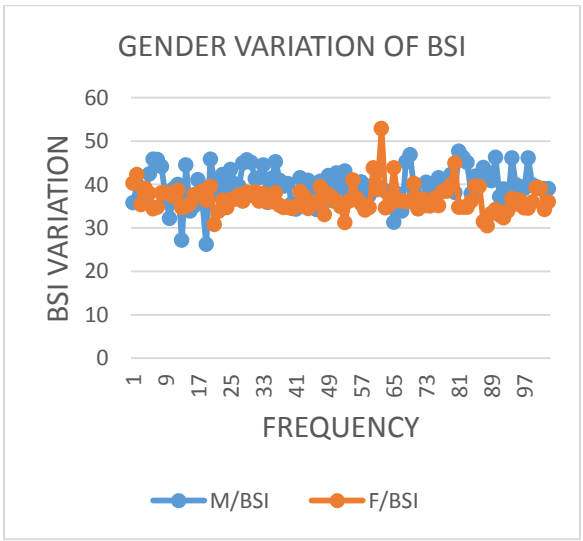

FIGURE 4.3 *Age and gender variation of BSI*

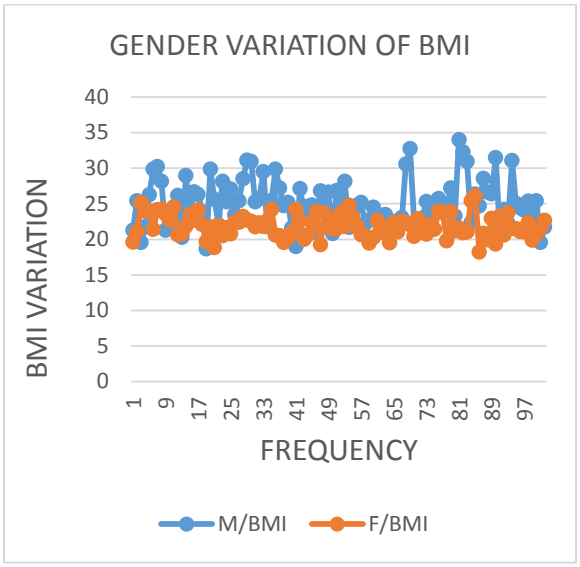

FIGURE 4.4 *Age and gender variation of BMI*

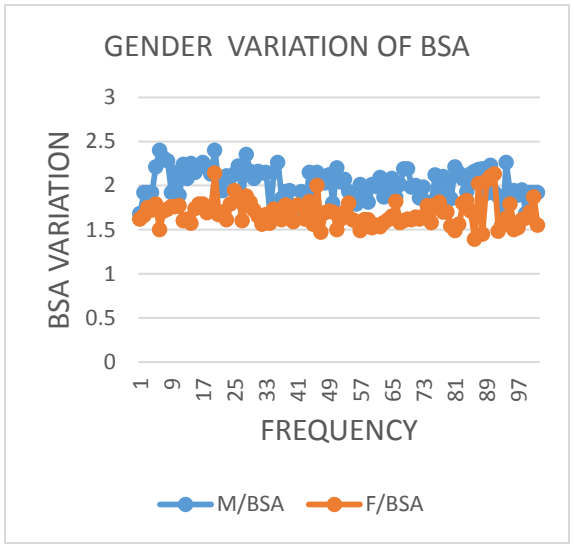

FIGURE 4.5 *Age and gender variation of BSA*

4.3 STATISTICAL REGRESSION ANALYSIS

DETERMINATION OF MALE BODY HEIGHT USING BODY WEIGHT MODEL EQUATION

WEIGHT = 1.14 HEIGHT -123.09 **4.1M**

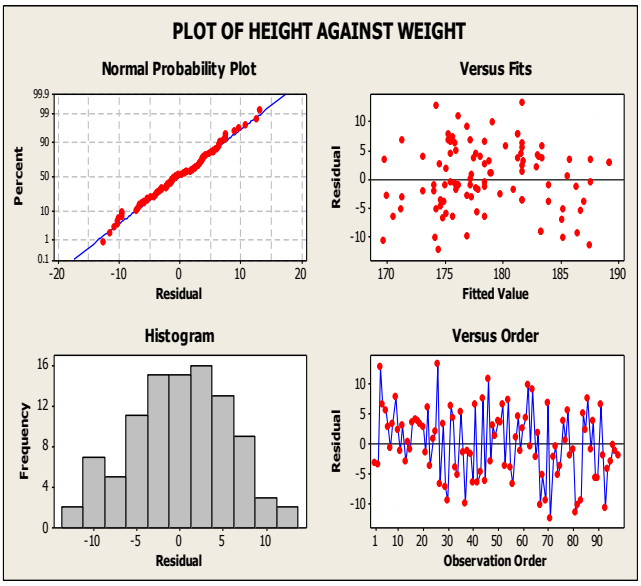

Figure 4.6 *Weight in relation Height variations for male*

DETERMINATION OF MALE BMI USING BSA MODEL EQUATION

BSA = 0.09BMI – 0.26 **4.2M**

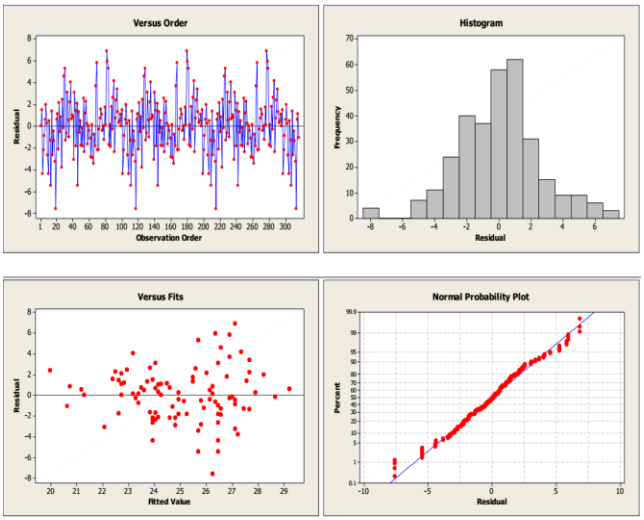

Figure 4.7 *BMI in relation to BSA variations for male*

DETERMINATION OF MALE BMI USING BSI MODEL EQUATION

BSI = 11.86 + 1.11BMI **4.3M**

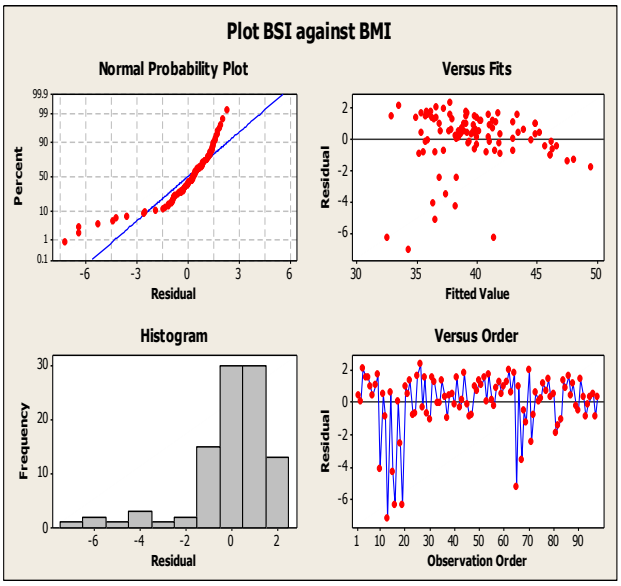

Figure 4.8 *BSI in relation BMI variations for male*

DETERMINATION OF FEMALE WEIGHT USING HEIGHT MODEL EQUATION

WEIGHT = 0.66 HEIGHT - 49.21 **4.1F**

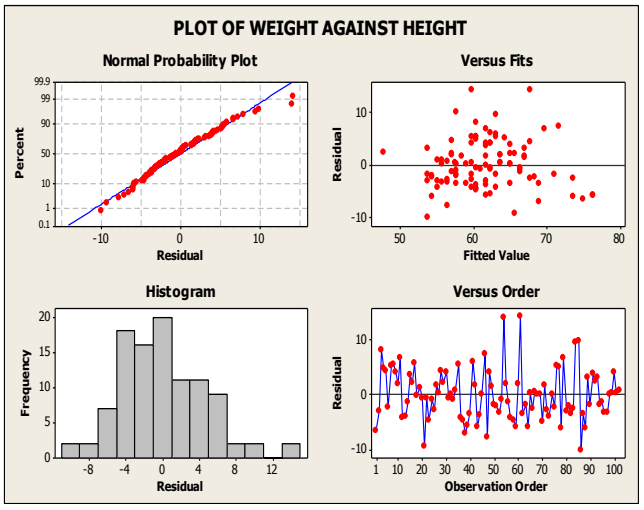

Figure 4.9 *Weight in relation Height variations for female*

DETERMINATION OF FEMALE BSI USING BMI MODEL EQUATION

BSI = 23.9147 + 0.58BMI **4.2F**

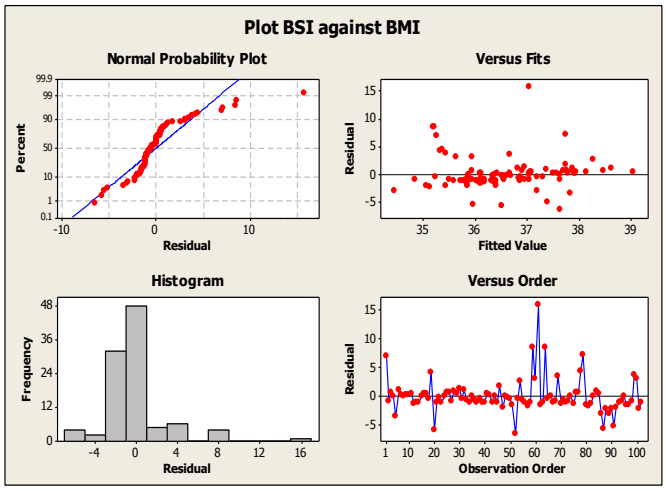

Figure 4.10 *BSI in relation to BMI variations for female*

DETERMINATION OF FEMALE BMI USING BSA MODEL EQUATION

BSA = 0.30BMI - 4.78 **4.3F**

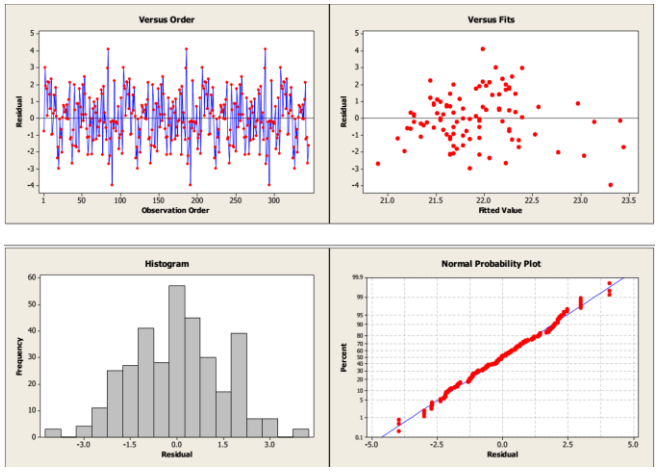

Figure 4.11 *BMI in relation to BSA variations for female*

4.4 ANALYSIS

4.4.1 BODY PARAMETERS

The five important body indexes were measured, these include: body height, body weight, BMI BSA and BSI using DuBois formula (**equation 2.6**) as the fundamental bases. The measured average male weight and height were 80.83 kg and 178.62 cm respectively. In addition, the mean male BMI, BSA and BSI were 25.19±1.4 kg/m^2, 2.02±0.09 m^2 and 39.81kg/m^2 respectively. While, the average female measurements were 61.87±18kg, 167.11±23cm, 21.91±0.15 kg/m^2, 1.69±0.12 m^2 and 36.58±3kg/m^2 for weight, height, BMI, BSA and BSI respectively. The summarized measured Height, Weight, BMI, BSA and BSI at various age and gender variations are shown in Table 4.1 and summarized in table 4.2, this also include the spread of the measured values. These values are compare with international measured values by ICRP, Asian, American and EC measurements as shown in Table 4.3.

Table 4.2. *REFERENCE BODY PARAMETERS*

STATISTICS	AGE	WEIGHT	HEIGHT	BMI	BSA	BSI
MALE	years	kg	cm	kg/cm^2	cm^2	kg/m^2
MEAN	45	80.83	178.64	25.19	2.02	39.81
MAX	80	110	195	33.99	2.4	47.65
MIN	20	52.1	156	18.64	1.5	26.20
MAX/MIN	4	2.11	1.25	1.82	1.6	1.82
FEMALE						
MEAN	46	61.87	167.11	21.91	1.69	36.58
MAX	80	81.9	189	26.08	2.14	52.84
MIN	20	43.7	146	18.19	1.39	30.45
MAX/MIN	4	1.87	1.30	1.43	1.54	1.74

Table 4.3 *THE MEASURED AND INTERNATIONAL BODY PARAMETERS*

Parameter	Asian (1998)	Study Values (African) 2016	ICRP RM (1975)	Revised ICRP RM (1995)
Male				
Age	35 (20-50)	45(20-80)	20-30	35(20-50)
Race	Caucasoid	African	Caucasoid	Caucasoid
Sex	Male	Male	Male	Male
Body weight (kg)	60	81	70	73
Height (cm)	170	179	170	176
BMI	22	25	24	24
BSA	1.78	2.02	1.80	1.90
Female				
Age	35(20-50)	46(20-80)	20-30	35(20-50)
Race	Caucasoid	African	Caucasoid	Caucasoid
Sex	Female	Female	Female	Female
Body weight	51	62	60	60
Body height	160	167	161	163
BMI	22	22	22	23
BSA	1.55	1.69	1.66	1.66

SUMMARY OF MODELED BODY PARAMETERS

Below are summarized modeled equations that could be used to predict various body parameter.

W = 1.14 H -123.09 4.1M
W = 0.66 H - 49.21 4.1F
BSI = 1.11BMI + 11.86 4.2M
BSI = 0.58BMI + 23.92 4.2F
BSA = 0.9BMI – 0.26 4.3M
BSA = 0.3BMI – 4.78 4.3F

Equation 4.1M, 4.2M and 4.3M are used to predict male body Weight, BSI AND BSA with known body height and BMI. In addition, equation 4.1F, 4.2F and 4.3F are modeled equations in order to determine female body weight, BSI and BSA using height and BMI.

4.5 CONCLUSION

In conclusion, the results of the evaluation of the relationships between measured and estimated body parameters shows that females had smaller body parameters (height, weight, BMI, BSI and BSA) as compare to their male counterparts. There was a significant correlation between body indexes and it also indicate that physical characteristics including height and weight are important determinants of BMI, BSA and BSI. The study confirm other studies, which shows that, BSI is a better indicator of body size than both BMI and BSA, However, BSA is also a better indicator than BMI. Even though BMI is the most commonly used parameter among the three body indices for clinical.

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