

# The use of Body Surface Index as a Better Clinical Health indicators Compare to Body Mass Index and Body Surface Area for Clinical Application

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## ABSTRACT

The relationship between body height and body weight has been described by using various terms. Notable among them is the body mass index, body surface area, body shape index and body surface index. In clinical setting the first descriptive parameter is the BMI scale, which provides information about whether an individual body weight is proportionate to the body height. Since the development of BMI, two other body parameters have been developed in an attempt to determine the relationship between body height and weight. These are the body surface area (BSA) and body surface index (BSI). Generally, these body parameters are described as clinical health indicators that described how healthy an individual body response to the other internal organs. The aim of the study is to discuss the use of BSI as a better clinical health indicator for preclinical assessment of body-organ/tissue relationship. Hence organ health condition as against other body composition. In addition the study is `also to determine the best body parameter the best predict other parameters for clinical application. The model parameters are presented as; modeled height and weight; modelled BSI and BSA, BSI and BMI and modeled BSA and BMI. The models are presented as clinical application software for comfortable working process and designed as GUI and CAD for use in clinical application.

**Keywords :** BSA, BSI, BMI, CAD, NPP

## I. INTRODUCTION

This study discusses the benefits of using body surface index in relation to other world known body parameters such as height, weight and BMI. Even though the height, weight and BMI has been used over the years as part of preclinical assessment of patients in clinical practice for diagnoses, However, due to more scientific discoveries a lot more is require to adequately

representing the total body composition for clinical applications.

Furthermore, the height and weight are described as the building unit of all these parameters. However, it depends on its mathematical formulation. The BMI is described as the ratio of the weight and the square of the height, described mathematically as;

$$BMI = \frac{WEIGHT}{Height^2} \quad (1)$$

Furthermore, knowledge of body indices is significant for clinical assessment of organ/tissue composition hence tissue/organ health (Garland, 2014; Glodny, *et al.*, 2009; Emamian, Nielsen, Pedersen & Ytte, 1993; Troell, Berg, Johansson & Wikstad, 1984; Wald, 1937). This is because, organ volume changes throughout human development from fetus through to maturity and to elderly, therefore, the evaluation of the organ development, as compare with human body parameters is crucial. This enables the hypothesis that the function of the various organ meets the metabolic requirements of the whole organism, which are best described by other factors including body parameters (height, weight, BMI, BSA and BSI).

### **Body Parameters**

Since the development of BMI, two other body parameters have been developed in an attempt to determine the relationship between body height and weight. These are the body surface area (BSA) and body surface index (BSI). To evaluate the surface region of a human body in relation to height and weight, the term body surface area was invented. It is specified as an estimated value that shows the relationship between the average body sizes to the height and normally increases with increasing age. The estimated body surface area of a human body is a measured total surface area of human body (Du Bois & Du Bois, 1916). Several scientists and authors have designed formulas to determine the body parameters and the relationship with the organ dimensions, this has contributed significantly to the understanding and solution to human health (Ferreira & Duarte, 2014; Sardinha, Silva, Minderico & Teixeira, 2006; Verbraecken, Van de Heyning, De Backer & Van Gaal, 2006; Shuter, 2000; Current, 1997; Mosteller, 1987; Haycock, Schwartz & Wisotsky, 1978; Gehan & George, 1970; Fujimoto, Watanabe, Sakamoto, Yukawa & Morimoto, 1968; Boyd, 1935).

All of these are broadly stated in the frame:

$$BSA = \alpha_0 H^{\alpha_1} * M^{\alpha_2}, \quad (2)$$

where, M is mass (kg), H is height (cm). All parameter values derived from various studies gave reasonably

similar results. The mean body surface area varied based on age and gender. Generally, the average BSA estimated value of an adult male is 1.9 m<sup>2</sup>, while the average body surface area for an adult female is approximately 1.6 m<sup>2</sup>. Furthermore, the average body surface area for younger children largely varied with age in the range of 1.07 m<sup>2</sup> and 1.14 m<sup>2</sup> between ages 10 to 16 years (IAEA, 1989).

This study make used of the most widely used BSA calculated formulae is the DuBois formula expressed as:

$$BSA = w^{0.425} * h^{0.725} * 0.007184 \quad (3)$$

Its important to note that with the DuBois formula expressed above the BSA is defined in meters (m), the height (h) in cm and the weight (w) measured in kg. Furthermore, BSA in relation to the body weight describes a new parameter called body surface index (BSI) which is a more precise indicator than both the BMI and the BSA. It is estimated by dividing the body weight by the calculated square root of its BSA, mathematically expressed as:

$$BSI = \frac{WEIGHT}{\sqrt{BSA}} \quad (4)$$

### **OBJECTIVE**

The aim of the study is to discuss the use of BSI as a better clinical health indicator for preclinical assessment of body-organ/tissue relationship. Hence organ health condition as against other body composition. In addition the study is `also to determine the best body parameter the best predict other parameters for clinical application.

### **II. MATERIALS AND METHODOLOGY**

The BMI machine was used to simultaneously measure the height and weight of the patients and automatically generate the body mass index with predetermined model equation of the weight divided

by the height squared as shown in equation 1. In centers where the BMI machine was not available, an improvised height measuring system and a weighing scale were used. Additionally, both the body surface index and the body surface area were calculated using a designed application software based on equation 3 and 4. Clinical these parameter were measured as pre-imaging tools as part of the clinical assessment of patients before imaging. The pre-imaging data collection process involved the collection of basic patients' information such as patient ID, gender, age, height, weight, and patients' comments, BMI, BSI and BSI before imaging in all the hospitals.

The model parameters are presented as body parameters, made up of the relationship BSI and BSA on one hand and BSI and BMI. Additionally, the relationship between BSA and BMI was also determine and a comparison between the summary of the modelled result done. Finally the equation predictors of the various equations were done and results used as a reference determinant.

### III. RESULTS

The results of the data were presents based on age and gender variation, as shown in Table 1 below.

Table 1: Measured values of body parameters.

STATISTICS	AGE	WEIGHT	HEIGHT	BMI	BSA	BSI
MALE	years	kg	cm	kg/m <sup>2</sup>	m <sup>2</sup>	kg/m <sup>2</sup>
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			1.78	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	89	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

### Modelled Body Parameters

The results of the models are presented as clinical application software for comfortable working process and designed as GUI and CAD for use in clinical application shirazu et al [9].

This section present the graphical relationship between BSI and other body parameters. It also shows the model equations for both male and female BSI in relation to BSA and BMI parameters. Below are the modelled regression analysis.

### REGRESSION ANALYSIS

#### Section A: BSI-M Vrs BSA-M

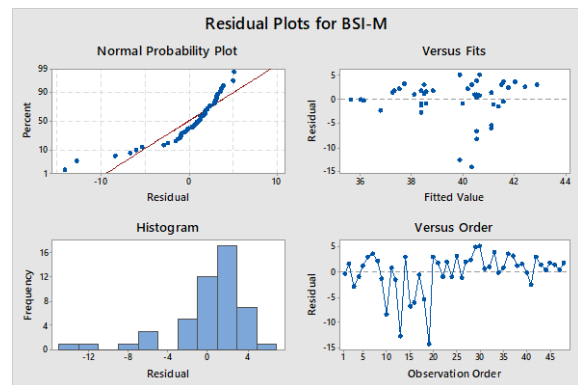
##### Model Summary

SD	R-sq	R-sq(pred)	P-Value
4.06	97.99%	97.95%	0.003

##### Regression Equation

$$BSI-M = 20.25 + 9.45 BSA-M \quad (5)$$

#### Plots for BSI-M versus BSA-M



#### Section B: BSI-M versus BMI-M

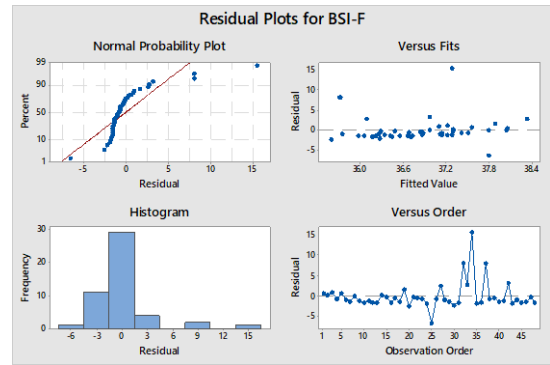
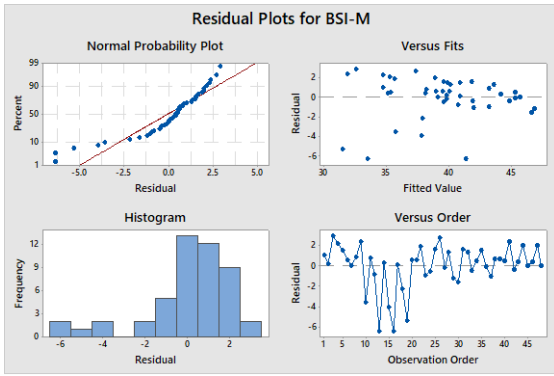
##### Model Summary

SD	R-sq	R-sq(pred)	P-Value
2.15	97.11%	74.27%	0.001

##### Regression Equation

$$BSI-M = 8.67 + 1.2278 BMI-M \quad (6)$$

**Plots for BSI-M versus BMI-M**



**Section C: BSI-F versus BSA-F**

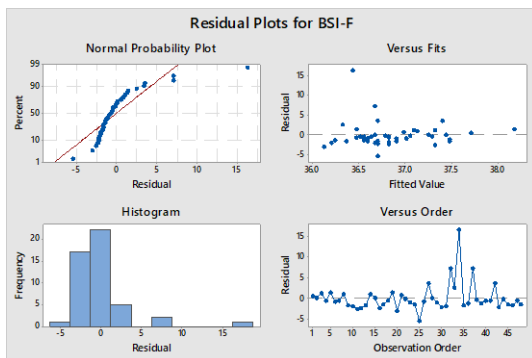
**Model Summary**

SD	R-sq	R-sq(pred)	P-Value
3.34	99.56%	99.70%	0.000

**Regression Equation**

$$BSI-F = 30.45 + 3.87 BSA-F \quad (7)$$

**Plots for BSI-F versus BSA-F**



**Section D: BSI-F versus BMI-F**

**Model Summary**

SD	R-sq	R-sq(pred)	P-Value
3.30	95.91%	96.03%	0.002

**Regression Equation**

$$BSI-F = 26.03 + 0.497 BMI-F \quad (8)$$

**Plots for BSI-F versus BMI-F**

**Section E: BSI-M versus BSI-F**

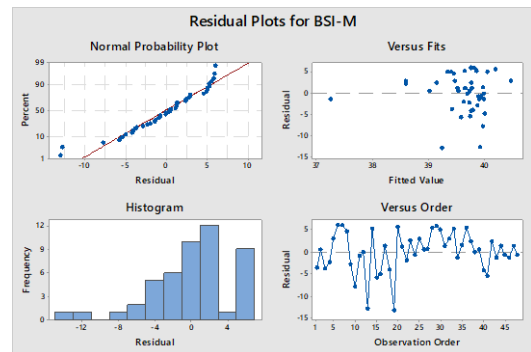
**Model Summary**

SD	R-sq	R-sq(pred)	P-Value
1.46	98.25%	99.00%	0.000

**Regression Equation**

$$BSI-M = 45.13 - 0.149 BSI-F \quad (9)$$

**Plots for BSI-M versus BSI-F**



**IV. Discussion of Results**

Section A discusses the modelled relationship between male BSI against BSA with a P-value of 0.003, Standard deviation of 4.06, R-sq and predictor R-sq value of 98% accuracy. This are summarized under modelled summary with a modelled regression equation (5) and Normal Probability Plot (NPP).

Section B discusses the modelled relationship between male BSI against BMI with a P-value of 0.001, Standard deviation of 2.15, R-sq and predictor R-sq

value of 99% accuracy. This are summarized under modelled summary with a modelled regression equation (6) and Normal Probability Plot (NPP).

Section C discusses the modelled relationship between female BSI against BSA with a P-value of 0.000, Standard deviation of 3.34, R-sq and predictor R-sq value of 99% accuracy. This are summarized under modelled summary with a modelled regression equation (7) and Normal Probability Plot (NPP).

Section D discusses the modelled relationship between female BSI against BMI with a P-value of 0.002, Standard deviation of 3.3, R-sq and predictor R-sq value of 96% accuracy. This are summarized under modelled summary with a modelled regression equation (8) and Normal Probability Plot (NPP).

Section E discusses the modelled relationship between male and female BSI with a P-value of 0.000, Standard deviation of 1.46, R-sq and predictor R-sq value of 99% accuracy. This are summarized under modelled summary with a modelled regression equation (9) and Normal Probability Plot (NPP).

Generally, to evaluate the relationship between body fat/muscles weight and body height BMI is used. However, where the clinical question is to be answered in term of the surface region of a human body in relation to height and weight, BSA and BSI are used. In recent times BSA is seen as an improvement of BMI because it account for the total body surface area in relation to the height and weight of the individual. Whilst the BSI is seen as an improvement of the BSA as it account for both body surface area in addition to the height and weight of the individual. In Ghana, BMI is determined to be 25.19 and 21.91, BSA was estimated to be 2.02 and 1.69 while BSI was determine to be 39.81 and 36.58 by Shirazu et al, as BSA for male and female respectively.

Indeed, BSA and BSI, which is significantly used to perform the following clinical services; for instance BSA and BSI is used to estimate the renal clearance (RC), as RC usually divided by either BSA or BSI to gain an appreciation of the true glomerular filtration rate (GFR). In addition the cardiac index is a measure of cardiac output divided by the BSA, giving a better approximation of the effective cardiac output. BSI on the other hand, is used to estimate weight in relation to BSA. The BMI, BSA and BSI define and show the relationship between the average body size to the height and normal increases with increasing age (Ferreira & Duarte, 2014).

It is of interest to note that from this study Body surface index is used to better describe both the BSA and BMI. These conclusions were drawn based on the excellent equation predictors of the modelled equations. That is, the predict relationship based on the linear relationship shows that, BSI can better be used to predict both BMI and BSA.

Furthermore, in literature, the metabolic requirements are correlated with the body parameters (BMI, BSA, BSI), which has a direct relationship between internal organs and other body parts as discussed by Shiraz al et [8].

## V. Disclaimer

This is a follow up studies to the work I did in 2016 and published in 2017 as part of determination of standard reference values of body indices in Ghana. The said paper was published as part of my PhD thesis with University of Cape coast.

## VI. REFERENCES

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