Mathematical Model for Determining the Medical Body Mass Index of Humans and the Achievement of Individual Personal Medical Transformation in Nigeria

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Citation

Abstract
The research is concerned with the development of a mathematical model for estimating the Medical Body Mass Index of human beings in relation to some of their anthropometric parameters (weight and height). The model was optimized to know whether it is possible for humans to have a maximum or minimum medical Body Mass Index. However, the optimization result showed that there is no specific human medical Body Mass Index that could be called a maximum or minimum. It also means that when human beings don’t watch their intake, they could assume any medical BMI whether high or low. Hence, the study places high emphasis on regular watching of weight and reduction in calorie intake in order to maintain a healthy medical BMI and thereby encouraging a personal medical transformation. The population sample for the research was the Taraba State of Nigeria’s Community.

1. Introduction

A question may be asked, what is Body Mass Index (BMI)? BMI stands for a person’s weight in kilograms divided by the square of his height in meters [1, 2]. A person’s BMI does not measure body fat directly, but rather it is moderately correlated with more direct measures of body fats obtained from skin fold thickness measurements such as bioelectrical impedance, densitometry (underwater weighing), dual energy x-ray absorptiometry (DXA) and other methods [3]. Furthermore, BMI appears to be as strongly correlated with various metabolic and disease outcome as are these more direct measures of body fatness [4, 6]. In general, BMI is an inexpensive and easy-to-perform method of screening for weight category, for example underweight, normal or healthy weight, overweight, and obesity [7, 9].

Estimating body mass index is so important in every country today. Many disease conditions make it impossible to gauge patients’ body mass index. This anthropometrics measurement is essential to calculate medicament does and doses. Anthropometrics measure is the single most universally applicable inexpensive and non-invasive method available for the assessment of size, Proportion and composition of the human body.
Thus, it would also be important to discuss in the cause of this work various mathematical approaches to estimate body mass index already used worldwide and a mathematical look at this anthropometric measurement in particular is essential. Body mass index estimation is essential to address the problem of obesity and weight stigmatization. The fact remains that obese people are regularly blamed for their weight, with common perception that weight stigmatization is justifiable and may motivate individuals to adopt healthier behaviours. Unknown to them that weight stigma is not a beneficial public health tool for reducing obesity: rather it threatens health, generates health disparities, and interferes with effective obesity intervention efforts. It makes the victims to be lazy, weak-willed, unsuccessful, unintelligent and have poor weight-loss treatment.

Moreover, it has been observed that due to peculiarities about generations, certain immunity, resistances and prevalence a generation A, might claim/achieve over an ailment, it is difficult for another immediate/next generation to enjoy such. For instance, HIV, jaundice and other diseases that have existed in the world for over centuries now are just having a higher spreading and penetration power of late. A country’s attention is supposed to be drawn to this reality because the healthy living of a nation’s citizens is a fundamental and necessary condition for a healthy and prosperous economy.

Similarly, findings have shown that resistances/immunities demonstrated by people are as result of their geographical locations. This is evident in the variation between the resistance/immunity an African can show over that of American in terms of water they drink, the food they eat and the diseases they could fight and win. Hence it is notable to remark here that for effectiveness in medication prescriptions and special intervention, each generation of human beings has to be studied in isolation considering their geographical locations and body response rates while addressing parameters such as popular food taken, body weight, with common perception that weight stigmatization is justifiable and may motivate individuals to adopt healthier behaviours. Unknown to them that weight stigma is not a beneficial public health tool for reducing obesity: rather it threatens health, generates health disparities, and interferes with effective obesity intervention efforts. It makes the victims to be lazy, weak-willed, unsuccessful, unintelligent and have poor weight-loss treatment.

1.1. Relevance of the Study

The study of Medical Body Mass Index of human beings is important to enable one know when he/she is underweight, normal weight, overweight and obese in order to take all necessary dietary and regular exercise precautions.

Likewise, with just having a weight measure and a measuring tape for one’s height, this model can be used to estimate family members’ BMI in an explicit form.

1.2. Health Consequences of Obesity in Adults

People who are obese are at increased risk for many diseases and health conditions, including the following:

(i) All-causes of death (mortality), High blood pressure (Hypertension)
(ii) High LDL cholesterol, low HDL cholesterol, or high levels of triglycerides (Dyslipidemia)
(iii) Type 2 diabetes, Coronary heart disease, Stroke, Gallbladder disease, Osteoarthritis (a breakdown of cartilage and bone within a joint)
(iv) Sleep apnea and breathing problems, Chronic inflammation and increased oxidative stress
(v) Some cancers (endometrial, breast, colon, kidney, gallbladder, and liver)
(vi) Low quality of life, Mental illness such as clinical depression, anxiety, and other mental disorders
(vii) Body pain and difficulty with physical functioning; according to [10].

It is useful for identifying if a person’s weight corresponds to his/her height, can also be used to develop a BMI scale for human beings.

Also, since mathematical modelling is useful for proper medication dosage then; this mathematical model for BMI of people developed in this research work could instrumental for prescribing the proper medication dosage and nutritional evaluation for a patient based on estimated BMI. This model is of utmost relevance in many remote places in the world as developing a scale with it helps in such places due to their inability to calculate as a result of illiteracy.

1.3. Relevance of the Study over Others

The study is mainly for adults in a particular geopolitical area (Wukari, Taraba State) in Nigeria and can be used in other areas of the country and continent as well.

2. Methodology

Under this section, we shall consider subheadings such as; Formulation of the model itself, Basic assumptions needed to give us a model that conforms to reality, establish a relationship between the model parameters, and evaluate the resulting model equations’ constants.
2.1. Formulation of the Model Equations

In similar manner, this section will also address a few subtopics as they unfold.

2.2. Basic Assumptions

2.2.1. BMI Versus Weight

An underweight person must have a low BMI and, an overweight person must also have a high BMI. Hence, an increase in weight of a person gives rise to a corresponding increase in BMI and the same applies for a decrease. Hence, we can confidently say that the BMI of a person is directly proportional to the weight of the person. Hence, mathematically:

\[ B \propto W \]

(1)

2.2.2. BMI Versus Height

Again, a short person will tend to have a lower BMI than a tall person of similar body builds because BMI is a function of height and vice versa. This implies that an increase in height of an individual leads to an increase in BMI and vice versa. Thus, the height of an individual is directly proportional to his/her BMI. Hence, mathematically:

\[ B \propto \frac{1}{H} \]

(2)

2.3. First Establishment of Model Parameter Relationship

From the parameter equations constructed above, if we add equations (1) and (2) we would have,

\[ B = k_1 W \]

\[ B = \frac{k_2}{H} \]

Adding gives

\[ 2B = k_1 W + \frac{k_2}{H} \]

\[ B = aW + \frac{b}{H} \]

(3)

Where: H = height of an individual human being
W = weight of an individual human being
BMI = Body mass index of human being
And x, y, a', b' and c' are the model constants.

2.4. Assumption Based on the Mathematical Behaviour of the Parameters Relationship

Under this heading, the nature of equation view was given to the relationship that existed between the variables of the model. A relationship graph was plotted for body mass index, weight and height and considering the equation about, it can be observed also that:

(i) We assume that, the relationship between BMI and weight is linear (seen by plotting of data collected).

\[ B = a' W + c_1 \]

(4)

(ii) Similarly, the relationship between BMI and height is non-linear, so let its nature of equation be

\[ B = \frac{b'H + c_2}{2} \]

(5)

(Where B and W retain their usual definitions as above, and c_1 and c_2 are constant)

2.5. Second Establishment of Model Parameter Relationship

Adding equations (4) and (5) yields,

\[ 2B = \left( a + a' \right) W + \frac{\left( b + b' \right) H}{2} + \left( c_1 + c_2 \right) \frac{H}{2} \]

\[ B = \frac{\left( a + a' \right) W}{2} + \frac{\left( b + b' \right) H}{4} + \frac{\left( c_1 + c_2 \right) H}{4} \]

\[ \therefore B = xW + \frac{y}{H} + z \]

(6)

Where: \( H \) = height of an individual human being
W = weight of an individual human being
BMI = Body mass index of human being
And x, y, a', b' and c' are the model constants.

3. Evaluating the Model Equation Constants

To evaluate the constants in the model above, equation (7) is going to be differentiated partially with respect to x, y, and z respectively following the Least Squares’ Method of obtaining model equation constants.

Hence, minimizing the proposed model using least squares method, we obtain the results below:

\[ Z_{\min} = \min \sum \left( B_i - xW_i - \frac{y}{H_i} - z \right)^2 \quad \forall i = 1, 2, ..., 10 \]

(8)

Where differentiating (8) with respect to each of the constants x, y and z gives,

\[ \frac{\partial z}{\partial x} = -2\sum_{i=1}^{10} \left( B_i - xW_i - \frac{y}{H_i} - z \right) W_i = 0 \]

(9)

\[ \frac{\partial z}{\partial y} = -2\sum_{i=1}^{10} \left( B_i - xW_i - \frac{y}{H_i} - z \right) \frac{1}{H_i} = 0 \]

(10)
\[
\frac{\partial z}{\partial z} = -2\sum_{i=1}^{10} \left( B_i - xW_i - \frac{y}{H_i} - z \right) = 0 \quad (11)
\]

\[
\sum_{i=1}^{10} B_i W_i = x\sum_{i=1}^{10} B_i W_i + y\sum_{i=1}^{10} \frac{W_i}{H_i} + z\sum_{i=1}^{10} \frac{W_i}{H_i} = 0 \quad (12)
\]

\[
\sum_{i=1}^{10} \frac{B_i}{H_i} = x\sum_{i=1}^{10} \frac{W_i}{H_i} + y\sum_{i=1}^{10} \frac{1}{H_i} + z\sum_{i=1}^{10} \frac{1}{H_i} \quad (13)
\]

\[
\sum_{i=1}^{10} B_i = x\sum_{i=1}^{10} W_i + y\sum_{i=1}^{10} \frac{1}{H_i} + z\sum_{i=1}^{10} 1 \quad (14)
\]

The next task here is to gather data in order to evaluate our model equation constants as could be seen in the next section.

### 3.1. Research Instrument Used

The research instrument used is known is random sampling technique. This is a situation where a certain sample of the Federal University Wukari members was randomly made to represent to entire population of the university community in the study. However, during the study, only the set of persons that are not deprived by nature leading to dwarfism, obesity and the likes were considered. Such natural situation(s) stated above may affect the authenticity of our research model and may not allow the model results to conform to reality. Also, the data collected were appropriate as they were directly from the university clinic, and the biological laboratory which has functional height measuring and weight measuring scales respectively. After all possible and positive screening of the data, some selected set of data were finally considered for the research.

#### Table 1. Measured data gathered from Federal University Wukari community of Nigeria.

<table>
<thead>
<tr>
<th>Weight W(kg)</th>
<th>Height H(m)</th>
<th>Body mass index (BMI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>1.74</td>
<td>22.4600</td>
</tr>
<tr>
<td>55</td>
<td>1.65</td>
<td>20.2020</td>
</tr>
<tr>
<td>60</td>
<td>1.72</td>
<td>20.2812</td>
</tr>
<tr>
<td>55</td>
<td>1.66</td>
<td>19.9994</td>
</tr>
<tr>
<td>66</td>
<td>1.82</td>
<td>19.9251</td>
</tr>
<tr>
<td>57</td>
<td>1.63</td>
<td>21.4536</td>
</tr>
<tr>
<td>70</td>
<td>1.78</td>
<td>22.0932</td>
</tr>
<tr>
<td>80</td>
<td>1.75</td>
<td>26.1224</td>
</tr>
<tr>
<td>63</td>
<td>1.72</td>
<td>21.2953</td>
</tr>
<tr>
<td>75</td>
<td>1.80</td>
<td>23.1481</td>
</tr>
</tbody>
</table>

### 3.2. Computation of the Summation Variables

Using the data collected in table 1 for our equations (12), (13) and (14) in order to obtain our summation evaluation results, we have that;

\[
\sum_{i=1}^{10} W_i = 649, \quad \sum_{i=1}^{10} W_i^2 = 42773, \quad \sum_{i=1}^{10} B_i = 216.9403
\]

\[
\sum_{i=1}^{10} \frac{B_i}{H_i} = 125.6564, \quad \sum_{i=1}^{10} \frac{1}{H_i} = 3.3656
\]

Hence, equations (12), (13), and (14) respectively become,

\[
42773x + 374.9978y + 649z = 14204.97 \quad (15)
\]

\[
374.9978x + 3.3656y + 5.7977z = 125.6564 \quad (16)
\]

\[
649x + 5.7977y + 10z = 216.9403 \quad (17)
\]

Hence, solving equations (15), (16), and (17) simultaneously gives,

\[
x = 0.3295, \quad y = 70.3876, \quad z = -40.5004
\]

Also, putting the values of x, y, and z in equation (7) yields,

\[
BMI = 0.3295W + \frac{70.3876}{H} - 40.5004 \quad (18)
\]

Thus, equation (18) is the developed model for the Body Mass Index of human beings (mainly Nigerians).

### 4. Results and Discussion

Under this heading, we shall be considering the following:

#### 4.1. Optimization of the Model

This approach is a technique for programming / optimizing an objective function or a model in order to know whether a model confirm to reality or not. However, in the concluding part of the previous chapter, data were collected in order to be able to evaluate our emerging model equation constants. Thus, our new model equation as from section (18) is;

\[
BMI = 0.3295W + \frac{70.3876}{H} - 40.5004
\]

Moreover, in this section we have to test in order to know whether the model has a minimum or a maximum value.

To do that we recall generally that, given a function f(x, y) that obeys the continuity of the functional partial derivatives and we

\[
A = \frac{\partial^2 f}{\partial x^2}; \quad B = \frac{\partial^2 f}{\partial x \partial y}; \quad C = \frac{\partial^2 f}{\partial y^2}
\]

**1)** If \(B^2 - AC < 0\), then \(f(x, y)\) has extreme value at \((x_o, y_o)\) and minimum if \(A > 0\) and it is maximum if \(A < 0\)

**2)** If \(B^2 - AC > 0\), or \(AC < B^2\) then \(f(x, y)\) has no extreme value. That is, it has a saddle point at \((x_o, y_o)\).

**3)** If \(B^2 - AC = 0\), then no information is derivable about its extreme values.
Similarly, importing the same idea in our model equation analysis, 

From equation (7),

\[
\text{BMI} = xW + \frac{y}{H} + z
\]  

(19)

But if from (19), we let BMI = B and we know that, \( x = 0.3295, y = 70.3876 \) and \( z = -40.5004 \) then by partial differentiation

\[
\begin{align*}
\frac{\partial B}{\partial W} &= x \\
\frac{\partial B}{\partial H} &= \frac{-y}{H^2} \\
\frac{\partial B}{\partial H^2} &= \frac{-y}{H^3}
\end{align*}
\]

(20)

Similarly, from (19)

\[
\begin{align*}
\frac{\partial B}{\partial W} &= \frac{-y}{H^2} \\
\frac{\partial B}{\partial H} &= \frac{-y}{H^2} \\
\frac{\partial B}{\partial H^2} &= \frac{-y}{H^3}
\end{align*}
\]

(21)

And finally,

\[
\begin{align*}
\frac{\partial^2 B}{\partial W \partial H} &= \frac{\partial}{\partial W} \left( \frac{\partial B}{\partial H} \right) = \frac{\partial}{\partial W} \left( \frac{-y}{H^2} \right) \\
\frac{\partial^2 B}{\partial H^2} &= \frac{\partial}{\partial H} \left( \frac{-y}{H^2} \right) = 0
\end{align*}
\]

(22)

From equations (20), (21) and (22), if we set

\[
\frac{\partial^2 B}{\partial W^2} = A^*, \frac{\partial^2 B}{\partial W \partial H} = B^*, \frac{\partial^2 B}{\partial H^2} = C^*
\]

Then,

\[
B^* - A^* C^* = 0
\]

(23)

(It means a human’s BMI has no local extremum or it has no specific maximum or minimum value. Hence, from our analysis in equation (23) above, it is clear that, human beings can have a very high or low BMI value. But the only snag here, as indicated by the study is that those with this very extreme BMI values become of health nuisance to their society and family at large. This is because, their loved ones would be restless over their situation should further thing happens.

4.2. Validation of the Model

After the model had become ready for use, the researcher conducted a pilot test using some people living in Taraba State community (the area of the research) to see whether or not the absolute difference between the model data generated and actual measurement done for the people could be approximately less or negligible (as in the table 2 below). Moreover, it was noted that this little difference in measurement however, as observed from the table 2 below is due to the fact that, the parameters considered by the researcher are not the whole parameter associated with the study of body mass index of a human being.

Hence, this confirms the views that, the model parameter relationship are inexact. In the same vein the model is developed and validated in Nigeria (Federal University Wukari, Taraba State). If considered logical could be used to make a universal generalizations about body mass index every other person in the world. However, the table below gives a validation of the questionnaire data to see whether the model really measure what it claim to measure in order to be able to conclude if the modal confirm to reality or not.

4.3. Calibration of the BMI Model for Adults and Their Respective Interpretations

For adults 20 years old and above, BMI is interpreted using standard weight status categories. These categories are the same for men and women of all body types and ages. The standard weight status categories and their associated BMI ranges for adults are shown in the following table.

4.4. Discussion of Results

From our optimisation result in equation (23) it was noted that human beings do not have any particular Medical BMI value that one could call the maximum or minimum BMI. It then implies that if people ignore the aspect of watching their weights and cutting down on their calorie intake (which is the core contribution of this study), then they can assume any high or low BMI values.

Likewise, from the summary table of comparisons and validation between our model data computations and the research measured/questionnaire data in table 2, it was obvious that our model gave a near exact solution to the BMI of an individual when compared to the measured/questionnaire data with a very negligible error of 0.1 unit or less in all cases for the gathered data and thus recommends our model as a standard tool for measuring human’s medical BMI. To this end, we can remark that the
aim of this research is largely achieved.

Moreover, the nature of the model proposed for this study as shown in equation (18) is completely non-linear, which as expected for most realistic situations in our day-to-day activities. And since modelling does not attempt to present exact but near-exact/approximate solutions to situations in real life, then this obviously accounts for the reason why the computed model data and the gathered questionnaire data in table 2 could not be the same. Likewise, we can remark here that the disparity in the both results buttressed the non-linearity property of the model.

5. Conclusion

According to the deductions from equation (23) of the study, it is obvious that a human’s BMI has no local extremum. This translate to the mean that it has no specific maximum or minimum value. Hence, according to the study a human being can have a very high or low BMI value. But the only snag here, as indicated by the study is that those with these various extreme BMI values become of a higher health burden to their society and family at large. This is because, their loved ones would be restless over their situation should further thing happens.

Notwithstanding, from our various levels of model analysis and the comparison made in table 2, it was clearly shown that the model actually measures what it claims/ was created to measure, and then we can recommend the research work as a standard for measuring the Human Medical BMI. Moreover, the correlation between the BMI and body fatness is fairly strong [3, 7], but even if 2 people have the same BMI, their level of body fatness may differ [12]. In general,

At the same BMI, women tend to have more body fat than men.

(I) At the same BMI, Blacks have less body fat than do Whites [13, 14]. And Asians have more body fat than do Whites [15]

(II) At the same BMI, older people, on average, tend to have more body fat than younger adults.

(III) At the same BMI, athletes have less body fat than do non-athletes.

The accuracy of BMI as an indicator of body fatness also appears to be higher in persons with higher levels of BMI and body fatness. While a person with a very high BMI (e.g., 35 kg/m²) is very likely to have high body fat, a relatively high BMI can be the results of either high body fat or high lean body mass (muscle and bone). A trained healthcare provider should perform appropriate health assessments in order to evaluate an individual's health status and risks.

Moreover according to scholars, if an athlete or other person with a lot of muscle has a BMI over 25, is that person still considered to be overweight? But, Body weight categories were defined according to WHO BMI cut-offs as follows: underweight as 18.4 kg/m² or below; normal-weight as 18.5-24.9 kg/m²; overweight as 25.0-29.9 kg/m², and obese as BMI of 30.0 kg/m² or greater.

According to the BMI weight status categories, anyone with a BMI between 25 and 29.9 would be classified as overweight and anyone with a BMI over 30 would be classified as obese.

However, athletes may have a high BMI because of increased muscularity rather than increased body fatness. In general, a person who has a high BMI is likely to have body fatness and would be considered to be overweight or obese, but this may not apply to athletes. A trained healthcare provider should perform appropriate health assessments in order to evaluate an individual's health status and risks.

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References


