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BMI-2: A Proposal for Modified Notion of BMI

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Abstract

Objectives: In this paper, we have justified that existing notion of Body Mass Index (BMI) does not signify the body fat mass with a good precision. So a new version of BMI called BMI-2 is proposed. **Method:** The body has some parts where chance of depositing the body fat is high i.e., waist, hip, thigh and neck etc. Here, in this paper, we have multiplied the circumferences of waist, hip, thigh and neck with the existing formula of BMI. **Findings:** A person with high circumferences of waist, hip, thigh and neck would be having comparatively higher value of new BMI-2 than that of others; even their old (existing) BMI values are same. **Improvement:** The new BMI-2 gives a comparatively better picture of health status by including the circumferences of some fat prone parts of the body. But if we had taken the weighted circumferences, the result would have been more accurate.

Keywords: BMI, FC Index, WC, WHR, Weighted Circumference

1. Introduction

BMI is a simple index of weight to height which is commonly used to classify normal weight, overweight and obesity in adults. It has been used since long for quantifying the obesity[1–3]. It is a number which is calculated by dividing the weight of the body (in kg) by square of the height (in meter). It is a cheap and easy method to access the body fat indirectly which may lead to many health's related problems. Because calculation is based on height and weight only, so it is a very handy tool for both clinicians and general public. We have many tools for measuring the body fatness like skin fold thickness measurement(with calipers),underwater weighing, bioelectrical impedance, Dual energy X-ray Absorptiometry (DXA), and isotope dilution; but many of these have the problem of standardization across observer and machines which makes the whole process complicated[4].

The correlation between BMI and body fatness is fairly good but it is still affected by age, sex, profession, training, etc. For example:

- With the same BMI value, women tend to have more body fat than men[5].
- With the same BMI value, older people tend to have more body fat than younger adults[6].
- Highly trained athletes may have a high BMI because of increased muscles rather than increased body fat.

Anyone with a BMI over 25.00 would be treated as overweight and anyone with a BMI over 30.00 would be classified as obese[7] according to Table 1.BMI is the one factor for giving the indication about some ailments or disease. Many institution or societies related to health recommend the following few factors to assess the risk for diseases: circumferences of waist, hip, thigh and neck, high blood pressure, physical inactivity[8,9] etc.

List of the diseases associated with obese and overweight person's is[10–12]:

- Hypertension
- Dyslipidemia
- Type 2 diabetes
- Coronary heart disease
- Stroke
- Gallbladder disease
- Osteoarthritis
- Sleep apnea and respiratory problems
- Some cancers i.e. endometrial, breast and colon[13,14].

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Along with being overweight or obese, the following conditions will put one at greater risk for many diseases specially heart disease[15].

- High blood pressure (hypertension)
- High LDL cholesterol ("bad" cholesterol)
- Low HDL cholesterol ("good" cholesterol)
- High triglycerides
- High blood glucose (sugar)
- Family history of premature heart disease
- Physical inactivity
- Cigarette smoking

Those who are considered obese (BMI >= 30) or overweight (25<BMI <30) with two or more risk factors (high BP or cholesterol etc)are advised to lose the weight.

2. Preliminaries

BMI is a measure of fat mass and muscles mass of human body determined by establishing relation between weight and height. It is measured by the formula: weight in kg divided by height square in meter[16,17].

$$BMI = \frac{Weight(Kg)}{Height^2(m)}$$

Indirectly BMI value gives an idea about the body fat. On the basis of BMI score, World Health Organization (WHO) classifies a person into different categories of health as mentioned into Table 1[18].

Table 1. International classification of adult underweight, overweight and obesity according to BMI

Classification	BMI(Kg/m^2)	
	Principal cut-off points	Additional cut-off points
Underweight	<18.50	<18.50
Severe Thinness	<16.00	<16.00
Moderate Thinness	16.00-16.99	16.00-16.99
Mild Thinness	17.00-18.49	17.00-18.49
Normal Range	18.50-24.99	18.50-22.99
		23.00-24.99
Over weight	>=25.00	>=25.00
Pre-obese	25.00-29.99	25.00-27.49
		27.50-29.99
Obese	>=30.00	>=30.00
Obese class I	30.00-34.99	30.00-32.49
		32.50-34.99
Obese class II	35.00-39.99	35.00-37.49
		37.50-39.99
Obese class III	>=40.00	>=40.00

Besides BMI, some new and sophisticated technologies have now come up, but they are expensive and time consuming, and also not comfortable for general purpose reading and practice[19].

2.1 Limitations of Existing Notion of BMI.

(1)BMI is not a perfect indicator of body fat because weight does not differentiate between lean body mass(bones, muscle, blood and water etc.) and fat mass[20,21]. It means that two persons having same BMI may have different percentage of body fat. With height and weight only, a single BMI formula cannot be good enough for all populations.

(2)Persons with more muscles but less fat may give high value of BMI. Athletes like football players, wrestlers, weightlifters and boxers have more muscles than fat.

(3)In older persons and others with reduced muscle mass, may underestimate the body fat.

(4)Some athletes may be deemed underweight according to the BMI, specifically those long distance runners and other endurance sports people who have low body fat and lean muscle fibers[22].

3. Modified Notion of BMI: A Proposal

Besides the limitation mentioned in section-2 above, the following proposition reveals a major limitation and drawbacks of the existing notion of BMI.

3.1 Proposition

BMI of a senior or adult person cannot continue to be a fixed index.

Proof: For a senior or adult person, his/her height becomes static. In most of the cases the height does not change but weight keeps on changing with time. For a given adult or senior person, suppose that height = h (constant).

Therefore BMI $= w / h^2$

Since w is not static with age in general, therefore BMI also is not static. Hence proved.

In existing formula of BMI, the parameter height (h) is in the denominator because of the logic that if two persons have equal mass then person having more height should have low BMI. We observe that this BMI is calculated on the basis of linear directional data whereas human body is three dimensional objects. The existing formula of BMI

is a good indicator in connection with majority of human population, but we need to introduce below a better indicator. We want to introduce the following logic:

If two persons have equal mass then person having more body surface area should have higher BMI. With this philosophy in mind we introduce a new notion of BMI, called by BMI type-2 or in short BMI-2. Before presenting the definition, we define another useful index called by FC index as below.

3.2 FC Index

FC index of a person stands an abbreviation for Four Circumferences (FC) together of the following:

Circumference of Waist (fat depositing area of body) = c1

Circumference of Hip (fat depositing area of body) =c2

Circumference of Thighs (fat depositing area of body) = c3

Circumference of Neck (fat depositing area of body) =c4

Thus FC = c1 + c2 + c3 + c4

Clearly FC will be more for healthy or fatty person. Thus for a high FC we get the information that the person is not thin. But we don't get any confirmation from FC whether the person is healthy or not, and that is demerit of FC. However FC contributes to formulate BMI-2.In our future research work, we will explore the possibility of weighted sum of ci for computing FC as below:-

FC=w1c1+w2c2+w3c3+w4c4

where w1+w2+w3+w4=1

In fact, for this we will have to explore a method to unearth the individual contribution of each ci towards FC.

In the existing concept of BMI, cross-section elements are not considered although we claim that the cross-section elements could play a significant role in most of the cases. With this philosophy in mind, we need to define BMI in another way for better analysis and result. We define BMI in a different way now.

3.3 BMI-2

The BMI-2 of a person is defined by:

$$BMI-2=\frac{(Weight^{*}FC)}{(Height)^{2}}$$

Thus, BMI-2 = BMI-1 * FC.

To avoid confusion, we have renamed the existing BMI by BMI-1.

Suppose there are N persons. If we rank them in ascending order of BMI-1and also BMI-2, we are likely to get two different sequences. We claim that the second sequence is more significant for medical results, analysis and diagnosis.

4. Case Study

We are calculating the modified BMI for men by including circumferences of waist, hip, thigh and neck into old formula of BMI.

4.1 Waist Circumference (WC)

A high WC is related to different types of diseases like type-2 diabetes, hypertension, dyslipidmia[23] etc. Besides keeping eyes over BMI value, WC should also be monitored time to time. It gives an estimate of increased abdominal fat even when no change in BMI is observed. Table 2 describes WC.

Table 2. Waist circumference

S.No.	Category	Measurement in cm
1	Normal Range	< 94 cm
2	High Risk	94-101.9 cm
3	Obese	>= 102 cm

4.2 Waist-Hip Ratio (WHR)

The WHO Expert Consultation on WC and WHR was held in Geneva, Switzerland on 8–11 December 2008. Waist–hip ratio (the WC divided by the hip circumference) was suggested as an additional measure of body fat distribution[24]. Table 3 discusses the norms of WHR.

Table 3. Waist-to-Hip Ratio (WHR) Norms[24]

Acceptable		Unacceptable		
Excellent	Good	Average	High	Extreme
<0.85	0.85-0.90	0.90-0.95	0.95-1.00	≥ 1.00

4.3 Thigh

According to the studies in Harvard Men's Health Watch, that thigh circumference, measured where your thigh meets your butt, of about 62 centimeters or 24.4 inches was the most protective[25].

4.4 Neck

The neck size is as important as the waist size. According to the research, having fatty neck increases the risk factor for high blood pressure, high triglycerides and lower levels of

HDL. Scientists from the Department of Family Medicine, Faculty for Health Sciences, Ben-Gurion of the Negev, Israel, suggested the safe neck size not more than 37 centimeters[26,27].

4.5 Threshold/Cut-Off Values

Cut-off sizes of waist, hip, thigh and neck are 94 cm 80 cm, 62 cm and 37 cm respectively. We have considered here the waist size of Europid people because of high upper limit of waist size among others. Table 4 summarizes the different threshold/cut-off values.

Table 4. Threshold values of different body-segments

Body Segment	Cut-off size(cm)
Waist Size(c1)	94(for Europid people)
Hip Size(c2)	80(0.85x94)
Thigh Size (c3)	62
Neck Size(c4)	37

4.6 Discussion

We have already observed that circumferences of waist (c1), hip (c2), thigh (c3) and neck (c4) are related to the health status. If any one of c1, c2, c3 or c4 goes beyond the threshold value, then person cannot be put into normal category of health.

In the Table 5, we have considered a case of an adult male with age 20, weight 80 kg and height 6 feet (1.83 meter). We have also considered here that weight may keep changing but height remains almost constant throughout life after certain stage of life. Suppose his circumferences of waist, hip, thigh and neck are 94 cm, 80 cm, 62 cm and 37 cm respectively. According to the old formula, his BMI value is 23.88(for weight 80 kg and height 1.83 meter).

It is generally observed that with time weight keeps on increasing. Suppose that man has managed to keep the values of c1, c2, c3 and c4 almost constant. And according to Table 5, all values of BMI-1 are less than 24.99, a threshold value which indicates that person is under normal category of health (according to BMI chart given in Table 1). Similarly, the value of c1, c2, c3 and c4 are also in the normal range category (though all are at their high end). Hence it may be concluded that person's health is under normal category. But it seems impossible that increase in weight will not change any one of the values of c1, c2, c3 or c4. Anyone of these would definitely get changed. So if any of these (c1, c2, c3 or c4) is increased, it means person's health is not under normal category of health.

Therefore, values of BMI-1 of Table 5 do not reflect correct status of the health. So we include the values of FC in the current formula of BMI-1 to get BMI-2.Table 6 provides values of BMI-1 and BMI-2 both.

Now according to Table 6, if BMI-1 is 23.88 and BMI-2 is65.19 then that person is in normal category of health. But the moment weight increases, the value of c1, c2, c3 or c4 would also be changed. Now the person cannot be put under normal category of health. Therefore, for the present example, threshold value of BMI-2 is 65.19. If any one of c1, c2, c3 or c4 increases due to weight gain, the value of BMI-2 will also increase and may go beyond 65.19.

Table 5. Four Constants (FC) and BMI-1

S. No.	c1	c2	c3	c4	FC=(c1+c2+ c3+c4)/100	Weight	Height (meter/m)	BMI-1
1	94	80	62	37	2.73	80	6feet (1.83meter)	23.88
2	94	80	62	37	2.73	81	6feet (1.83meter)	24.18
3	94	80	62	37	2.73	82	6feet (1.83meter)	24.47
4	94	80	62	37	2.73	83	6feet (1.83meter)	24.77
5	94	80	62	37	2.73	83.5	6feet (1.83meter)	24.92

Table 6. BMI-1 v/s BMI-2

S. No.	c1 (cm)	c2 (cm)	c3 (cm)	c4 (cm)	FC=(c1+c2+ c3+c4)/100	weight	Height (meter)	BMI-1	BMI2= (BMI1)*(FC)
1	94	80	62	37	2.73	80	6 feet (1.83meter)	23.88	65.19
2	94	80	62	37	2.73	81	6 feet (1.83meter)	24.18	66.01
3	94	80	62	37	2.73	82	6 feet (1.83meter)	24.47	66.80
4	94	80	62	37	2.73	83	6 feet (1.83meter)	24.77	67.62
5	94	80	62	37	2.73	83.5	6 feet (1.83meter)	24.92	68.03

5. Conclusion

It may be concluded that along with BMI-1, it would be advisable to look into the BMI-2 values also, so as to get more accurate picture of the health status.

6. References

1. Anna A. Comparison of selected motor skill related performance and academic achievement among the sixth grade respondents. International Journal of Physical Education, Fitness and Sports. 2013 Jun; 2(2):1–56.
2. Li G .The research of relationship between BMI classification and physical function of male college students. 2013, International Workshop on Computer Science in Sports (IWCSS), Association for Computing Machinery (ACM) Wuhan: Atlantis Press, China; 2013.
3. Obesity and overweigh [Internet]. 2016 [cited 2016 Jun]. Available from: www.who.int /mediacentre/factsheets/ fs311/ en/ index.html.
4. Obesity prevention source [Internet]. 2016 [cited 2016 Mar]. Available from: https://www.hsph.harvard.edu/obesity-prevention-source/obesity-definition/how-to-measure-body-fatness.
5. Vella C, Kravitz L. Gender differences in fat metabolism. IDEA Health and Fitness Source. 2002; 20(10):36–46.
6. About adult BMI [Internet]. 2015 [cited 2015 May 15]. Available from: www.cdc.gov/healthyweight/assessing/ bmi/adult_bmi/.
7. Kyung WB, Chi HJ. The effects of 108-bae program on body composition and physical fitness of obese high school students. Indian Journal of Science and Technology. 2015 Sep; 8(7):1–5.
8. Yan LH, Hee KD, Ho KS. An analysis of nutrients intake, related factors of anemia and bone density in ballet dancers. Indian Journal of Science and Technology. 2015 Oct; 8(25):1–6.
9. Myeong KI, Jin KS, Ryoung PH, Hyang LJ, Woon KS. The long-term effect of aquarobics exercise program on physical function and mental health in elderly women. Indian Journal of Science and Technology. 2015 Oct; 8(26):1–12.
10. Do you know some of the health risks of being overweight [Internet]. 2012 [cited 2012 Dec]. Available from: http:// www.niddk.nih.gov/health-information/health-topics/ weight-control/health_risks_being_overweight/Pages/ health-risks-being-overweight.aspx.
11. Kim, Hyun-Sook. Factors Influencing Underweight and Overweight among Male and Female Adolescents from Multicultural Fam. Indian Journal of Science and Technology.2016 Feb 9(6), Doi no: HYPERLINK "http://dx.doi.org/10.17485/ijst%2F2016%2Fv9i6%2F85155" 10.17485/ ijst/2016/v9i6/85155
12. Preetha N, Ramaswamy L. Assessment of emerging adult women for poly cystic ovarian syndrome symptoms. Indian Journal of Science and Technology. 2016 Aug; 9(30):1–5.
13. Kabat K, Moonseong H, Anthony BM, Thomson ER. Scaling of weight for height in relation to risk of cancer at different sites in a cohort of Canadian women. American Journal of Epidemiology. 2013 Jan; 177(1):93–101.
14. What is the definition of body mass index determine your BMI and save your life [Internet]. 2009 [cited 2009 Jul 26]. Available from: http://EzineArticles.com/2664285.
15. Accessing your weight and health risk [Internet]. 2016 [cited 2016 Feb]. Available from: http://www.nhlbi.nih.gov/ health/educational/lose_wt/risk.htm.
16. Using the BMI-for-age growth chart [Internet]. 2015 [cited 2015 Dec 19]. Available from: www.cdc.gov/nccdphp/ dnpa/growthcharts/ training/modules/module1/text/module1print.pdf.
17. Ferra Y. The health status model in urban and rural society in west Sumatera, Indonesia: an approach of structural equation modeling. Indian Journal of Science and Technology. 2016 Jan; 9(4):1–8.
18. BMI classification [Internet]. 2016 [cited 2016 Jan 27]. Available from: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html.
19. Understanding body fat analysis [Internet]. 2015 [cited 2015 Oct]. Available from: http:www.tanita.com/data/File/ tanita_methods.pdf.
20. Body mass index: considerations for practitioners [Internet]. 2016 [cited 2016 Mar 4]. Available from: http://www.cdc.gov/obesity/downloads/bmiforpactitioners.pdf.
21. Hull HR, Thornton J, Wang J, Pierson RN, KaleemZ, Pi-Sunyer X, Heymsfield S, Albu J, Fernandez JR, VanItallie TB, Gallagher D. Fat-free mass index: changes and race/ ethnic differences in adulthood. International Journal of Obesity. 2011; 35(1):121–7.
22. Yoshimura A. What are the limitations of body mass [Internet]. 2015 [updated 2015 Aug 4, cited 2012 Apr 10]. Available from: http://ezinearticles.com/?What- Are-The-Limitations-Of-Body-Mass-Index?&id=6992875.
23. Waist circumference and waist hip-ratio [Internet]. 2015 [cited 2015 Dec 11]. Available from: http://apps.who.int/ iris/bitstream/10665/44583/1/9789241501491_eng.pdf.
24. Waist to Hip Ratio (WHR) [Internet]. 2015 [cited 2015 Sep 20]. Available from: www.topendsports.com/testing/tests/ WHR.htm.
25. Thigh size: an indicator of heart disease [Internet]. 2015 [cited 2015 Sep]. Available from: https://www.healthstatus.com / health_blog/ heart-disease-2/ thigh-size-indicator-heart-disease/.
26. Lee A. Your neck size is important to your health [Internet]. 2015 [updated 2016 Jul 12, cited 2013 Jul 23]. Available from: http://www.collectivewizdom.com/Your Neck Size Is Important to Your Health. html.
27. Jagadamba A, Sumit G, Karthiyanee K, Vinutha S. Neck circumference as an anthropometric measure of obesity in diabetics. North American Journal of Medical Sciences. 2013 Jan; 5(1):28–31.