Body Mass Index (BMI) is a Popular Anthropometric Tool to Measure Obesity Among Adults

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Abstract: *This paper tries to discuss aspects of Body Mass Index (BMI) that represents an index of body fat content in human, and is extensively used worldwide to measure different grades of obesity. BMI is simple, inexpensive and non-intrusive method of screening for weight categories. It is directly related to various morbidity and premature mortality in many nations irrespective of age, sex, social status, and ethnicity. This study also tries to show some drawbacks of body mass index that arise due to gender, age, social status, and ethnic differences; and also for confidence on self-reported values of weight and height for BMI measurement. At present underweight, overweight, obesity, physical inactivity, and unhealthy eating habits are all responsible for the various non-communicable diseases. The aim of the study is to discuss aspects of BMI in brief.*

Keywords: Body mass index, underweight, overweight, obesity

I. INTRODUCTION

In the early and middle of the 20th century obesity was a problem of only high-income countries, such as almost every country of Europe and the USA. Low-income countries have burdened with high levels of under-nutrition, such as stunting, wasting, underweight, and infectious diseases (Tebekaw et al., 2014; Mohajan, 2020a, 2021). But in the 21st century, obesity has expanded to low- and middle- income countries of every region of the world (Caballero, 2007; WHO, 2020). At present obesity is considered as one of the most fatal health issues worldwide. Hence, elapse of time; obesity remains not a local problem but becomes a global concern. Therefore, accurate measurement of obesity is needed for the treatment of underweight, overweight, and obese people (Mohajan & Mohajan, 2023).

Body Mass Index (BMI) is a popular and reliable anthropometric tool to measure obesity, and the assessment of a person's nutritional and health status that applies to both adult men and women (Aryal, 2020). It is also a reliable risk indicator for various diseases that can develop due to a higher percentage of body fat. At present it is extensively used in many fields because of its simplicity in measurement and its availability, such as in medical office, laboratory, gym, home, etc. (Finucane et al., 2011). In these fields it is used by all people, both amateur trainers, as well as professionals, scientists, and researchers (Zygmunt et al., 2019).

World Health Organization (WHO) considers BMI as a predictor of obesity. It has classified overweight and obesity depending on BMI measurement (WHO, 2000, 2005). At present BMI is the best available anthropometric estimate of body fatness for public health purposes. It is related to both physical and psychological health, such as overall mortality, chronic somatic illnesses, psychiatric disorders, etc. (Petry et al., 2008; Luppino et al., 2010). Body Mass Index (BMI) is a measure of human body fat based on height and weight. A person's weight is calculated in kilograms or pounds and divided it by the square of height in meters or inch.

Hence, its unit is kg/m^2 or $lb/inch^2$ (Nuttall, 2015). The BMI can be finding out using a table or a chart. An ideal BMI is lies within the range $18.5 \pounds BMI \pounds 29.9$. BMI also provides nutritional status in adults (Henriques et al., 2019).

We have some alternative indirect anthropometric measurements indices, such as body volume index, *Benn index,* Ponderal index, etc. (Huxley et al., 2010; Apell et al., 2011). There are some important direct anthropometric measurements, such as waist circumference (WC), waist-hip-ratio (WHR), bioelectrical impedance, hydrodensitometry (*hydrostatic* underwater weighing), isotope dilution, sagittal abdominal diameter, dual energy x-ray absorptiometry (DXA), magnetic resonance imaging (MRI), computer tomography (CT) scan, and skin-fold thicknesses (Steinberger et al., 2005; Freedman et al. 2013). These measurements are thought to be more specific indicators of visceral fat accumulation, adverse metabolic profile and disease risk that give accurate values of body fat (Schneider et al., 2010). But direct measurements of body fat require more time and money, better facilities, highly trained personnel, tedious methodology, lack of available retrospective data, technical difficulties, etc. On the other hand, BMI provides ready result, and one can easily find it from chart or easily can calculate using a calculator

II. LITERATURE REVIEW

In any research, the literature review is an introductory section, where works of previous researchers are highlighted (Polit & Hungler, 2013). It helps the novice researchers to understand the subject, and it serves as an indicator of the subject that has been carried out previously (Creswell, 2007). Feon W. Cheng and her coworkers examine the association between baseline body mass index and all-cause mortality in a well-characterized cohort of older persons (Cheng et al., 2006). Mika Kivimäki and his associates have tried to examine the risk of common health conditions among people with obesity and obesity-related diseases, and illustrate the role of obesity in the development of complex multi-morbidity of elderly people (Kivimäki et al., 2022). Robert C. Weisell has studied on the BMI risk-based cut-off points, and has observed that it is needed for a tailoring of the cut-off points for Asia. He has advised that it is very important to conduct a thorough review on these points to provide them publicly (Weisell, 2002).

Paul Deurenberg and his coauthors have studied the BMI, percent body fat, gender and age of populations of American Blacks, Caucasians, Chinese, Ethiopians, Indonesians, Polynesians, and Thais. They have found that percent body fat and BMI differs in the ethnic groups (Deurenberg, 1998). Trishnee Bhurosy and Rajesh Jeewon have shown the potential drawbacks of body mass index (BMI), when it is used to test overweight or obesity risk. These arise due to gender, age, social status, and ethnic differences in body fat composition. They have suggested for taking these factors into consideration when BMI is used in public health sector (Bhurosy & Jeewon, 2013). S. P. Apell and his coauthors have analyzed BMI from a physical perspective with emphasis on dimensional analysis, scaling with mass and relevant length-scales, such as waist circumference (WC) as well as relating it to body metabolic rate and heat loss (Apell et al., 2011).

Sameer Al-Ghamdi and his coworkers have found in their research works that increasing age, being married and high serum cholesterol be the significant predictors of overweight and obesity (Al-Ghamdi et al., 2018). Mark P. Silverman and Trevor C. Lipscombe derive the mathematically exact BMI probability density function (PDF), as well as the exact bivariate PDF for human weight and height, where weight and height are shown to be correlated bivariate lognormal variables whose marginal distributions are each lognormal in form (Silverman & Lipscombe, 2022). Andre Henriques and his coauthors aim to evaluate several domains of obesity related knowledge according to the BMI in a representative sample of Portuguese-speaking dwellers in mainland Portugal (Henriques et al., 2019).

Vasanthakumar N. Bhat believes that fast food consumption is a major cause of obesity all over the world. He has examined the association between the average frequencies of eating a meal from a fast-food restaurant per week and Body Mass Index. In his study he finds that the higher is a person's BMI, the more importance a person assigns to the cause of his obesity being the kinds of foods marketed in restaurants and grocery stores (Bhat, 2016). J. Thavamani has tried to create awareness and preventive health measures among students on Body Mass Index, and preventive measure for obesity through counseling students on healthy nutrition and the importance of physical activities (Thavamani, 2019). Clarisa I. Rodríguez and her coauthors have tried to compare mean weight, height, and body mass index (BMI) values as per different measurement techniques and analyze the influence of socioeconomic level (Rodríguez et al., 2019).

III. RESEARCH METHODOLOGY OF THE STUDY

To lead in academic world an academician takes the research as an essential and influential work of his/her way of life (Pandey & Pandey, 2015). Methodology is a guideline of any research, which is considered as an organized procedure that follows scientific methods efficiently (Kothari, 2008). It is a system of explicit rules and procedures in which research is based (Ojo, 2003). It tries to describe the types of research and the types of data *(Somekh & Lewin, 2005)*. Research methodology is a strategy for planning, arranging, designing, and conducting a meaningful and valuable research, which tries to develop logic to generate theory within which the research is conducted (Remenyi et al., 1998; Legesse, 2014). It tries to create new knowledge basis on the existing knowledge (Goddard & Melville, 2001). A researcher tries to reflect his/her philosophical beliefs and interpretations of the world prior to the starting research, where reliability and validity are two most important and fundamental features for the evaluation a research (Crotty, 1998; Mohajan, 2017, 2020b).

Before discussing BMI we have briefly discussed underweight, overweight, and obesity. Then we have consulted historical background and categories of BMI. Finally, we have taken steps to discuss limitations and drawbacks of BMI. To prepare this article we have consulted books of famous authors, national and international journals, e-journals, handbooks, theses, etc.

Objective of the Study

The dominant objective of this study is to discuss the aspects of BMI. At present BMI is one of the most popular anthropometric tools to measure body fitness. Some other minor objectives of this study are as follows:

- to introduce the origin of BMI,
- to highlight underweight and overweight, and
- to show the drawbacks of BMI.

Obesity

Obesity is regarded as one of the most important health issues worldwide. It is already affected more than one-third of the population around the world, and this figure is increasing alarmingly (WHO, 2021). If such escalation continues, about 85% of US citizens and an estimated 20% of the world population will be obese, and another 38% will be overweighed by 2030 (Wang et al., 2008; May, 2013; WHO, 2020).

Scientists have found that there is a strong relationship between health and weight. Obesity is associated with a variety of risk factor for developing some diseases, such as hypertension, cardiovascular diseases, Alzheimer disease, asthma, metabolic syndrome, liver steatosis, gallbladder disease, osteoarthritis, obstructive sleep apnea, certain types of cancer, hypercholesterolemia, metabolic syndrome, musculoskeletal disorders, and type 2 diabetes; and consequently, causes early death (Huxley et al., 2010; Mohajan & Mohajan, 2023). These diseases develop in human bodies through the increased mass of adipose tissue and the increased secretion of pathogenic products from enlarged fat cells (Bray, 2004).

Through the maintaining a healthy weight an individual can prevents and controls many diseases and conditions. Every person needs to know what weight they should bear to be healthy (Aryal, 2020). It appears that individuals with a high socioeconomic status are more conscious than those with a lower socioeconomic status. In 2014, the highest overweight and obesity prevalence have found in western developed countries (69%), Central and Eastern Europe (61%), Latin America and the Caribbean (57%), and the Middle East, North Africa, and Central Asia (56%) (Marrodán et al, 2013).

Underweight

BMI is considered as an indicator of under-nutrition. The International Dietary Energy Consultative Group (IDECG), and the Food and Agriculture Organization (FAO) have examined both appropriate cut-points of the BMI at the lower end of the spectrum. The join group has developed three classes of Chronic Energy Deficiency (CED) as; $BMI < 16.0$ indicates CED grade III, $16.0 \pounds BMI \pounds 16.9$ indicates CED grade II, and $17.0 \pounds BMI \pounds 18.4$ indicates CED grade I (James et al., 1988; Mohajan, 2019). An individual may be underweight because of genetic or metabolic

causes, lack of food, gastrointestinal problems, hyperthyroidism (overactive thyroid), cancer, tuberculosis, etc. (Luder & Alton, 2005; Mohajan, 2022).

Being too thin due to underweight a person is in endangering of health. Underweight persons are prone to infections and osteoporosis. Women with severe underweight causes amenorrhea, infertility, pregnancy complications, anemia, hair loss, etc. (Tebekaw et al., 2014). Sometimes underweight may happen anorexia nervosa and bulimia nervosa to emphasis on thinness. Symptoms of anorexia nervosa are loss of appetite that results the body weight drastically drops (Nagy et al., 2022). For bulimia nervosa, an individual takes a large quantity of food in a short period of time that may causes self-induced vomiting, laxatives, fasting, and intense physical exercises for preventing weight gain (Ruchkin et al., 2021).

Body Mass Index (BMI)

The Body Mass Index (BMI) is the relation between limited information, weight and height that does not account for body composition. It is defined as the body mass divided by the square of the body height, whose unit is kg/m^2 or $lb/inch^2$; where height is measured in meters/inch, and mass in kilograms/pounds (Taylor et al., 1998). BMI provides a simple numeric measure of a person's thickness or thinness. It is used to screen weight categories and health problems associated with weight. Moreover, it is widely used in determining public health policies. The BMI scale determines whether the person falls into one of five different categories, such as in underweight, normal, overweight, obese, and severely obese (WHO, 2004, Mohajan & Mohajan, 2023). At present BMI is the best available and highly used anthropometric estimate of body fatness for public health purposes. Higher BMI usually mean higher body fat and higher health risks (Bhurosy & Jeewon, 2013).

The metric formula of BMI is as follows (WHO, 2004):

$$BMI = \frac{mass_{kg}}{height_m^2}, \qquad\qquad (1)$$

where unit is kg/m^2

If pounds and inches are used, a conversion factor of $703 \times \dfrac{kg/m^2}{lb/in^2}$ is applied to measure BMI.

Therefore, the English formula of BMI is as follows (WHO, 2004):

$$BMI = \frac{mass_{lb}}{height_{in}^2} \times 703, \qquad\qquad (2)$$

where unit is $lb/inch^2$.

A high BMI indicates high body fatness that causes serious health problems, such as heart disease, diabetes, high blood pressure, and stroke. It is a reliable indicator of body fatness for most people. Due to its simplicity, it has come to be widely used for preliminary diagnoses. But, it is less accurate in body builders and pregnant women (Innocent et al., 2013).

Higher BMI indicates obesity and lower BMI indicates underweight. Both obesity and underweight are accompanying with subjective lower welfare, and normal BMI is related to higher welfare (Aryal, 2020). BMI significantly increases with the older ages, and this might elevate the risk of NCDs among them. As BMI increases, there is a direct increase in body fatness (Kivimäki et al., 2022).

Historical Background of BMI

Belgian Flemish astronomer, mathematician, statistician, and sociologist, Lambert Adolphe Jacque Quetelet (1796-1874), has developed Body Mass Index (BMI), what he called "*social physics*" (Mardolkar, 2017). World Health Organization (WHO) formerly called BMI the Quetelet index (WHO, 2000). The aim of Quetelet's data collection was

not for determining disease risk, but rather he was attempting to anthropometrically quantify the "average" man (Quetelet, 1835).

The term "*Body Mass Index (BMI)*" is coined in 1972 by the US physiologist Ancel Benjamin Keys (1904-2004) and his coauthors. After this renaming quickly BMI gained traction in the scientific community (Quetelet, 1835). Professor Keys has studied on the influence of diet on health (Keys et al., 1972). J. S. Garrow and J. Webster have measured human body composition by body density, body water, and body potassium in a series of female and male subjects; and results support a weight-height index BMI. After this study, BMI has become one of the most common parameters in nutritional, metabolic, and cardiovascular studies (Garrow & Webster, 1985). The BMI cut-points were derived from the relationship between body fat percentage, BMI, and associated disease risk (Fitzpatrick, 2014).

Classification of BMI

In1993, the WHO assembled an Expert Consultation Group that developed uniform categories of the BMI. Four categories were established by WHO as: underweight, normal, overweight, and obese (WHO, 1995). An individual is considered underweight if his/her BMI is under 18.5, normal weight if it is 18.5 to 24.9, overweight if it is 25 to 29.9, and obese if it is 30 or more. A BMI of 25 to 29.9 is referred as ''pre-obesity,'' (Di Angelantonio & Bhupathiraju, 2016). Linear regression shows that a BMI of 16.9 in men and 13.7 in women represents a complete absence of body fat stores (Garrow & Webster, 1985).

In 1997, the International Obesity Task Force subdivides obesity based on BMI as; i) class I obesity; BMI 30 to 34.5 (low risk), ii) class II obesity; BMI 35 to 39.5 (moderate risk), and iii) class III obesity; BMI 40+ (high risk). The ranges of BMI values are given in Table 1 (WHO, 2016; Yarborough et al., 2018; CDC, 2021):

Table 1. The ranges of BMI values

Category	BMI (kg/m^2)
Underweight (Severe thinness)	< 16.0
Underweight (Moderate thinness)	16.0–16.9
Underweight (Mild thinness)	17.0–18.4
Normal range	18.5–24.9
Overweight (Pre-obese)	25.0–29.9
Moderately obese (Class I-low risk)	30.0–34.9
Severely obese (Class II-moderate risk)	35.0–39.9
Very severely obese (Class III-high risk)	$\geq$ 40.0

Source: WHO, (2016).

Limitations of BMI

No doubt BMI presents a good measurement of obesity. But BMI has some major drawbacks and some cases fails to provide real information about some parts of body composition, muscle, bone, fat, and some other tissues (Seidell & Flegal, 1997; Muralidhara, 2008). This is mainly due to some environmental factors, such as physical activity level, gender, age, social status, and ethnic differences in body fat composition and distribution coupled with increased reliance on self-reported values of weight and height (Kesavachandran et al., 2012; Bhurosy & Jeewon, 2013). For example, a person of heavy muscular may be falls into the "overweight" category; actually s/he may be a very low body fat possessing real healthy person (Griffiths et al. 2011). On the other hand, an elderly and weak person, who has a little muscle but a high percentage of body fat, whose BMI may be within

$18.5 \pounds BMI \pounds 24.9$; actually s/he may be an overweighed person. For example, a person aged above 70 who possesses a normal BMI, but s/he may has a higher risk of death than a person of aged 30 who is overweighed. Therefore, elderly persons considering BMI as their true healthy measurement may be misleading and frequently overlook their

prevalence of diseases (dos Santosa & Sichierib, 2005). Consequently, an overweight older adult suffers from various psychiatric problems, such as to lose weight may start starvation (Flicker et al., 2010).

Some diseases, such as diabetes and cardiovascular are seen even in Singaporean people of lower BMI and low abdominal fated, but these diseases are seen extensively among Indian people who have higher BMI and excess abdominal fat (Kesavachandran et al., 2012). BMI does not accurately predict overweight or obesity of Northern India people (Dudeja et al., 2012). For example, in Indonesians, Thais, and Ethiopians the cut-off values for obesity based on BMI could be as low as 27, whereas, in Blacks and Polynesians, the cut-off point could be slightly higher than the now used value of 30 (Deurenberg et al., 1998).

Polynesians have a low proportion fat mass to lean mass; but suffer from a higher risk of diabetes. The opposite situation is seen among Europeans (WHO, 2004). Blacks have less body fat than the Whites (Wagner & Heyward, 2000). Generally, after the age of 50, women have generally higher prevalence of obesity than men due to the redistribution and internalization of visceral or subcutaneous fat, which is not effectively measure by BMI (Humayun et al., 2009).

For cardiovascular risk, BMI is a less reliable predictor. BMI does not adequately and efficiently reflect the overweight or obesity status of all populations. The cut-offs of BMI provided by the WHO, do not adequately reflect the overweight or obesity status of all populations (Kesavachandran et al., 2012). For example, a higher body fat percentage is correlated with lower BMIs among Asians, while higher BMIs are seen among Pacific Islanders who have more muscle mass and less body fat (Weisell, 2002).

Most cases BMI is established on the basis of self-reported anthropometric data, where body weight is under-reported and body height is over-reported that lead misclassification of BMI categories. With this BMI reports, doctors' treatment for non-communicable diseases (NCDs) are not done properly (Lin et al., 2010). We have observed that BMI and its cut-off values are quite inappropriate for many ethnic groups; because there is a different relationship between their BMI and body fat content. WHO stresses on the direct measurement of the body fat and to appropriate data from large scale studies (Muralidhara, 2008).

Athletes typically have a greater muscle, which contribute to a high BMI, mislabeled as overweight or obese by BMI standards (Nevill et al., 2006). Athletes also have significantly lower waist circumference and shows lower BMI compared to the general population (Dudeja et al., 2001). BMI, disease risk, and body fatness vary by age, gender, social status, and ethnicity. Therefore, older adults and athletes are at risk for misclassification of BMI (Nevill et al., 2006).

IV. CONCLUSION

Since 1980s obesity becomes one of the most fatal health issues worldwide. Actually, obesity is preventable and curable, and an obese person can rebuild his/her body fitness as like a normal person through the maintenance of scientific methods. Obesity in older ages can be taken as a powerful predictor for mortality. It has a relationship of premature mortality and morbidities. BMI is used for estimating nutritional and health status of an individual. It is related with both physical and psychological health. It does not measure overweight or obesity risk and mortality risk very accurately irrespective of gender, age, social status, and ethnicity. So that with BMI measure some other direct measures, such as waist circumference (WC), waist-hip-ratio (WHR), etc. should be considered in parallel for the better treatment of obesity. Although BMI has some drawbacks, it remains one of the most widely used tools to screen obesity risk in the worldwide.

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