BMI as a Broadly Used, Misapplied, and Insufficient Measure: A Narrative Review

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ABSTRACT

There may not be a more widely known tool than the Body Mass Index (BMI). Its widespread acceptance, however, comes in spite of much evidence and history that suggests such should not be the case. The purpose of this narrative review was to examine the history, applications, and effectiveness of the BMI as an anthropometric tool. Relevant studies on the BMI's origins, applications, and usefulness compared to other anthropometric measures were extracted from PubMed and Google Scholar and examined. The evidence posits that the BMI was not created for its present-day utility and is thus heavily misapplied. The literature also suggests that other anthropometric measures may be more effective at the assessments to which the BMI is popularly called upon. This narrative review concludes with a call for future research in developing a superior alternative to the BMI for assessing body composition in a similarly widespread fashion.

Introduction

The Body Mass Index (BMI) was first known as Quetelet's Index, created in 1832 by statistician Adolphe Quetelet. Quetelet's Index originally served as a way of describing the bell-shaped normal distribution of men's weight relative to height within European populations (Eknoyan, 2008). The index was later validated by Ancel Keys in 1972 as superior to the other indices of its times, including the ponderal index (weight/height^3) (1972). Keys also renamed Quetelet's Index as Body Mass Index (1972). The very same BMI is used present-day, although its ubiquitous use has garnered much controversy for decades. Thus, the purpose of this narrative review is to analyze the history, applications, and effectiveness of the BMI as a measure of body composition, utilizing relevant published literature spanning from 1972 (the first mention of BMI by Keys) to 2022 from PubMed and Google Scholar databases. Substantial evidence suggests that despite broad use, BMI is often misapplied and serves as an insufficient indicator of body composition as well as metabolic health.

Broadly Used

BMI is perhaps one of the most widely used health metrics in the world. It is integrated into health and fitness standards set by the World Health Organization (WHO), the U.S. Centers for Disease Control and Prevention (CDC), FitnessGram®, and many other organizations (*Defining Obesity*; "Exercise Prescription...", 2018; *FitnessGram*®, 2019; "Physical Status," 1995). BMI often serves as an inclusionary/exclusionary criterion, a classification tool, and/or as a predictor of health risks. Even within policy making, BMI's use is profuse, spanning from insurance companies to the U.S. Equal Employment Opportunity Commission. BMI is often utilized as a criterion for health coverage, and insurance premiums can be altered as a form of positive punishment to those who do not change their lifestyles and bodies to comply (Dhurandhar, 2016).

Quetelet's original aim for the BMI likely explains its adept ability to be applied broadly, as it was created to describe large populations and aid in prediction making within a field pioneered by Quetelet called "social physics"

(Eknoyan, 2008). Thus, the BMI was created as a cost-free and quick-to-use mathematical formula. Whereas other attempts to describe the human body (skinfolds, bioelectrical impedance, etc.) require some combination of expensive technology and a high level of operational skill, BMI calculations require nothing more than height and weight measurement via a stadiometer and scale, and a working knowledge of basic arithmetic. Regardless of environmental settings and access to technology, BMI is one of the most accessible and practical ways to conduct anthropometric analyses (Fletcher, 2014; Prentice & Jebb, 2001). The simplicity of BMI still serves Quetelet's original aim as well in being used to describe large populations, which only furthers its widespread use as BMI is easily used in tracking population-level anthropometric changes across regions and time (Fletcher, 2014). However, despite the ease of access and dissemination of BMI as a measure of body composition, its broad use does not necessarily imply validity in assessing body composition.

Keys made note of this, stating that "so long as the standard is accepted and all sets of data on individuals are referred to it, the validity of comparisons between individuals or groups will be independent of the 'quality' of the table" (1972). While this may be true in a statistical sense, it disregards the need for quality in a measure that now broadly impacts the lives of many. If BMI is not of high quality, then the risk of individuals being misclassified increases greatly. For example, if a given weight at a given height is mistakenly classified as obese according to BMI, then every individual at that given weight and height will be misclassified as obese regardless of body composition since the standard is universally accepted. This means that any consequence, whether it be economic or otherwise, that comes from being misclassified as obese has been passed onto every person at the given weight and height. Keys attempts to separate validity from quality, but in an applicable sense those two things cannot be separated because they are one and the same. A measure that is not of high quality is not a valid measure by definition; a high-quality measure of adiposity cannot simultaneously be an invalid measure of adiposity. When an invalid measure is passed off as valid anyway and then broadly utilized, misapplications ensue as the original application itself is a misapplication.

Misapplied

Quetelet's Index was not well known immediately after its inception, but Keys' endorsement and renaming of the BMI led to an increase in popularity and usage over the years. Particularly, Keys endorsed the BMI as a superior tool when compared to the ponderal index and the simple "weight/height" index regarding correlation with obesity (1972). As a ratio index of body weight to height, BMI is not a measure of body fatness and cannot directly highlight excess body fat; it can only directly highlight excess relative body weight. Whether or not the excess relative body weight is considered a positive or negative adaptation has to do with the context in which the weight was gained and the constituents of the excess weight. For this reason, many critiques of the BMI point out that a higher BMI in athletes often mislabels them as overweight or obese when the excess weight is derived from additional lean body mass (compared to the normative values) and not from fat. It is important to note, however, that mislabeling does not occur solely within athletic populations. A study by Hannan et al. found that in adolescent women, body fat percentage could range from 18.1% to 32.5% while BMI remains fixed at 20 (1995). In adult women, body fat percentage could change ± 5% without any change in BMI (Hannan et al., 1995).The variance in levels of adiposity within a single BMI value further supports the notion that BMI is not a measure of body fatness. It should not be possible for two individuals with the same value in a measure of adiposity to have different levels of adiposity. Whether as a direct measure or as a surrogate, use of BMI to discern body fatness is a misapplication of the measure, and that misapplication affects more than just athletes or physically active individuals.

It is worth noting that Keys was aware of this crucial misapplication of the BMI and relative weight indices in general, stating that "in the middle range of the various weight indices,… it is unlikely that any weight index will provide an acceptable indication of adiposity or body fatness" (1972). While it is true that outliers exist on either end of a normal distribution curve, most individuals reside within the middle range of that very same distribution curve. Meaning, for most individuals, BMI likely does not provide any acceptable insight on body composition, and namely

body fat levels. Meaning, for most individuals, the BMI is grossly misapplied. WHO defines obesity as "abnormal or excessive fat accumulation that presents a risk to health…" and concurrently uses the BMI in that definition, stating that "A body mass index (BMI) over 25 is considered overweight, and over 30 is obese" despite the fact that, as already mentioned, the BMI does not measure body fatness at all ("Physical Status," 1995). BMI holds little to no face validity in the discussion and definition of obesity when obesity is defined as excess body fat because BMI is not an appropriate tool for assessing body fat.

Incongruencies in the definition of obesity are rampant in published literature and governing organizations around the world, which only fuel the misapplication of the BMI further. For example, while WHO mentions excess body fat when defining obesity, the CDC defines obesity as a range of weight that is above what is normally considered healthy for a given height, using the BMI in this definition and giving no mention of body fat (*Defining Obesity*). The American Medical Association and the American Heart Association join the CDC in neglecting to emphasize body fat while simultaneously employing the BMI as a qualified measure in their definition of obesity (Eckel et al., 1998; Stoner & Cornwall, 2014). Obesity is largely understood as an excess of body fat. The definitions of obesity that make no mention of body fat but instead rely on body weight likely employ a logical school of thought as illustrated in Figure 1.

Figure 1. A typical flow of inferences regarding the Body Mass Index (BMI).

The issues, however, are that excess body weight does not necessarily equate excess body fat, and excess body fat does not necessarily equate poor metabolic health (Eckel et al., 2005; Freedman et al., 2005; Sims, 2001; Stefan et al., 2008; Tomiyama et al., 2016). The definition of a medical term, such as obesity, cannot be at the mercy of connotations, implied meanings, or correlations upon correlations. This becomes even more pertinent when evidence in the medical community that suggests a strong relationship between BMI and body fat percentage is misconstrued as valid reasoning to use BMI as a diagnostic tool for obesity (Alves Junior et al., 2017).

For research and discussion in general to productively occur around the subject of obesity, a uniform definition and measure is necessary. Unfortunately, there is no uniform definition of obesity, as the definition shifts from a focus on body fat to a focus on body weight depending on the governing organization in question. Fortunately, there is a uniform measure of obesity being employed by these organizations, but unfortunately that measure is the BMI. Placing the validity/effectiveness of a given definition aside, the BMI cannot logically be a direct measure of excess body weight and a direct measure of excess body fat at the same time, given that it is a formula that only accounts for one of those variables. Therefore, the BMI is being largely misapplied whenever it is extrapolated to a measure of excess body fat.

In endorsing the use of the BMI, Keys mentions that "not more than half of the total variance of body fatness is accounted for by the regression of body fatness on the body mass index," which further underscores any and every attempt at utilizing the BMI to discern adiposity. The goal behind discerning adiposity from the BMI is to then discern metabolic health from adiposity. This was known to Keys, who stated that "in both medical and popular uses of relative weight data the interest, conscious or unconscious, is on the implication for body fatness" (1972). Following the stream of logic illustrated in Figure 1, it is true that the BMI directly correlates with body weight. The subsequent correlation

between excess body weight and body fat, however, is not always present (Prentice & Jebb, 2001). That shaky correlation is then rocked further by extrapolating excess body fat to poor metabolic health when that subsequent correlation is not always present either, as exemplified by the phenomena of metabolically healthy obesity (Eckel et al., 2005; Freedman et al., 2005; Sims, 2001; Stefan et al., 2008; Tomiyama et al., 2016) and normal weight obesity (Di Renzo et al., 2006). As it stands, the BMI is broadly being employed to highlight metabolic health through the lens of obesity, which is a known risk factor and key component of metabolic syndrome, when the BMI only has valid footing as a measure of relative body weight.

Insufficient

Table 1. Studies comparing the BMI to other measures/predictors of obesity or metabolic health.

Study	*Study Design*	*Conclusion*
Lee et al. (2008)	Meta-analysis	BMI appears to be a poor discriminator for cardiovascular disease risk factors compared to waist-to-height ratio.
Savva et al. (2013)	Meta-analysis	Waist-to-height ratio may be superior to BMI at predicting cardiovascular disease risk factors.
Simmonds et al. (2015)	Meta-analysis	Childhood BMI does not appear to accurately predict adult obesity or disease.
Yusuf et al. (2005)	Case-control	BMI may be unable to predict myocardial infarction as well as waist-to-hip ratio, waist circumference, or hip circumference.
Reis et al. (2009)	Prospective	Measures of abdominal obesity (namely waist-to-hip ratio) appear to predict mortality independent of BMI. Waist-to-hip ratio also offers additional prognostic information that is absent with BMI.
Swainson et al. (2017)	Cross-Sectional	Waist-to-height ratio was a superior predictor of whole-body fat percentage and visceral adipose tissue mass compared to BMI.
Groothof et al. (2021)	Case Study	Changes in muscle mass more closely mirrored changes in renal and metabolic health compared to BMI.

If the misapplications of the BMI are completely ignored, the index still proves to be an insufficient measure of body composition, obesity, and metabolic health. Its insufficiency is rooted in the preponderance of evidence that finds other measures to be more effective, as seen in Table 1. BMI-for-age appears to be an attempt in correcting some of the insufficiencies that the BMI presents in regard to assessing health risk and body composition, especially in younger people. BMI-for-age uses percentile rankings to classify where the threshold for increased health risk and

obesity begins for people of a given age. The CDC provides BMI-for-age charts, as do other organizations (*BMI-for-age*; *Data Tables*). The limitation with BMI-for-age percentiles is that the given threshold for obesity is inherently relative. Percentiles are a relative means of measure; in that they rank an individual in reference to similar peers. Obesity itself is not a relative phenomenon, yet BMI-for-age attempts to be a measure of obesity that places individuals in a percentile rank in comparison to the BMI distribution for a given age. This allows the threshold for what is considered obese to be moved throughout the years as populations fluctuate. However, if the goal in classifying obesity is to delineate metabolic health status from an excess accumulation of body fat, then changes in a population's demographic overtime does not logically impact the metabolic state of a single body, suggesting that BMI percentile rankings are an insufficient adjustment to the already insufficient BMI.

In terms of assessing body composition, the BMI remains insufficient as it cannot provide any useful information regarding the composition of the body (the entire point of the measurement). Moreover, valid measures of body fat percentage are relatively inexpensive, widely available, and vary in the amount of expertise/experience needed to properly assess body fat to the point that it is practical for any clinical, recreational, or research-based institution to make use of measures superior to the BMI (Kasper et al., 2021).

Conclusion

BMI is tasked with assessing body composition and metabolic health risks; it is a poor tool for both of those tasks and yet is widely used. Assessments of metabolic health are better measured directly rather than estimated/predicted from BMI scores. In many instances where the BMI is currently used to assess metabolic health, such as in clinical practices, it is very much feasible, affordable, and reproduceable to directly measure blood glucose levels, blood pressure, resting heart rate, and other direct markers of metabolic health, even without financially expensive blood samples. Furthermore, the current use of the BMI to define obesity has created the need for phenomena such as normal weight obesity and metabolically healthy obesity to describe much of the population that finds itself misclassified in terms of metabolic health, given that obesity is used to infer metabolic health. If obesity is meant to be a metabolic condition, or a condition of excess body fat, then there is a need to standardize the definition of obesity as a medical community to reflect that; the BMI does not reflect a view of obesity as a condition of metabolic health or increased adiposity.

Assessments of body composition are better executed through measurements of body fat percentage and lean body mass. The only advantage that the BMI lends over measures of body fat percentage is the uniformity of the index's classifications, although that was not always the case. Furthermore, several organizations such as the American College of Sports Medicine and the American Council on Exercise have already begun implementing normative tables for body fat percentages ("Health-Related...", 2018; Muth, 2010). There remains a need for further research and development of standardized measures of body composition that are simultaneously valid and as widely accessible as the BMI. The issue of reproducibility in body composition measurements such as skinfolds, bioelectrical impedance, and hydrostatic weighing due to a variety of measurement tools and body density formulas renders virtually all body composition measurements as unsuitable alternatives to the BMI for widespread adoption; the issue of cost is not a concern given skinfold calipers are relatively inexpensive, portable, and valid in trained individuals, which includes medical professionals (Kasper et al., 2021; Loenneke et al., 2013). Nonetheless, the many different direct body composition measurements available would be far more suitable than the BMI for use with a smaller sample/population, but none can realistically be proposed as an alternative to the BMI for broad use despite its insufficiencies. Until a different measurement improves in its ability to be widely employed and disseminated, the BMI will likely remain broadly used and misapplied.

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