The Mathematical Formatting of Obesity in Public Health Discourse

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Rising rates of obesity are of widespread public concern and are targeted by public health policy around the world. In this paper, we examine the origins of the most common definition of obesity, known as the Body Mass Index (BMI). We draw on Skovsmose's concept of formatting, combined with a historical examination of the origins of the BMI, to show how obesity is a form of realized abstraction. We discuss how mathematics therefore formats obesity, indicate some of the consequences of the particular way this occurs through the BMI, and suggest some possibilities for mathematics teaching arising from this work.

Introduction

Obesity rates have been widely reported to be increasing in both children and adults, leading to higher rates of mortality and diseases like heart disease and diabetes. Societal effects include a less healthy population and increased pressure on health care systems. In response, governments around the world have developed public health policies, including school-based and public education programs[1]. Public and educational discourses tend to focus on the negative effects of obesity, contrasted with the positive effects of exercise and a healthy diet. In schooling, obesity, diet, and fitness are typically addressed in health and physical education curricula. Obesity discourse is, however, partially based on mathematical constructs. In this paper, we focus on a standard measure of obesity: the Body Mass Index (BMI). We examine the history and recent use of this measure as an example of the mathematical formatting of society (Skovsmose, 1994). We conclude with reflections on the role of mathematics education in empowering students and citizens to participate critically in the production and consumption of public health information.

The Obesity Epidemic

The discourse of an "obesity epidemic" has infiltrated the collective cultural consciousness. For example, a recent U.S. poll found that childhood obesity was the most common childhood health concern reported by the adult participants, with 55% of participants selecting this option, compared to 52% for bullying (which, arguably, may be weight-related in many cases) and 49% for drug abuse (Allen, 2014). In Canada, the overall prevalence of obesity has increased from 9% to 21% over the past 25 years (Elgar & Stewart, 2008). More specifically, the 2013 edition of the Canadian Community Health Survey (CCHS), which uses self-reported height and weight data, found that 18.8% of adults were obese (Statistics Canada, 2014). When considering men and women separately, marked gender differences were seen: 62% of men and 45% of women were considered to be either overweight or obese. Although the proportion of overweight or obese women has remained stable since the 2010 edition of the CCHS, the combined rate of overweight/obesity in men had a statistically significant increase from the 2012 edition of the CCHS (Statistics Canada 2014). While increases in the percentage of the U.S. population in the "obese" category, as measured by the BMI, were seen from 1976 to 2000, this percentage has stabilized in recent years: Flegal et al. (2012), using nationally-representative data from over 5,000 U.S. adults, found that there was no statistically significant difference in the proportion of men or women who were "obese" between 2003 and 2008.

Similar trends have been seen with regard to obesity in children and adolescents: substantial increases in the proportion of obese young people in the 1980s and 1990s, followed by a plateau in the 2000s (Ogden, Carroll, Kit, & Flegal, 2012). Using a nationally representative sample of over 4,000 U.S. children and adolescents, Ogden and colleagues found no statistically significant difference in the proportion of obese young people between 2007-2008 and 2009-2010. However, when considering this dataset from 1999-2000 to 2009-2010, statistically significant increases in the proportion of obese children and adolescents (ages 2 to 19) were seen for boys, but not for girls. In contrast, research involving adolescents in Ontario, Canada (McCrindle et al., 2010) found a statistically significant increase each year from 2002 to 2008 in the proportion of adolescents, both girls and boys, who were obese. The most recent edition of the CCHS found that levels of overweight/obesity in Canadian youths aged 12 to 17 are stabilizing: 20.7% of participants were found to be overweight or obese in the 2013 survey, which is similar to the percentage reported in the 2008 survey, although an increase over the percentage (18.7%) reported in the 2007 survey (Statistics Canada, 2014). The self-reported levels of physical activity in the 2013 survey were not statistically significantly different between the "normal" weight participants and the overweight/obese participants.

A Critical Mathematics Education Perspective

Understandings of obesity are heavily influenced by medical and epidemiological research, fields that are both based, in part, on mathematical foundations. Mathematics is not simply a neutral tool in these endeavours. For Skovsmose (1994), mathematics can be understood as formatting society—in this case, public health discourse. This idea does not simply mean that mathematics is used as a tool to understand obesity. Rather, it means that mathematics contributes to the creation of obesity as a concept and as a problem. Skovsmose uses the term "realised abstraction" to describe the way in which "thinking models" become in some sense "real". This idea is similar to discourse theories that emphasize how language is not simply a means of describing the world or of transmitting thoughts between people; language influences what it is possible to say and to see, providing categories, structures, and ways of organizing experience. Moreover, both discourse in general and mathematics in particular are not simply tools; their use reflects the interests of those who use them (e.g., Edwards & Potter, 1992). They contribute to and reflect prevailing ways of understanding the world to the extent that they become largely invisible—reflecting what Foucault (1979/2008) calls regimes of truth.

Realised abstractions arise, of course, through historical processes. As Skovsmose (1994) suggests:

> Every society and every culture has developed a realm of realised abstractions. But from what sources? They must be brought into existence by some creative act. We may, for instance, be able to

> trace some realised abstracts back to ideological structures or to metaphysical systems. However, as realised abstractions they have obtained the status of laws and principles for the formation of certain social entities. They have to be taken into consideration as part of reality. They are not any longer just models for our thinking. […] the concepts come to life (p. 52).

This observation suggests a method with which to examine the role of mathematics in the production of realized abstractions in society (not dissimilar to Foucault's method of genealogy, although in our case not nearly so extensive in its execution). In the case of obesity, a concept that is now widely used to organize public, education, and health policies, we can trace the origins of its definition, paying attention to the way mathematics has shaped its development and implantation in public discourse. We can also, through this process, uncover the interests at stake and the social effects of the particular way the concept of obesity has been realized.

What is BMI?

BMI is calculated using the formula $\text{BMI} = \text{weight}/(\text{height})^2$.[2] According to the Centres for Disease Control and Prevention (2014a), BMI values fall into four categories: Underweight ($\text{BMI} < 18.5$), Normal weight ($18.5 \leq \text{BMI} \leq 24.9$), Overweight ($25.0 \leq \text{BMI} \leq 29.9$), and Obese ($\text{BMI} > 30.0$). For example, an individual who is 1.63 m tall would need to weigh less than 49 kg to be considered underweight, 49 to 66 kg to be considered normal weight, 66 to 79 kg to be considered overweight, and more than 79 kg to be considered obese. For children (ages 2 to 19), the BMI formula is used in a different way than it is used for adults, due to children's rapidly changing growth patterns, and gendered differences in body fat percentage (which, oddly, the BMI does not consider for adults). A child's BMI is calculated using the standard formula, and then the BMI and age are plotted on a graph (one for boys and one for girls) that shows percentiles (Centres for Disease Control and Prevention, 2014b; Dieticians of Canada, 2013). Children are considered underweight if their BMI/age data are less than the 5th percentile, normal weight if their BMI/age data range from the 5th to less than the 85th percentile, overweight if their

BMI/age data range from the 85th to less than the 95th percentile, and obese if their BMI/age data are greater than or equal to the 95th percentile (Centres for Disease Control and Prevention, 2014b).

It is apparent that the definition of obesity, based on the BMI, involves a number of assumptions, including the selection of weight and height as variables, the ratio weight:height^2, and the cut off points for the different weight categories. On what, then, are these assumptions based?

History of the BMI Formula

The Body Mass Index (BMI) formula was formerly known as the Quetelet Index, in deference to Adolphe Quetelet (1796-1874), the Belgian statistician who derived the formula. Quetelet was a polymath, with a strong interest and talent in both the arts and sciences, and he made significant contributions to a variety of fields, including statistics, meteorology, visual arts, mathematics, and astrology (Eknoyan, 2008). In 1835, he published *Physique Sociale, ou Essai sur le Development des Facultés de L'Homme* (published in 1842 in English as *A Treatise on Man and the Development of his Faculties*), in which he sought to describe l'homme moyen (the average man), in terms of a variety of social and physical characteristics (Eknoyan, 2008; Faerstein & Winkelstein, 2012). Quetelet used population census data of men from the Netherlands as the basis for his statistical work, creating formulas to fit the existing data (Brody, 2014). He struggled to fit the relationship between weight and height data using a Gaussian (bell) curve, a pattern followed by many of the other variables he examined. Quetelet (1842) noted the following:

> If man increased equally in all his dimensions, his weight at different ages would be as the cube of his height. Now, this is not what we really observe. The increase of weight is slower, except during the first year after birth; then the proportion which we have just pointed out is pretty regularly observed. But after this period, and until near the age of puberty, weight increases nearly as the square of the height. The development of the weight again becomes very rapid at the time of puberty, and almost stops after the twenty-fifth year. In general, we do not err much when we

> assume that, during development, the squares of the weight at different ages are as the fifth powers of the height; which naturally leads to this conclusion, in supporting the specific gravity constant, that the transverse growth of man is less than the vertical (p. 66, emphasis in original).

Due to his recognition of this relationship, Quetelet's Index was derived as the formula now known as BMI. Despite the index's recent, widespread use as an indicator of obesity, "In developing his index, Quetelet had no interest in obesity. His concern was defining the characteristics of 'normal man' and fitting the distribution around the norm." (Eknoyan, 2008, p. 49). Notably, Quetelet's "normal man" was based on data from men in the Netherlands in the 1800s, a rather homogeneous Anglo-Saxon population. As a result, the widespread use of this index to describe obesity in both men and women in a worldwide population is problematic.

Quetelet's Index was not well-known by the general public for more than a century after its publication. Indeed, obesity was not a major societal concern until the 20th century, when the relationship between obesity and ill health became a focus, particularly by the insurance industry (Eknoyan, 2008). In 1943, Louis Dublin, a statistician and vice-president of the Metropolitan Life Insurance Company, developed tables of "ideal weights" for men and women based on height and weight data from insurance clients (Jarrett, 1986). These tables used data from individuals aged 25 to 29, as they tended to have the lowest mortality rates (Wildman & Medeiros, 2000). Presuming that this low mortality rate was linked to body weight is flawed statistical reasoning. Arguably, lower rates of disease and age-related ill health (most of which are unrelated to being overweight or obese) are a more likely explanation for young adults' low mortality rates. As with the dataset upon which Quetelet's Index was based, the Metropolitan Life tables were based on a rather homogeneous dataset comprised mostly of individuals of Caucasian descent (Pekar, 2011). Data were included from people who were wearing clothing and shoes during the measurements, and 20% of the data were self-reported (Jarrett, 1986); both of these factors decrease confidence in any claims derived from the dataset.

The Metropolitan Life tables were separated by frame size, with the acceptable weight for each height being divided into thirds, relative to small, medium, and large frame sizes. Problematically, these divisions were not based on any measurements of bone structure; rather, Dublin noticed that "healthy" weights (i.e., those associated with low mortality) encompassed a range of up to forty pounds, and then, in order to account for this range, he divided it arbitrarily into thirds, based on his explanatory notion of bone structure (Gaesser, 2002; Pekar, 2011). Weights falling into the lowest 20-25% and highest 30% for a height were considered undesirable with regard to insurance purposes (Eknoyan, 2008). Similar to the use of the BMI as a measurement of obesity, the Metropolitan Life tables were used out of context: These tables were initially intended for use as an actuarial tool. However, Dublin did promote the link between excess weight and early mortality (Oliver, 2006). The widespread adoption of the Metropolitan Life tables has been cited as the impetus for a dieting frenzy that began in the 1940s and continues to this day, as people—mostly women—sought to match the "ideal" weights promoted by the tables (Crossen, 2003). The tables were revised in subsequent decades using more recent actuarial data from Metropolitan Life clients, and actual measurements of body frame (elbow breadth) were incorporated, but many of the aforementioned problems remained, including the lack of consideration of age or ethnic background (Crossen, 2003; Gaesser, 2002; Himes & Bouchard, 1985).

Dublin's tables remained in common use well into the 1970s, when a study by Keys, Fidanza, Karvonen, Kimura, and Taylor (1972) shifted the focus of the obesity measurement conversation, by confirming the validity of Quetelet's Index. In so doing, these researchers challenged many of the assumptions underpinning the Metropolitan Life tables. For example, they argued that the sample used as the basis of the tables was not random and thus should not have been generalized, since "certainly persons examined in connection with application for life insurance are far from being a random sample of the population" (p. 330). Other ratios, such as weight/height, $(\text{weight})^{1/3}$/height (ponderal index), and weight/height^3 (Rohrer index), were considered in this study, but Quetelet's Index best fit existing weight and height data. Keys and colleagues suggested referring to this index as the body mass index, the first known use of this term. To examine this index, these researchers used data from nearly 7,500 men in Japan, South Africa, the United States, and several European countries. As with Quetelet's original dataset on which his index was based, Keys and colleagues' dataset also only included men, a major oversight since the BMI is applied to both women and men. The men in this study were subjected to skinfold measurements (to show subcutaneous fat) and density measurements (to show body composition). When comparing these precise measurements to the aforementioned ratios, Keys and colleagues found that "the body mass index seems preferable over other indices of relative weight" (p. 341), and noted that it was simplistic in its application.

This simplicity in application arguably underpinned the promotion of the BMI as a tool for measuring (or at least estimating) a person's "fatness". The World Health Organization has been using the BMI to calculate worldwide obesity statistics since the early 1980s (Marchand, 2010), while the U.S. National Institutes of Health (NIH) began using the BMI in 1985 (Singer, 2009). At this point, the NIH defined overweight individuals as those who were in the 85th percentile of BMI by gender: 27.8 for men and 27.3 for women (Singer, 2009). However, in 1998, the NIH changed their BMI "cut-off" points to 25 for overweight and 30 for obese individuals, with men and women now grouped together despite their differences in body fat (Singer, 2009); as Cohen and McDermott (1998) reported, 25 million Americans who were not considered overweight previously were suddenly placed in that category, simply due to the NIH's new "cut-off" points for the BMI measurement. Cohen and McDermott pointed out a few of the key problems with the BMI: lack of consideration of body composition, gender, and frame size. These issues, and others, will be considered in the next section.

Critically Interrogating Obesity and the BMI

It is apparent from our brief historical account of the BMI that a number of assumptions, generalizations, and simplifications were included in the development of the formula and its application. We summarize the most significant issues and highlight some of their implications.

1. The BMI does not take into account body composition (Cohen & McDermott, 1998). Fat, bone, and muscle all have different densities (fat = 0.9 gm/mL, muscle = 1.06 gm/mL,

and bone = 1.85 gm/mL), but these differences are not measured by the BMI (Devlin, 2009). Consequently, individuals may have the same BMI, but very different body compositions and thus, different health risks. A bodybuilder, athlete, or other highly muscular person (who has a low percentage of body fat) would have the same BMI as a same-height individual with a far higher percentage of body fat, as long as they weigh the same amount. Arguably, the former person is the less "overweight" with regard to obesity-related health concerns, but both individuals would have the same BMI and thus would be considered equally "overweight".

2. Quetelet's formulation of the BMI, as well as subsequent verification (Keys et al., 1972), was based on measurements of White European men. As such, the BMI has been generalized from one category of person to apply to both genders and all racial backgrounds. In similar fashion, the Metropolitan Life tables were based on White men and women in their twenties (who applied for life insurance), but were applied to the population as a whole. Again, these data were used to make generalizations about a more diverse population, including people of all ages.
3. The formula for BMI (weight/height^2) overestimates "fatness" in tall people and underestimates "fatness" in short people (including children) (MacKay, 2010; Marchand, 2010). That is, for a given weight, BMI is inversely proportional to height^2. Since the BMI formula is used for people of all heights, these issues with scaling imply that for a given body shape, a taller person is less healthy (i.e., more obese) than a shorter person (MacKay, 2010).

Quetelet's goal was not to define obesity, but to describe a population. His formula, now known as the BMI, was descriptive—and descriptive of a very specific population. Mathematics, however, derives its power in part from generalization. In the case of what is considered "normal" weight, these generalizations take particular kinds of people as "normal". When indices like the BMI or the Metropolitan Life tables become widely used (facilitated by information technology, mass communication, and mass health care systems), these generalizations become realized abstractions. That is, what was originally developed as a description has shifted to become *prescriptive*. These norms are now used to define what people *should* weigh and, indirectly, what they should look like.

Our summary of the problems with defining obesity comes from the health literature, so it is clear that health researchers are well aware of the limitations of the BMI. The literature shows that other indices have also been considered, so there is no sense that BMI is *the* definitive measure. Nevertheless, when the mathematical force of the BMI as the "preferred" index, partly due to its simplicity, is implanted into health care systems and public health and education policy, these kinds of subtleties tend to be smoothed off, leaving only a definitive (i.e., It defines people) formula, with various cut-offs based on statistical analyses for what constitutes obese, overweight, normal, or underweight. The BMI, moreover, is not simply a technical tool; it has real consequences for real people. For example, the implementation of "BMI report cards" for students in elementary and secondary schools has been reported in the U.S., the U.K., and Malaysia (Flaherty, 2013).

Our point, then, is not that obesity does not exist or that obesity is not associated with health risks. Our point is that the certainty of science, through the use of mathematics, turns a fuzzy and complex phenomenon into a normative, prescriptive abstraction, which in turn leads to concrete interventions, in the form of advice, medication, and penalties. This normativity, in turn, is likely to feed into wider discourses relating to such topics as body image, femininity, masculinity, and identity.

Implications for Mathematics Education

The learning and teaching of mathematics in school can address the role of mathematics in society (Skovsmose, 1994). In the case of obesity, for example, students could study the history we have recounted in this paper, collect data of their own, test different indices, and discuss the validity of their findings. This kind of work relates to curriculum goals for statistics, algebra, and other mathematical topics. Such explorations could also be developed as cross-curricular topics, so that, for example, health education and mathematics education are combined. In this way, the role of mathematics in defining health can be discussed.

We do not see mathematics education, however, as something confined to schools and curricula. In an increasingly information-rich society, there is scope for a stronger form of public mathematics education. Citizens must engage with information about health in general and about themselves in particular, in order to make decisions about their lives, their families, and their communities. Public mathematics education would not presume that citizens are incapable of using information effectively; rather, it would prompt them to look "beyond the data" rather than accepting the prescribed role of passive consumers of health information.

Notes

1. For example, in the U.K., Public Health England emphasizes the negative effects of obesity on children and promotes various policies including school health plans, healthy diets, and physical activity for children (See www.noo.org.uk/LA/tackling/education). In Ontario, Canada, the government has set a goal of reducing childhood obesity by 20% over five years (See www.health.gov.on.ca/en/public/programs/obesity/.)

2. An alternate formula, using the Imperial measurement system (pounds and inches), is: BMI = weight/(height)^2*703, with 703 being a conversion factor. Consequently, the units for the BMI are either kg/m^2 or lb/in^2, although these units are rarely cited with a BMI value.

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