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CHAPTER 3

HOW BODY SIZE BECAME A DISEASE

A history of the body mass index and its rise to clinical importance

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Introduction

Taller people tend to weigh more than shorter people. But how does weight vary with height? The body mass index (BMI, calculated as weight (W) divided by height (H) squared) is one way to express weight adjusted for height. It is widely used, with the advantages of being technically uncomplicated, non-invasive, easy to measure and calculate. Where did it come from? How did it become the definition of a disease?

Quetelet and the relation of weight to height

The 19th-century Belgian statistician Adolphe Quetelet (1796–1874), originally trained as an astronomer, had wide-ranging interests in social and physical characteristics of human populations, addressing topics such as natality, mortality, crime, education and more. Stigler (1986) provides an extensive account of Quetelet's contributions; see also Eknoyan (2008) and Weigley (2000). A pioneer in statistical data gathering and statistical thinking, Quetelet wanted to discover the mathematical laws governing social as well as physical phenomena. A minor aspect of his work was the investigation of development of body measurements from birth through adulthood, and among these was the relation of weight to height in adults. In a brief footnote in his 1835 book "Sur l'homme," Quetelet observed that, for adults, weight varied as the square of height (Quetelet, 1835, Vol. 2, p. 54).

He derived this from empirical observations, not from theoretical considerations. Quetelet recognized that "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" (Quetelet, 1835, Vol. 2, p 52). He took the 12 tallest and the 12 shortest men within a data set and found their average heights and also their average weight/height values. He observed that the ratio of mean height of the shortest men to the tallest men was in the proportion of 5 to 6. He observed that the ratio of mean weight/height of the shortest men to the tallest men was also in the proportion of 5 to 6. As long as these two proportions are the same as each other, then, as Quetelet's footnote points out, it can be shown that weight increases as the square of stature.[1] He repeated these observations for women, with the same finding. Quetelet was interested in the properties of what he called the "l'homme moyen" (the average or typical individual)

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and did not attempt to investigate departures of weight from what was expected based on stature. Quetelet did not propose an index. However, because of his observations, the ratio of weight divided by height squared (W/H^2) later became known as Quetelet's index.

Other early empirical investigations agreed with Quetelet's findings that weight varied as the square of height. In 1869, Benjamin Gould, the actuary for the US military, published extensive data on newly demobilized Civil War soldiers (Gould, 1869). Beyond investigations of topics ranging from ages at enlistment, place of birth and extending even to topics such as hair and eye colours, Gould also addressed anthropometry (body measurements), not only weight and height but also many other physical dimensions. As had Quetelet before him, Gould observed empirically that weight did not vary as the cube of height but rather as the square. According to Gould, "... we are irresistibly led to the singular and interesting discovery that the mean weights, vary strictly as the squares of the statures. … The fact here elicited was observed by Quetelet" (Gould, 1869, p. 409).

Quetelet's index – just one of many

Quetelet's index was just one of a number of different indicators used for descriptive and research purposes in the 19th and early 20th centuries to express weight adjusted for height. Such indicators were simply ways to standardize weight for height, so that descriptions and comparisons of weight could be made across individuals of different heights. As noted by Gray and Mayall (1920) and by Billewicz, Kemsley, and Thomson (1962), the nomenclature attached to these indicators is not always consistent, and it would require a good deal of historical research to establish their origins.

The Broca index, *weight (kg) = height (cm) −100*, is said to have been developed around 1871 (Laurent et al., 2020; Rössner, 2007) by the French neuroscientist Paul Pierre Broca (1824–1880), although its origins are obscure (Gray & Mayall, 1920). In 1898, the Italian doctor Ridolfo Livi (1856–1920) argued that because weight is a measure of volume, the correct index would be the cube root of weight, divided by height, which he called the "indice ponderal" or ponderal index (Livi, 1898). Swiss physician Fritz Rohrer (1888–1926) developed the Rohrer index, weight divided by height cubed, that also used the cube rather than the square (Rohrer, 1908, 1921). In a later version, William H. Sheldon (1898–1977), the influential creator of the concept of somatotypes (Vertinsky, 2002, 2007), used an inverted form of the index, which he also called ponderal index.

In a very large sample of US military conscripts, however, Davenport observed, "Were short people and tall people of the same shape, then it would be true that their weight would be expected to vary with the cube of any one dimension. But this assumption is not true" (Davenport, 1920, p. 470). He summarized his findings by saying, "for young adult males the best index of build is apparently obtained by dividing weight by the square of stature" (Davenport, 1920, p. 475).

In these discussions, weight for height indicators was viewed as a method of standardizing weight for height for descriptive purposes. For instance, Livi (1898) felt that his index could be used to examine how weight varied by factors such as sex, age, race or environmental conditions after adjusting for differences in height.

Life insurance and the beginnings of "ideal weight" standards

On a different track, weight for height tables began to be developed and then to be used as an indicator of risk for life insurance purposes. Czerniawski (2007) provides a detailed

analysis of the development of such tables between the 1830s (when Quetelet published what is perhaps the first example of a weight for height table) and 1943, when the Metropolitan Life Insurance company presented tables of "ideal weights" by height for men and women. Beginning as descriptive, such tables were transformed to a tool used for actuarial purposes by life insurance companies and then to recommendations for the general population going from "average" to "ideal" weights. Shephard (1907) presented a table compiled in 1897 of the average heights and weights by age of men who had been accepted for life insurance, stating that weights of 20 percent above or below those average weights indicated a poor actuarial risk. In 1908, Symonds (1908), discussing the same table, asserted that someone who was 20 percent or more above the standard weight for age should be considered overweight. Since the 1897 standard weights increased with age, the weight considered overweight on this basis also increased with age. Later, Armstrong, Dublin, Wheatley, and Marks (1951), discussing the 1943 Metropolitan Life tables, recommended a fixed set of standards based on the ideal weight for ages 25–30, with 10 percent over that weight considered overweight and 20 percent over ideal weight being pathological overweight or obesity.

Throughout the 1960s and 1970s, the 1959 Metropolitan Life tables (Metropolitan Life Insurance Company (MLIC), 1959) played a dominant role in identifying what were called "desirable" weights (Weigley, 1984). Seltzer (1965) commented on the severity and often unrealistic requirements of the desirable weights in these tables. A discussion and critique of some of the shortcomings of the 1959 version of the Metropolitan Life tables and the later 1983 version (MLIC, 1983) was presented at the 1985 NIH Conference on the Health Implications of Obesity (Harrison, 1985). Knapp critiqued both the concept of "ideal weight" and the construction of the Metropolitan Life tables, calling the methods by which the tables were constructed "almost unfathomable" (Knapp, 1983, p. 507). Jarrett (1986) quoted Knapp but added that he questioned the "almost." Andres, Elahi, Tobin, Muller, and Brant (1985) reanalyzed the data on which the 1983 Metropolitan Life tables were based and concluded that weight standards should be adjusted for age and should be higher for older adults, a finding that was the subject of some controversy (Willett, Stampfer, Manson, & Vanitallie, 1991).

Weight–height indices and fatness

Early attempts to use weight and height to create an indicator of adiposity (body fatness) were limited by the methods of measuring adiposity then available before the advent of methods such as dual-energy x-ray absorptiometry (DXA) and magnetic resonance imaging. One method involved weighing a person underwater and then following the principles set out by Archimedes to determine body density (Forbes, 1999). Although this method, called hydrodensitometry or hydrostatic weighing, provided accurate estimates of body density, converting body density to a measure of fatness required assumptions about body composition that might not be accurate at the individual level. Another method was to use callipers to measure the thickness of subcutaneous fat levels at different body sites (skinfold measurements). With these, one approach was to characterize adiposity simply by the sum of the skinfold measurements; another approach was to use prediction equations (e.g., Wilmore and Behnke 1969) to generate estimates of body fat from skinfold measurements. Because of the difficulties in obtaining measures of adiposity, much of the discussion in the 1960s and 1970s about weight–height indices was based on theoretical considerations or on comparisons of different indicators against population distributions of weight for height, not on comparisons with measures of adiposity. These discussions typically evaluated different values for the

power of height in power-type indices of the general form W/H^p, generally including W/H, W/H^2 and some index using a power of 3, such as $H/W^{1/3}$.

An early attempt to address the issue of indices of adiposity (Billewicz et al., 1962) had adiposity data from densitometry only for 81 men and women from Taiwan and 98 American infantrymen in training, not enough for a detailed analysis. Therefore, Billewicz et al. (1962) primarily compared various functions of weight and height to the distribution of weight for height in several other population samples, making the assumption that, in a normal unselected population, the distribution of body weight at each level of height would reflect, in a general way, the distribution of adiposity. This is really the same problem of describing how weight varies with height that Quetelet had already addressed without making any assumptions about adiposity. Billewicz et al. (1962) concluded that, of the weight–height indices, Quetelet's index was the best approximation to adiposity but that a better approximation to adiposity would be to use the ratio of weight to standard weight from a life insurance table of standard weights for height.

As had Billewicz et al., Khosla and Lowe (1967) also evaluated weight–height indices in the absence of any measures of adiposity, simply by comparing them to the distributions of weight for height and inferring their relationship to adiposity from this comparison. They felt that Quetelet's index was the best and used it to compare groups within an industrial population that differed in height. This comparison demonstrated that the senior staff weighed more than the wage-earners because they were taller and thus not necessarily because they were more obese.

Other discussions similarly evaluated weight–height indices as indicators of adiposity despite not using any actual measures of adiposity. Evans and Prior (1969) extended Khosla and Lowe's approach to Rarotongans and Pukapukans, two Polynesian populations in the Cook Islands. They concluded that weight/$height^2$ was satisfactory as a method of adjusting weight for height within genetically homogeneous groups but that it should be interpreted with caution to compare different racial groups. Similar conclusions were reached by Lee, Kolonel, and Hinds (1981) who compared weight for height among five different ethnic groups in Hawai'i – Caucasians, Chinese, Filipinos, native Hawaiians, and Japanese – and felt that the relation of BMI to height differed across groups, therefore preferring the approach suggested by Benn (1971) of calculating a specific power of height for a given population to minimize correlations with height for an index.

Florey compared three different power-type indices but firmly rejected the idea that an index of weight and height could serve as a measure of adiposity: "One must conclude that the indices are at most weight corrected for height, and should not be used as indices of adiposity or physique in the belief that they are valid measures of these qualities" (Florey, 1970, p. 102). Florey felt that the appropriate nomenclature would be an "index of corrected weight" to remove any idea that these were indices of fatness and concluded that all three indices were poor measures of adiposity.

Quetelet's index gets a new name and a lukewarm recommendation

In 1972, American physiologist Ancel Keys studied four indicators of weight for height (three weight–height indices and the percent of standard weight-for-height) and their correlation with body fat, as assessed by skinfold measurements in a healthy all-male sample from five countries, including Japanese farmers and fishermen, Bantu workers in South Africa, university students and executives from Minnesota, railroad workers in Italy and the US, and samples of rural populations in Finland and Italy (Keys, Fidanza, Karvonen, Kimura, & Taylor,

1972). Of these indicators, he felt that the best was W/H^2, which he renamed the "body mass index" (BMI) and suggested as an approximate indicator of fatness for research purposes. But Keys' recommendation was lukewarm: "the body mass index, W/H^2, proves to be, if not fully satisfactory, at least as good as any other relative weight index as an indicator of relative obesity" (Keys, et al., p. 339). Keys rejected the idea of using BMI to label people as overweight and characterized such value judgments as "scientifically indefensible" (1972, p. 341).

BMI categories began to be used as labels

Bray (1978) recommended a cut point for overweight at a BMI of 25 and for obesity at a BMI of 30. These values were loosely based on an adaptation of the 1959 Metropolitan Life tables from the "Obesity in Perspective" conference held in 1973 at the Fogarty Center (Bray, 1975). The value of 25 approximately corresponded to the top of the range of acceptable or recommended range of weights for height and the value of 30–120 percent of the top of the range. Garrow (1981) suggested that obesity be classified as follows: Grade 0, BMI 20–24.9; Grade I, BMI 25–29.9; Grade II, BMI 30–40; and Grade III, BMI > 40. He went on to say that "the choice of 25, 30 and 40 as boundaries between grades 0, I, II and III is arbitrary and can be justified only on grounds of convenience" (Garrow, 1981, p. 3). These arbitrary cut points at 5-unit or 10-unit intervals ending in 0 or 5 are more likely to represent a form of digit preference than to correspond to any specific biological reality. These recommendations were intermittently used but not considered definitive.

BMI continued to be just one among numerous possible indicators of weight for height. The *Obesity in America* conference held in 1977 at the Fogarty Center recommended the use of an adaptation of the 1959 Metropolitan Life insurance tables to evaluate relative weight for clinical purposes and suggested that investigators should in addition consider using the BMI (Bray, 1979). A 1982 workshop on body weight, health, and longevity sponsored by the Nutrition Coordinating Committee of the National Institutes of Health (NIH) and the Centers for Disease Control (CDC) recommended that, in order to establish age-related desirable weights, data on weight and height should be analysed and presented separately by sex, age, and duration of follow-up, with age divided by decades (Simopoulos & Van Itallie, 1984). The committee also recommended that data on weight and height be additionally expressed as the BMI with a median, range, and standard deviation presented for each age and gender group.

Explicit definitions of overweight in terms of BMI were created in 1985 and began to be used for US government publications and research studies. In 1985, as part of its series of consensus conferences on a wide variety of topics, NIH convened a short conference on the health effects of obesity (*Health Implications,* 1985). As part of this effort, the panel investigated several methods to express weight adjusted for height, such as weight–height tables, and suggested that physicians consider the use of BMI as an additional factor in evaluating patients. The panel described BMI as a simple measurement that minimized the effect of height and would be useful for descriptive or evaluative purposes. This recommendation, along with Keys' observations, contributed to the gradual adoption of BMI over the next decade as a standard international measure of weight for height for adults. A practical factor at the time that limited the use of BMI was the difficulty in calculating such an index before the advent of pocket calculators; thus, the panel recommended that nomograms be used to facilitate calculations of body mass index.

The 1985 conference recommended a definition of overweight as a BMI equal to or greater than 27.8 for men or 27.3 for women. To arrive at this definition, the panel combined

information from life insurance tables with national survey data on measured weight and height. These BMI cutoffs represented the sex-specific 85th percentile of the BMI distribution for persons aged 20–29 years in the second National Health and Nutrition Examination Survey (NHANES II). The rationale for selecting this age group as the reference population was that young adults are relatively lean, and the increase in body weight that usually occurs with age is due almost entirely to fat accumulation. The panel also noted that these values corresponded approximately to a weight 20 percent above the midpoint of the sex-specific median weight range across all heights for a medium frame in the 1983 Metropolitan Life weight-for-height tables (MLIC, 1983). These definitions were adopted within the US government and widely used within the US, but not elsewhere.

There was still no real consensus over what categories to use (Kuczmarski & Flegal, 2000). The overweight criteria based on the BMI cutoffs of ≥27.8 for men and ≥27.3 for women were used to report the prevalence of overweight among US adults in every annual edition of the government publication "Health United States" beginning in 1985 and continuing through 1998. The quinquennial US Dietary Guidelines, beginning in 1980, conformed pretty closely to a BMI of 25 as the dividing line to define overweight (Flegal, Troiano, & Ballard-Barbash, 2001). Yet, different BMI levels were suggested in the report "Diet and Health: Implications for Reducing Chronic Disease Risk" (National Research Council, 1989), which suggested a "desirable BMI" of 20–25 for those 25–34 years old, increasing with age to a desirable BMI of 24–29 for those over 65.

Weight loss treatments become a medical issue

Weight loss was not always seen as a salient medical issue (Maddox, Anderson, & Bogdonoff, 1966; Maddox & Liederman, 1969; Puhl & Brownell, 2001). For tax purposes, the IRS did not allow costs of weight loss as a medical deduction until 2002. Health insurance did not cover weight loss treatments (Gibbs, 1995). Research showed that, in more than half of doctor visits, weight and height were not even measured (Graham, 2012). A timeline review (Kyle, Dhurandhar, & Allison, 2016) shows the changes that took place over time to further the concept of obesity first as a medical issue and then as a disease.

Weight-loss drugs had a checkered history (Colman, 2005). It was difficult to define clinical efficacy, and there were concerns about possible side effects. Fenfluramine had been approved in 1973, but only for short-term use. Renewed interest in weight-loss drugs increased in the 1990s with the advent of several new drugs. The drug combination fenfluramine/phentermine, known as fen-phen, was an anti-obesity treatment that utilized two anorectics (Weintraub, 1992a, 1992b). In addition to popularizing off-label use of these two drugs, the fen-phen studies began a transition from short-term to long-term drug treatment of obesity. The first drug to garner Food and Drug Administration (FDA) approval in the US for the long-term treatment of obesity was dexfenfluramine, an isomer of fenfluramine. In 1996, dexfenfluramine (marketed as Redux) was approved for longer term use. The use of these medicines exploded, with approximately 14 million prescriptions written for fenfluramine or dexfenfluramine from 1995 until they were withdrawn for safety reasons in 1997 (Yanovski, 2005). Although these medicines were intended for weight loss, 25 percent or more of users were not overweight (Blanck, Khan, & Serdula, 2004; Khan, Serdula, Bowman, & Williamson, 2001). Other medications appeared. Sibutramine, a norepinephrine and serotonin reuptake inhibitor, marketed in the US as Meridia, was approved by the FDA in 1997 but withdrawn in 2010 for safety reasons. Orlistat, marketed by Roche as Xenical, was approved by the FDA in 1999. Xenical was described as a potential blockbuster by an

industry analyst who predicted that the market could be between $5 billion and $10 billion (Sharpe, 1999). Sales, however, proved disappointing.

The limited medical concern for obesity was seen as a barrier for wider acceptance of the use of weight-loss medications. According to a Reuters report (Bruton, 2000) entitled "Quest for blockbuster obesity drug vexes firms," companies believed that, for drugs like Xenical and Meridia to reach their potential, the possibility of a pharmaceutical treatment for obesity had to be more widely accepted. Many consumers still saw obesity more as a cosmetic concern than as a health issue. The Reuters report quoted Terence Hurley, a Roche spokesman, as saying "Part of our challenge moving forward with Xenical is to "medicalize" weight management to physicians."

WHO and NIH use BMI to define "obesity"

An important step towards international standardization occurred in 1993. A World Health Organization (WHO) expert committee met in Geneva for a week and produced a lengthy report on the uses of anthropometry (body measurements) to assess health and nutritional conditions including malnutrition, stunting, thinness, and overweight for all segments of the population – from newborn infants to older adults ("Physical Status", 1995). For adults, the panel used BMI to define three grades of overweight. They selected the tidy cut points of 25, 30, and 40, describing the method used to establish cut-off points as largely arbitrary and noting that Grade 2 overweight (BMI 30–40) was relatively common in industrialized countries. The panel noted that, "in essence, it has been based upon visual inspection of the relationship between BMI and mortality; the cut-off of 30 is based on the point of flexion of the curve" ("Physical Status", 1995, p. 313). No reference was provided for this statement. The expert committee defined obesity as the degree of fat storage associated with clearly elevated health risks but noted the lack of scientific consensus on exactly what level of fat this might be. They stated explicitly, "there are no clearly established cut-off points for fat mass or fat percentage that can be translated into cut-offs for BMI" ("Physical Status", 1995, p. 312). The panel did not offer any definition of obesity in terms of BMI.

In 1995, the International Obesity Task Force (IOTF, now called World Obesity Policy & Prevention) was formed by Philip James, the then director of the Rowett Research Institute (World Obesity Federation, n.d.). The object of this self-appointed task force, funded primarily by the pharmaceutical industry (Moynihan, 2006a), was to persuade the WHO to convene a special consultation in Geneva that would be solely devoted to obesity (W. P. James, 2008). The IOTF's mission was to inform the world about the urgency of the problem and to persuade governments that now was the time to act. WHO was initially reluctant but agreed to hold the consultation on the condition that it be delayed for six months. Eventually, WHO convened a three-day expert consultation on obesity in 1997, resulting in a lengthy report published in 2000 (WHO, 2000). The consultation received a substantial grant from the IOTF (W. P. T. James, 2002), and the IOTF itself prepared the draft report for the consultation, which was accepted with only minor modifications. The final WHO report largely followed the IOTF document.

The publication of the official report of the WHO consultation was delayed (W. P. James, 2008). The proposal had not been part of the WHO usual planning process nor agreed to by the WHO Executive Board. However, subsequent discussions with the then-WHO Executive Director resulted in WHO deciding to publish the report as part of the WHO Technical Report Series, "Obesity: Preventing and Managing the Global Epidemic" (2000). Due to backlogs in report preparation, the Technical Report Series publication was delayed.

However, WHO agreed to issue an interim document in 1998 ("Obesity: Preventing and Managing the Global Epidemic", 1998) that differed slightly from the final version. The IOTF sent free copies of the interim document directly to every Minister of Health in the 192 WHO member countries and to other interested persons and organizations. In the interim version of the report, WHO expressed deep appreciation for both the financial and technical contributions of the IOTF in convening the consultation.

The 1997 WHO consultation made a key terminological change from the 1995 WHO report. The section on BMI included a table on the classification and described it as being "in agreement" with the 1995 WHO report. In fact, although the BMI cut points were the same (with an additional cut point at 35.0), the terminology was not. The 1997 consultation decided to use the term "obesity" instead of "overweight" for BMI values of 30 or above, with little explanation or justification for the change. BMI, heretofore a simple indicator of weight adjusted for height, was transformed into the definition of excess fat.

In 1995, NIH had convened an expert panel to develop clinical practice guidelines for primary care practitioners, reviewing relevant scientific literature through 1997 ("Clinical Guidelines", 1998). The NIH panel overlapped with the IOTF to some degree, with the chair of the panel and several members also being members of the IOTF (International Obesity Task Force, 2000). The NIH panel adopted the same cut points for BMI and almost the same terminology as the 1997 WHO definition, citing the then as yet unpublished WHO report as the source for these definitions.

Suddenly, the US government was defining "obesity" as a BMI of 30 or above. Overnight, millions of Americans were classified into an ominous new category. The new cut points were described in the *New York Times* as providing the pharmaceutical industry with "a booming new market for diet pills for the obese, practically served to the companies on a silver platter by the government" (Stolberg, 1999). The new definitions also expanded the definition of overweight to include BMIs of 25 and 26. Some critics, including the former surgeon general C. Everett Koop, urged the panel not to broaden the definition of overweight, saying "it will confuse the public and the medical community. It needlessly stigmatizes millions of Americans and lacks a solid scientific rationale" (Squires, 1998).

Overweight is one of the conditions discussed by Schwartz and Woloshin (1999), where expanding disease definitions have increased prevalences of relatively common conditions. A later example of expanding disease definitions had to do with BMI categories for children and adolescents. The BMI range called "overweight" for children was renamed as "obese" in 2007 with little rationale (Moynihan, 2006b; Ogden & Flegal, 2010).

Reimbursement for treating obesity

In the 1990s and earlier, insurance coverage for treatment of obesity was limited (Gibbs, 1995), in part because of language in the US Medicare Coverage Issues Manual that stated bluntly: "Obesity itself cannot be considered an illness… Program payment may not be made for treatment of obesity alone since this treatment is not reasonable and necessary for the diagnosis or treatment of an illness or injury" (National Coverage Determination, n.d.). In 2001, an IOTF member who had joined the Centers for Disease Control and Prevention (CDC) organized and chaired a meeting at CDC entitled "Including Obesity Treatment in Benefit Plans" on the topic of reimbursement of health care providers for obesity treatment. Following the recommendations from this workshop, CDC put in a formal request to the Centers for Medicare and Medicaid Services (CMS) that this language be removed from the manual because it was a barrier to insurance coverage for treatment of obesity. The language

was removed in 2004 ("National Coverage Determination"). Versions 1 through 4 of the coverage determination documents are accessible through CMS ("National Coverage Determination", n.d.).

This critical move opened the door for providers to get reimbursed for obesity treatments and for health insurance to cover anti-obesity medications. Stern, Kazaks, and Downey (2005) assessed the acceptance of obesity as a chronic disease and acceptance of its treatment by health management organizations, private insurers, and the government as a major reimbursement challenge. Baum et al. (2015) felt that although financial incentives and attitudes towards obesity management were changing, continuing limitations to reimbursement included perceptions of modest efficacy by patients and physicians alike, historical safety issues and regulatory obstacles. Oliver opined that "the disease characterization has less to do with the health consequences of excess weight and more with the various financial and political incentives of the weight loss industry, medical profession, and public health bureaucracy" (Oliver, 2006, p. 611).

When did obesity become a disease?

Obesity was sometimes but not always seen as a disease. Bray in 1978 asserted that "obesity is a symptom of disease, like hypertension, anemia or fever, not a disease itself" (Bray, 1978, p. 102). References to obesity as a disease began to creep into the literature. The summary of the 1985 NIH conference alluded indirectly to obesity as a disease ("Health Implications", 1985). Just over a decade later, the 1998 NIH guidelines stated forthrightly, "Obesity is a complex multifactorial chronic disease" ("Clinical Guidelines", p xi). The Obesity Society (TOS) in the US (Allison et al., 2008) and the World Obesity Federation (Bray, Kim, & Wilding, 2017) also endorsed the view that obesity should be considered a disease. In 2013, the American Medical Association (AMA) recognized obesity as a chronic disease (AMA, 2013a, p. 461), although the AMA's own Council on Science and Public Health had recommended against adopting the resolution (AMA, 2013b, pp. 335–343). European guidelines also endorsed the view of obesity as a disease (Yumuk et al., 2015; Frühbeck et al., 2019), not without some discussion (Müller & Geisler, 2017; Vallgarda et al., 2017).

Obesity becomes a disease – but what is obesity?

Discussions of obesity as a disease typically include extensive discussions of the definition of a disease but little or no discussion of the definition of obesity. According to the 1985 conference report, "Obesity is an excess of body fat frequently resulting in a significant impairment of health" ("Health Implications", 1985, p. 1073) but "because the amount of body fat… is a continuous variable within the population, all quantitative definitions of obesity must be arbitrary" ("Health Implications", 1985, p. 1074). WHO states "Overweight and obesity are defined as abnormal or excessive fat accumulation that may impair health" (WHO, 2020). But how is an excess of body fat defined? And what health impairments are involved?

Bray (1976) noted the major difficulties in identifying how much body fat should be considered obese and suggested that, as a working guideline, men with more than 20 percent fat and women with more than 28 percent fat should probably be considered obese. The report from the 1977 conference at the Fogarty Center (Bray, 1979) noted that, once a measurement of body fat was established, there was still the problem of interpreting the results because no one knew how much body fat was normal or desirable. The 1995 report from the WHO expert committee similarly noted the lack of any consensus ("Physical Status",

1995, p. 420). One set of standards was developed by Lohman, Houtkooper, & Going (1997), who estimated percent body fat with prediction equations applied to triceps and subscapular skinfold measurements in NHANES. They then presented age and sex-specific percent body fat standards based on the population distribution of the values of the estimated percent fat, although it is not clear how these standards were determined. In a comprehensive literature review of the performance of anthropometric measurements relative to body fat reference standards, Sommer et al. (2020) found that the cut-offs for the reference tests ranged from ≥ 30 percent to ≥ 43 percent body fat in women and from ≥ 20 percent to ≥ 34.6 percent in men using DXA, with most studies using a body fat percentage >35 percent in women and > 25 percent in men as the standard for defining obesity (similar but not identical to the Lohman criteria). Sommer et al. note that despite the wide use of these and other cut-offs, cut-offs were chosen arbitrarily and not necessarily with any scientific basis.

Even though it is unclear where these body fat criteria come from or why they should be considered to represent obesity, numerous articles, as reviewed by Sommer et al. (2020), have compared a BMI of 30 or above to body fat criteria and found that not only do most people with BMI of 30 meet the body fat criteria for obesity but also many people with BMI below 30 also meet these criteria, sometimes leading to the suggestion that the BMI criteria for obesity should be lowered. For instance, Blew et al. (2002) suggest that BMI >25 rather than BMI > 30 may be superior for diagnosing obesity in postmenopausal women.

In fact, it is clear that obesity considered as the degree of fat storage associated with elevated health risks does not have an exact definition. Rather, the level of body fat associated with health risks varies considerably. According to a 2011 scientific statement from the American Heart Association (Cornier et al., 2011), at a given BMI, there is a significant variability in individual body fatness and the associated risk for health conditions. This variability is related to factors such as age, sex, genetics, and ethnicity, but it is also a result of differences in body fat distribution and composition. Similarly, a 2017 statement from two professional endocrinology societies states that, scientifically speaking, BMI is a poor predictor of health and is inadequate as the sole guide for clinical decision-making. BMI at any level is not clinically sufficient as a medical diagnosis of disease for a given individual (Mechanick, Hurley, & Garvey, 2017).

Florey cautioned in 1970 that BMI and other indices should not be used as measures of adiposity. In 1972, Keys gave BMI a lukewarm recommendation and pointed out that it was "scientifically unacceptable" to use BMI to define overweight. Nonetheless, despite these early cautions, BMI came into widespread use as a measure of adiposity and was used to define overweight and obesity. Going full circle, BMI then became the target of numerous commentaries that criticized it for not measuring body composition and for being a poor measure of obesity (e.g., Ahima & Lazar, 2013; Blundell, Dulloo, Salvador, & Fruhbeck, 2014; Burkhauser & Cawley, 2008; Flint & Rimm, 2006; Franzosi, 2006; Gonzalez, Correia, & Heymsfield, 2017; Green, 2016; Kahn & Bullard, 2016; Kragelund & Omland, 2005; Müller, Braun, Enderle, & Bosy-Westphal, 2016).

Some attempts to clarify and rationalize definitions of obesity continue to use the BMI cut points of 25 and 30 but add additional criteria. These include the Edmonton Obesity Staging System developed by Sharma and Kushner (2009), the proposed definition by Garvey and Mechanick (2020) as Adiposity-based Chronic Disease (ABCD), and the European approach described by Hebebrand et al. (2017). All these approaches conserve the use of BMI as a measure of adiposity and continue to use the same BMI categories. There is little critical discussion of the cut point of 30 as opposed to other possible higher or lower cut points; rather, the value of 30 seems to be accepted uncritically, demonstrating the proposition that,

once a label is established, there is a tendency to accept it rather than examine its accuracy (Foroni & Rothbart, 2013).

There is also little discussion of labelling people as having or not having a "normal weight" or "healthy weight" also simply on the basis of their BMI, although there is no clear definition of either of these terms either. In many, if not most countries in North America, Europe, and Latin America, well over half the population is above "normal" weight, calling into question what normal means in this context. In the context of BMI categories, "normal" is associated with younger people, people of white or Asian ethnicity, and wealthier people. The NIH report states, "Overweight and obesity are especially evident in some minority groups, as well as in those with lower incomes and less education" ("Clinical Guidelines", p. xi). In fact, a common finding is that people in the overweight category of BMI have the same or slightly lower mortality as those in the normal weight category (Flegal, Kit, Orpana, & Graubard, 2013). The entire concept of a single normal or healthy weight applicable across age, sex, and ethnicity groupings and even across the lifespan for a given individual has been criticized (Dixon, Egger, Finkelstein, Kral, & Lambert et al., 2015).

It would appear that the general population does not necessarily agree with the BMI categories promulgated by WHO and NIH. This is sometimes referred to as "misperception," but it might better be called "disagreement." In Denmark, 70 percent of men and 50 percent of women who self-reported a BMI of 25 or above did not view themselves as overweight (Matthiessen et al., 2014). In Mauritius, where 50 percent of adults were classified as overweight or obese, 45 percent of overweight or obese men by the WHO categories and 38 percent of women misclassified their status (Caleyachetty, Kengne, Muennig, Rutter, & Echouffo-Tcheugui, 2016). Misclassification was higher among those who reported their health as good or excellent. In England, almost 30 percent of those with BMI levels at or above 25 underestimated their status relative to the WHO categories, with higher proportions of minority groups underestimating their status (Muttarak, 2018). In a large representative Canadian sample (Herman, Hopman, & Rosenberg, 2013), 40 percent of men and 16 percent of women who reported an overweight or obese BMI classified their weight as "about right." On the other hand, 21 percent of women who reported a BMI in the "healthy weight range" classified themselves as overweight. In a qualitative study of older people in a relatively affluent rural area of the US, researchers found that participants, all with BMI levels of 30 or above, did not accept the designation of obesity as a disease, and many rejected the label of "obese" outright (Batsis et al., 2021). Researchers seem baffled by why lay people do not agree with their scientific categorizations, even suggesting in one case that perhaps misperception has increased because of improvements in fashion design for overweight women (Muttarak, 2018).

Limitations and issues with current uses of BMI

BMI is a simple way to adjust weight for height, useful for descriptive purposes and to facilitate comparisons of weight among people of different heights. It slowly became medicalized and ultimately became used as the definition of a disease. This is far from its original purpose and far from its original meaning. Because it is easy to measure and calculate, BMI creates a "streetlight effect" – a type of observational bias, whereby we look for our lost keys where the light is brightest. Attempts at international standardization have resulted in the creation and overuse of arbitrary BMI categories that don't identify the same level of health risks across individuals or populations. These categories have become used to arrive at population estimates that are in effect diagnoses of disease based solely on height and weight.

People are classified as having a disease without having ever received a diagnosis and indeed often without any medical encounter at all; yet, the estimates are treated as though they represented the prevalence of a clinically diagnosed disease. BMI is not a good measure of fat mass, but a number of studies (e.g., Han et al., 2010; Spahillari et al., 2016; Srikanthan, Horwich, & Tseng, 2016) have found that low muscle mass is more of a risk than high fat mass. Bosy-Westphal and Müller (2021) suggest that obesity should not even be considered as a question of body fat per se but should be addressed in terms of body composition, and that the use of both BMI and of body fat percentage should be avoided. They call for a new paradigm focused on fat-free mass instead and point out that, at older ages, a higher BMI may indicate more adequate fat-free mass.

Even though the many limitations of BMI are well known, and BMI is often criticized, that hasn't stopped its widespread use for purposes well beyond those for which it was intended. BMI, a simple measure of weight adjusted for height, has undergone considerable elaboration and transformation to now serve as a measure of disease, enmeshed in a complex web of medical, social, and commercial interests. The fixation on BMI may distract attention from more important aspects of health and disease.

Notes

1 **Brief explanation of Quetelet's derivation**

Let H_S be the average height of the shortest men and H_T be the average height of the tallest men. Let W_S be the average weight of the shortest men and W_T be the average weight of the tallest men. Quetelet observed that $H_S/H_T = 5/6$ and that the ratio of (W_S/H_S) to (W_T/H_T) was also 5/6. Therefore, $H_S/H_T = (W_S/H_S)/(W_T/H_T)$. Applying elementary algebra to rearrange the terms, multiplying both sides of the equation by H_S and dividing both sides by H_T show that (H_S squared)/(H_T squared) = W_S/W_T. Thus, as Quetelet observed, the ratio of weights at different heights is proportional to the ratio of the square of the heights. Now dividing both sides by H_S squared and multiplying both sides by W_T show that $W_S/(H_S$ squared) = $W_T/(H_T$ squared).

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