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ORIGINAL ARTICLE

How much energy is locked in the USA? Alternative metrics for characterising the magnitude of overweight and obesity derived from BRFSS 2010 data

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Abstract
Objectives Four metrics to characterise population overweight are described.
Methods Behavioural Risk Factors Surveillance System data were used to estimate the weight the US population needed to lose to achieve a BMI < 25. The metrics for population level overweight were total weight, total volume, total energy, and energy value.
Results About 144 million people in the US need to lose 2.4 million metric tonnes. The volume of fat is 2.6 billion litres—1,038 Olympic size swimming pools. The energy in the fat would power 90,000 households for a year and is worth around 162 million dollars.
Conclusions Four confronting ways of talking about a national overweight and obesity are described. The value of the metrics remains to be tested.

Keywords Obesity · Measurement · Health policy · Population health

Introduction

There is no single, perfect way to convey an idea, and this is particularly apparent when one is trying to convey numerical information about a health outcome (Peters et al. 2009). Different measures are more or less useful for different purposes. For an epidemiologist, a policy maker, a legislator or a member of the lay public the same information expressed in slightly different ways can produce profoundly different emotional and intellectual responses from incomprehension through to outrage. As a broad generalisation, one might say that epidemiologist are comfortable working with rates, such as the under-five mortality rate, but sometimes neglect the absolute numbers affected. Policy makers and legislators may have a closer eye on the absolute numbers affected, wanting to know, for instance, how many children under the age of 5 actually died. For the lay public, rates are an obscure way to present information and the absolute numbers can seem overwhelmingly large, potentially leading to indifference (Slovic 2010).

To overcome meaninglessly large numbers of deaths or incomprehensible rates, people have expressed numbers according to non-standard metrics that would convey both the magnitude of the problem and elicit a sense of moral outrage in anticipation of action. A classic example of this is the Boeing 747 crash metric. The number of maternal deaths is "the equivalent of five 747 jumbo jets crashing daily and killing all passengers and crew" observed one WHO Africa Region press release (World Health Organization 2004). The value of this particular metric lies in its broad applicability in development (DSW 2008) and advocacy (Beattie 2010; Christian Medical Fellowship 2010), where one seeks not only understanding, but also a shift from simple understanding through to action. In domains in which death does not occur, however, or does not occur in large enough numbers, an equivalence with crashing jet-liners is counterproductive, either giving a sense of "not that many deaths," or the equivalence simply does not hold leading to incomprehension. Trying to

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convey a sense of the magnitude of morbidity, for instance, would fail using the crashing jet metric.

Obesity is a case in point. Causing no deaths directly, it is nonetheless a significant risk factor for diabetes, heart disease, kidney disease, and some cancers (Reilly and Kelly 2011; Bellanger and Bray 2005; Jiang et al. 2007). Given what is known, how then can impactful and accurate statements about the magnitude of the problem be made? Health researchers in the non-communicable diseases area clearly understand the significance of obesity as a determinant of health, as do health policy makers in the area. It is not enough, however, for this narrow group to appreciate the issues if we are to achieve real change that influences obesity at the population level. Legislators and the lay population need to appreciate the problem, but traction among these groups is less obvious.

The traditional approach to conveying a sense of the magnitude of overweight and obesity is to discuss it in terms of the percentage of the population with a body mass index (BMI) over 25 (Overweight), over 30 (Obese I), or over 35 (Obese II). There is perhaps no more visually compelling exposition of this idea than the US Centers for Disease Control's (CDC) slide presentation of the explosion of obesity and overweight across the 50 States of the US between 1985 and 2010 (Obesity and Overweight for Professionals 2012). Nonetheless, visually confronting as the presentation is, even the CDC acknowledged that the exposition was designed "for professionals," and without an accompanying explanation it is likely to leave a lay audience cold.

Part of the challenge then, in conveying a sense of the magnitude of the obesity problem, appears to lie in the available metrics. BMI is not an intuitive measure of overweight and obesity and does not convey any sense of how much actual weight (i.e. fat) is needed to be lost. Using the latest publicly available Behavioural Risk Factor Surveillance System (BRFSS) data from the CDC we explore some alternative metrics for the magnitude of overweight and obesity in the US population which may have the requisite realism and shock value for policy change. The first metric we develop is of the total amount of weight (kg) the population needs to lose. The second metric is the total volume of fat the population needs to lose. The third metric is of the energy stored in the overweight and obese population. The fourth and final metric is the dollar value of the energy stored in the overweight and obese population.

Methods

Data on overweight and obesity are derived from the 2010 BRFSS conducted by the CDC in collaboration with the relevant US states and territories. The CDC describes the objectives and survey process in the following terms (Centers for Disease Control 2011). The objective of the BRFSS is to collect uniform, state-specific data on preventive health practices and risk behaviours that are linked to chronic diseases, injuries, and preventable infectious diseases that affect the adult population. Data are collected from a random sample of adults (one per household) through a telephone survey. The health characteristics estimated from the BRFSS pertain to the adult population, aged 18 years or older, who live in households. No direct method of compensating for non-telephone coverage is employed by the BRFSS; however, post-stratification weights are used, which may partially correct for any bias caused by non-telephone coverage. These weights adjust for differences in probability of selection and nonresponse, as well as noncoverage, and must be used for deriving representative population-based estimates of risk behaviour prevalence.

Among the questions asked in the BRFSS is self-reported height and weight, from which BMI is calculated. BMI is used as a measure of the degree to which a person is overweight or obese and is calculated as the weight of the person (kg) divided by their squared height (m); where a person with a BMI ≥ 5 is categorised as overweight, a person with a BMI ≥ 30 is categorised as Obese I, and a person with a BMI ≥ 35 is categorised as Obese II (World Health Organization 2000, p. 9). BMI is not an ideal individual measure of body fat, because it does not account for people with high BMI who carry higher than average muscle mass or people with low BMI who carry lower than average muscle mass. At a population level, however, this is averaged out, giving a reasonable indication of the population's level of body fat (Heo et al. 2012; Flegal et al. 2009).

For any person with a BMI ≥ 25 to return to normal weight (BMI 18.5–24.99) they either need to grow in physical stature (unlikely) or they need to lose weight. Through a straightforward transformation of the BMI formula, the amount of weight that has to be lost to return an overweight or obese person to normal weight can be calculated as

$$\text{Weight needed to lose} = \text{weight} - \left(25 \times \text{height}^2\right),$$

where height is in m, weight is in kg, and 25 is the BMI value at the border of healthy and overweight. Knowing the amount of body fat any overweight or obese individual needs to lose allows the estimation of the total amount of body fat needed to lose for the entire population of the US to achieve a BMI < 25. This gives the first metric examined.

One kilogram of body fat has a volume of approximately 1.0874 litres (Siri 1956). Olympic-sized swimming pools

vary in volume, but 2,500 m^3 (or 2.5 million litres) is a typical size (Olympic-size swimming pool 2012). From knowing the amount of weight to lose (Metric 1), it is possible to make a straightforward calculation of the volume of the fat needed to lose, and express that in terms of the Olympic swimming pool metric (Metric 2).

The third and fourth metrics rely on the calculation of the excess energy stored in the bodies of overweight and obese individuals. The energy in body fat is approximately 37,600 kJ/kg (Kent 2000, p. 170). The most recent US estimates for household energy consumption come from the 2005 Residential Energy Consumption Survey (RECS) (US Energy Information Administration 2005). These data allow the estimation of the annual household energy needs that are stored in the excess body fat of the US population (Metric 3), and the dollar value of that energy (Metric 4). The metrics requires the conversion of RECS estimates in British thermal units (Btu) to kilojoules [1 kJ = 0.9 Btu (Plunkett 2007)].

All data analysis was conducted using the R statistical environment (R Development Core Team 2013), and the survey package for the adjustment of estimates (and errors of estimate) according to the survey design of the BRFSS (Lumley 2012).

The analysis utilised a public use data set containing anonymised data collected with informed consent, made freely available for secondary data analysis by the Centers for Disease Control, US government (Centers for Disease Control 2011). Institutional ethics committee clearance was neither required nor sought for this analysis.

Results

In the US there are approximately 144 million people who are overweight or obese; i.e., approximately 60.8 % of the adult population. Table 1 shows the break down by sex and by age group of the numbers of people involved and the mean amount of weight that has to be lost to return the whole population to the normal weight category (BMI < 25). The data are further disaggregated into the separate BMI categories of Overweight, Obese I, and Obese II.

There are more overweight and obese adult males in the US population than adult females—approximately 80 million males and 64 million females. Although males are on average taller than females, meaning that for any given BMI ≥ 25 males need to lose more kilogrammes of weight than females, over the total population of people who are overweight and obese, the weight the average male needs to lose is approximately the same as the average female ($\sim$16.5 kg). This is because females are over represented in the category BMI ≥ 35, whereas males are over represented in the category $25 \leq$ BMI < 30.

Metric 1, metric tonnes of weight in excess body fat

The total amount of weight that the 144 million overweight and obese people living in the US would need to lose is approximately 2.4 million metric tonnes, with a standard error of estimate around 12,000 tonnes (2,386,701 t $\pm$ 12,209).

Metric 2, Olympic-sized swimming pools filled with excess body fat

The excess weight has a volume of approximately 2.6 billion litres with a standard error of estimate around 12 million litres (2,595,368,248 l $\pm$ 12,208,907). An Olympic-size swimming pool can hold 2,500 million litres, which means there is enough excess fat in the population of the US to fill 1,038 Olympic-size swimming pools ($\pm$4.9).

Metric 3, households powered for a year by excess body fat

One kilogram of human body fat contains approximately 37,600 kJ of energy, or 35,640 Btu. Stored in the excess body fat of the US there is approximately 8.506×10^{13} Btu. Household consumption data show that the average US household's annual energy consumption is around 949 million Btu. This means that there is enough energy stored in the excess body fat of the US to power approximately 90,000 households for a year with a standard error of estimate around 450 households (89,633 $\pm$ 458.5).

Metric 4, dollar value of the energy stored in excess body fat

The average amount of money spent by US households on energy is USD$1,810 per household (US Energy Information Administration 2005). If there is enough energy for 90,000 households, the dollar value of the energy multiplies out in a straightforward fashion—approximately 162 million dollars with a standard error of estimate around 800,000 dollars (USD$162,235,427 $\pm$ USD$829,898).

Discussion

The choices that are made in the health sciences about the metrics to use in understanding or reporting research is influenced by both scientific and a political considerations (Reidpath 2007). Metrics like the Boeing 747 crash metric have important shock value and cannot be summarily dismissed simply because they are shocking—they invite the audience to realise that they would not tolerate large

Table 1 The population in millions, of people in different categories of overweight and obese, broken down by sex and age group (mean ± standard error)

	Weight categories			
	Over weight $25 \leq BMI < 30$	Obese I $30 \leq BMI < 35$	Obese II $35 \leq BMI$	Total
Males	47.6 ± 0.34 (7.3 ± .03)	21.6 ± 0.24 (22.4 ± 0.05)	10.7 ± 0.17 (46.1 ± 0.3)	79.9 ± 0.43 (16.6 ± 0.09)
Females	33.5 ± 0.22 (6 ± .03)	18 ± 0.17 (18.7 ± 0.04)	12.7 ± 0.14 (41.1 ± 0.18)	64.1 ± 0.29 (16.5 ± 0.08)
18–24	5.4 ± 0.16 (6.4 ± .14)	2.4 ± 0.11 (20.6 ± 0.23)	1.6 ± 0.09 (43.1 ± 0.65)	9.4 ± 0.21 (16.3 ± 0.33)
25–34	12.8 ± 0.20 (6.8 ± 0.07)	6.1 ± 0.14 (20.8 ± 0.11)	4.2 ± 0.12 (44.9 ± 0.62)	23.1 ± 0.27 (17.4 ± 0.22)
35–44	17.0 ± 0.21 (6.9 ± 0.05)	8.7 ± 0.15 (20.9 ± 0.09)	5.4 ± 0.12 (44.5 ± 0.38)	31.1 ± 0.29 (17.3 ± 0.15)
45–54	17.1 ± 0.17 (6.9 ± 0.05)	8.8 ± 0.13 (21.0 ± 0.07)	5.2 ± 0.09 (43.8 ± 0.3)	31.1 ± 0.23 (17.0 ± 0.12)
55–64	13.1 ± 0.12 (6.9 ± 0.04)	6.8 ± 0.08 (20.8 ± 0.06)	4.1 ± 0.06 (43.2 ± 0.24)	24.1 ± 0.15 (17.1 ± 0.1)
65–99	15.6 ± 0.11 (6.5 ± 0.03)	6.7 ± 0.07 (19.9 ± 0.05)	3 ± 0.05 (39.1 ± 0.22)	25.2 ± 0.13 (13.9 ± 0.07)

In parentheses: the average amount of weight (kg) that a person in each category would need to lose to have a body mass index (BMI) <25

numbers of jet-liners crashing everyday, so they should not tolerate that same number of child deaths that occur in less visible ways or less visible places.

There is little doubt that many countries, like the US have serious issues with overweight and obesity in the population. How then can one convey the magnitude of the issue in such a way that it might shift public opinion more radically? Metrics of mortality are clearly inappropriate; however, the four metrics suggested here—or their variants—may carry the right kind of fact/shock value balance to support policy shifts.

The most significant limitation with the estimates provided here is that self-reported height and weight biases BMI downwards (McAdams et al. 2007). Both men and women tend to overestimate their height and under estimate their weight, which means that the true values of BMI are likely to be even greater than those reported here, which would have led to a higher estimate of the weight needed to lose (Krul et al. 2011). Another issue discussed in the "Methods" is that BMI is correlated with, but does not perfectly predict body fat content. An individual with a high BMI may be extremely muscular and an individual with a low BMI may have little muscle but a relative abundance of fat. For population level estimates, however, BMI appears to be fairly robust (Heo et al. 2012; Flegal et al. 2009). As a consequence the estimates based on the new metrics reported here are likely to be under rather than estimate the true level of excess fat/energy.

2.4 million metric tonnes of human lard, 1,038 olympic-sized swimming pools of human tallow, enough human cellulite to power 90,000 homes for a year, or USD$162 million of human dripping seems to have all the makings for some very confronting ways of talking about a nation with a serious overweight and obesity problem. Whether they are useful for motivating policy changes with real impact is an empirical question that remains to be tested.

What is already known about this subject

- The traditional approach to conveying a sense of the magnitude of overweight and obesity is to discuss it in terms of the percentage of the population with a BMI over 25 (Overweight) or over 30 (Obese).
- Part of the challenge then, in conveying a sense of the magnitude of the obesity problem, appears to lie in the available metrics.
- BMI is not an intuitive measure of overweight and obesity and does not convey any sense of how much actual weight (i.e. fat) is needed to be lost.

What this study adds

- Using the latest publicly available BRFSS data from the CDC, we explore some alternative metrics for the magnitude of overweight and obesity in the US population which may have the requisite realism and shock value for policy change.

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Conflict of interest None.

References

Beattie T (2010) Marginal musings: maternal mortality: the equivalent of three 747 s crashing every day [Internet]. http://tina-beattie.blogspot.com/2010/02/maternal-mortality-equivalent-of-three.html. Cited 28 Apr 2012

Bellanger TM, Bray GA (2005) Obesity related morbidity and mortality. J La State Med Soc 157(1):S42–S49

Centers for Disease Control (2011) BRFSS annual survey data: survey data and documentation [Internet]. http://www.cdc.gov/

brfss/technical%5Finfodata/surveydata/2010/overview_10.rtf. Cited 8 Jun 2012
Christian Medical Fellowship (2010) MDG 5—saving the lives of mothers [Internet]. http://www.cmf.org.uk/publications/content.asp?context=article&id=25517. Cited 28 Apr 2012
DSW (2008) What about reproductive health? Improving the success of development cooperation. German Foundation for World Population (DSW), Hannover
Flegal KM, Shepherd JA, Looker AC, Graubard BI, Borrud LG, Ogden CL et al (2009) Comparisons of percentage body fat, body mass index, waist circumference, and waist-stature ratio in adults. Am J Clin Nutr 89(2):500–508
Heo M, Faith MS, Pietrobelli A, Heymsfield SB (2012) Percentage of body fat cutoffs by sex, age, and race-ethnicity in the US adult population from NHANES 1999–2004. Am J Clin Nutr 95(3):594–602
Jiang Y, Chen Y, Manuel D, Morrison H, Mao Y, Obesity Working Group (2007) Quantifying the impact of obesity category on major chronic diseases in Canada. Sci World J 7:1211–1221
Kent M (2000) Advanced biology. Oxford University Press, Oxford
Krul AJ, Daanen HAM, Choi H (2011) Self-reported and measured weight, height and body mass index (BMI) in Italy, the Netherlands and North America. Eur J Public Health 21(4):414–419
Lumley T (2012) Survey: analysis of complex survey samples. R package version 3.28-2
McAdams MA, Van Dam RM, Hu FB (2007) Comparison of self-reported and measured BMI as correlates of disease markers in US adults. Obesity (Silver Spring) 15(1):188–196
Obesity and Overweight for Professionals (2012) Data and statistics: U.S. Obesity Trends|DNPAO|CDC [Internet]. http://www.cdc.gov/obesity/data/trends.html. Cited 28 Apr 2012
Olympic-size swimming pool (2012) Wikipedia, the free encyclopedia [Internet]. http://en.wikipedia.org/wiki/Olympic-size_swimming_pool. Cited 8 Jun 2012
Peters E, Dieckmann N, Västfjäll D, Mertz C, Slovic P, Hibbard J (2009) Bringing meaning to numbers: the impact of evaluative categories on decisions. J Exp Psychol Appl 15(3):213–227
Plunkett JW (2008) Plunkett's energy industry almanac. Plunkett Research, Ltd., Houston
R Development Core Team (2013) R: a language and environment for statistical computing [Internet]. R Foundation for Statistical Computing,Vienna. http://www.R-project.org
Reidpath D (2007) Summary measures of population health: controversies and new directions. In: Kawachi I, Wamala S (eds) Globalization and health. Oxford University Press, New York, pp 187–200
Reilly JJ, Kelly J (2011) Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review. Int J Obes (Lond) 35(7):891–898
Siri W (1956) The gross composition of the body. In: Tobias C, Lawrence J (eds) Advances in biological and medical physics. Academic Press, New York, pp 239–280
Slovic P (2010) The more who die, the less we care. In: Slovic P, Michel-Kerjan E (eds) The irrational economist: decision making in a dangerous world. Public Affairs Press, New York, pp 30–40
US Energy Information Administration (2005) Residential energy consumption survey (RECS) [Internet]. http://205.254.135.7/consumption/residential/data/2005/#tabs-2. Cited 8 Jun 2012
World Health Organization (2000) Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organization, Geneva. Report No.: Technical Report Series 894
World Health Organization, Regional Office for Africa (2004) WHO says maternal mortality is a "silent emergency"—WHO|Regional Office for Africa [Internet]. http://www.afro.who.int/en/media-centre/pressreleases/item/594-who-says-maternal-mortality-is-a-silent-emergency.html. Cited 28 Apr 2012