South African trends in BMI and obesity

Literature Review

9th May 2014

Ben Walwyn (WLWBEN001)

bwalwyn@gmail.com

Introduction

Overweight and obesity is recognised as one of the main causes of death and burden of disease worldwide (Ezzati *et al.*, 2002). In 2005, 4.8% of global deaths were attributed to high body-mass index (WHO, 2009), when there were around 1.1 billion overweight and more than 300 million obese individuals (Haslam and James, 2005). 2008 data now put estimates (Finucane *et al.*, 2011) at 1.46 billion overweight (34% of world's population) and 500 million obese, and mean BMI growing by about 0.4 kg/m^2 per decade since 1980. In North America and Australasia, female BMI rose by 1.2kg/m^2 per decade. Effects are seen in all countries, low, middle and high-income (WHO, 2009). Data extracted from the 1998 South African health survey estimate mean BMI of 24.1 for males and 28.6 for females, 28% of the population overweight and an astounding 38.6% of females obese (Joubert *et al.*, 2007). This is an epidemic (Haslam and James, 2005; Stevens *et al.*, 2012) spreading through global trends of high energy consumption and physical inactivity.

BMI First, in order to quantify trends and effects of excess weight, a comparative measure is needed. Body-mass index (BMI) – originally called the Quetelet Index (kg/m^2) after Adolphe Quetelet (1796-1874), who first observed that weight is proportional to the square of height (Eknoyan, 2008) – is the conventional and most often used anthropometric measure. The index is nearly uncorrelated with height (Willett *et al.*, 1999) and, in this regard, no other measure has been seen to be superior.

The World Health Organisation's expert committee on use of anthropometric measures published a technical report in 1995 that provided a set of guidelines for appropriate measures in various life-stages and the corresponding definitions of healthy and unhealthy criteria. The report was focussed on the public health implications – determining risk of mortality and morbidity

– of the measure and the use in epidemiological studies rather than medical practice (de Onis and Habicht, 1996). The report identified BMI as the measure of choice for adults, with strong identification of at-risk individuals (WHO, 1995) and the added advantage of practicality and objectivity (Willett *et al.*, 1999). However, this means assuming that the only cause of weight variation adjusted for height is fat mass (Kopelman, 2000), ignoring the effect of lean mass. It's also important to bare in mind that BMI values are more informative relative to each other (de Onis and Habicht, 1996), and may not provide sufficient information on an individual basis due to variation of responses to excess weight (Kopelman, 2000).

The report also provided cut-off values for categorising risk levels of excess weight – indicating those most at risk and separating those least at risk – which are mainly used for public communication purposes (Finucane *et al.*, 2011). The actual selection process was rather arbitrary (WHO, 1995), based on a visual inspection of the BMI and mortality relationship. Most notably, there was a significant rise in all-cause mortality from both sexes above a BMI of 25 (Stevens *et al.*, 1998) and point of inflection in the curve at a BMI of 30 (WHO, 1995). The WHO set cut-offs at 25, 30 and 40, representing classes 1, 2 and 3 overweight. Class 1 and 2 are referred to in literature as overweight and obesity respectively.

Background

The study of its causes and effects (Haslam and James, 2005; Kopelman, 2000) shows that body weight increases when there is a positive energy imbalance between intake and expenditure. Individuals in excess of recommended healthy weights are at higher risk of various forms of cancer, cardiovascular diseases, respiratory disorders, diabetes (type II), osteoarthritis (Kopelman, 2000; Haslam and James, 2005), reproductive function complications, liver and gall bladder disease (Kopelman, 2007), stroke, chronic back pain and asthma (Guh *et al.*, 2009). BMI is linearly correlated with cholesterol (Ezzati *et al.*, 2005), and other risk factors (Ezzati *et al.*, 2002), meaning excess weight acts in association with and through other conditions to increase risk.

Descriptive statistics provide a useful overview of the size of the risk by country, region or on the global level. Mean BMI is highest in North America and Australasia and lowest in Sub-Saharan Africa (Finucane *et al.*, 2011). However, the problem in America is blurred by a disproportionate prevalence and mortality in certain population groups (Ladabaum *et al.*, 2014). Southern Africa, though included in the Sub-Saharan Africa region, has a very large obesity rate of 36.4% in females (Stevens *et al.*, 2012). This type of distortion is expected for an aggregating statistic and is due to the variation in environmental, genetic and psychosocial factors, relating largely to diet and physical activity, that cause and influence the effect of overweight and obesity (Kopelman, 2000; Haslam and James, 2005). Some of these factors are measurable (Ezzati *et al.*, 2002) and, hence, many studies have estimated trends in BMI means and overweight and obesity prevalences over time and the corresponding social interaction. Studies have, therefore, informed on the relationships with these various indicators in recent times.

Covariates

Sex Mean BMI is slightly higher for women than men globally (Finucane *et al.*, 2011), and much higher for women in South Africa (Joubert *et al.*, 2007), indicating a significant independent indicator coefficient. It has also increased more worldwide in women than men (0.5 per decade compared to 0.4) (Finucane *et al.*, 2011). Globally, more women are obese than men, 297 million (13.8%) compared to 205 million (9.8%) (Finucane *et al.*, 2011). Using

1998 South African data (Joubert *et al.*, 2007) overweight prevalence was 27.3% for males and 29.1% for females and obesity prevalence was 11% for males and 38.6% for females. This is an extremely high rate – in comparison the US rate, the highest BMI high-income country, is 35.5% (Ladabaum *et al.*, 2014).

The variation between men and women is not constant and is seen in most plots with other covariates (Ezzati *et al.*, 2005; Stevens *et al.*, 2012; Sassi *et al.*, 2009). Separate models are usually fitted and results presented for the two sexes. Interactions are dependant on varying factors – country, population group, income and others.

Age The relationship between age and BMI tends to be bell-shaped in most populations (Sassi *et al.*, 2009). However, the steepness and the the point at which BMI as well as prevalence rate for obesity start to drop varies between countries (Finucane *et al.*, 2011). Furthermore, this decline in mean BMI may not be an indication of the relationship with BMI, but due to the cross-sectional survey design of most studies. Reverse causation might occur due to the mortality of at-risk individuals and decrease in weight of the ill at old ages (Willett *et al.*, 1999), which lowers the validity of BMI as a measure of risk at higher ages. The bell-shape applies to age relationship with obesity, but less so with overweight (Sassi *et al.*, 2009), perhaps reflecting the effect of mortality on those at high risk.

The changes in BMI with age in South Africa appears to be similar across both sexes(Joubert *et al.*, 2007) and follows the age patterns of most other countries. Adult ages categories for obesity studies typically start at 15, if there are sufficient data.

Geographical Area BMI means and prevalence rates are significantly different between developed countries, mainly by regions. OECD countries all report increases, but some more significantly than others (Sassi *et al.*, 2009), indicating regions explain variation over and above any existing relationship to income. Generally, the trend is negative, with male mean BMI significantly increased in all regions but central Africa and south Asia in recent decades (Finucane *et al.*, 2011). Female regional trends were flat for central and eastern Europe and central Asia, and increasing everywhere else. Female BMI increased in south Asia, however, indicating an interaction effect with sex.

Countries with 50% or more overweight women increased from 29 countries in 1980 to 101 in 2008. Most countries developing such considerable problems in such short time were regions with existing high BMI (Stevens *et al.*, 2012). Furthermore, the more substantial part of the increase in prevalence rate occurred in the period from 2000-2008 for developing regions. Some of the regions with no weight gain include high-income countries, for example Japan and Singapore in Asia. This contradicts the disease of affluence and "Western" paradigm often associated with obesity (Haslam and James, 2005; Prentice, 2006).

Culture and ethnicity Another reason for the invalid diagnosis of obesity as a symptom of western culture, is the the social role the body plays in other regions. Body perception can act as a psychological brake for increasing weight (Prentice, 2006), and where these don't exist, the opposite can also be true. Perceptions amoung many African and Pacific Island populations, which associate fatness with socioeconomic status or beauty (Kopelman, 2000), breed satisfaction and acceptance in middle-aged women and might explain the correspondingly high rates of obesity – which might help explain South Africa's severe burden of obesity in female women.

Data stratified by race in the US, show varying significance of covariates for different groups (Ladabaum *et al.*, 2014). Beyond this interaction, racial inequalities still exist in South Africa and so population groups might also be proxy indicator for socio-economic status, which has a relationship with BMI (Ezzati *et al.*, 2002).

Socio-economic status Much of the effects of excess weight has for a long time been predominantly experienced by high-income countries, causing 8.4% of their deaths and 6.4% of the disability-adjusted life years (Ezzati *et al.*, 2002). Following this evidence, Ezzati et al. (2005) performed a cross-sectional estimation of the relationship of national income accounting for urbanisation and food share of household expenditure, with age-standardised mean BMI (Ezzati *et al.*, 2005). As incomes rise, mean BMI increases rapidly to a peak, before falling again. Mean BMI increases most rapidly at an income of about US$5000, peaks at $12500 for women and US$17000 for men, and declines thereafter. Country BMI declines more for women than men at high levels of income. At the time of this study, SA's income was at US$7500, indicating a continuing of increasing BMI and prevalences should be expected.

Within country income-BMI relationships show clearly higher relative risk of obesity for lower social classes (Sassi *et al.*, 2009). A similar relationship is seen for education level estimates, with higher risks of overweight and obesity. Both these relationships are much more significant for women than men.

There are enough data from the US (Ezzati *et al.*, 2005) that indicates an upward shift of the income-BMI relationship over time (1980-2000). This would place developing nation on a higher BMI trajectory than anticipated previously, increasing their burden of disease. However, it must be noted that the US was initially excluded from the income-BMI analysis, as it was an outlier with very high mean BMI at a high level of income. The increase may just represent the regional trend identified above, although it seems likely at least part of globally rising BMI is due to rising income effects.

Urbanisation and migration are linearly related with rising BMI (Ezzati *et al.*, 2005). Urban areas are a proxy for *obesogenic* environmental and life-style changes that affect energy intake and expenditure, and hence, weight. Urban migration include the exposure to occupation and transportation changes that require less physical activity and specific food types (Kopelman, 2000). Urban obesity in SA (33%) was higher than non-urban (25%) in 1998.

Note that in the context of increasing risk, BMI data need frequent updating. Prevalence rates also become outdated (Prentice, 2006), as using cut-offs for categorising overweight and obesity implies a tipping point – an increasing mean BMI will approach this point and significant proportions of the population might be newly recognised as overweight or obese.

Data All single-country studies use national survey data (Joubert *et al.*, 2007; Ladabaum *et al.*, 2014), while regional and global studies collect data from all relevant studies and appropriately select and collate them (Finucane *et al.*, 2011; Sassi *et al.*, 2009). This type of data is cross-sectional, mainly household based, using multi-stage probability sampling stratified by geographical area for selection (Sassi *et al.*, 2009), making it nationally representative. Using different survey years allows for analysis in time as well (Ladabaum *et al.*, 2014; Finucane *et al.*, 2011), although data are often scarce (in time) in developing countries (Prentice, 2006).

There are two major limitations of cross-sectional data. First, design factors of each individual survey can change, like sampling scheme and interview methods. Second, studies no not prospectively follow a cohort of individuals, so in effect individuals are only measured at one point in time. For analysis of certain covariates like diet and physical activity it is difficult to extract accurate data, since there is not constant monitoring and there is only one time-point available to gather the information.

The most recent US study of 1988-2010 data showed an increase in mean BMI corresponding to an increased proportion of individuals who perform no leisure-time physical activity from 19.1%-51.7% for women and 11.4%-43.5% for men, while reported caloric intake did not significantly rise within this period (Ladabaum *et al.*, 2014). But diet and physical activity in this case are self-reported, and based totally on individual 24-hour recall. Although it is clear physical activity impacted on BMI levels, better design and implementation is needed to estimate to what extent that versus increases in caloric intake (the physiological causes of BMI) are responsible for rising BMI trends.

Self-reported data are biased, underestimating weight and, therefore, BMI (Finucane *et al.*, 2011). Comparison of the US health examination and health interview surveys show a clear underestimation of obesity rates for men and more so for women when self-reported (Sassi *et al.*, 2009). Overweight men in this study tend not underestimate their weights, however. It is relatively easy to measure height and weight, the benefit of using BMI, and this is most often the case.

Studies of the effect of excess weight must use prospective data (Guh *et al.*, 2009), but these are not sufficiently nationally representative and frequent enough to be used in estimating national trends.

Methods Age-standardisation is a method required to compare country-mean BMI values since age structures differ between countries and BMI is correlated with age. The latest WHO standard population is used to weight the mean BMI values calculated per age-group in each country(Ezzati *et al.*, 2005).

Multilevel methods are used to handle the clustering of survey data in specific geographical areas (Gelman and Hill, 2007). Multilevel models decompose the variations between individuals and between high-level groups – households or regional areas. Single level models underestimate the standard error unaccounted for in additional variation between groups. The OECD report (200) outlines a two-level model that measures variation between households and within households. The hierarchy can extend to higher levels, and the statistical model in the most recent global trend study (Finucane *et al.*, 2011), uses Bayesian and multilevel modelling methods to inform parameter estimates of areas where there was missing data. It does so by nesting country estimates within subregions, regions and the globe, each with non-informative priors.

Regression can also be undertaken using normal linear regression (Ladabaum *et al.*, 2014), if there are extensive enough data. In order to model prevalences though, the independent variable, overweight or obesity, must be transformed (Stevens *et al.*, 2012). A proportions is by definitions bounded by 0 and 1, whereas the linear function of explanatory variables is continuous over the whole number line. The transformation proportions is called a logit-link and is defined: $s = log(\frac{p}{1-p})$.

Covariates can often fluctuate in the short-term and so, to better determine the relationship with BMI. To smooth the relationship, instead of defining a yearly value of the variable, a weighted average is used. Income, urbanisation and availability of food types were included as a 10-year average in a recent study Finucane *et al.* (2011). Non-linear relationships can be modelled using higher order polynomials, however, the result may be a fluctuating relationship. In this case, another smoothing technique of using splines in conjunction with redefining the baseline is used to model the relationship of age with BMI (Finucane *et al.*, 2011). This study included a cubic spline knots at 45 and 60, including new cubic terms when age is greater than 45 and 60 respectively, and shifted the baseline age to 50. In the regression equation, for z being age:

$$\beta(z_i) = \beta_1 z_i + \beta_2 z_i^2 + \beta_3 z_i^3 + \beta_4 (z_i - 45)_+^3 + \beta_5 (z_i - 60)_+^3$$

Conclusion

A global study of major risk factors (Ezzati *et al.*, 2002) showed that for developing high-mortality countries like South Africa, the burden of disease is dominated by undernutrition and infectious diseases, contributing the most to the loss of life, but as the country develops economically and combats poverty and communicable diseases, it faces additional risks of mortality and morbidity. Income growth, urbanisation and social influences increase the risk of 'double burden' (Prentice, 2006), the risk that additional mortality and morbidity from excess weight, tobacco and alcohol falls on developing countries already dealing with multiple epidemics. The outlook is already grim. 66% of non-communicable disease deaths occurred in low-income countries in 2005 (WHO, 2009). Overweight increased by approximately 5% and 17% and by 6% and 5% per decade for men and women respectively in South Africa from 1980-2008, and has accelerated in the last decade(Stevens *et al.*, 2012). There is no indication of the epidemic halting. More analysis is needed to identify disparities, understand the dynamics of changing distributions and set targets for stabilisation and intervention in the future.

References

de Onis, M. and Habicht, J. P. (1996). Anthropometric reference data for international use: recommendations from a world health organization expert committee., *The American Journal of Clinical Nutrition* **64**(4): 650–658.

Eknoyan, G. (2008). Adolphe quetelet (1796-1874) the average man and indices of obesity, *Nephrology Dialysis Transplantation* **23**(1): 47–51.

Ezzati, M., Hoorn, S. V., Lawes, C. M. M., Leach, R., James, W. P., Lopez, A. D., Rodgers, A. and Murray, C. J. L. (2005). Rethinking the "diseases of affluence" paradigm: Global patterns of nutritional risks in relation to economic development, *PLoS Med* **2**(5): e133. M3: doi:10.1371/journal.pmed.0020133.

Ezzati, M., Lopez, A. D., Rodgers, A., Hoorn, S. V. and Murray, C. J. (2002). Selected major risk factors and global and regional burden of disease, *The Lancet* **360**(9343): 1347–1360.

Finucane, M. M., Stevens, G. A., Cowan, M. J., Danaei, G., Lin, J. K., Paciorek, C. J., Singh, G. M., Gutierrez, H. R., Lu, Y., Bahalim, A. N., Farzadfar, F., Riley, L. M. and Ezzati, M. (2011). National, regional, and global trends in body-mass index since 1980: systematic analysis of health examination surveys and epidemiological studies with 960 country-years and 9.1 million participants, *Lancet* **377**(9765): 557–567. M3: Article.
URL: *http://search.ebscohost.com/login.aspx?direct=truedb=buhAN=58729435site=ehost-live*

Gelman, A. and Hill, J. (2007). *Data analysis using regression and multilevel/hierarchical models*, Cambridge University Press.

Guh, D., Zhang, W., Bansback, N., Amarsi, Z., Birmingham, C. L. and Anis, A. (2009). The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis, *BMC Public Health* **9**(1): 88. M3: 10.1186/1471-2458-9-88.
URL: *http://www.biomedcentral.com/1471-2458/9/88*

Haslam, D. W. and James, W. P. T. (2005). Obesity, *The Lancet* **366**(9492): 1197–1209.

Joubert, J., Norman, R., Bradshaw, D., Goedecke, J., Steyn, N. P. and Puoane, T. (2007). Estimating the burden of disease attributable to excess body weight in south africa in 2000, *South African Medical Journal* **97**(8): 683–690.

Kopelman, P. (2007). Health risks associated with overweight and obesity, *Obesity Reviews* **8**: 13–17.

Kopelman, P. G. (2000). Obesity as a medical problem, *Nature* **404**(6778): 635–643. M3: 10.1038/35007508; 10.1038/35007508.
URL: *http://dx.doi.org/10.1038/35007508*

Ladabaum, U., Mannalithara, A., Myer, P. A. and Singh, G. (2014). Obesity, abdominal obesity, physical activity, and caloric intake in u.s. adults: 1988-2010, *The American Journal of Medicine* .

Prentice, A. M. (2006). The emerging epidemic of obesity in developing countries, *International journal of epidemiology* **35**(1): 93–99.

Sassi, F., Devaux, M., Cecchini, M. and Rusticelli, E. (2009). The obesity epidemic: analysis of past and projected future trends in selected oecd countries.

Stevens, G. A., Singh, G. M., Lu, Y., Danaei, G., Lin, J. K., Finucane, M. M., Bahalim, A. N., McIntire, R. K., Gutierrez, H. R., Cowan, M., Paciorek, C. J., Farzadfar, F., Riley, L. and Ezzati, M. (2012). National, regional, and global trends in adult overweight and obesity prevalences, *Population Health Metrics* **10**(1): 22–22.
URL: *http://search.ebscohost.com/login.aspx?direct=truedb=cmedmAN=23167948site=ehost-live*

Stevens, J., Cai, J., Pamuk, E. R., Williamson, D. F., Thun, M. J. and Wood, J. L. (1998). The effect of age on the association between body-mass index and mortality, *N Engl J Med* **338**(1): 1–7. doi: 10.1056/NEJM199801013380101; M3: doi: 10.1056/NEJM199801013380101; 29.
URL: *http://dx.doi.org/10.1056/NEJM199801013380101*

WHO (1995). Physical status : the use of and interpretation of anthropometry, report of a who expert committee, *Technical report*, World Health Organization.

WHO (2009). *Global health risks: mortality and burden of disease attributable to selected major risks*, World Health Organization.

Willett, W. C., Dietz, W. H. and Colditz, G. A. (1999). Guidelines for healthy weight, *N Engl J Med* **341**(6): 427–434. doi: 10.1056/NEJM199908053410607; M3: doi: 10.1056/NEJM199908053410607; 19.
URL: *http://dx.doi.org/10.1056/NEJM199908053410607*