**Mind the Gap:
Revisiting the Concentration Index for Overweight**

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Abstract: Much analysis of the socioeconomic gradient of overweight/obesity has involved the calculation of concentration indices for the incidence of these conditions. However this analysis ignores the severity of the conditions, in particular whether there is a gradient to how far are people above the relevant thresholds. Calculation of the concentration index for severity based measures for a dataset for Ireland reveals a much stronger gradient than for the incidence based measures. It is recommended that analysis of severity should always accompany analysis of the incidence of overweight/obesity.

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Mind the Gap: Revisiting the Concentration Index for Obesity and Overweight

1. Introduction

The concentration index (CI) is a standard tool for measuring income related inequalities in overweight and obesity (see Wagstaff and Van Doorslaer, 2000). The CI is a function of the covariance between the incidence of overweight/obesity and the rank of whatever variable is being employed to measure the socioeconomic gradient (e.g. equivalised income). The incidence of overweight (obesity) is defined here as having a body mass index (BMI) in excess of the World Health Organisation threshold of 25 (30).[1] The incidence of overweight is a binary variable and, as such, it ignores much information which may be of relevance. For example, there is now considerable evidence that not only do risk ratios for all-cause mortality rise with the incidence of overweight, but that risk ratios also rise with the severity of overweight i.e. the excess of BMI over the threshold of 25 (see Aune et al, 2016 and Global BMI Mortality Collaboration, 2016).

It thus seems worthwhile to explore the socioeconomic gradient not just of the incidence of overweight but also of its severity. Focussing solely on the CI for incidence runs the risk of underestimating the extent to which lower income groups may be more exposed to the higher risk ratios for all-cause mortality associated with elevated BMI. In this note we suggest that the CI explicitly take account of severity and that such indices are an essential addition to indices based merely on incidence. In section 2 we briefly review evidence concerning the

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[1] Since by definition a BMI in excess of 30 must also be in excess of 25, we will confine discussion to the case of overweight. In the empirical analysis we will present results for both overweight and obesity.

impact of overweight severity on risk ratios for all-cause mortality. In section 3 we present a CI which takes account of severity while in section 4 we apply this to Irish data on overweight and obesity.

2. Body Mass Index and All-Cause Mortality

Two recent comprehensive meta-analyses have reviewed evidence concerning BMI and all-cause mortality (Aune et al, 2016 and Global BMI Mortality Collaboration, 2016). They suggest that in terms of all-cause mortality, the lowest risk ratios are associated with BMI in the region of 23-24 amongst never smokers.[2] Global BMI Mortality Collaboration find that compared to those with BMI in the 22.5-25 region, risk ratios rise to 1.07, 1.28, 1.54, 2.01 and 2.38 as BMI increases to 25-27.5, 27.5-30, 30-35, 35-40 and >40 respectively.[3]

This evidence somewhat contradicts earlier evidence of what became known as the obesity paradox, whereby lower or unchanged risk ratios were observed for individuals who were overweight or mildly obese (Doehner et al 2010 and Flegal et al, 2013). However, the more recent studies take account of the potentially confounding effect of smoking and ill health on BMI. Smoking and/or the presence of chronic diseases can have a reverse causal effect on BMI, hence analysis is best carried out on non-smokers, without a chronic disease and excluding the first five years of follow-up.

Overall, the results from the meta-analyses indicate an approximately linear association between BMI and relative risk ratios for all-cause mortality above a BMI threshold of 25.

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[2] Never smokers without known chronic disease are the preferred group for analysis as analysis of the relationship between BMI and mortality can be distorted by the effects of smoking and/or ill-health on BMI.

[3] While there are criticisms of BMI as an indicator of adiposity (see Burkhauser and Cawley, 2008) it remains easily the most widely available measure and hence is most suitable for comprehensive meta analyses.

Thus in analysis of the socioeconomic gradient of overweight it seems natural to focus attention on those with BMI above this threshold and also, given the results above, to examine not just the incidence of overweight but also its severity. In the next section we briefly outline how the CI provides a summary statistic of such a gradient.

3. The Concentration Index

Given a cardinal health variable, h, where h_i is the value of that variable for individual i, if r_i is the fractional rank of individual i in the income distribution (or whatever measure of household resources is being used), then perhaps the most-widely cited version of the CI is

$$CI = \frac{2 * \text{cov}(h_i, r_i)}{\mu_h}$$

where μ_h is the mean value of the health variable (Wagstaff and Van Doorslaer, 2000). However as discussed in Erregeyrs and Van Ourti (2011), the particular variant of the CI employed depends upon both the underlying nature of the health variable and also normative decisions to be made by the analyst. In the case of a binary variable, Erregeyrs (2009) has suggested the following normalisation: $E=4\mu_h CI$ and this is the appropriate CI when dealing merely with the incidence of overweight.

Suppose however we wish to take account not just of the incidence of overweight but also its severity. One possibility is simply to apply the CI formula above for BMI for the whole population. However, this strategy ignores the critical threshold BMI of 25 and instead gives a CI for the whole distribution of BMI, including values of BMI below 25 which are not of concern.

Another possibility is simply to discard all observations where BMI is below 25 and then calculate the CI for that subset of the population with BMI above 25. We could regard this as a conditional CI, but again it ignores critical information in that it does not take account of the differential incidence of obesity across the income distribution.

Our preferred approach is to follow the gap-based approach to measuring poverty. Here we calculate the proportional gap, $g_i=(BMI_i-z)/z$ for each individual, where z takes a value of 25 when looking at overweight or 30 if we are looking at obesity. For those whose gap is negative however, we simply set it equal to zero, since, according to the principle of focus, we are only interested in gaps for those above the threshold.[4] In that case, we do not need to apply the Erregeyrs correction and can simply use the formula for the CI above, where we replace h_i with $g_i*I(BMI, z)$ and I is an indicator function which takes on a value of unity if someone is above the threshold and zero otherwise. Unlike the case with poverty analysis, we do not apply the concentration curves to powers of gaps as the meta-analysis indicates that relative risk ratios rise linearly with BMI.

In the next section, we briefly describe our data and present results for the CI for the incidence of overweight and obesity using the Erregeyrs correction and also the gap measure.

4. Data and Results

Our data comes from the first two waves of the Growing Up in Ireland (GUI) child cohort. This tracks the development of a cohort of children born in Ireland in the period November 1997-October 1998 (see Williams et al, 2009). Weight was measured to the nearest 0.5 kg using medically approved flat mechanical scales and height was measured to the nearest mm using a height measuring stick.

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[4] For examples of how poverty measures can be applied to obesity see Joliffe (2004) and Madden (2012).

As we are dealing with children aged nine and then thirteen years of age, BMI thresholds will differ by age and gender. Consequently we compare *normalized* BMI figures, where BMI is divided by the appropriate overweight/obesity thresholds provided by Cole et al (2000). Note that this normalization does not affect the calculation of the CIs.

We use equivalised family income as our ranking variable. This figure is derived from a sequence of questions on family net household income (i.e. income from all sources after deductions for tax, social insurance and all other levies have been made). This is then equivalised via an adjustment for size and composition, with a weight of 1.0 for the first adult, 0.66 for subsequent adults (i.e. aged >14) and 0.33 for children (aged <14).

In all, the original sample in wave 1 consisted of 8568 children. However, allowing for observations where either height, weight or income data was missing in either wave, our sample size reduces to a balanced panel of 6554 of which 3219 are boys and 3335 are girls.

Given the reduction in size from the original sample the issue of non-random attrition arises. The greatest loss of observations comes when keeping only those children who appear in both waves i.e. the attrition between waves 1 and 2. Quail et al (2014) confirm that such attrition is non-random and correspondingly, the data was re-weighted so that the weight in wave 2 was the product of the original sampling weight for wave 1 and the attrition weight which took account of non-random attrition. In the analysis which follows we use these wave 2 weights as we are only carrying out analysis on the balanced panel i.e. those observations who appear in both waves.

In table 1 we provide some summary statistics of normalized BMI and also of the incidence of obesity and overweight by gender and for the whole sample. We see that both obesity and overweight are higher for girls than boys, and also that rates of obesity and overweight change very little between waves 1 and 2.

Table 2 provides values for the CI using both the incidence and gap approaches. Looking at the total sample first we observe a mild socioeconomic gradient for the incidence of overweight in wave 1 with a statistically significant value of the CI of -0.036. However, the gradient for the gap measure which takes account of the severity of overweight is over twice as great! The same pattern is evident in wave 2. The CI for incidence has increased to -0.0604, but that for the gap again is around twice as large at -0.1125. Given that relative risks rise in a linear manner with BMI above 25, this suggests that focusing solely on the incidence based measure could lead to a substantial underestimate of the extent to which relative risks are greater for those with lower income. The results by gender are slightly different. The difference between the incidence and gap based CIs is less pronounced for girls, but in the case of boys we see that the incidence based CI for wave 2 is not significantly different from zero, while the gap based CI shows a value of -0.058.

When the focus turns to obesity, the divergence between the CI based upon incidence and that based upon severity becomes even more stark. The gap based CIs are around five times greater than those based merely upon incidence and these differences are evident for the total population and by gender.

In terms of trying to put a more intuitive interpretation of what such a difference implies, Koolman and van Doorslaer (2004) have shown that multiplying the value of the index by 75 gives the percentage of the health variable which would need to be transferred from the poor to the rich in order for there to be no socioeconomic gradient. Thus to take a simple example, in the case of overweight for the total sample in wave 2, a CI of -0.0604 indicates that about 4.5% of overweight would need to be "transferred" from the poorer half of the sample to the richer half to being about equality in overweight by socioeconomic status. When account is taken of the severity of overweight, then about 8.5% of BMI above 25 would need to be

"transferred" from poor to rich. Naturally, given the figures in table 2, the results for obesity are even more stark.

5. Conclusion

This note has suggested that in analyzing the socioeconomic gradient of obesity/overweight via the concentration index (CI), analysts should calculate not just the incidence based CI, but also the CI based upon the gap between BMI and the relevant threshold. Evidence from the most comprehensive reviews of the link between BMI and all-cause mortality indicates that relative risk ratios rise with BMI above 25, and results for a sample of adolescents in Ireland show that CIs for such gap based measures are a multiple of those for incidence based measures. Thus, in focusing merely on the incidence based measures there is a danger that the socioeconomic gradient for the risks associated with elevated BMI will be substantially underestimated.

This study did not require ethical approval.

I acknowledge helpful discussion with Owen O Donnell. The normal disclaimer applies.

Table 1: Summary Statistics (standard errors in brackets)

	Boys		Girls		Total	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
BMI (Normalised)	.7558 (.0027)	.7419 (.0027)	.7711 (.0033)	.7593 (.0033)	.7633 (.0021)	.7504 (.0021)
Obesity (Normalised)	.0465 (.0044)	.0434 (.0043)	.0720 (.0067)	.0709 (.0064)	.0589 (.0040)	.0568 (.0038)
Overweight (Normalised)	.2126 (.0091)	.2271 (.0095)	.2976 (.0114)	.2889 (.0110)	.2540 (.0074)	.2572 (.0073)

Table 2: Concentration Indices for Incidence and Gap Measures of Overweight/Obesity (standard errors in brackets)

	Boys		Girls		Total	
	Wave 1	Wave 2	Wave 1	Wave 2	Wave 1	Wave 2
Obesity Incidence	-.0055 (.0083)	-.0223*** (.0080)	-.0370*** (.0100)	-.0582*** (.0099)	-.0223*** (.0065)	-.0403*** (.0063)
Obesity Gap	-.0612 (.0598)	-.1630** (.0637)	-.1929*** (.0473)	-.2104*** (.0452)	-.1378*** (.0374)	-.1989*** (.0374)
Overweight Incidence	.0094 (.0161)	-.0081 (.0165)	-.0729*** (.0177)	-.1122*** (.0174)	-.0360*** (.0120)	-.0604*** (.0120)
Overweight Gap	-.0065 (.0266)	-.0580** (.0245)	-.1215*** (.0205)	-.1478*** (.0210)	-.0792*** (.0164)	-.1125*** (.0161)

*** p<0.01, ** p<0.05, * p<0.1

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