A study into the detrimental effects of obesity on life expectancy in the UK

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February 2009

Abstract

This paper is an investigation into the effect of excess body fat on mortality within the UK. Health surveys from the UK are used to apply a Cox proportional hazards model to UK-specific data (Health and Lifestyle Survey, 1985) to provide an analysis, at various ages, of the effects of obesity on life expectancy. We explore the issues by replicating and extending US research with UK data using both Body Mass Index (BMI) and Waist to Height (WTH) as obesity measures. We measure the impact of obesity in adults on life expectancy and find that mortality risk associated with obesity in the UK is similar to that found in US studies. However, importantly, we also show WTH to be a better indicator of mortality risk than BMI. Our results include the number of years of life lost (YLL) for UK lives in various severity categories of obesity compared with lives of the same age at optimum levels of BMI or WTH. The research emphasizes how important it is for the government to promote healthy lifestyles in order to avoid premature death.

1. Introduction

Obesity is a condition used to describe high levels of body fat and is associated with increased risk of morbidity and mortality. One measure of obesity commonly used is the Body Mass Index (BMI), defined as weight/height^2. Individuals are classed as overweight if their BMI is between 25 kg/m^2 and 30 kg/m^2, obese if it is between 30 and 40 kg/m^2 and morbidly obese if it is greater than 40 kg/m^2. Using BMI to measure obesity, the Health Survey for England (HSE) shows that the proportion of adults classed as obese has increased in the UK from 15% in 1993 to 25% in 2006 [1]. The same survey shows that the proportion classed as morbidly obese has increased from 0.8% in 1993 to 2.1% in 2006.

An alternative measure of obesity is provided by the waist to height ratio (WTH). There are no comparable accepted definitions of obesity using WTH as there are with BMI. However, the higher the value the more likely a person is to be obese. Broadly similar percentages of the obese population to those found using BMI are produced if a WTH cut-off of 0.6 is used for 'obese' and 0.74 for 'morbidly obese'. According to the HSE the percentage of adults with a 'raised waist circumference' (males > 102 cm, Females > 88cm) has increased from 23% in 1993 to 39% in 2006.

Based on the presumption that the underlying causes of obesity are diet as well as excessive eating, the period of this trend has also coincided with an increase in public awareness in nutrition, partly as a result of education initiatives by the government, the medical profession, charities (such as the British Heart Foundation) and celebrity chefs. According to the government, the ramifications of the obesity 'epidemic' are potentially enormous, whose consequences will be felt in years to come as a result of poor health and lower life expectancy. It believes that the problem begins at an early age and so the focus of the first stage of the government's recently published strategy is on children [2]. In the preamble to the strategy it notes that that the cost of obesity will be felt by every single part of society, not just in headline financial or health terms but in very personal ways, describing obesity as the equivalent of the 'climate change' of public health.

The reasons for this public and government concern are clear to see. Obesity is associated with an increased risk of various life threatening diseases. Many studies have found that obese individuals are at increased risk of cancer [3-6], cardio-vascular diseases and diabetes [7]. These diseases lead to decreased life expectancy. Studies into the relationship between BMI and mortality have found that the risk of death increases when BMI is less than 20 kg/m^2, is optimal between 20 kg/m^2 and 25 kg/m^2 and increases for BMI categories above this [8-9]. Research also shows that obesity exerts a large, statistically significant and negative effect on employment for both males and females after controlling for health [10]. In addition, obesity has important indirect effects on employment through health status and other factors. It appears that the negative effect is greater for the severely obese than the obese, and greater for females than males.

The relationship between BMI and mortality is often termed J or U-shaped and has been found to flatten out as age increases, decreasing the mortality risk associated with obesity [11-12]. A cohort US population based study found that 40 year old obese non- smoking males were found to live to age 77.5 compared to age 83.4 for a male with optimal body mass [13]. Another cross-sectional study found that obese males lost 2-3 years of life, depending on age, with increasing age lowering the expected loss [14-17].

The majority of the research into the effects of obesity on mortality is based on US population samples. US research is useful when assessing the impact of excess body fat on the UK population but research based on UK specific data would be more relevant when answering UK-specific questions. However, there is a dearth of research into obesity using UK-specific data. The aim of this paper is to redress some of this balance by considering the effect of obesity on life expectancy in the UK.

Much of the quoted research uses BMI as an indicator of unhealthy body-fat. Studies [18–19] suggest that waist-to-height ratio (WTH) is a better measure for intra-abdominal fat, which has more associated health risks than fat stored in other parts of the body. BMI also overestimates fat in muscular people. In this paper we explore these issues by replicating and extending US research with UK data using both BMI and WTH as obesity measures. We measure the impact of obesity in adults on life expectancy and find that mortality risk associated with obesity in the UK is similar to that found in US studies.

For example, we find that a non-smoking 30-year old male with a BMI of 34 is expected to live 4 years less than a male of the same age with a BMI of 24. Using a combined US smoking and non-smoking dataset, [14] found that the corresponding white US males lost 3 years. The equivalent figure for female 30 year olds in both the UK and US is 2 years. These examples suggest that obesity is more of a problem for males than females. The research presented here also supports other studies [17-18] that indicate WTH is a better risk measure than BMI. This study finds that a 30-year old non-smoking male with a WTH of 0.66 is expected to live 4 years less than a male of the same age with a WTH of 0.5. The equivalent figure for females is 3 years. When smokers are included in the analysis, 30 year-old males lose 1 year and females 2 years.

2. Approach

The aim of the research is to estimate the number of years of lost life (YLL) experienced by people with different BMI and WTH measurements by considering changes in life expectancy at different ages. Such information may be valuable for developing preventive policies that seek to manage and reduce obesity in populations and for estimating the burden of obesity on society. YLL is defined as the difference in life expectancy between an individual whose measurements are optimally healthy and an individual with a sub-optimal measurement; measuring the difference will show how obesity can affect longevity. In order to proceed we needed to combine information from three sources: the Health and Lifestyle Survey 1985 [20], the Health Survey of England [21] and UK life tables.

The Health and Lifestyle Survey 1985 (HALS) is a cross-sectional study of health and behaviour based on a representative random sample of the UK population, as explained in further detail below. It provides information on weight, height and waist measurements as well as follow-up data on the cause of death of participants who have died. The data are similar to data used in [14] for the US population, so the methodology used in that study is replicated in this paper, allowing direct comparison of results between the UK and US analysis.

The Health Survey of England (HSE) provides information on the prevalence of obesity in the population by age and gender. This survey is conducted annually for the NHS in order to monitor the nation's health through surveying the population for specified health issues.

Life tables provide information on the probability of death at different ages so that we can compare the longevity of obese lives with optimal lives by age and sex. We combine the three sources of information as follows:

- An estimate of the distribution of BMI within the population is made for each year of adult life from 18 to 85 years using data from HSE (2006)

- An estimate of the Cox proportional hazards ratio for death based on BMI, WTH levels and age is obtained through investigating the association between the obesity of participants at the start of the study and their subsequent mortality. Data from HALS is used to parameterize the model.

- The probability of death during each year of adult life is obtained from the 2006 interim life tables for the United Kingdom, produced by the Office for National Statistics. This provides the overall UK population mortality, which can be decomposed into life tables for obese groups.

The role of the Cox model is to identify the relationships between risk factors that affect a subject's survival. In this study it is used to identify, for each sex, the relative level of mortality risk for different levels of obesity. For each age, the relative risks associated with different levels of obesity are combined with the distribution of obesity in the population to decompose the population life table into impaired life tables for obese groups. Using the resulting impaired life tables, the median life expectancy can be derived and compared with the most healthy in order to calculate YLL. The median is used to allow direct comparison with past research [13-17].

2.2 Health and Lifestyle Survey 1985

The Health and Lifestyle Survey (HALS) is a snapshot of the population's health and physiological characteristics from 1985 and is similar to the US data used in [14]. Funded by the Health Promotion Research Trust, it provides UK data on the following attributes: smoking behaviour, alcohol consumption, diet and physical exercise; associated health implications; beliefs and perceptions about health and lifestyle; relationships between lifestyle and physiological status and the effect of cognitive ability on these issues. HALS has advantages over the data used in [14] in that the initial fieldwork is around 10 years more up to date and has a longer period of follow up.

Data for HALS were collected through an interview covering the individual's background, smoking status and beliefs. Physiological information was collected through a nurse visit. The dataset included 7,414 respondents from the age of 18. This sample was compared with census data from 1981 and was found to be reasonably demographically representative, with older people slightly under represented; 97.8% of the sample is linked with the NHS central register allowing death information for these respondents to be updated periodically. This has been completed as far as 2005 and so far 2,431 deaths have been recorded.

HALS was the basis of [20] which in 1996, through the use of observational diagnosis and logistic regression analysis, found that BMI was not a significant predictor of death from all causes. However, it did find that WTH was significant in predicting all-cause mortality using a similar form of regression analysis. In addition, the graphical analysis based on the number of deaths for different BMI deciles also showed a clear trend.

We conducted these tests again on the data to see if these relationships had changed due to the collection of ten years' more data. For the graphical test, sample values of BMI and WTH were obtained from HALS, split into deciles and compared with the number of subsequent deaths. Figures 1 and 2 show the 20 year all-cause number of deaths by decile based on BMI and WTH, respectively. For each measure, a clear trend is apparent for both sexes.

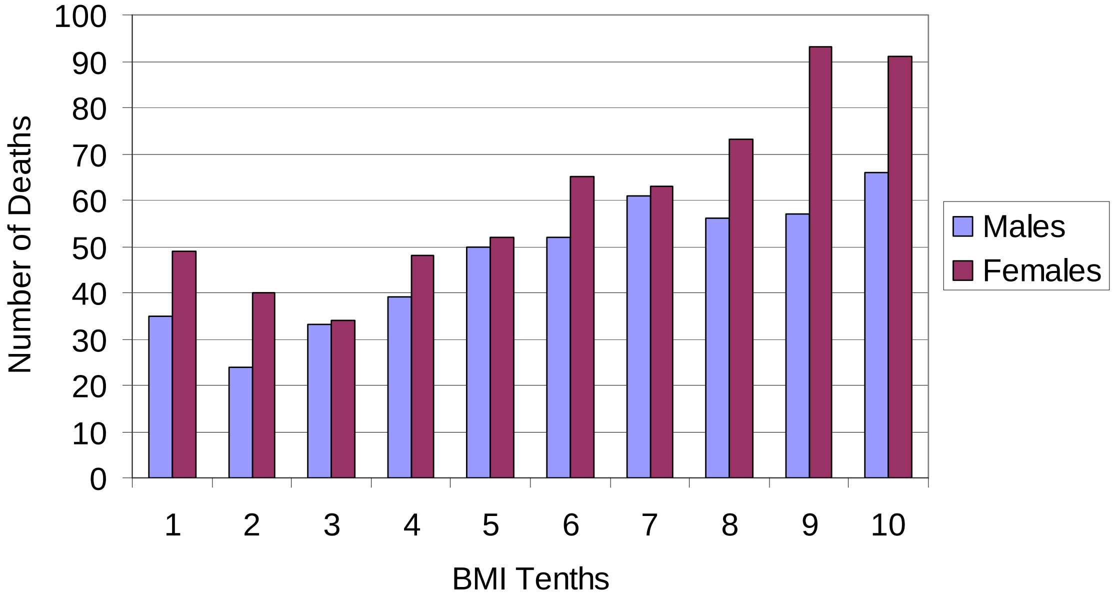

Figure 1: Number of Deaths by Tenth of BMI Distribution (HALS)

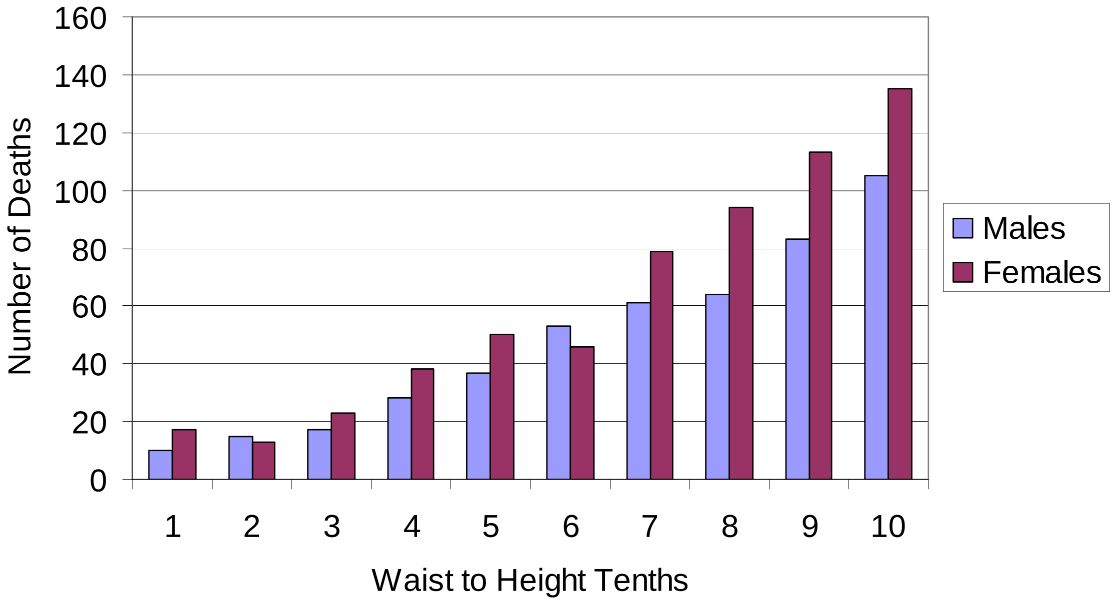

Figure 2: Number of Deaths by Tenth of WTH Distribution (HALS)

Logistic regression analysis of the probability of death versus either BMI or WTH category confirms that a high level of either indicator is statistically significant at the 0.01 level of probability. Our study provides results using both BMI and WTH as an indicator for risk of excess of bodyweight. BMI allows comparison with the majority of past research, especially [14] as the same methodology is used here. WTH results are included because our analysis shows that it has a stronger association with mortality than BMI, as appears to be the case from the above graphical analysis.

3. The model

Using the HSE data the proportion of the population in the following BMI categories were estimated: under 17, [17-18), [18-19),…….[44-45) and over 45. The equivalent categories for WTH were: under 0.36, [0.36-0.38), [0.38-0.40),……[0.78-0.80) and over 0.8. To produce categorical estimates of BMI and WTH, data smoothing was required since there are not enough raw data to produce precise estimates without there being distortions across ages caused by sample error. We adopted the same smoothing procedure as used in [14] on the health survey data. The probability of being in the following 34 overlapping BMI categories was estimated: [13-18), [14-19), [15-20),…….[44-49). The equivalent categories for WTH were: [0.28-0.36), [0.30-0.38), [0.32-0.40),……[0.80-0.88). Individuals were assigned a score of one if their BMI or WTH fell within an interval and zero otherwise. This produced binary variables that were regressed on age to a third degree polynomial via logistic regression.

Using US data, the authors in [22] found that a third degree polynomial accurately characterised the convex relationship between change in age and BMI. [14] used this relationship, and because we found no contradictory evidence from the UK, the same assumption was made for BMI and WTH in this study. The probability of being in each interval was estimated for each age from 18 to 85 using the resulting equations. Then, within each age, the probability of being in each one unit interval was estimated as the moving average of the wider intervals containing the one unit interval. A smoothed distribution of BMI and WTH for ages 18 to 85 was obtained. Having carried out this procedure, we verified that the smoothed total population obesity distribution was very close to the unsmoothed distribution. The mean values of BMI/ WTH for each interval (m_i) were then calculated from the health survey data. For the purpose of projecting years of life lost (YLL), all the individuals in an obesity category are assumed to have the average measurement for that category.

3.1 Hazard Ratios for BMI Levels by Age of Adult Life

Before estimating the model, the following adjustments were made to the data with reference to [23] in their critique of past research in the field. Individuals with missing height, weight or waist values were removed from the dataset. Pregnant females were also excluded. To control for cigarette smoking, the analysis was conducted on two data sets: non-smokers and all lives (non-smokers and smokers together). A summary of the HALS population sample is given in Table 1.

Measure	Smoking Status	Male Subjects	Male Deaths	Female Subjects	Female Deaths
BMI	Non-smokers	1685	473	2609	608
BMI	All	3,297	952	3979	893
WTH	Non-smokers	1678	472	2597	603
WTH	All	3281	949	3958	887

Table 1: HALS population samples and number of deaths

The following points should be noted:

- Some research [24] suggests that participants who die early may distort the results because terminal illness is associated with low body fat. Other research [25] suggests that this effect is marginal. After due consideration we decided not to remove people who died within 3 years.

- No account in our analysis was taken of other kinds of risk factors (such as diabetes or high blood pressure) in estimating between the predictor variables and mortality. This is, therefore, potentially an area for further research.

- The proportional hazards model assumes that the parameters are constant over time. To check that this assumption was met in practice, we plotted Shoenfield residuals against survival time for each independent variable. As with [14], we found them to be independent of time and so concluded that this assumption was met.

- Unlike the US study, on which our methodology is based, we took no account of ethnicity. This was because our UK dataset was too sparse to distinguish between ethnic groupings. The US findings were that the influence of obesity on mortality was much greater in the white than the black population. This is discussed in more detail in section 4 below.

- The sample size at high BMI or WTH is small in this dataset. The consequence is that there will be more uncertainty around the results obtained for the proportional hazard ratios at the highest levels of BMI or WTH.

Cox proportional hazard models were estimated separately for: non-smokers, and for smokers and non-smokers combined. The statistical package, SPSS 16.0, was used to fit the Cox proportional hazards models in each case using the following predictor variables: BMI, BMI^2, WTH, WTH^2, Age and Age^2. The inclusion of quadratic terms allows the effect of a predictor variable to change over the range of inputs. For example, BMI might have a disproportionately large effect on mortality at very high levels and it is necessary to take account of this possibility. Maximum likelihood estimation was used to fit the parameters to the model as is explained in detail in [26]. Interaction terms (BMI x Age, BMI^2 x Age etc) were also tested and incorporated where the model fit was enhanced as a result.

The Cox proportional hazards model assumes that the effect of the covariates is constant over time. In this case, the hazard can be interpreted as the force of mortality (or the instantaneous rate of mortality). For example, the effect on the force of mortality of a male, aged 40, with a BMI of 35 kg/m^2 is constantly proportional to these modelled covariates. To illustrate, if the individual's force of mortality in five years is doubled when having these characteristics compared to the optimum then the individual's force of mortality in 10 years time is also doubled when compared to the optimum.

The following proportional hazards models were estimated for males and females:

$$h_i(t) = h_0(t)\exp(b_1x_{1i} + b_2x_{2i} + b_3x_{3i} + b_4x_{4i} + b_5x_{5i})\mathrm{h_i(t)}$$

where

x_{1i} = Age
x_{2i} = Age^2
x_{3i} = BMI or WTH
x_{4i} = BMI^2 or WTH^2
x_{5i} = BMI or WTH x Age of i^{th} individual

and

$h_i(t)$ =hazard (force of mortality) of i^{th} individual at time t,
$h_0(t)$ =baseline hazard at time t

The b parameters were fitted by comparing the change in the chi-square statistic from adding each variable into the model. If the significance of the change is more than 0.05 then the variable is rejected. Final parameter estimates are shown in Tables 2 and 3 for BMI and WTH. Note that we do not report the values of b_5 in the table for BMI and that b_2 and b_3 values are not reported in the WTH table. This is because they did not improve the model fit. The final values shown in these tables were used to estimate the hazard rate (i.e. force of mortality) of BMI levels or WTH values from age 18 to 75.

The chi-square significance test was used to test if the accuracy of the initial model, using age only, is sufficiently improved by including the other parameters. For females, the model including BMI did not pass the test. However, the fitted parameters look reasonable as compared to those in the model for males where the inclusion of the parameters is shown to significantly enhance the model fit.

Generally we found that the fit of the models using WTH is much better than with BMI. This is consistent with earlier investigations reported above in which WTH appeared to be a better predictor of mortality than BMI. As WTH is more closely associated with mortality than BMI, the effect of including smokers in the dataset did not reduce its value as a predictor variable as it did with BMI.

It seems likely that including smokers in the dataset causes some confounding when fitting the model because there are more deaths at lower body fat levels. BMI was not found to significantly enhance the fit of the model over age alone when fitting the hazards model to the combined smokers and non-smokers dataset. This is why BMI results are only shown for non-smokers. The results of the analysis for two datasets are shown for WTH: non-smokers and combined non-smokers and smokers.

We found that including smokers reduces the effect of WTH on the amount of relative risk. WTH was still useful when smokers are added to the non-smoking dataset but its inclusion became less significant for males. Neither b_2 nor b_3 were statistically significant and are omitted from the WTH tables. All the remaining parameters are statistically significant at the 95% level of probability.

coefficient	Male	Female
b_1	0.1724	0.1087
b_2	-0.0005104	0
b_3	-0.1949	-0.1605
b_4	0.0040378	0.0030

Table 2: BMI Cox proportional hazard model parameters

Dataset	Non-Smokers		Smokers and Non-Smokers	
Sex	Male	Female	Male	Female
b_1	0.1886	0.1518	0.1681	0.1406
b_4	11.43	7.439	8.328	6.631
b_5	-0.1534	-0.0901	-0.1291	-0.0829

Table 3: WTH Cox proportional hazard model parameters

3.2 Estimating Median Years of Life Lost

The 2006 interim life tables for the United Kingdom produced by the Office for National Statistics were used to provide the conditional probability of deaths for the total population. This section describes how the smoothed BMI distribution, together with the hazard ratios and the life tables are used to produce estimates of YLL. Results with WTH are produced in a similar way.

Steps involved in this method are as follows (as used by [14]):

- Estimate the probability of being in the i^{th} BMI category for the j^{th} age (π_{ij}) for i = 1 to 30 and for j = 18 to 85. This is obtained from the smoothed BMI distribution described in section 3.

- Calculate the mean of each BMI category from health survey data = μ_i

- Use the μ_i figure and the midpoints of ages (i.e. 18.5, 19.5 etc) in the Cox proportional hazards equations to obtain hazard ratios (λ_{ij}).

- Make total probability of death in one year conditional upon surviving to the start of age interval (from UK life tables) = γ_j.

- For each integer-defined age interval the probability of death within the interval is estimated, conditional upon having survived to the start of that interval and being in the first BMI category.

$$\gamma_{1j} = \frac{\gamma_j \lambda_{1j}}{\sum_{i=1}^{k} (\pi_{ij} \lambda_{1j})}$$

- The probability of death in following year conditional upon living to the start of the j^{th} age interval and being in the i^{th} BMI category was estimated as being:

$$\gamma_{ij} = \gamma_{1j} \left[\frac{\lambda_{ij}}{\lambda_{1j}} \right]$$

- The median age of death as the expected age of death for each age, s, and BMI category, i, was found by interpolating between the minimum integer values of m and m-1 satisfying:

$$0.5 \geq \prod_{j=s}^{m} (1-\gamma_{ij})$$

- Years of life lost for a person aged x in the i^{th} BMI category relative to a person with optimum BMI (in this case 24 kg/m^2 for males and 26 kg/m^2 for females) is found by taking the expected age of death for the i^{th} category from the age in the optimum BMI category.

4. Results

In this section we report the years of life lost for different values of BMI and WTH and for different sub-groups with and without smokers. Our results show the YLL for individuals with the sub-optimum value of BMI or WTH, respectively.

We start with the results based on BMI. The results are shown in Figures 3 and 4 for males and females for a representative range of ages: 30, 50 and 70. We found that the optimum BMI for males is 24 and for females is 26.

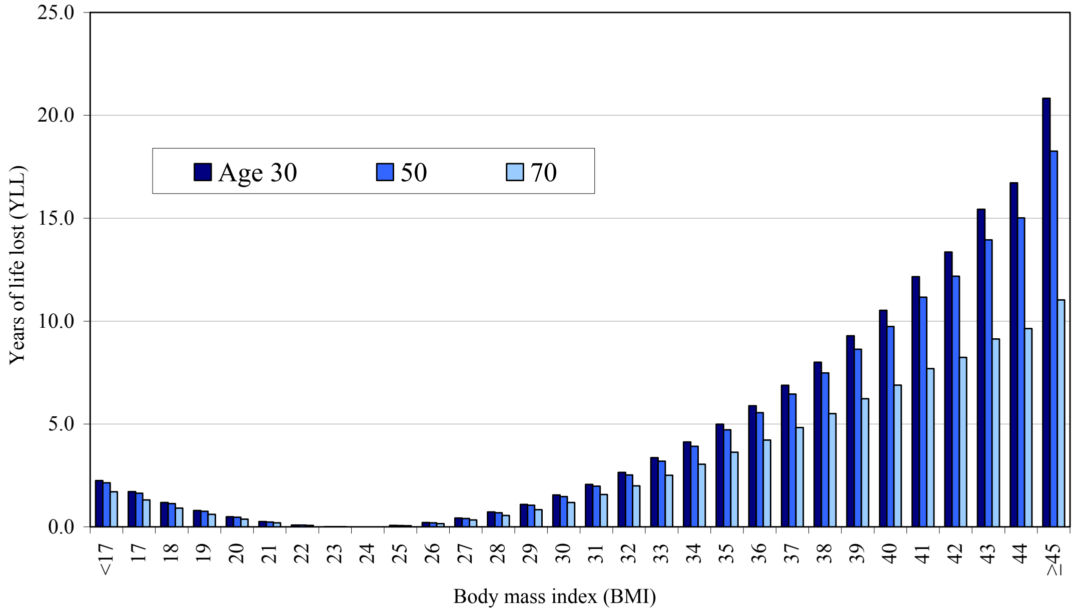

Figure 3: Male non-smokers, YLL relative to BMI of 24

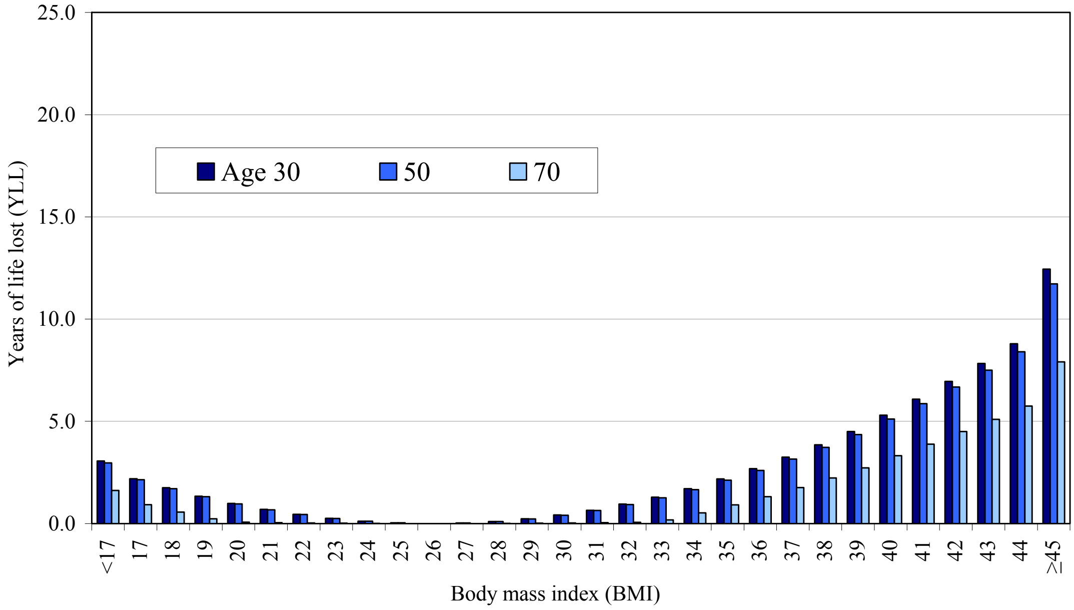

Figure 4: Female non-smokers, YLL relative to BMI of 26 by age

For males, the expected YLL across all ages would be 1 to 2 years for individuals with low BMI (up to 19) and 4 to 16 years for individuals with BMI in excess of 35.

For females, the expected YLL across the range of ages would be 1 to 2 years for individuals with low BMI (up to 19) and 2 to 10 years for individuals with BMI in excess of 35.

Figures 3 and 4 illustrate the huge impact which obesity has on life expectancy. As expected, the YLL curve flattens with increasing age. This is because, as age increases, future expected lifetime decreases. This will tend to have a dampening effect on YLL at older ages.

For females, compared to males, there is less variability across the BMI distribution as a function of age. Also, the YLL figures are lower for females than males. These results are all consistent with the findings from the US [14].

We now consider the results based on WTH. We found the following optimum values of WTH: 0.50 (males) and 0.46 (females) for non-smokers and 0.56 (males) and 0.48 (females) for all lives. We report results separately for non-smokers and all lives (including smokers) since, as mentioned earlier, we found significant differences between those two groups. The results are shown in Figures 5 to 8.

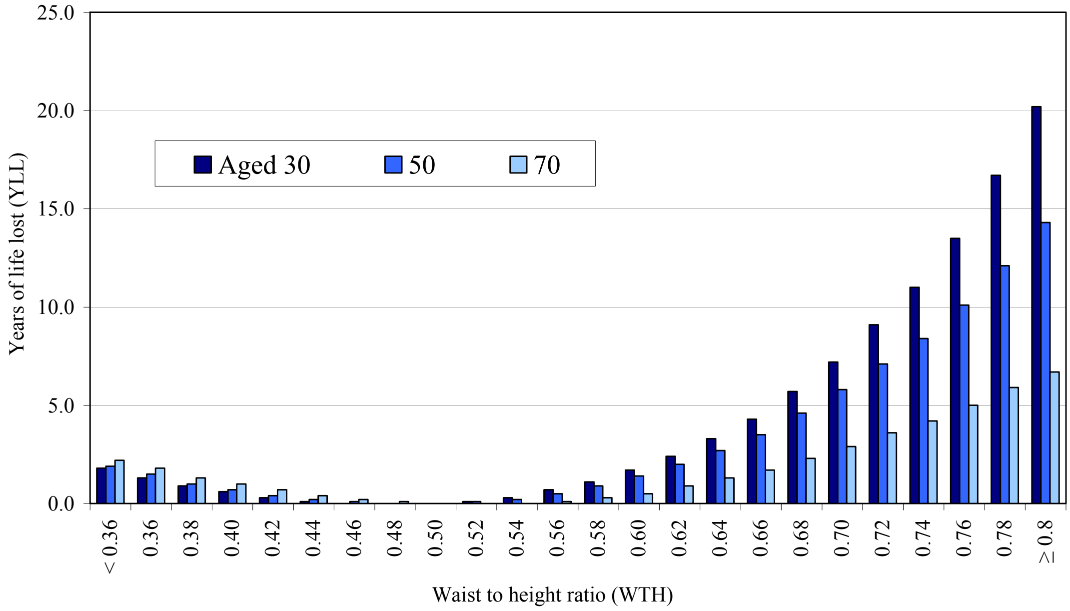

Figure 5: Male non-smokers, YLL relative to WTH of 0.50 by age

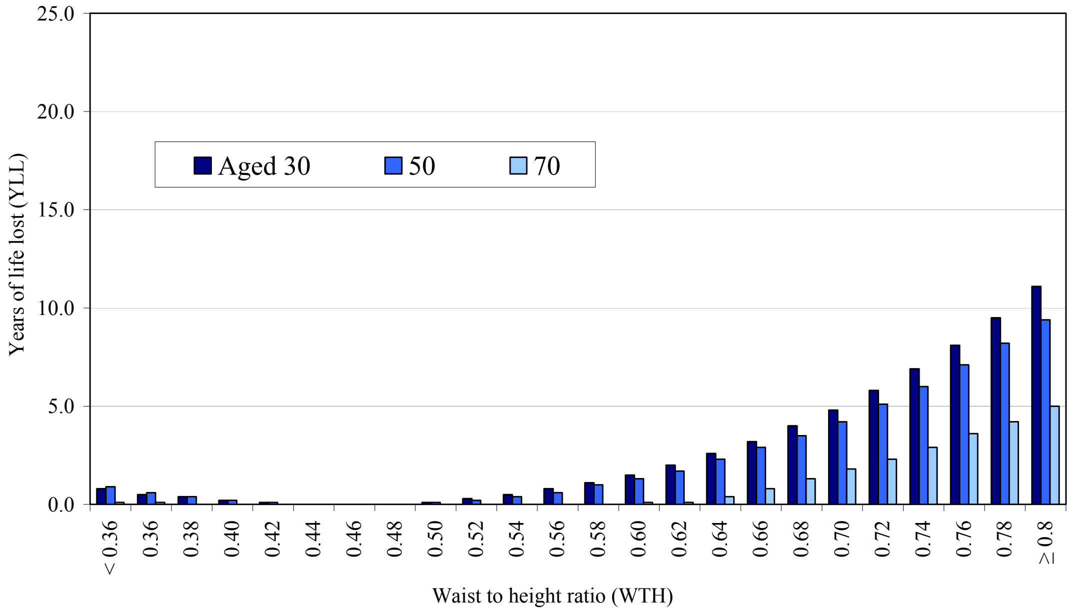

Figure 6: Female non-smokers, YLL relative to WTH of 0.46 by age

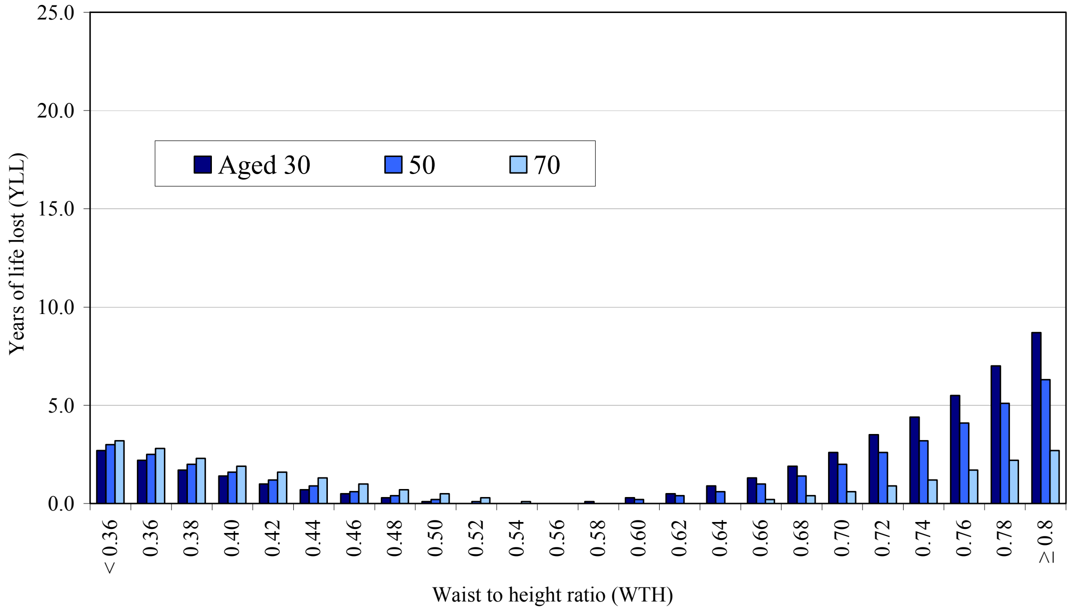

Figure 7: Males including smokers, YLL relative to WTH of 0.56 by age

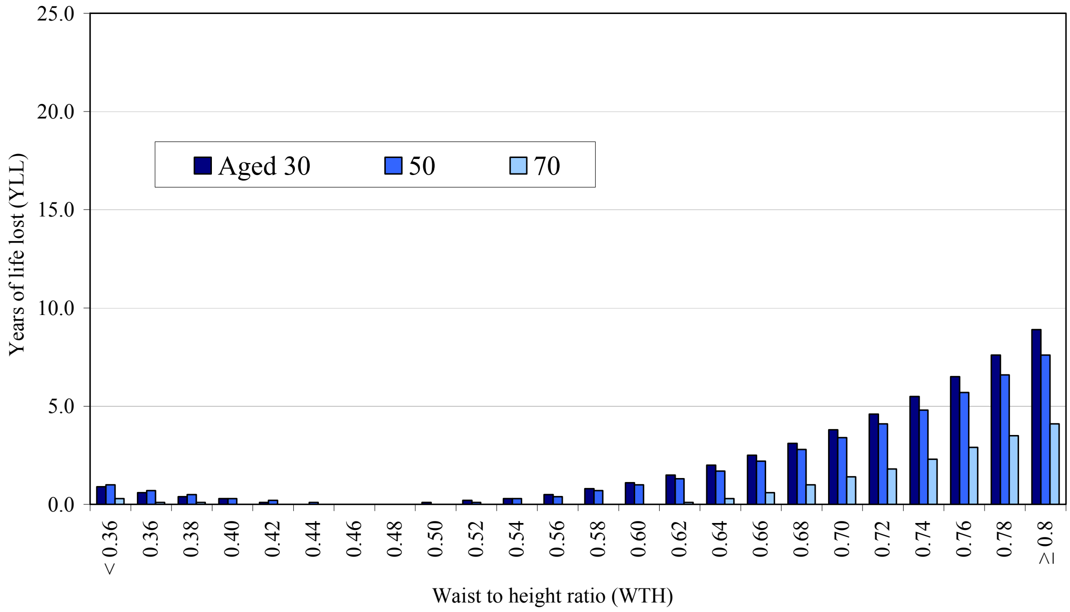

Figure 8: Females including smokers, YLL Relative to WTH of 0.48 by Age

It can be seen that similar comments can be made for the WTH results as with the BMI results. The YLL figures are lower for WTH than BMI. Also, it can be seen that the effect of including smokers is to dampen the YLL figures quite considerably.

5. Implications of findings

The overall pattern suggests, for both BMI and WTH, the following important findings:

- a J-Shaped association between the obesity index and YLL.
- YLL for females is less variable between age groups than the YLL for males.
- Males have a greater YLL than females

The results indicate that obesity decreases life span. For instance, a 30-year old non-smoking male with a BMI greater than 45 was found to lose 20.8 years of life compared to his counterpart with a BMI of 24. A 30-year old male in the optimum BMI category is expected to live another 50.1 years so this equates to a reduction in life expectancy of 42%. For 30-year old females the equivalent figure is 23%. These figures draw comparisons using the extreme top end of the BMI distribution and are only relevant to a small minority of individuals. There are much smaller differences for people in lower obesity and overweight categories, with females seeing less of an effect from higher BMI than males.

It is interesting to consider the converse of YLL. That is, to calculate the years of life which the above figures imply that obese individuals could gain if they were to reduce their BMI by losing weight or reduce their WTH by reducing their waist size. Table 4 shows the implied extra years of life which a 30 year old male of average height 1.75m would have if he had weighed less. For example, the 30 year old could live a further 2.3 years if he had weighed 97 rather than 107 Kgs. It should be noted that this assumes that, purely by losing weight, the individual gains the extra years of life. It may well be that there are additional lifestyle factors involved. In other words, we assume that the individual currently weighing 107 Kgs would automatically adopt the lifestyle characteristics of an individual weighing 97 Kgs.

Table 5 shows the corresponding results for females. Tables 6 and 7 show the equivalent results for a reduction in waist size.

			Kgs lost									
BMI group	Weight (kg)	Age (years)	*2*	*4*	*6*	*8*	*10*	*12*	*14*	*16*	*18*	*20*
			Improvement in life expectancy (yrs)									
30 (obese)	92	30	0.3	0.5	0.7	0.9	1.1	1.2	1.3	1.3	1.3	1.3
35 (obese)	107	30	0.5	1.0	1.5	1.9	2.3	2.7	3.0	3.3	3.6	3.8
40 (morbidly obese)	123	30	0.8	1.6	2.4	3.1	3.7	4.4	5.0	5.5	6.1	6.5

Table 4: Implied improvement in life expectancy from losing weight: non – smoking, 30 year old males of average UK height, 1.75m [weight for BMI of 24 is 74 Kgs]

			Kgs lost									
BMI group	Weight (kg)	Age (years)	*2*	*4*	*6*	*8*	*10*	*12*	*14*	*16*	*18*	*20*
			Improvement in life expectancy (yrs)									
30 (obese)	78	30	0.1	0.2	0.3	0.3	0.3	0.3	0.2	0.1	0.0	-0.2
35 (obese)	91	30	0.3	0.7	0.9	1.2	1.4	1.5	1.7	1.8	1.9	1.9
40 (morbidly obese)	104	30	0.6	1.1	1.6	2.0	2.4	2.8	3.2	3.5	3.8	4.0

Table 5: Implied improvement in life expectancy from losing weight: non- smoking 30 year old females of average UK height, 1.62m [weight for BMI of 26 is 68 Kgs]

			Centimetres lost									
BMI group	Waist (m)	Age (years)	*2*	*4*	*6*	*8*	*10*	*12*	*14*	*16*	*18*	*20*
			Improvement in life expectancy (yrs)									
0.6 (obese)	1.05	30	0.3	0.6	0.8	1.0	1.2	1.3	1.4	1.4	1.4	1.4
0.67 (obese)	1.17	30	0.6	1.2	1.7	2.2	2.6	3.0	3.3	3.5	3.8	4.0
0.74 (morbidly obese)	1.3	30	1.1	2.3	3.3	4.1	4.9	5.7	6.3	6.9	7.4	7.9

Table 6: Implied improvement in life expectancy from reducing waist size: non-smoking 30 year old males of average UK height, 1.75m [waist size for WTH of 0.50 is 0.88m]

			Centimetres lost									
BMI group	Waist (m)	Age (years)	*2*	*4*	*6*	*8*	*10*	*12*	*14*	*16*	*18*	*20*
			Improvement in life expectancy (yrs)									
0.6 (obese)	0.97	30	0.2	0.5	0.6	0.8	0.9	1.1	1.2	1.2	1.3	1.3
0.67 (obese)	1.08	30	0.5	0.8	1.2	1.5	1.8	2.1	2.3	2.5	2.7	2.8
0.74 (morbidly obese)	1.2	30	0.7	1.3	1.8	2.4	2.8	3.3	3.7	4.0	4.4	4.7

Table 7: Implied improvement in life expectancy from reducing waist size: non-smoking 30 year old females of average UK height, 1.62m [waist size for WTH of 0.46 is 0.75m]

This study suggests that females have no increased risk of mortality from being “overweight”, using BMI as a risk measure (BMI: 25-30kg/m^2), in any age range whereas there is a small increased risk for males. By contrast, the WTH results suggest “overweight” has more of an impact on females than males. This is indicated by the optimal female WTH measurements being less than those for males. The results for non-smokers using both WTH and BMI show the YLL from the more severe obesity categories increasing more steeply for males than females. Including smokers in the analysis moves the optimal WTH measure upwards and reduces the increased mortality risk from obesity. Overall, the WTH findings suggest that increased risk begins from categories in excess of 0.54-0.56 whereas previous studies have found the risk to increase from 0.5 [27]. The analysis using WTH produced more reliable output than the analysis based on BMI when smokers are included. This suggests that WTH is a better measure of obesity risk than BMI as it is less diluted by the presence of smoking-related risk factors.

Our results based on BMI are similar to those found by [14], for the US population, where a J-shaped association between BMI and mortality was also found. However, our results for the UK suggest a steeper growth in YLL as BMI increases and smaller YLL from BMI categories in the unhealthy low range (BMI less than 20). As with [14], males were observed to have higher YLL for a specific BMI than females. [14] also found being “overweight” not to be a serious health issue - with females only showing signs of increased risk of mortality in the highest “overweight” BMI category of 29.

When making comparisons between this study and that for the US described in [14] it is important to note that the results that we are comparing in [14] are only in respect of white males and females whereas our study includes all ethnicities. There is a different mix of ethnicity within the UK compared to the US but we have already noted that ethnicity data were sparse in our sample. [14] also considered YLL for black males and females and found a much flatter relationship between YLL and BMI than our study. Therefore, if the US study had combined the results for the white and black populations, their overall results would also have been flatter. By implication, it is possible that our study might have been diluted by the effect of combining ethnic groupings. There is the possibility that significant differences exist between different ethnicities within the UK. However, there were insufficient data available to examine this possibility further.

The J-shaped association is similar to that found by [6] and [11] for US data. However, the curves found in this study are shifted to the right with a comparatively small increased risk of mortality in lower healthy BMI categories (BMI 20-25). The increased YLL for males compared to females with the same BMI levels found from analysis of the HALS data is consistent with these other studies. There is less directly comparable research to the findings for WTH although they are supported by the results of the BMI analysis. The results presented here are consistent with those in [27] with possibly a small shift to the right of the increased risk measure from 0.5 to 0.54-0.56.

6. Further Considerations

When fitting the female proportional hazards model, BMI was not found to increase the accuracy of the model fit significantly (according to the chi-square test). This suggests that age on its own may be better at predicting mortality than including BMI However, there are arguments for including BMI even in this case since all other models calibrated found that the inclusion of BMI or WTH improved the accuracy of the model. Although including BMI in the female model is not justified by our analysis, the parameter values are comparable to those obtained in the male models and so they have been retained. In addition, the female fitted model produces results that are reasonably consistent with previous research.

The relatively small sample size of individuals in higher BMI categories also means that as BMI and WTH increases, the derived hazard ratios become less precise. These have a large influence on the YLL figures. It would be helpful to calculate confidence intervals. However, as noted in [14], this is very difficult to do in practice since the data used in the study come from 3 different sources. We note instead that our results do seem to be supported by results of other studies [6] [11] [14]. To clarify this uncertainty it would be helpful to apply a similar analysis on a large dataset from the UK containing a higher proportion of overweight and obese individuals.

Growth in the UK of the obese and morbidly obese categories of the population has been substantial since the start of the HALS investigation (1985). A similar study repeated now would have a higher sample of these individuals but it would take time before a suitable period of follow-up has elapsed to provide reliable results. Finally, a weakness in our approach is that YLL calculations assume that BMI remains constant over the individual's future lifetime. Therefore, the YLL results described earlier are always a result of comparing an individual in (and remaining in) a certain BMI category with an individual in (and remaining in) the optimum BMI category. In extending this research is would be preferable to use longitudinal data in which there would be included continuous measures of body fat at every age, although clearly this would have implications in terms of cost and time needed to do the research.

7. Conclusions

This paper covers a topic that is important to the planning of health care, social policy and insurance in the UK. It validates recent government policy [28] and the surrounding publicity over nutrition. Through an analysis of the Health and Lifestyle Survey (1985), this study suggests that the mortality risk associated with obesity in the UK is similar to that found in US studies. It finds that a 30-year old male with a BMI of 34 is expected to live 4 years less than a 30 year-old male with a BMI of 24. The equivalent figure for females is 2 years which reflects the overall results that suggest obesity is more of a problem for males than females.

This research also supports other research that indicates WTH is a better risk measure than BMI because this study found it to be a stronger predictor of mortality risk than BMI. The evidence presented here suggests that government policy and future research should therefore place more emphasis on WTH as a risk measure. The proportion of obese individuals in the UK negatively influences mortality rates. If current trends continue, it is likely that obesity will become an even larger influencing factor. Medical advances will probably mitigate this influence to some extent but at increased cost to society. Obesity is a preventable condition and a relatively recent phenomenon. If obesity trends continue it is likely that the treatment of obesity-related disease will be wasteful of scarce health resources by increasing the prevalence of diseases such as diabetes and heart disease.

On present trends, health care providers will find themselves treating more people for diseases caused by excess body fat. This study has focused on the relationship between obesity and mortality. Many of the diseases associated with obesity, such as diabetes, are also associated with factors such as smoking habits or genetic pre-disposition. Thus, it is difficult to separate out the influences of each with any certainty in order to estimate morbidity as well as mortality reductions. In this regard, further work is needed around rates of obesity-associated diseases and their relationship to age, gender and other risk factors. Nevertheless, the research presented here emphasizes how important it is for the government to promote healthy lifestyles in order to avoid premature death (i.e. YLL).

Acknowledgment

This project is funded by a research grant from the Actuarial Profession in the UK.

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