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The Effect of Obesity on Mortality Rates in the United Kingdom

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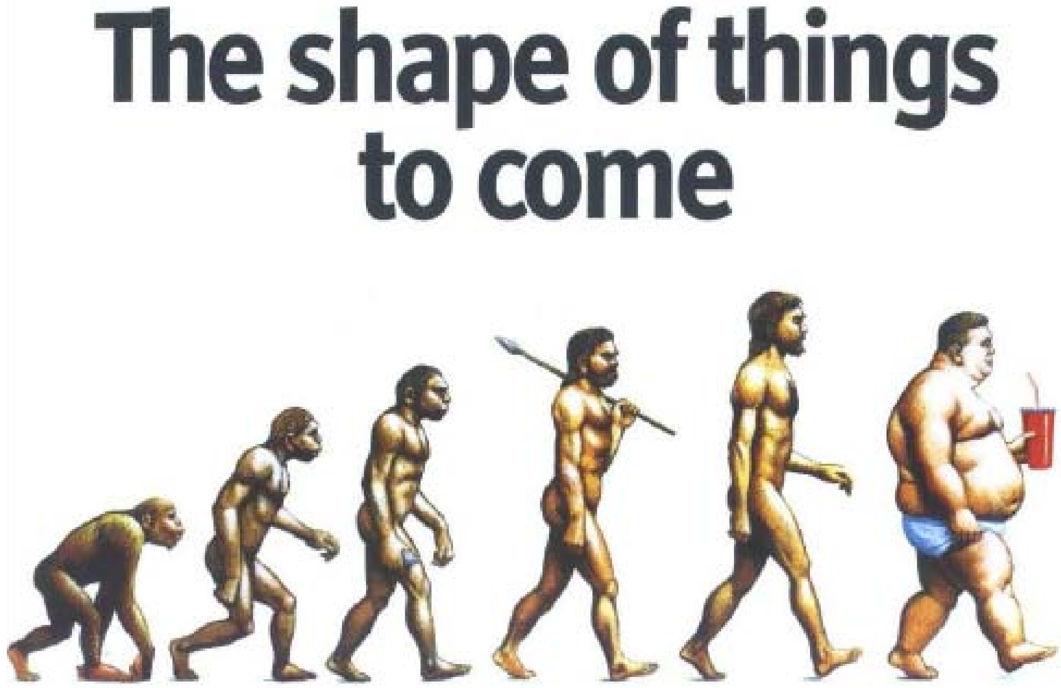
Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in Actuarial Science.



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Abstract

This paper is an investigation into the effect of excess body fat on mortality within the UK. The effect of obesity on mortality rates is considered through an analysis of current actuarial, epidemiological and demographic research. Health surveys from the UK are then used to investigate the change in the distribution of the UK population's body mass over the last 25 years. After a discussion of the issues raised by this research the analysis is supplemented by applying a Cox proportional hazards model to UK-specific data (Health and Lifestyle Survey, 1985) to provide an analysis of the effect of obesity on life expectancy, for people of various ages. The analysis finds that overweight and obesity is related to increased mortality in men and women. It also finds that this increased risk decreases with age and that overweight might not seriously effect life expectancy in women. 35 year-old obese men were found to live on average 4 years less than men with healthy body fat levels. The equivalent figure for women is 1 year. These results are similar to previous studies based on US-specific data.

Finally, there is a brief discussion of the challenges that obesity poses for the insurance industry.

CONTENTS

Introduction

Obesity is a condition used to describe high levels of body fat and is associated with increased risk of morbidity and mortality. This study will show that it has increased in the UK by almost 20% in the last ten years. Many health practitioners now believe that the UK is on the verge of an epidemic. This period has also coincided with an increase in public interest in nutrition, partly as a result of education initiatives by the government, the medical profession, charities (such as the British Health Foundation) and celebrity chefs. Over the last few years, especially, obesity has been in the news headlines regularly and people have become more aware of the associated health problems.

From the perspective of British society this topic is of great interest to the public. It is worthy of research to ensure that individuals are given the correct information and that health care is planned efficiently.

The British insurance industry also needs to understand and take into account any developments that could alter life expectancy and morbidity rates. Mortality and morbidity assumptions are an integral input into many insurance products and so research into this area is extremely pertinent.

Whilst researching this topic it was found that most of the research into the effects of obesity on mortality is based on data sampled from the United States. Most likely this is because the US population has a larger proportion of overweight and obese people and there has therefore been a greater impetus for research in the US in past years.

US research is useful when assessing the impact of excess body fat on the UK population but more research based on UK specific data is necessary. We use a prospective health study, The Health and Lifestyle Survey (1985), which is based on a representative sample of the UK population to investigate the effect of the range of excess body fat on the life expectancy of people of various ages. Whilst preparing this paper no existing research was found that used UK-specific data to estimate the effect of body fat and age on mortality. This new research provides a useful addition to the understanding of the obesity problem within the UK.

The paper is made up of six sections:

- The 1st section looks at the context of obesity in determining future mortality. This section is a review of the relevant literature.

- The 2nd section defines obesity and discusses the different ways it can be measured. This section consists of a review of the relevant literature and guidelines issued by health authorities.

- The 3rd section looks at the key epidemiological research into the risks associated with obesity. This section is a review of the relevant literature.

- The 4th section investigates the trends in the distribution of body mass index within the UK population over the last 25 years and is based on information from health surveys.

- The 5th section concentrates on the analysis of the effect of obesity on life expectancy within the UK population. This presents the data, methodologies and results of this analysis conducted by the author.

- Finally, the 6th section considers the implications for the UK insurance industry.

The conclusion highlights the key points and ties together the various strands of the research and analysis.

Section 1 Mortality Issues

This section illustrates the relevance of biomedical obesity research when considering mortality trends for the current UK population. Key papers reviewing mortality trends are discussed.

1.1 Background into UK Mortality Research

Willet et al (2004) presents a comprehensive analysis of the key trends for UK mortality rates in the future. Five key forces driving mortality in the 21st century are identified:

- the `cohort effect';
- the `ageing of mortality improvement';
- increased uncertainty at younger ages;
- changes in the prevalence of cigarette smoking; and
- widening social class differentials.

1.1.1 The Cohort Effect

“The cohort effect” is the name given to the pattern of mortality improvement experienced by lives born between 1925 and 1941 as described in Figures 1 and 2 (Willet et al, 2004).

The charts show that in the 1960s 30-34 year-olds experienced a great increase in mortality improvement whereas in the 1970s 40-44 year-olds experienced a great increase in mortality improvements. This trend continues to the 1990s.

The forces underlying this trend are not fully understood but the following cultural changes are associated with it:

- This cohort followed a healthier lifestyle than that of previous generations. They were aware of the negative health effects of smoking and so smoked less cigarettes then previous generations. This cohort also benefited from the relatively healthy diet prevalent in postwar years
- This generation was not as exposed to the harsh living conditions of the 1930s depression as previous generations.
- People born between 1925 and 1940 would not have been involved in active service during the Second World War.
- This generation also benefited from the creation of the welfare state with massive improvements in education and health services occurring subsequent to the Second World War.

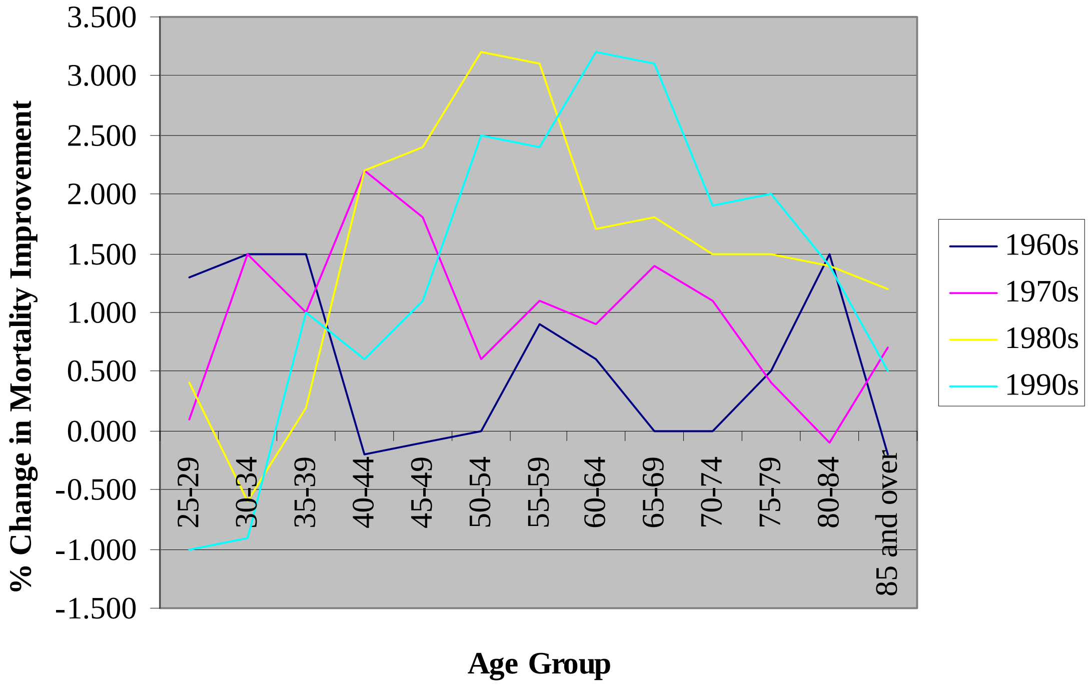

Fig 1, Average annual rate of mortality improvement, England and Wales population, by age group and decade, males (Willet et al, 2004).

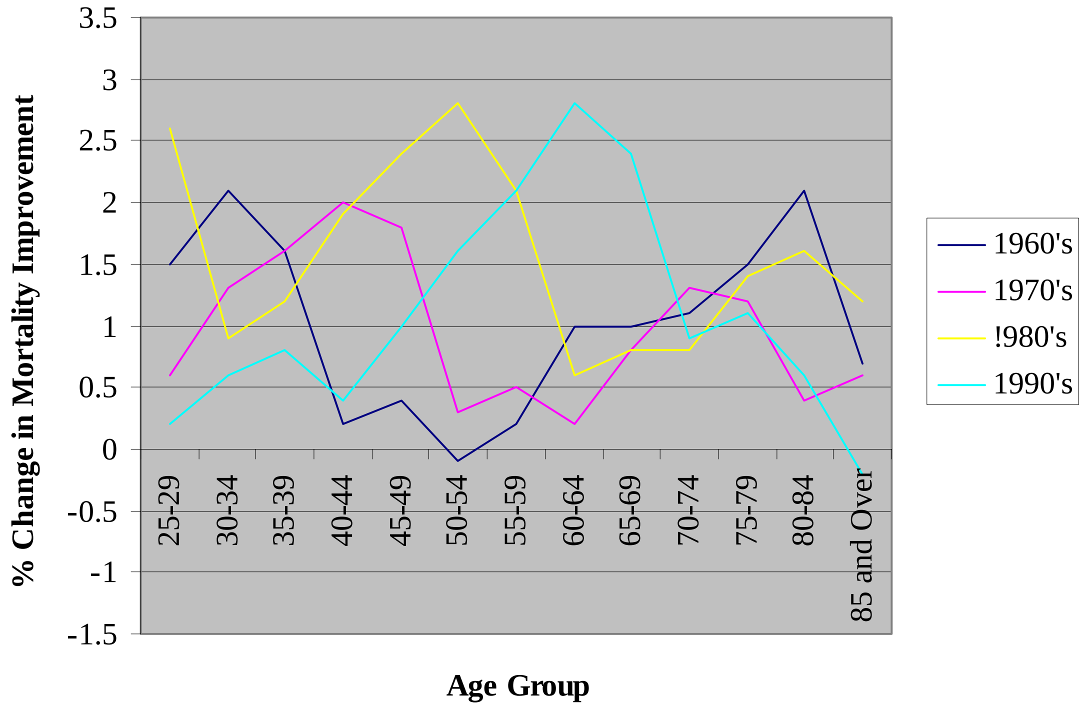

Fig 2, Average annual rate of mortality improvement, England and Wales population, by age group and decade, females (Willet et al, 2004).

The cohort effect is also seen in cause of death data with higher rates of improvement seen in the mortality rates from all major causes of death.

1.1.2 Ageing of Mortality Improvement

The second force identified is the ageing of mortality improvement. This is related to the cohort effect but relates to a more overarching trend of mortality improvement seen by progressively older ages over the last 80 years. The age at which mortality improvement is greatest has been increasing, leading to an acceleration of mortality improvement at older ages. This indicates that the maximum has not yet been reached in terms of mortality improvement for older ages and the fact that the healthy cohort is yet to reach these ages would confirm this. It seems reasonable to believe that people born before the healthy cohort were receiving the benefits outlined earlier but were not exposed from such an early time in their lives.

1.1.3 Increased Uncertainty at Younger Ages

The age range 20-39 has seen a decrease in mortality improvements since 1950 with mortality rates increasing in the 1980s and 1990s (Willet et al, 2004). Due to a large range of causes of death in this category it has a particularly volatile experience. It seems likely that improvements in mortality for this age group will not be easily achievable in the future and that this figure will hover around the origin.

1.1.4 Prevalence of Cigarette Smoking

The figures on cause of death suggest that those causes of death which have seen the largest mortality improvement are associated with cigarette smoking. In fact a simple analysis of the effect of a change in smoking patterns conducted in Willet et al (2004) found that smoking may be responsible for a large part of the mortality improvement seen:

	Before Adjustment		After Adjustment	
Age Group	1980s	1990s	1980s	1990s
40-49	2.3%	0.8%	0.9%	-0.3%
50-59	3.1%	2.7%	1.6%	1.8%

Table 1, Mortality improvement, influence of cigarette smoking, males (Willet et al, 2004).

This was consistent with another study that found smoking was responsible for between a quarter and a third of the improvement in heart disease mortality since the 1970s (National Heart Forum, 1999).

In the long term there appears to be a negative cohort effect as lung cancer rates at older ages are correlated with smoking levels at age twenty for each cohort. Fig 3 depicts this trend for males; a similar trend can be seen for women. This seems to suggest that people smoking at younger ages who subsequently give up are more susceptible to lung cancer at older ages, depending on how long they smoked for, than people who never smoked. Lung cancer rates appear to be correlated with smoking patterns and these patterns correspond to ages of the healthy cohort described earlier.

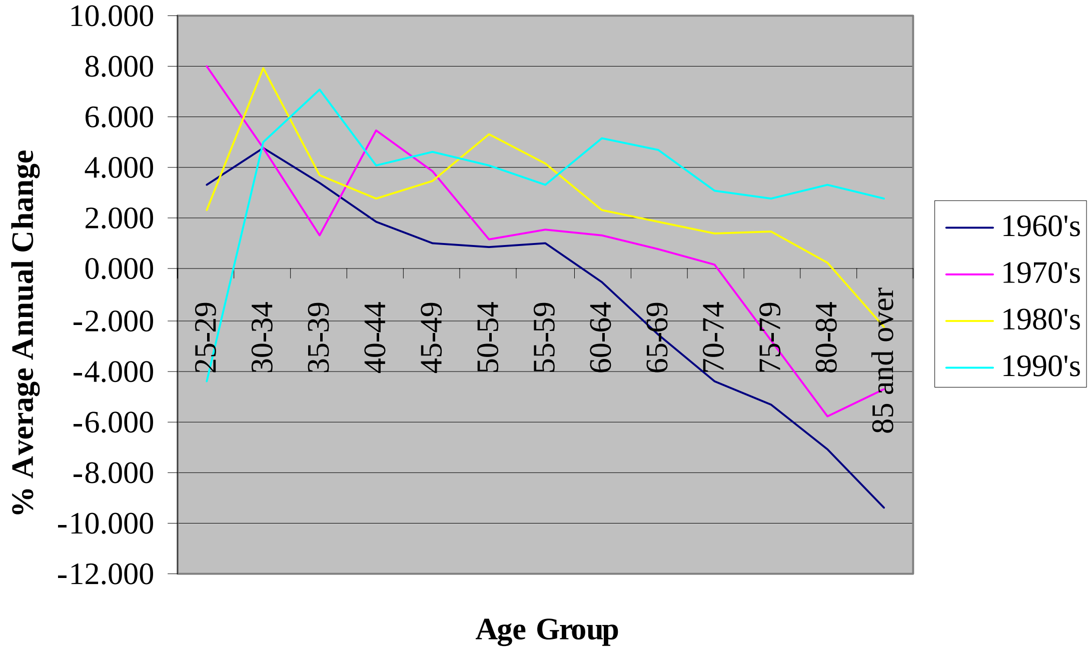

Fig 3, Average change in lung cancer mortality rates, England and Wales population, males, by Decade and Age Group (Willet et al, 2004).

1.1.5 Widening Social Class Differentials

Mortality has improved for the better off classes more than for the worse off social classes since the end of the Second World War. Table 2 illustrates this point for part of that period. Improvements in heart disease mortality appear to be one of the main reasons for this. Before the 1970s there was no difference for heart disease mortality between social classes but now this is not the case. In addition, heart disease mortality improvement is one of the major factors behind mortality improvement in recent times. Another reason for the difference could well be that smoking prevalence increases as you move down the social classes.

Class	Heart Disease	Lung Cancer	Stroke	Accidents	Suicide	Other	All Cause
I professional	1.4%	0.3%	0.3%	0.1%	0.0%	0.6%	2.7%
II	1.2%	0.3%	0.3%	0.1%	0.0%	0.7%	2.6%
IIIN	1.0%	0.3%	0.2%	0.1%	0.0%	0.4%	1.9%
IIIM	0.6%	0.3%	0.2%	0.1%	-0.1%	0.5%	1.5%
IV	0.6%	0.3%	0.2%	0.1%	0.0%	0.6%	1.8%
V unskilled workers	0.0%	0.2%	0.1%	0.1%	-0.1%	0.2%	0.5%
Total	0.8%	0.3%	0.1%	0.1%	-0.1%	0.6%	1.9%

Table 2, Components of average annual mortality improvement rates 1970-72 to 1991-93, England and Wales population, males aged 20-64 (Willet et al, 2004).

1.2 Trends in Cause of Death

The three major causes of death within the UK are heart disease, cancer and stroke. Obesity is linked to all of these (discussed in section 3) and so it makes sense to look at recent trends in these diseases. Table 3 outlines the distribution of causes of death.

	Age Group						
Cause of death	20-29	30-39	40-49	50-59	60-69	70-79	80+
Infectious diseases	2	3	5	5	10	30	91
Cancers	7	17	59	227	655	1531	2817
Circulatory	5	17	71	215	668	2028	5685
Respiratory	2	5	10	35	138	574	2256
Other health related	19	29	55	88	167	492	2047
Violence and accidents	48	48	42	37	34	63	207
All Causes	83	119	241	606	1671	4719	13104

Table 3, Deaths by cause, England and Wales population, 2001, males, deaths per 100,000 lives (Willet et al, 2004).

From 1990 mortality from heart disease has fallen rapidly for all age groups with the biggest fall occurring in the 40-64 age group who experienced a 50% reduction from 1989 to 2001.

Reductions in smoking and saturated fat intake over this period together with better and more widely available treatment may help to explain this trend. This is supported by data on heart attack incidence showing a decrease of 35% for males and females over the same period (Willet et al, 2004).

From 1990 mortality from stroke has also fallen, but not quite as significantly, with the equivalent reduction being 30%. There are similar risk factors associated with heart disease and it seems likely that this cause of death has reduced for similar reasons (Willet et al, 2004).

It is worth noting that the UK has higher than average mortality for the over 65s when compared to other developed countries as a result of poorer circulatory disease (stroke and heart disease) figures. This would indicate that there is potential for mortality improvements for this age group in the UK (Willet et al, 2004).

Finally, cancer is the biggest cause of death in the UK. Improvement has been steady for this cause of death as a result of improved medicines and treatments but incidence of disease has not fallen. It has remained constant or slightly increased over the period 1989 – 2001 (Willet et al, 2004).

This section has reviewed the trends underlying mortality changes in the UK over the last century. The following section briefly discusses the contrasting views on predicting future mortality and how obesity might be an important factor.

1.3 Predicting Mortality

Vaupel and Kitowski (2005) argue that mortality rates have improved linearly over the last 150 years at approximately 3 months per year and that this will continue into the future. Such forecasts were criticised by Olshanksy (2005). A major flaw with extrapolating past increases in mortality improvement is that the majority of past increases have been due to increases within younger age groups. New improvements would need large increases in life expectancy at older ages which would need the future to be different from the past (Olshansky et al, 2005). Due to the cohort effect this might be possible within the UK but only for the next 30 years until the cohort exhibiting the peak in mortality improvement has died.

Another reason why these projections might be flawed is because they rely on medical advances that have not yet occurred and also because new health trends have not been taken into account. A major health trend Olshansky (2005) highlights is obesity.

Much of this analysis (Olshansky et al, 2005) is based on research undertaken in the US where obesity rates have increased by 50% per decade in the last 20 years. In the US 20% of men and 34% of women are currently obese; striking figures when the link between obesity and increased morbidity and mortality rates (which is discussed in section 3) is considered.

Olshansky (2005) highlights the potential of a negative cohort effect as a result of the obesity problem in the US which might act as a negative version of the cohort effect that figure 1 describes. The following indicators are suggested as being behind such an effect:

- Obesity rates are increasing, especially among children, and are likely to continue to rise based on past trends.
- Child and young adult age groups have seen large rises in obesity. Therefore these age groups will exhibit obesity related risks for more of their lifespan than previous generations.
- Body Mass Index (BMI) levels have increased for all age groups in the US.
- Incidence of diabetes has steadily increased along with related mortality over the last 20 years. As the predominant cause of diabetes is obesity there is reason to believe that as younger generations become more obese the incidence of diabetes will continue to rise. This link is discussed further in section 3.1.

Section 2 Defining Obesity

The following measures have been used to measure body fat:

- Body mass index (BMI)
- Waist circumference
- Waist to height
- Height to weight tables

2.1 BMI

BMI is defined:

BMI = Weight (kg) / Height^2 (m^2)

The world health organisation uses this measure to define the following categories of body weight:

	Obesity Class	BMI (kg/ m^2)
Underweight		< 18.5
Normal		18.5 – 24.9
Overweight		25.0 – 29.9
Obesity	1	30.0 – 34.9
	2	35.0 – 39.9
Morbid obesity	3	> 40.0

Table 4, BMI range (WHO, 2000).

This classification is based on studies of white males and should be adjusted for other racial groups such as black or asian.

BMI has become widely used as a measure of body fat. Most studies on the subject use this measure. Subsequently BMI is used in the underwriting of life insurance by insurance companies (Swiss Re, 2004). A problem associated with this measure is that it overestimates body fat in muscular people. Hence the need to use lifestyle questions to supplement raw data when underwriting lives.

2.2 Waist Circumference

The National Institute for Health (NIH) in the US advises health practitioners to use this measure in addition to BMI when assessing individuals for risk of disease.

	Cut-off point
Men	> 102 cm (40 inches)
Women	> 98 cm (35 inches)

Table 5, Cut off points for waist circumference (NIH).

			Disease risk relative to normal weight and normal waist circumference	
Classification	Obesity class	BMI (kg/ m^2)	Below cut-off points	Above cut-off points
Underweight		< 18.5	-	-
Normal		18.5 – 24.9	-	-
Overweight		25.0 – 29.9	Increased	High
Obesity	1	30.0 – 34.9	High	Very high
	2	35.0 – 39.9	Very high	Very high
Morbid obesity	3	> 40.0	Extremely high	Extremely high

Table 6, BMI and waist circumference range (WHO, 2000).

2.3 Waist to Height

In an analysis of the Health and Lifestyle Survey (1987), Cox and Whichelow (1996) found that waist to height was a better predictor of all-cause and cardiovascular mortality than BMI. This survey is discussed in detail in section 5.2.1. As this survey is based on a large sample representative of the UK population this measure might be worth considering when analysing UK-specific data.

2.4 Height to Waist

Prior to BMI becoming the standard measure, height-to-waist tables were used by medical practitioners and insurance underwriters. BMI replaced it because it is a simpler, single measure which does not require many tables for varying heights.

Section 3 Risks Associated With Obesity

This section looks at the risks associated with varying levels of body fat as measured using BMI. Literature regarding the associated health issues and the resulting increase in mortality is presented.

3.1 Associated Health Issues

In the Royal College of General Practitioners evidence to the House of Commons Health Committee Report into Obesity (2004) the following diseases of organs are associated with obesity:

Cardiovascular System	Hypertension Coronary Heart Disease Cerebrovascular Disease Deep Vein Thrombosis Varicose Veins
Gastro Intestinal System	Hiatus Hernia Cholelithiasis Fatty infiltration of the liver Haemorrhoids Hernia Colorectal Cancer
Respiratory System	Breathlessness Sleep apnoea
Pregnancy	Increased obstetric complications
Musculoskeletal System	Osteoarthritis
Breast	Postmenopausal Breast Cancer
Uterus	Uterine and Cervical Cancer
Skin	Fungal Infections Intertrigo Cellulitis Lymphoedema
Urological	Stress Incontinence
Metabolic	Type 2 Diabetes The Metabolic Syndrome*
*The Metabolic Syndrome denotes a clustering of highly significant risk factors for cardiovascular disease, namely: Central Obesity, Hypertension, Hyperlipidaemia, Pro-coagulant State, Insulin Resistance, Hyperinsulinaemia, Glucose Intolerance, Accelerated Arterial Disease, Premature death from cardiovascular disease.	

Table 7, List of diseases associated with obesity (RCGP, 2004).

Swiss Re (2004) identifies a high correlation between obesity and the following symptoms:

- Increased blood pressure
- Increased cholesterol
- Increased triglyceride levels
- Impaired glucose tolerance
- Premature atherosclerosis
- An abnormally large heart

Measures of body fat such as BMI are used to signal that these symptoms are present.

Figure 4 shows relative risks for males for various diseases (Calle et al, 1997). This study was made up of people who had never smoked and who had no history of heart disease. The reference BMI category is 23.5 – 24.9. Other studies suggest that the relative risk associated with obesity of cancer is more significant with some health experts believing that around 14% of cancer deaths in men and 20% in women are attributable to obesity (Health Committee, 2004).

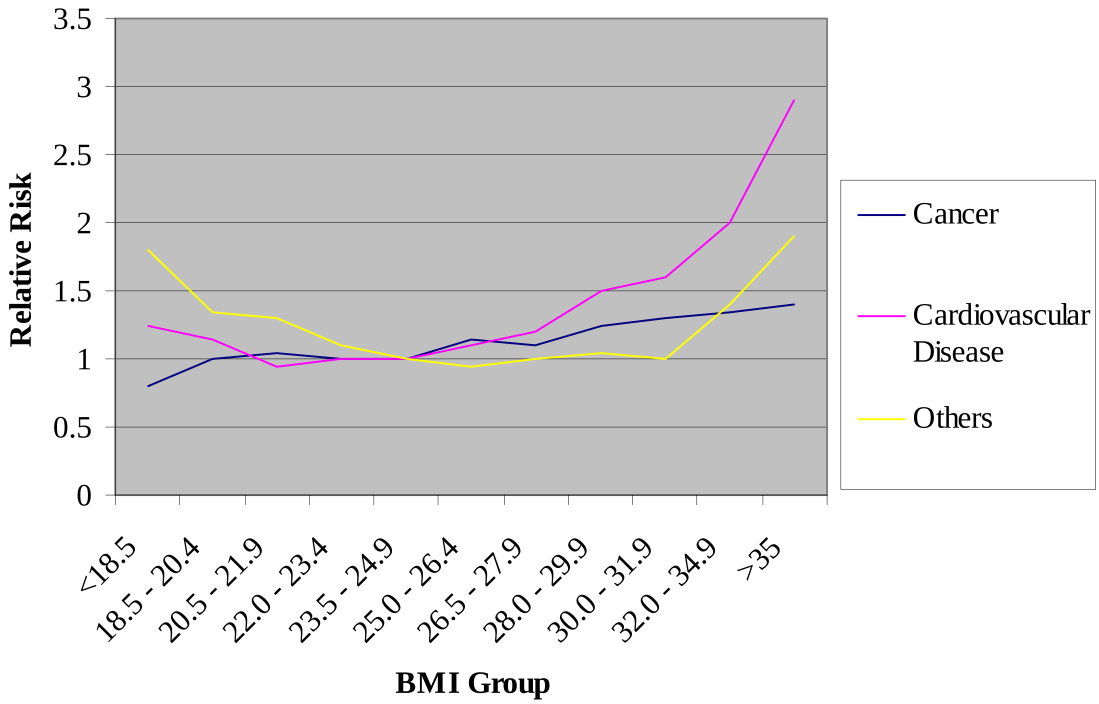

Fig 4, Relative risks associated with obesity and disease, males (Calle et al,1999; Calle et al, 2003).

Another study also found these effects in males (Shaper et al, 1997), as shown in figure 5. In this study the reference category was the 20-21.9 BMI range and the relative risk ratios have been adjusted for age, smoking, social class, alcohol consumption and physical activity.

Here the increased risk of diabetes in obesity is clearly seen. This would also lead to an increase in the risk of diseases associated with this condition such as: blindness, kidney failure, stroke, osteoarthritis and damage to the nervous system which can lead to limb amputation.

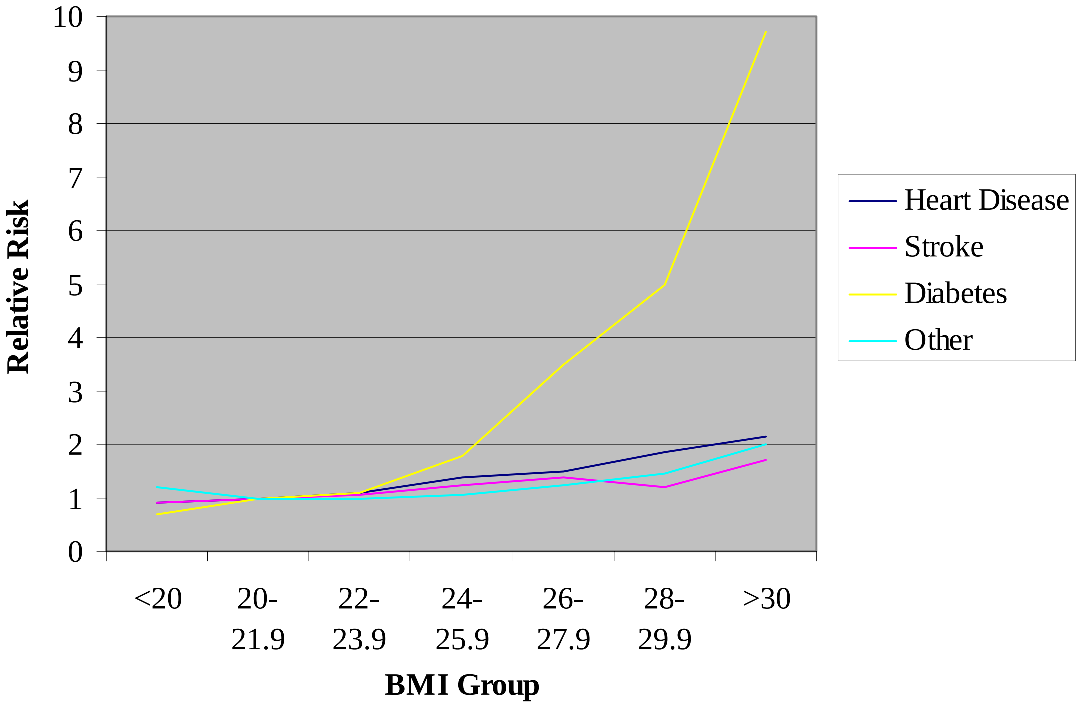

Fig 5, The relative risks associated with obesity and disease, males (Shaper et al, 1997).

3.2 Studies into Obesity and All Cause Mortality

Numerous studies have been conducted into the relative risk of death between BMI groups. Nearly all have found a U or J-Shaped association. Seidell et al (1999) provides a good summary of evidence and research issues for these studies. These fall into the following categories:

- Failure to control for cigarette smoking as this effects weight and could interact with BMI at different levels to cause varying results.
- Failure to eliminate effects of existing illness at baseline. Although this was found to cause more confounding problems (Allison et al, 1999), other studies have suggested it might have benefits (Stevens et al 2001). Failure to control for this

might lead to higher relative risks at lower BMI where low weight is a result of pre-existing illness.

- Inappropriate adjustment for intermediate risk factors in the relation between BMI and mortality such as hypertension, hyperlipidemia and diabetes.
- The use of BMI as an estimate of body fat.
- Age, period and cohort effects that may modify the association between BMI and mortality.
- Failure to take into account lifestyle, social and ethnic factors of study samples when compared to the population as a whole.
- Insufficient sample size and duration of follow up affecting the strength of the association between BMI and mortality.
- Reliance on self-reported weight.

A study by Calle et al (1997) which accounted for the above factors found the relationship between BMI group and relative risk as displayed in figure 6. This was based on a non-smoking sample and the reference category was the BMI group 23.5-24.9. This relationship is typical of other studies such as Bender et al (1998) and Seidell et al (1996).

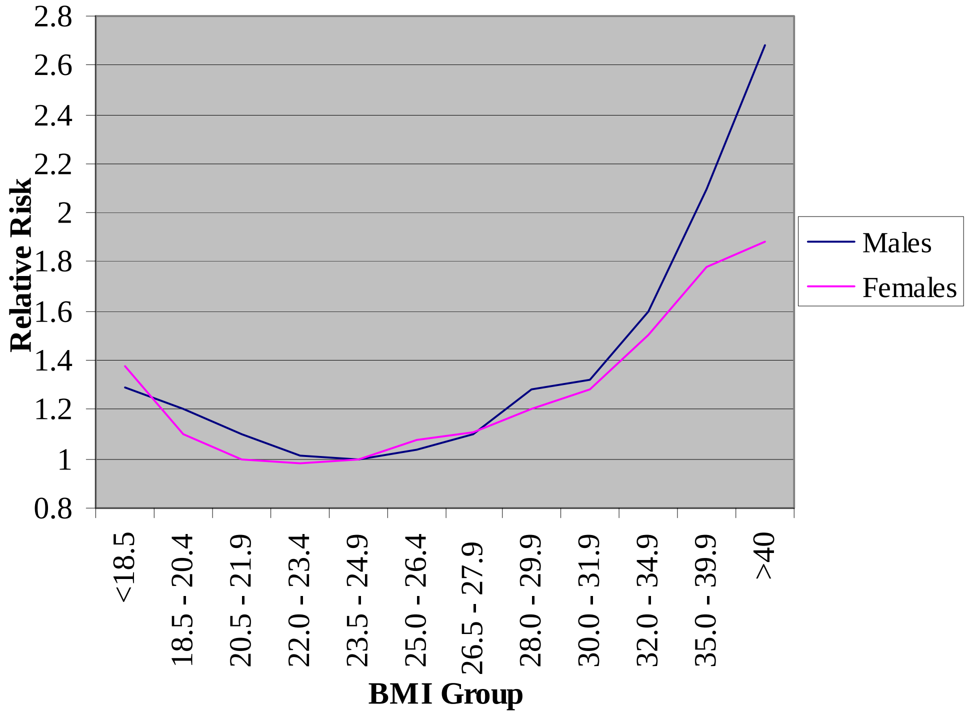

Fig 6, Relative risk of mortality by BMI group and sex (Calle, 1997).

3.3 Studies into the Effect of Age on All Cause Mortality

Stevens et al (1999), in a study of the American Cancer Society's Cancer Prevention Study 1 (which ran from 1960 through to 1972 and contained 62,116 Men and 262,019 women who had never smoked or had any history of heart disease, stroke or cancer), found that the risks associated with greater BMI levels followed the usual J-shaped relative risk profile but only until age 75, when only unhealthily low BMIs provided an increased relative risk. Stevens also found that the relative risk curves flattened with age so that the relative risk at obese levels decreased with age. These results are displayed in figures 7 and 8.

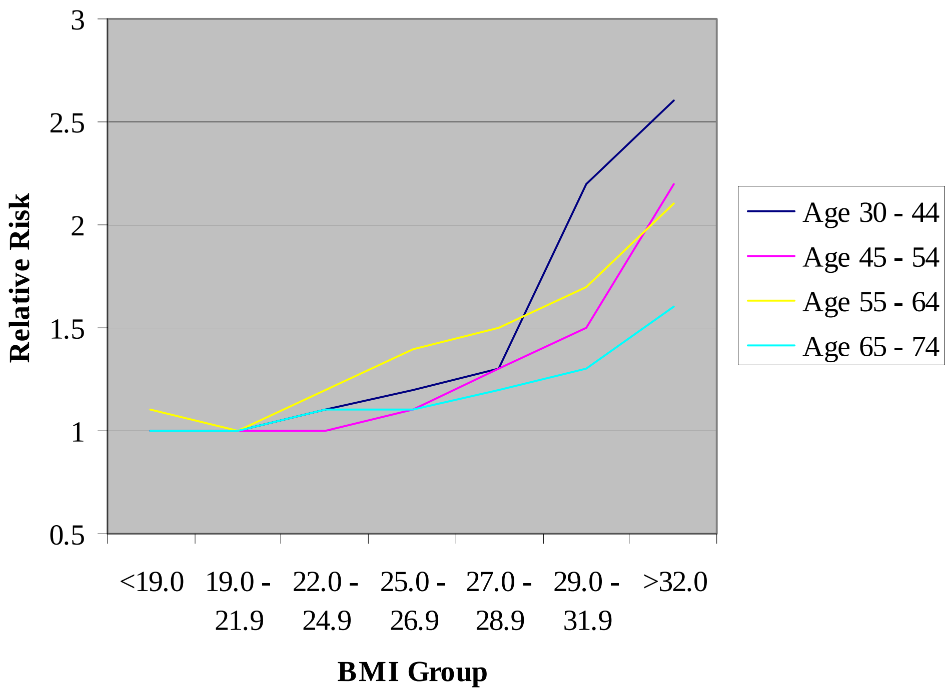

Fig 7, Relative risk of mortality by BMI group and age group, males, reference category 19.0 – 21.9 (Stevens et al, 1999).

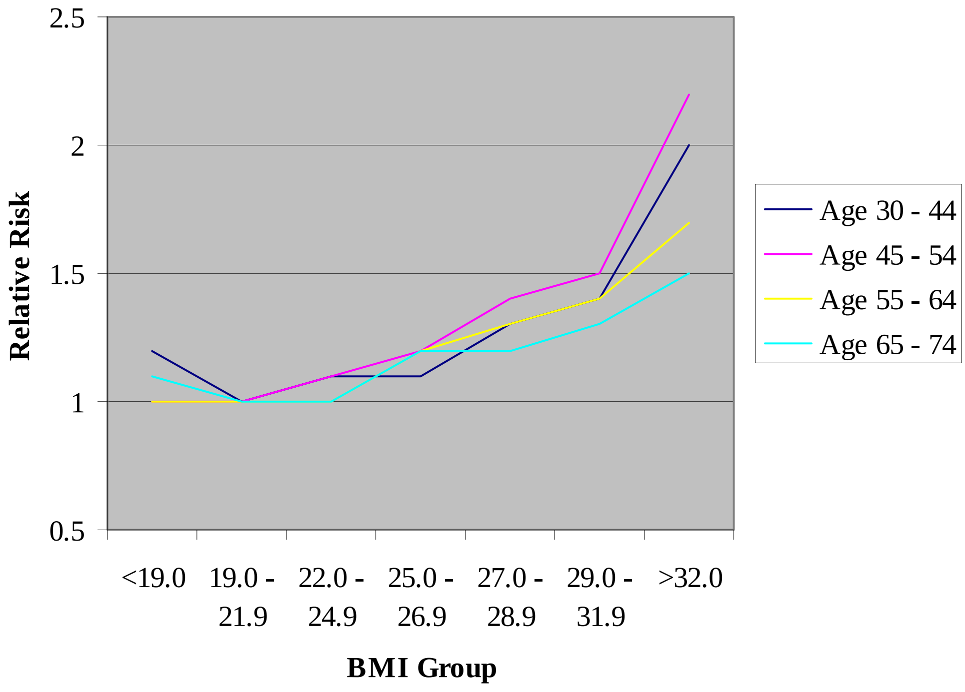

Fig 8, Relative risk of mortality by BMI group and age group, females, reference category 19.0 – 21.9 (Stevens et al, 1999).

3.4 Studies into BMI and Life Expectancy

Following a review of the literature 3 studies were found that attempted to quantify the life expectancy of individuals with varying degrees of BMI. All used a life table analysis: the first, Fontaine et al (2003), used a prospective study; the second, Peeters et al (2003), used a cohort-based study and the third, Olshansky et al (2005), used a simple probabilistic analysis together with the data from Fontaine. These results are shown in table 8 (Peeters et al, 2003) and figures 9 and 10 (Fontaine et al, 2003).

Both studies aim to estimate relative years of life lost. This is a measure of how many years of life expectancy an individual with a certain BMI loses compared to an individual with the optimal BMI.

BMI Group		**Life Expectancy**		
	Female Nonsmoker	Female Smoker	Male Nonsmoker	Male Smoker
Life Expectancy at 40 years of age				
Group 1	46.28	40.21	43.35	36.31
Group 2	42.99	40.05	40.30	35.00
Group 3	39.19	33.00	37.54	29.65
Years lost from the age of 40 years relative to BMI group 1				
Group 2	3.29	0.16	3.05	1.30
Group 3	7.08	7.21	5.82	6.66
Group 1	Normal Weight			
Group 2	Overweight			
Group 3	Obese			

Table 8, Effect of overweight and obesity in adulthood on life expectancy at 40 years of age, 3574 subjects studied (Peeters et al, 2003).

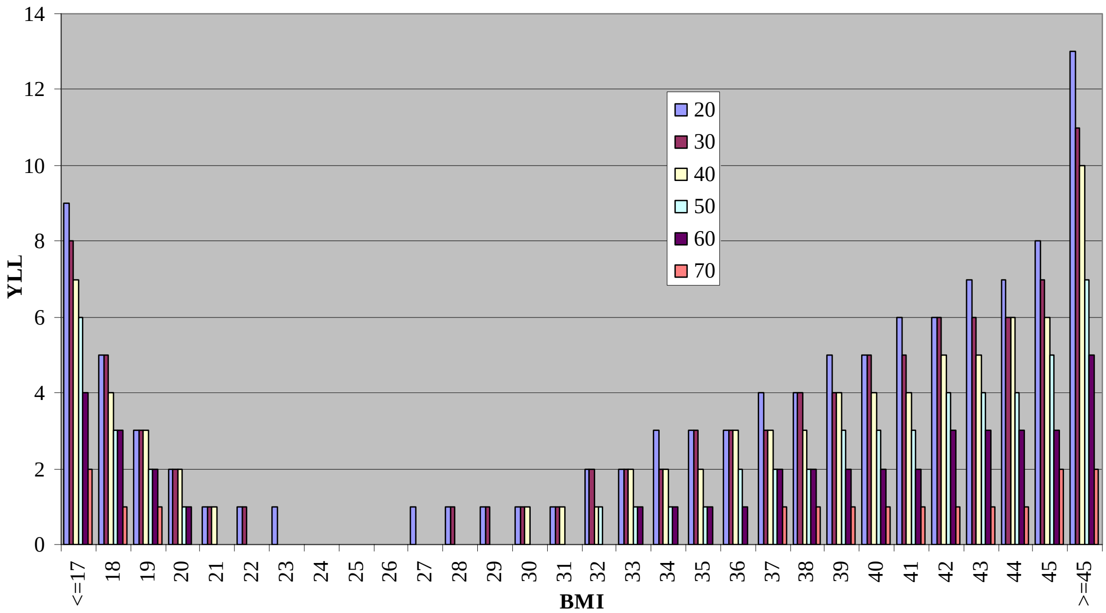

Figure 9, Years of life lost by BMI and age, males (Fontaine et al, 2003).

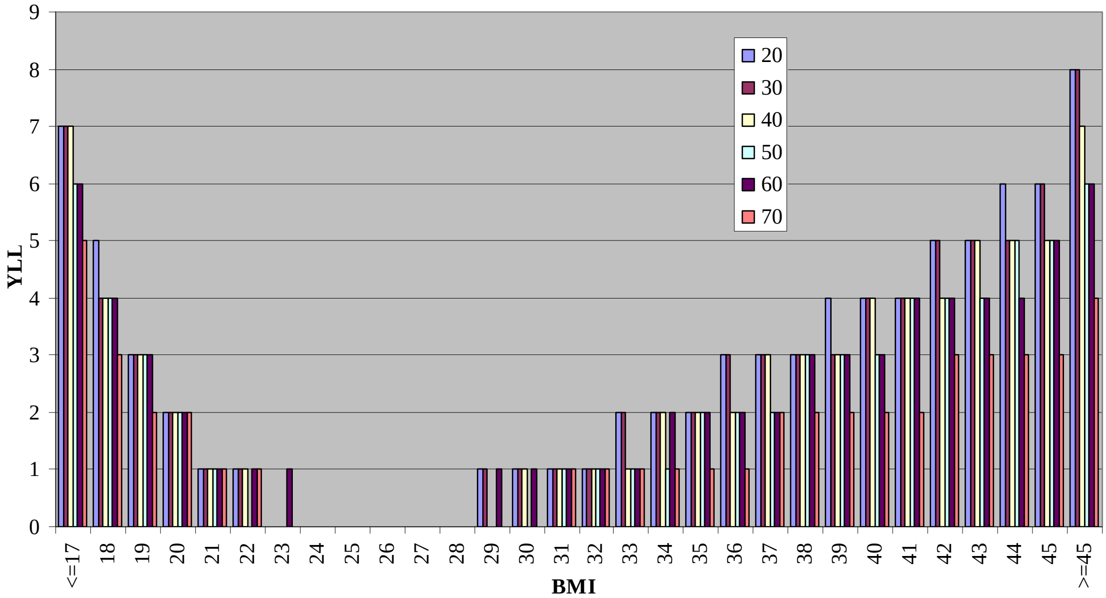

Figure 10, Years of life lost by BMI and age, Fontaine 2003, females.

As Peeters is cohort-based it is limited to producing estimated years of life lost for a person of 40 years of age by groups of BMI (normal, overweight and obese). Fontaine produces a complete analysis by age and BMI of years of life lost. Both studies found that obesity resulted in substantial years of life lost in males and females. For instance, obese male non-smokers aged 40 lost 5.82 yrs in Peeters and in Fontaine 2-3 yrs, on average (across the range of obese BMIs). These figures are not directly comparable (Allison et al, 2003). Fontaine's figure of 2-3 years is equal to $E[YLL|BMI = E(BMI|BMI>=30)]$ where $E(BMI|BMI>=30)$ is the mean BMI of the proportion of population who have a BMI greater than 30. Peeters' figure is $E[YLL|BMI>=30]$.

The other differences between the two approaches are:

- Fontaine estimated the YLL at a certain age if BMI is constant at this age throughout life. ie "Given that an individual has a BMI of 37 how much longer would they live if the BMI was 24". Instead Peeters produces estimates of YLL at age 40 for BMI categories regardless of future changes in BMI.

- Both studies ignore the effects of past BMI levels. Peeters ignored BMI history before 40 years of age. Fontaine ignored historic BMI levels for each age investigated.

- Fontaine produces medians whereas Peeters produces means.

- Peeter's study is based on people aged 40 from 1950 onwards. The experience of this cohort might not be suitable for people who are aged 40 now to compare themselves with. Fontaine's study uses more recent data which is more representative of the current health and lifestyle environment.

- Peeter's cohort study provides a thorough analysis of the BMI risks within the cohort studied (Peeters et al, 2003). Fontaine provides a better analysis for individuals of the risks of maintaining a certain BMI level other than the optimum for a range of ages.

These studies raise the question about how BMI might change with lifespan. Moonseong et al (2003) provides a methodology for use with a pooled database of epidemiological studies with a total of 14,375 subjects giving a total of 75,351 data units. This study proposes the following equation for forecasting future BMI (Y) at time t (years) based on age, sex (1 for males, 0 for females) and BMI at baseline.

$$Y(t) = 0.266 + 0.0014Age - 0.036Sex + 0.985BMI$$
$$+ (0.759 - 0.0051Age - 0.026Sex - 0.016BMI)t$$
$$+ (-0.0037 - 0.00011Age + 0.00033Sex + 0.00016BMI)t^2$$

This relationship is demonstrated in figures 11 and 12.

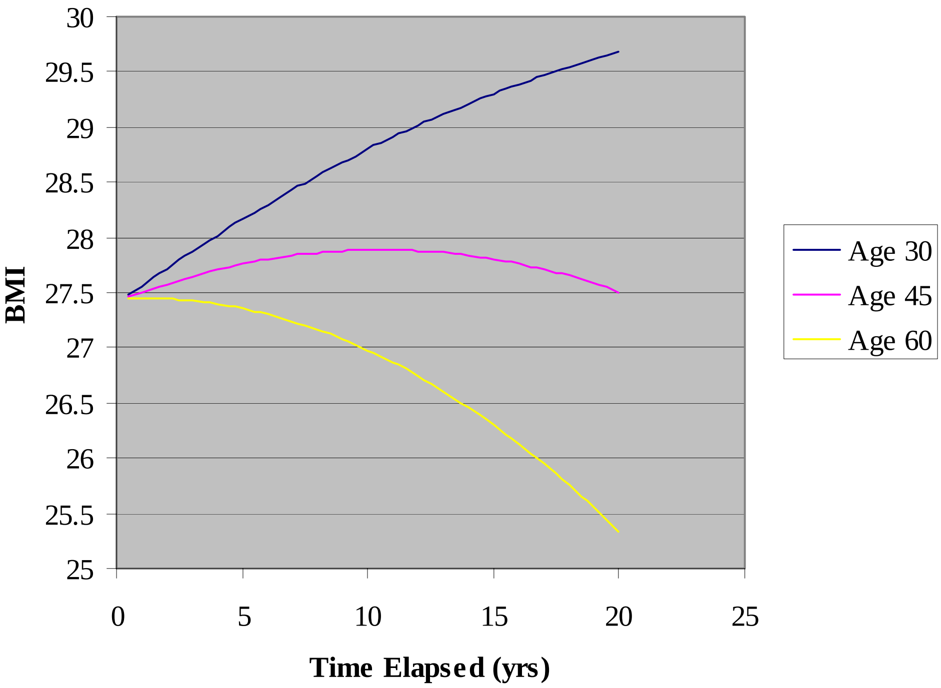

Fig 11, BMI by time elapsed since measurement and age, males (Moonseong et al (2003).

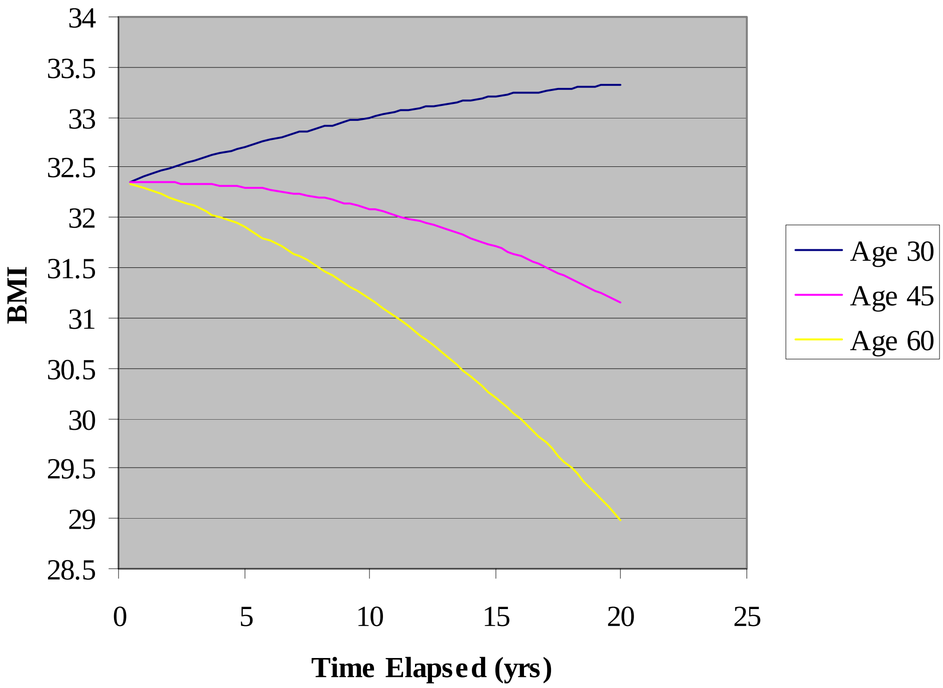

Fig 12, BMI by time elapsed since measurement and age, females (Moonseong et al, 2003).

Section 4 Obesity Within the UK

4.1 Studies into Childhood Prevalence of Obesity

In the UK Chinn and Rona (2001) found the following increase in childhood obesity.

	1974	1984	1994	1974 to 1984 change	1984 to 1994 change
English boys	58/4139	18/3259	52/3016	0.8	1.2
English girls	59/3871	38/3008	75/2858	0.3	1.4
Scottish boys	20/1172	19/2141	44/2072	0.8	1.2
Scottish girls	20/1078	38/2105	66/2036	0.1	1.4

Table 9, Obese proportions within the child population, UK (Chinn and Rona, 2001).

This study also found that the proportion overweight was 5-6% in both 1974 and 1984 in boys and 9-10% in girls, and it rose to 9-10% in boys in 1994, to over 13% in girls and to nearly 16% in Scottish girls.

Rising overweight within childhood is likely to lead to higher levels of overweight and obesity for that cohort in later years (Power et al, 1997).

4.2 Estimation of Obesity Levels in the UK 1980-2004

We collected data on obesity rates from 1980 to 2004 in the UK using the National Heights and Weights Survey (1980), the Health and Lifestyle Survey (1985) and the Health Survey for England (1991-2004). Pregnant women were excluded from each dataset. A problem with this analysis is that the first two studies used data from the UK whereas the Health Survey for England is specific to England, as the title suggests. With the lack of more suitable data it was necessary to use what was available.

The best fit lines were fitted using least squares regression in Microsoft Excel.

The following results were found:

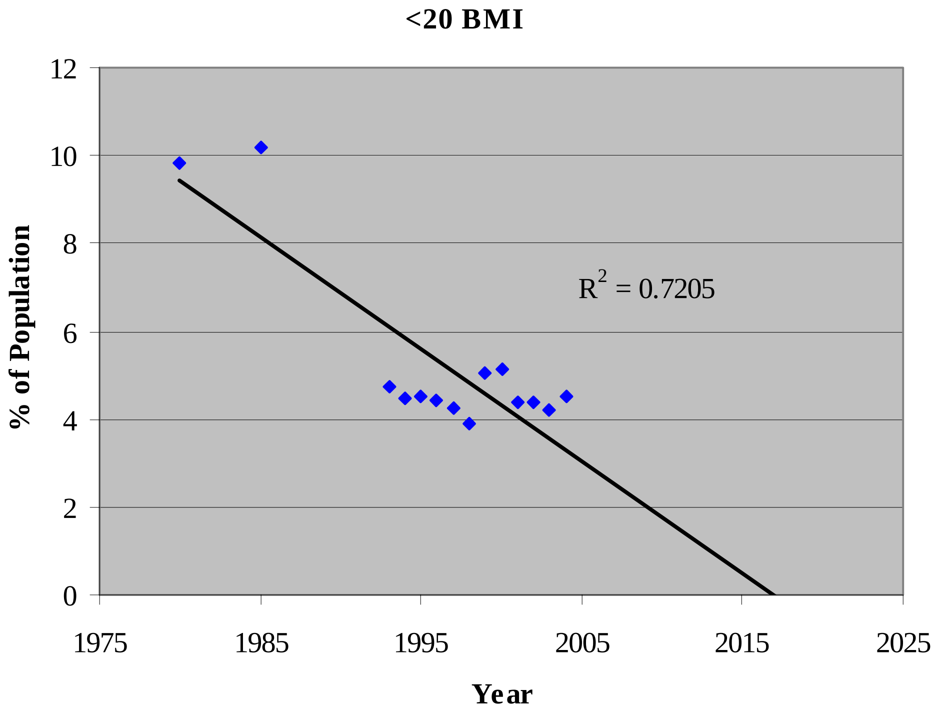

Fig 13, Less than 20 BMI group as a % of population, 1980 – 2004.

It seems unlikely that this fit line is a true representation of the likely future movement for this BMI category. If the two early data points were removed the trend would be level at just over 4%.

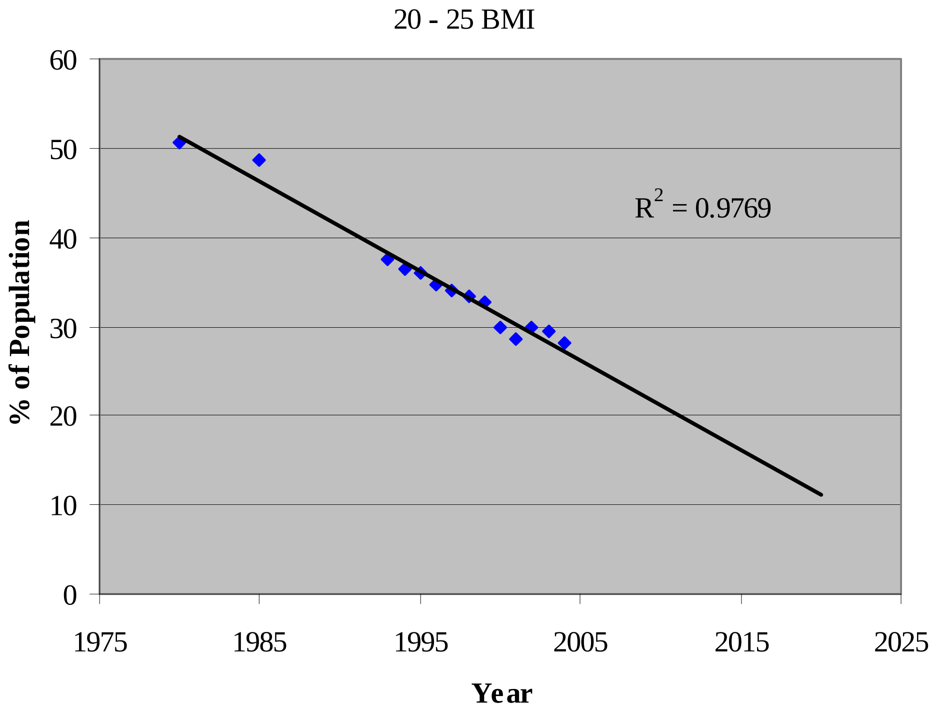

Fig 14, 20 to 25 BMI group as a % of population, 1980 – 2004.

The high R^2 value indicates the good fit of the linear line to this data. The closer the R^2 value becomes to 1 the better the fit of the line. There does seem to be a clear decreasing trend of the proportion of the population in the healthy BMI group.

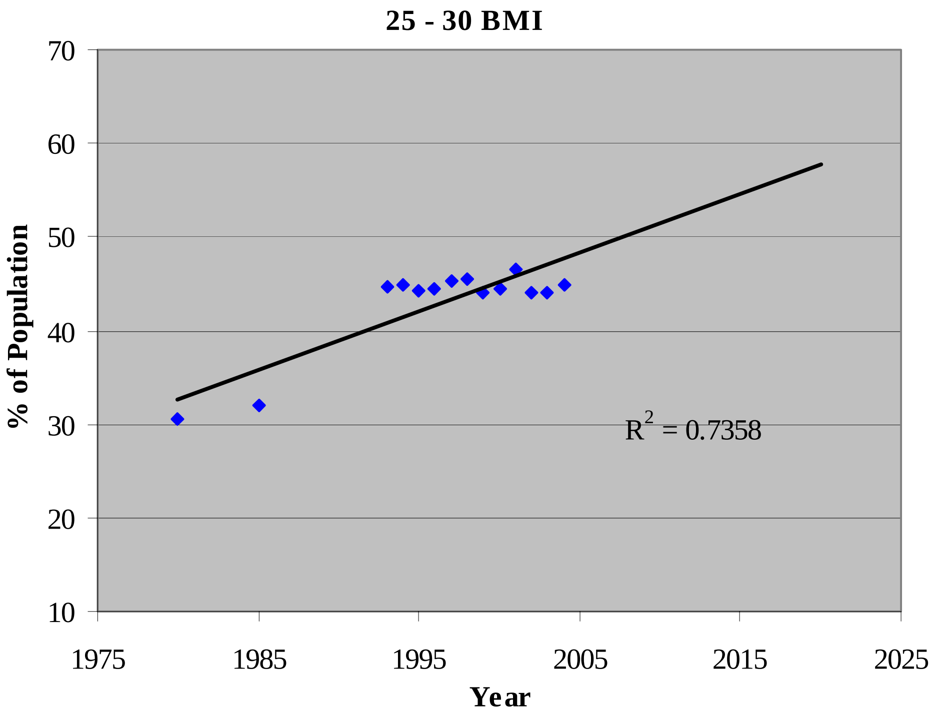

Fig 15, 25 to 30 BMI group as a % of population, 1980 – 2004.

As with the lowest BMI category this category also shows a static trend if the health survey data is considered independently of the older data.

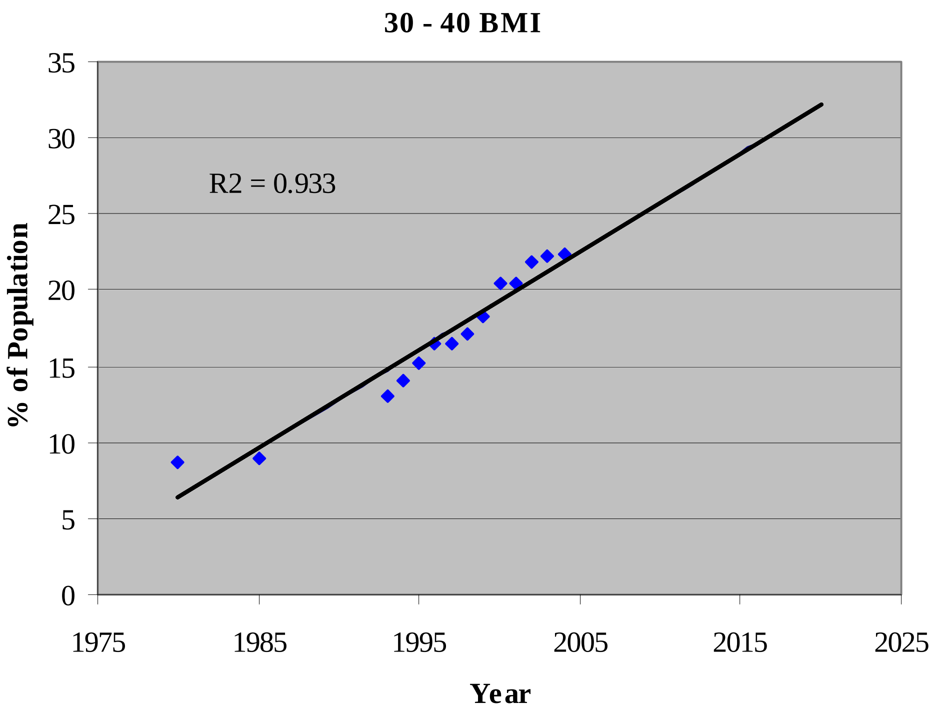

Fig 16, 30 to 40 BMI group as a % of population, 1980 – 2004.

This category shows a clear linear trend. The proportion of obese people in the population appears to be increasing and will be about 30% in ten years time if current trends continue.

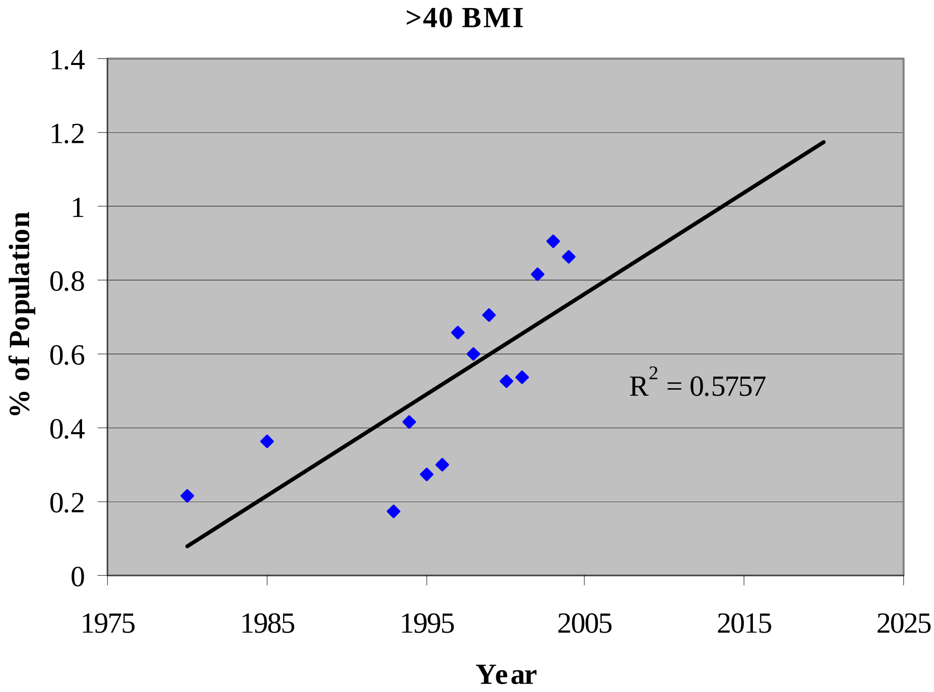

Fig 17, greater than 40 BMI group as a % of population, 1980 – 2004.

The R^2 fit of the line for this category is the poorest of all but there does not seem to be a static trend in the health survey data as with the other poor fits. It looks more likely that there is an increase in the proportion of morbidly obese people in the population. The reason for the poorer fit is probably due to the small number of people in the samples at this weight and therefore the error associated with these observations is likely to be higher.

4.3 Discussion

When comparing the increases seen in the proportion of the population in the higher BMI categories with the figures for heart disease mortality and incidence (as discussed in section 1.2) it is surprising to note that heart disease figures have improved substantially. Figure 18 shows this graphically. Heart disease figures are taken from the Office of National Statistics. It is likely, given the risks associated with obesity, that in the future heart disease incidence will stop improving and that mortality trends from this disease will be moderated by available treatment. Even if mortality improvements do continue, obesity levels could be expected to act as a braking effect on this rate of improvement and most probably have done in the past (Olshanksy et al, 2005; Swiss Re, 2004; House of Commons, 2004).

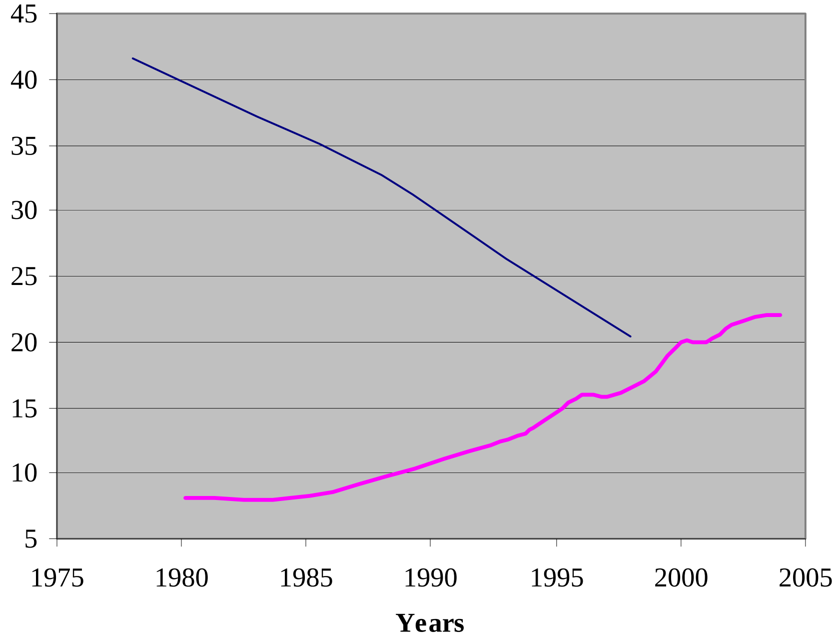

Figure 18 : Proportion (%) of Population in BMI category 30-40 kg/m^2.
Number of deaths per 1000 of England and Wales population due to cardiovascular disease.

Cancer research UK believes that 1 in 8 cancer deaths in the UK and 1 in 6 in the US are attributable to overweight and obesity (House of Commons Health Committee, 2004). As the US has a heavier population it seems likely that at current rates of growth the UK could see overweight and obesity as even more of a driver of cancer mortality. As medicine advances this could also mean other causes of cancer mortality become less important and body fat might emerge as the main health issue. It certainly is something that most people can modify themselves, unlike their genes.

Obesity and overweight are also related to other causes of death. The link with diabetes is probably one of its most serious consequences. Health problems with diabetes store up over time so as more people are diagnosed at younger ages it is likely that they will develop associated diseases at younger ages. For instance, there is a very strong association between heart disease and diabetes (House of Commons, 2004).

It is difficult to estimate the effect of changes in the body fat make-up of the nation on future mortality due to the complex interactions in the future of medicinal advances, the availability of treatment, lifestyle factors, such as education and fitness levels and other competing forms of death that might be indirectly associated with obesity. Nonetheless, many studies have found increased mortality from increased BMI. Also health survey data suggests that in the UK there has been a substantial increase in the number of people becoming obese.

As discussed, Willet et al (2004) found the reduction in smoking levels within the population to be a key force for mortality improvement in the 20th century (even so smoking is still a major health issue). Data also suggests that obesity is another major health issue for the UK. It seems likely that, as cohorts of continuously fatter younger people age, the health consequences of obesity will cause higher levels of disease within increasingly younger age groups. This will be compounded because as younger people become fatter so do the middle aged as these young people age. There will be a negative cohort effect due to body fat in the population.

This cohort effect might not be enough to outweigh the effects of medicinal advances and so mortality rates might continue to improve but if current trends continue obesity will increasingly moderate mortality improvements.

Two questions to come out of this analysis are:

- How much longer can healthy weight individuals expect to live than those in overweight categories within the UK?

- What would the effect be on UK population mortality rates if everyone was at the optimum weight?

Studies have already been identified that attempt a similar analysis on US data. If this analysis was done on UK-specific data it could provide a valuable contribution to the understanding of the effect of obesity on mortality within this country. Section 5 describes the methodology, results and conclusions of the analysis we carried out to answer these questions.

Section 5 Estimating Life Expectancy

This section reports on our investigations into the effect of obesity on life expectancy using UK-specific data. It considers the selection of methodology, review of the data, an explanation of the methodology used, presentation of the results, analysis of results and the limitations of the analysis.

5.1 Selection of Methodology

In section 3.4 two studies were identified that looked at the life expectancy for various BMI categories. Both of these studies used Cox proportional hazards models. Another method not discussed is to use a generalized linear model incorporating proportional hazards as outlined in Renshaw (1988). An advantage of the Renshaw approach is the closeness to standard actuarial mortality ratios of the derived excess mortality factors.

The key factor in determining the methodology used was the availability of suitable data. It was necessary to find a health survey that also included follow up data on deaths of the subjects. After a search of publicly available data, the Health and Lifestyle Survey (1985) (HALS1) was identified. As the data is similar in design to that used in Fontaine et al (2003) it was felt that it would be best to use the same methodology. This would allow direct comparison of results between the UK and US data. Another advantage of using this methodology would be to allow direct comparison with Olshanksy et al (2005) which developed the Fontaine results further.

Section 3.2 identified some of the key research issues when investigating obesity and mortality rates (Seidell et al, 1999). How these apply to this study will be discussed in the methodology, section 5.2 and limitations, section 5.5. Due to the lack of available data it was not possible to screen datasets in relation to these issues although HALS1 provided very good case data in order to take these into account.

5.1.2 Health and Lifestyle Survey 1985

The survey was funded by the Health Promotion Research Trust with the main aims of:

- Investigating the behaviours and habits of smoking, alcohol consumption, diet and physical exercise in a nationally representative sample.

- Determining the health implications of those behaviours for individuals.

- Understanding how these behaviours related to individual beliefs and perceptions about health and lifestyle.

- Determining associations between lifestyle and physiological status in the nation.

- Investigating the effect of cognitive ability on these issues.

Data was collected through an interview on 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 demographically representative, although older people were slightly under represented.

97.8% of the sample is flagged with the NHS central registrar allowing death information for these respondents to be updated yearly. This has been done up to 2005 and so far 2,431 deaths have been recorded.

To summarise, HALS 1 is a prospective longitudinal study similar to that evaluated in Fontaine et al (2003). HALS 1 has advantages over the data used in Fontaine in that the initial fieldwork is around 10 years more up to date and that it has a longer period of follow up.

HALS1 was the basis of Cox and Whichelow (1996) which, through the use of observational diagnosis and logistic regression analysis, found no association between BMI category and all-cause mortality. In the regression analysis BMI was not found to be a significant predictor of death from all causes. However, it did find that ratio of waist circumference to height was significant in predicting all-cause mortality when used in logistic regression analysis and the graphical analysis of this indicator 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. SPPS 13.0 was used to perform the logistic analysis with death as the outcome variable.

For the graphical test, deciles of the distribution of the variables (BMI and waist to height) were obtained. Figures 19 and 20 show the 20 year all-cause mortality by decile, for each variable. In this analysis a clear trend can be seen for both variables.

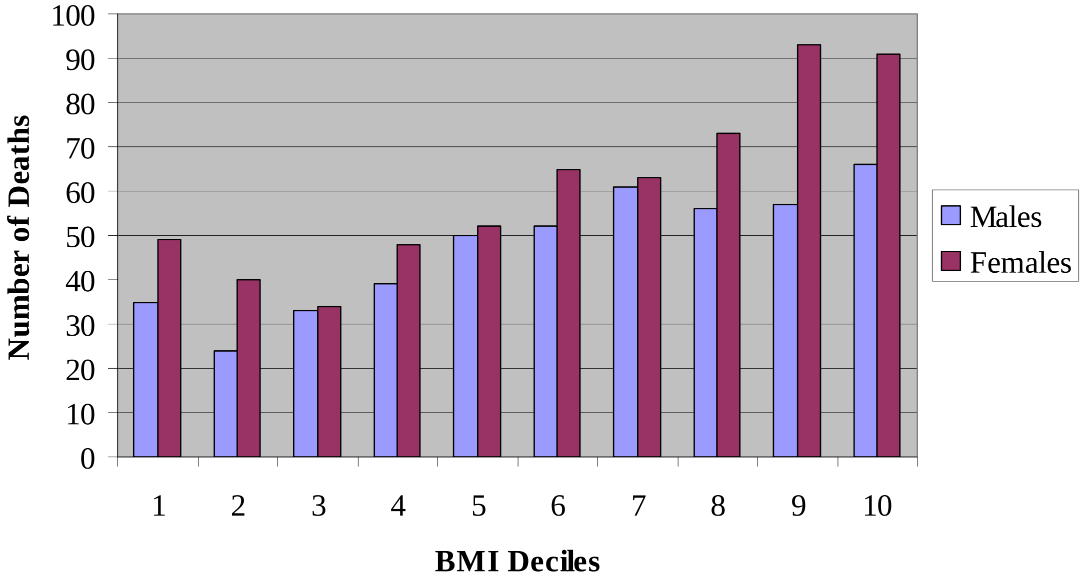

Figure 19, Number of deaths by BMI deciles of the HALS1 sample.

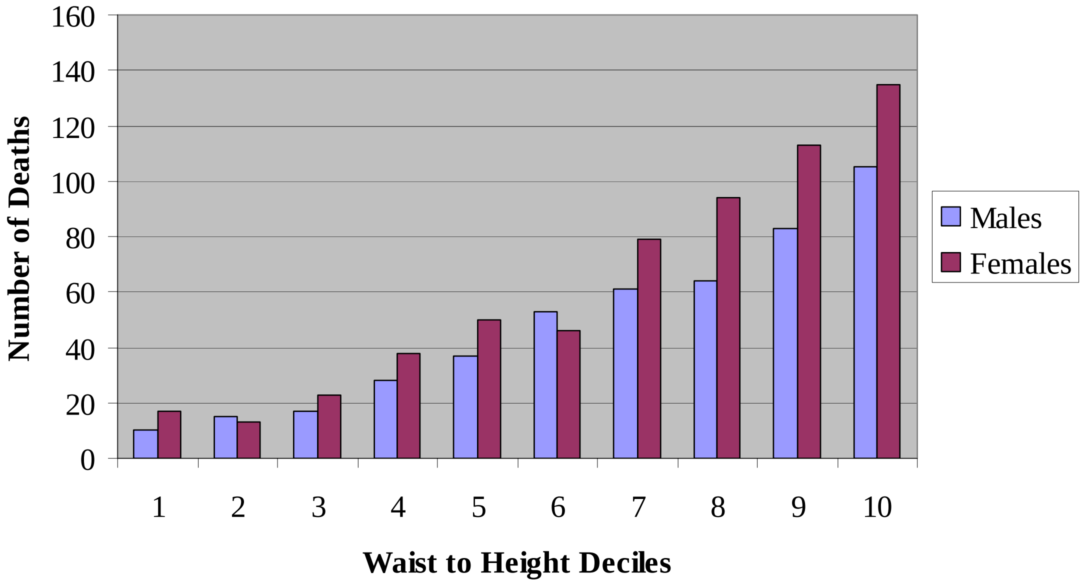

Figure 20, Number of deaths by waist to height deciles of the HALS1 sample.

Logistic regression analysis showed both variables to be significant predictors of death. The significance value of the BMI and waist to height variable in the fitted models was less than 0.01 which means that the inclusion of the variable in the model improved the prediction of the outcome variable, death.

Although both tests indicate that waist to height is a better predictor they also indicate that BMI is sufficient. As BMI has been used in many studies including Fontaine et al

(2003) it was decided that BMI should be used as the measure of risk reduction for ease of comparison of results.

5.2 Methodology

For comparisons of life expectancy between BMI categories, years of life lost (YLL) can be used. YLL is defined as the difference between the number of years a person would be expected to live if they were not obese and the number of years expected to live if the person were obese. Analysis was produced for males and females separately.

The methodology used in Fontaine et al (2003) combines 3 sources of information:

- An estimate of the distribution of BMI within the population for each year of adult life from 18 to 85 years.
- An estimate of the Cox proportional hazards ratio for death based on BMI levels and age.
- The probability of death during each year of adult life.

5.2.1 Estimating BMI Distribution

Data on BMI distribution was taken from the Health Survey for England 2004 available from the UK data archive. The Health Survey for England was used in section 4.2. It is conducted annually for the NHS in order to monitor the nation's health through assessing proportions of the population with specified health issues.

The proportion of the population in body mass index categories from less than 17, 17 to < 18, 18 to <19 and so on until greater than or equal to 45 was estimated. This was done using the following smoothing procedure on the health survey data. By smoothing the data it was possible to make the continuous variable, BMI, categorical with fine graduations of 1 unit. The raw data would not be sufficient in size to produce such precise estimates.

The probability of being in the following 34 overlapping BMI categories was estimated:

>=13 to 18, >=14 to 19, >=15 to 20 ….. >=44 to <49

For each interval, each subject was assigned a score of one if their BMI fell within each BMI category, zero otherwise. This produced 34 binary variables that were regressed on age to a third degree polynomial via logistic regression.

Fontaine et al (2003) found that a third degree polynomial characterised the convex relationship between change in age and BMI. The probability of being in each 5 unit 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 sample of the obtained smoothed distribution can be seen in section 1 appendix 1. A smoothed distribution of BMI for ages 18 to 85 was obtained.

The mean BMI for each one unit interval (μ_i) was calculated from the health survey data. This is shown for some of the ages and BMIs in appendix 1, section 2.

5.2.2 Estimating Hazard Ratios for BMI Levels by Age of Adult Life

When analysing the data using the Cox proportional hazards model we considered the points raised by Seidell et al (1999) and outlined earlier in section 3.2.

- To control for cigarette smoking, people who were currently smoking were removed from the sample. This left a total of 1,685 males with 473 deaths and 2,609 Females with 608 deaths.

- People who died within three years of baseline were not removed due to the conflicting research in this area as discussed earlier, in section 3.2.

- There was no adjustment for intermediate risk factors in the relationship between BMI and mortality.

- Age at the beginning of the investigation was taken into account in the analysis and it was checked to make sure that the proportional hazards assumption was met. This was done by plotting the Shoenfield residuals against survival time for each independent variable as discussed in Fontaine et al (2003). As these were found to be independent of time this assumption is met.

- Failure to adequately control for socio-economic status and ethnicity was not a problem as a reasonably representative sample of the UK population was used.

- The duration of follow up is sufficient as proved in the earlier analysis in section 3.2. However, sample size at high BMI levels is small in this dataset leading to a high variance in the results obtained for the proportional hazard ratios at these levels.

- As the survey used a nurse to take physiological measurements this survey did not rely on self-reported figures. Weight tends to be under reported if self-reported.

SPSS 13.0 was used to fit the Cox proportional hazards models using BMI, BMI^2, Age and Age^2 as covariates. Maximum likelihood estimation is used to fit the parameters to the model and is explained in detail in Cox (1984) and Collett (2003). Interaction terms (BMI x Age, BMI^2 x Age etc) were tried but the model fit was not enhanced.

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

$$h_i(t) = \exp(\beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i})\, h_0(t)$$

where

	Male	Female
β_1	0.1724	0.13313
β_2	-0.00051049	-0.00019543
β_3	-0.19486	-0.16646
β_4	0.0040377	0.0030125

x_{1i} = Age of i^{th} individual
x_{2i} = Age^2 of i^{th} individual
x_{3i} = BMI of i^{th} individual
x_{4i} = BMI^2 of i^{th} individual

and

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

These equations were used to estimate the hazard of BMI levels from age 18 to 75. A sample of the obtained hazard ratios are in appendix 1, section 3.

5.2.3 Life Tables

The 2004 interim life tables for the United Kingdom produced by the Government Actuary's Department (GAD) were used to provide conditional probability of deaths for the total population. These are the most up-to-date available and were equivalent to the US tables used by Fontaine et al (2003). A sample of this table is included appendix 1, section 3.

5.2.4 Estimating Years of Life Lost

This section describes how the smoothed BMI distribution, together with the hazard ratios and the life tables are used to produce years of life lost estimates.

Steps involved in this method are (as used by Fontaine et al (2003)):

- 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 5.2.1 (results in appendix 1, section 1).

- Mean of each BMI category from health survey data = μ_i (results in appendix 1, section 2).

- Use the μ_i figure and the midpoints of ages (ie 18.5, 19.5 etc) in the Cox proportional hazards equations to obtain hazard ratios (λ_{ij}). See appendix 1, section 3.

- Total probability of death conditional upon living to the start of age interval = γ_j. See appendix 1, section 3.

- For each integer-defined age interval the probability of death within the interval is estimated, conditional upon having lived to the start of that interval and being in the first BMI category. Results in appendix 1, section 4 and 5.

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

- The probability of death conditional upon living to the start of the j^{th} age interval and being in the i^{th} BMI category was estimated as being: (results in appendix 1, section 4 and 5)

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

- The median age of death as the expected age of death for each age s and BMI category i was estimated as the minimum integer value of m satisfying: (results in appendix 1, section 8)

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

- Years of life lost is for a person in the i^{th} BMI category and of age X relative to the optimum BMI (in this case 24 kg/m^2 for males and 27 kg/m^2 for females) is found by taking the expected age of death at the i^{th} category from the optimum BMI category. (results in appendix 1, section 9)

The results of these stages are tabulated for males in appendix 1. Due to the size of the output it is not easy to present entirely and so intervals of five for age and three for BMI are given.

5.3 Results

We found the optimum BMI for males to be 24. The YLL due to obesity for ages 20, 30, 40, 50, 60 and 70 compared to the optimum BMI are displayed in figure 21 for males.

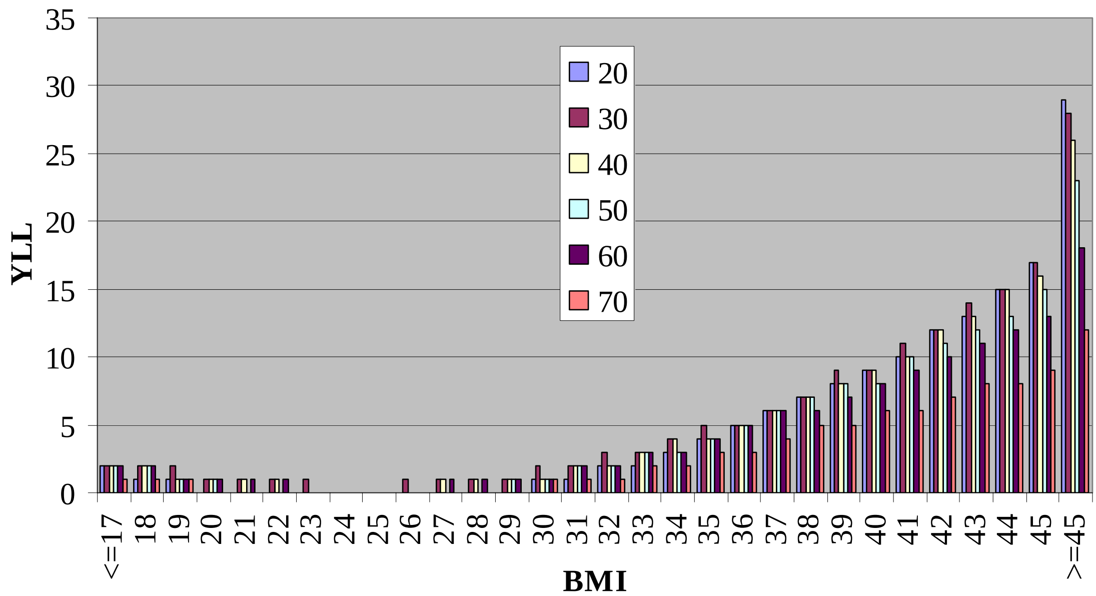

Figure 21, Years of life lost by BMI and age, males, HALS1

The optimum BMI for females was found to be 27. The YLL due to obesity for ages 20, 30, 40, 50, 60 and 70 compared to the optimum BMI are displayed in figure 22 for females.

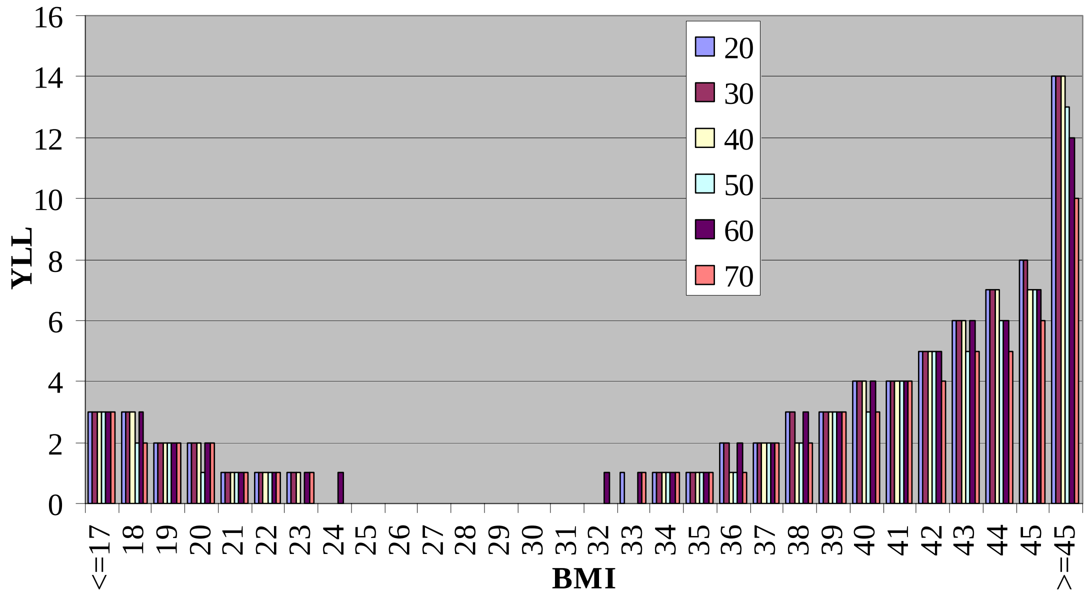

Figure 22, Years of life lost by BMI and age, females, HALS1

The overall pattern suggests a J-Shaped association for both sexes between BMI and YLL. For both sexes, ages of over 70 see lower relative risks.

For males, average YLL across the range of ages would be 1 to 2 years for individuals with low BMI’s (<17 to 19) and 4 to 20 years for individuals with BMIs in excess or equal to 35.

For females, average YLL across the range of ages would be 1 to 3 years for individuals with low BMI’s (<17 to 19) and 1 to 11 years for individuals with BMIs in excess or equal to 35.

20 year-old males in the top BMI category, >= 45, are estimated to have 29 YLL compared to those in the optimum category of 24. This pattern is repeated as age increases but the YLL value decreases.

For females there is less variability across the BMI distribution as a function of age. 20 year-old females in the top BMI category, >= 45, are estimated to have 13 YLL compared to those in the optimum category of 27. The results for females also indicate larger YLL figures in the lower BMI categories.

5.4 Analysis of Results

The results were analysed independently and in relation to those found by Fontaine et al (2003).

The results indicate that obesity has a profound effect on life span. A J-shaped association between BMI and YLL was observed. For instance, a 20-year old male with a BMI greater than 45 was found to lose 29 years of life compared to a 20-year old with a BMI of 24. A 20-year old male in the optimum BMI category is expected to live another 61 years so this is a reduction in life expectancy of 48%. For 20-year old females the equivalent figure is 22%. 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 BMIs than males.

There is a marked difference between the effect of BMI on females and males with the optimum BMI being 27 for females and 24 for males. Also this study suggests that females have no increased risk of mortality from being overweight in any age range whereas there is a small increased risk for males. Overall this study suggests that overweight is not a serious mortality issue as it only causes small increases in YLL for both sexes.

When comparing figures 21 and 22 with figures 9 and 10 it can be seen that these findings are similar to those found by Fontaine et al (2003) but with steeper growth in YLL as BMI increases and smaller YLL from BMI categories in the unhealthy low range (BMIs less than 20). As with Fontaine et al (2003), males were observed to have higher YLL for a specific BMI than females. Fontaine also found overweight to not 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 these two studies it is necessary to note that the Fontaine et al (2003) results are for white males and females whereas this study did not consider ethnicity. This is due to the different ethnic mix within the UK compared to the US. Fontaine et al (2003) also considered YLL for black males and females and found a much flatter relationship between YLL and BMI. If the US study had not separated by race the overall results would have been flatter. Similarly it is possible that our study might have been diluted by the effect of different racial groupings. There is the possibility that large differences exist between different ethnicities within the UK.

The J-shaped association is similar to that found by Calle et al (1997) and Stevens et al (1998). 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 risk in observed in males compared to females with the same BMI levels found in our analysis of the HALS1 data is consistent with these other studies.

5.5 Limitations

The results and conclusions of this study are subject to various limitations.

As discussed, using BMI as a proxy of body fat may not be the best measure. BMI measures fat mass and fat free mass, so its use may mask the different health consequences associated with fat mass and fat free mass. Cox (1996) found that waist to height was a better predictor of all-cause mortality. The analysis conducted at the beginning of this investigation also found a stronger relationship between waist to height and mortality in the HALS1 data including deaths up to 2005 (section 5.1.2). The advantage of using BMI is that it has become a standard indicator. It would be interesting to repeat this study using waist to height as a covariate instead of BMI.

Another issue is the relatively small sample size of individuals in higher BMI categories. As a result, in this study, as BMI increases the derived hazard ratios become less precise and these have a large influence on the YLL figures. However, the results found in this study do seem to be supported by results of other studies – Fontaine et al (2003), Stevens et al (1999), Calle et al (1997). To clarify this uncertainty it would be useful to use a similar analysis on a large dataset from the UK which contained a larger proportion of overweight and obese individuals.

Smoking was controlled for by excluding all subjects who currently smoked. As smoking effects bodyweight and mortality, there may be some confounding effect due to previous smoking habits, which were ignored in this study.

The use of population-based life tables is not consistent with the removal of smoking from the sample population. Perhaps it may be more appropriate to adjust the UK life tables for smoking or use life tables based on non-smokers. However this study still gives a good indication of the effect of obesity on life expectancy.

As previously discussed in section 3, some studies argue to control for pre-existing disease by removing all subjects who die in early follow up. This was not done in this study and the effect, if any, of this would be to underestimate YLL due to obesity (Fontaine et al, 2003).

The YLL calculations assume that BMI remains constant across age. For clarification this study did not consider how much longer a person could be expected to live if they currently have a BMI of 37 and gain or lose weight at the same rate as others with this BMI and suddenly had a BMI of 24 and gained and lost weight at the same rate as others with a comparable BMI. This study considered the simpler YLL as a result of being a certain BMI compared to the optimum.

5.6 Estimating the Effect of Obesity on Mortality Rates

Through further analysis of these results, using the methodology outlined in Olshanksy et al (2005), the effect of obesity on UK mortality rates can be estimated by calculating the reduction in the rates of death that would occur if everyone who is currently obese were to lose weight to the optimum BMI for that sex.

5.6.1 Steps

Estimate the conditional probability of death at age x of the non obese population, $(q(x_{no}))$:

$$(q(x_{no})) = [q(x) - q(x_o)P(x_o)] / P(x_{no})$$

$q(x)$	=	conditional probability of death at age x for the entire population obtained from life tables, appendix 2 (q(x))
$q(x_o)$	=	conditional probability of death at age x for the obese population, assume that everyone who is obese has a obesity level of 33 for males and 34 for females, the means based on distribution of UK obese (greater than 30) BMI's, appendix 2 $(q(x_o))$
$P(x_o)$	=	is the proportion of the population at age x that is obese
$P(x_{no})$	=	1 - $P(x_o)$, the proportion of the population not obese

To estimate new mortality rate without the effect of obesity $q(x_a)$:

$$q(x_a) = q(x_o)P(x_o) + q(x_{24})P(x_o)$$

5.6.2 Results

The adjusted mortality rates for males are tabulated in appendix 2.

When calculating the effect on median life expectancy, for 18 year olds, of removing obesity from the population, male life expectancy increased by 0.44 years and female life expectancy by 0.14 years.

As with the previous analysis these figures are probably underestimates due to the use of cross-sectional rather than cohort data (Peeters et al, 2003b).

Section 6 Implications for insurance

There are implications for pension, life insurance, critical illness, long-term care and general insurance organisations. There are also implications for the buyers of longevity bonds who would be interested in any modifiers of future mortality improvement.

6.1 Life Insurance

Life insurance is the most directly effected. It is probable that the life insured population has a lower prevalence of overweight and obesity then the general population due to the following reasons

- Underwriting filters out obese individuals through the charging of higher premiums or the refusal of companies to write business for obese individuals.
- Insured lives tend to be from higher social economic groups then the general population.

The impact of obesity effects new and existing business.

Swiss Re (2004) identifies the following groups as being generally representative of the insured population:

- 30-44 years olds
- Individuals with no previous history of disease
- Non-smokers
- Males

The evidence presented in section 3 suggests that these groups see a particularly large increase in the relative risk of mortality associated with obesity. Therefore it is reasonable to say that insured lives have an increase in the relative risks associated with obesity compared to the general population.

Swiss Re (2004) suggests that for existing business this risk is moderated by the following two factors:

Strong competition within markets that are price sensitive can mean that small changes in mortality assumptions turn profits into losses. If the overall BMI of the in force business of a company increases this could force the mortality rates to change.

As social factors are deemed to be a significant contributor to rising obesity levels, future social policy and lifestyle changes will directly effect obesity rates in the future.

Swiss Re (2004) also suggests that for new business the underwriting process with regard to body fat needs to be carefully managed. If this is done then new business should not be as much of an issue for life insurers where the mortality assumptions should hopefully not be open to change.

Childhood obesity could cause a negative cohort effect that may have a large effect on mortality rates in the future. This means that insurance companies will have to be wary of such an effect and ensure their future pricing strategies fully consider such a possibility.

6.2 Impact on pensioners

The research presented in this study suggests that obesity has less of an effect on older people of pension age. The issue here is that the sample size at these ages is generally small, especially at high BMIs. There is considerable variance in the results. Nonetheless many studies do seem to concur with this conclusion.

Corrada et al (2006), in one of the few studies to concentrate on the effect at older ages, finds that there is increased mortality at age 73 years and over for individuals that were overweight or obese at age 21. It also finds that there is no increased mortality for individuals who are currently obese at age 75 years and over.

As retirement age is generally 65 these results are not directly applicable to pension mortality but they are worthy of consideration. Due to the increase in the availability of enhanced annuities, understanding the complexities of the effect of obesity is important in determining product prices, especially in a competitive market. Corrada et al (2006) would suggest that enhanced annuities should not be made available to obese individuals.

6.3 Critical Illness and Long Term Care Insurance

Although this paper concentrates on the mortality implications of body fat morbidity there are obvious associated issues for these types of insurance products.

For critical illness insurance similar underwriting considerations as for life insurance apply. Long term care insurance might need to consider the health implications of ageing people with years of being overweight. For instance, people storing up health issues from younger ages may be in need of long term care insurance benefits from an earlier age.

6.4 General Insurance

There is inherent long term risk involved in general insurance as a result of bodily injury claims so any effect on mortality rates related to body fat will affect claims awards in this area.

There are also liability issues for many organisations; court cases in the United States have now occurred and are ongoing. It is increasingly likely that class action suits could be initiated against fast food restaurants for mis-selling food as a healthy, regular diet. The implications of this are that the following organisations might be at risk: fast food companies, food manufacturers, marketing agencies, advertising agencies, medical profession, school authorities, employers and directors and officers.

CONCLUSION

This paper covers a topic that is important to the planning of health care, social policy and insurance within the UK. It validates recent government policy (Health Committee, 2004) and the surrounding publicity over nutrition.

This paper has reviewed the relevant literature, identified trends in the distribution of the UK population's body fat levels and furthered the understanding of the problem in the UK by providing new research.

In section 1 we have attempted to illustrate the importance of obesity in determining future mortality by outlining the main trends behind mortality in the last century. As these trends are a result of social factors, obesity, as a new social problem, is proposed as a factor to allow for when considering future mortality trends.

Section 2 looks at the various measures of body fat used by researchers, health organisations and insurance companies. BMI is found to be the most widely used. However, research suggests waist to height is a better measure. This study decides to concentrate on using BMI due to the large amount of data available on this measure.

Through a review of the relevant literature, the section 3 finds that individuals with increasing BMIs have an increasing risk of cardiovascular disease, cancer, and stroke. The most serious health problem associated with obesity is diabetes which, although not directly a cause of mortality, significantly increases mortality risk in diagnosed individuals. The mortality risk associated with varying levels of BMI is found by many studies to be J-Shaped with an increased risk at BMI levels less than 20 and increased risk at BMI levels above 25. This section establishes the link between high BMI levels and mortality risk.

In section 4 the trend in the proportion of the UK population in various BMI categories is considered. These trends seem to indicate a decrease in the proportion in the healthy BMI category (20—25 kg/m^2) and an increase in the proportion in the overweight, obese and morbidly obese categories (25+ kg/m^2). When these trends are considered, together with the risks identified in section 3, obesity is identified as a major health issue in the UK.

Through an analysis of the Health and Lifestyle Survey (1985), section 5 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 lives 4 years less that 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 and overweight is less of a problem for females then for males. This research is important as there is a lack of research using UK-specific data. It supports other research conducted in the US.

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. The extent of this influence will be mitigated by medicinal advances. Considering past advances in medicine it seems unreasonable to think that gains in the future will not occur. Medicinal advances are likely to produce a larger positive effect on mortality improvement than any negative effect due to obesity so that gains are still experienced. However, these gains would be much larger if the proportion of obese people in the UK were to decrease. Also treatment of obesity-related disease is likely to divert research and attention from other health issues.

It seems likely that health practitioners will find themselves treating more people for diseases caused by excess body fat in the future. Many of the diseases that are associated with excess body fat can be caused by other factors, such as an individual's genes or smoking habits. Smoking has decreased in the UK and this has contributed to mortality improvements. The research presented here would suggest that the government should continue to try to promote healthy lifestyles in order to avoid the health issues and National Health Service costs associated with obesity.

Section 6 shows that the social phenomenon of obesity poses many challenges for insurers. In particular, life companies need to allow for obesity as a risk factor. This reflects the demand from people with healthy body fat levels for competitive life insurance premiums and the opportunity to offer enhanced annuities to obese pensioners. Insurers offering life insurance that do not specifically underwrite for obesity might find themselves with a severe negative-selection effect. However, with more people becoming obese there is also demand from this part of the population for life products. In addition, annuity providers who offer enhanced annuities will want to consider body fat as a suitable risk factor. If these products are available then pension companies will need to ensure that the mortality assumptions for their normal annuities are properly adjusted. They may find themselves with healthier than expected customers as obese individuals have gone elsewhere.

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Appendix 1

1 π_{ij} Beginning of BMI interval, Proportion of population in BMI categories of one unit (Health Survey 2004)

Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>= 45
20	0.04295	0.07896	0.08364	0.05442	0.02587	0.01374	0.00913	0.00402	0.00145	0.00054
25	0.02838	0.06435	0.08434	0.06766	0.03733	0.01874	0.01051	0.00435	0.00157	0.00058
30	0.01860	0.05194	0.08180	0.07792	0.04815	0.02367	0.01157	0.00450	0.00163	0.00060
35	0.01274	0.04265	0.07796	0.08471	0.05711	0.02811	0.01235	0.00453	0.00164	0.00061
40	0.00940	0.03618	0.07423	0.08871	0.06393	0.03183	0.01294	0.00451	0.00163	0.00061
45	0.00756	0.03197	0.07131	0.09081	0.06874	0.03473	0.01336	0.00447	0.00162	0.00060
50	0.00663	0.02954	0.06945	0.09174	0.07177	0.03671	0.01365	0.00445	0.00161	0.00060
55	0.00631	0.02854	0.06870	0.09200	0.07320	0.03773	0.01378	0.00444	0.00161	0.00060
60	0.00642	0.02878	0.06904	0.09193	0.07314	0.03770	0.01376	0.00445	0.00161	0.00060
65	0.00689	0.03016	0.07042	0.09173	0.07162	0.03658	0.01355	0.00446	0.00162	0.00060
70	0.00766	0.03263	0.07275	0.09149	0.06867	0.03435	0.01315	0.00448	0.00162	0.00060
75	0.00871	0.03613	0.07588	0.09119	0.06432	0.03105	0.01255	0.00447	0.00162	0.00060
80	0.01007	0.04050	0.07949	0.09068	0.05868	0.02683	0.01175	0.00442	0.00160	0.00059
85	0.01192	0.04536	0.08299	0.08962	0.05204	0.02200	0.01074	0.00430	0.00156	0.00058

2 Mean BMIs

μ_i	18.59797	21.55775	24.47847	27.45516	30.50111	33.47094	36.46648	39.22913	42.35853	50.16609

Cox regression parameters

Age	0.172	Bmi	-0.195	Bmi^2	0.004	Age^2	-0.001

3 λ_{ij} Age-specific hazard ratios for BMI Categories

Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45	γ_j
20.5	2.986012	2.710415	2.640298	2.759531	3.109084	3.753738	4.879095	6.626075	10.09605	40.75649	0.000763
25.5	6.289711	5.709197	5.561504	5.812655	6.548951	7.906846	10.27729	13.95711	21.26625	85.84915	0.000862
30.5	12.91471	11.72274	11.41948	11.93517	13.44701	16.23519	21.10244	28.65825	43.66616	176.2747	0.000981
35.5	25.8496	23.46379	22.85679	23.88898	26.91502	32.49573	42.23783	57.36126	87.4005	352.8247	0.001194
40.5	50.43564	45.78064	44.59633	46.61025	52.51442	63.40304	82.41104	111.9187	170.5288	688.4031	0.001661
45.5	95.92598	87.07241	84.8199	88.65027	99.8797	120.5893	156.7415	212.8635	324.3369	1309.307	0.002412
50.5	177.8483	161.4337	157.2575	164.359	185.1786	223.5745	290.6013	394.6523	601.3259	2427.476	0.003997
51.5	200.6052	182.0902	177.3796	185.3899	208.8734	252.1824	327.7857	445.1507	678.2697	2738.088	0.004356
52.5	226.0431	205.1803	199.8724	208.8984	235.3598	284.1606	369.3509	501.5985	764.2782	3085.294	0.004796
53.5	254.4468	230.9624	224.9876	235.1477	264.9342	319.867	415.762	564.6273	860.3143	3472.98	0.005142
54.5	286.1273	259.7189	253.0001	264.4253	297.9204	359.6928	467.5274	634.9275	967.4297	3905.391	0.005539
55.5	321.4238	291.7578	284.2102	297.0448	334.6718	404.0644	525.2015	713.252	1086.772	4387.159	0.006078
60.5	566.2671	514.003	500.706	523.3174	589.6065	711.8588	925.2714	1256.569	1914.615	7729.058	0.010429
65.5	972.4771	882.7215	859.886	898.7175	1012.559	1222.509	1589.012	2157.964	3288.059	13273.47	0.016541
70.5	1627.992	1477.735	1439.507	1504.514	1695.092	2046.562	2660.113	3612.578	5504.431	22220.69	0.026884
75.5	2656.685	2411.484	2349.1	2455.183	2766.184	3339.739	4340.981	5895.287	8982.562	36261.46	0.046448
80.5	4226.128	3836.074	3736.837	3905.589	4400.314	5312.699	6905.427	9377.943	14289.03	57683.01	0.076723
85.5	6553.302	5948.459	5794.576	6056.253	6823.405	8238.207	10707.99	14542.03	22157.48	89446.92	0.119284

4 $\pi_i\lambda_{ij}$									not all values shown for sum		
Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45	Sum
20	0.128238	0.214019	0.220829	0.150179	0.080428	0.051591	0.04454	0.026609	0.014674	0.021985	3.014105
25	0.178485	0.367385	0.469037	0.393283	0.244489	0.148205	0.107995	0.060698	0.033474	0.050151	6.40761
30	0.240173	0.608901	0.934167	0.93004	0.647418	0.384336	0.244143	0.128945	0.071111	0.10654	13.27075
35	0.329357	1.000775	1.781955	2.023644	1.537004	0.913314	0.521777	0.25985	0.143303	0.2147	26.75875
40	0.473987	1.65654	3.310584	4.134616	3.357154	2.018076	1.066068	0.504456	0.278199	0.416804	52.52199
45	0.724951	2.784126	6.048818	8.049973	6.866052	4.187548	2.09442	0.952127	0.525082	0.786689	100.3497
50	1.179676	4.768296	10.92171	15.0775	13.29081	8.208247	3.965486	1.755282	0.968008	1.45029	186.6307
55	2.027866	8.325857	19.52548	27.3282	24.49822	15.24351	7.238135	3.166242	1.746129	2.616087	337.8442
60	3.636432	14.79119	34.56921	48.10984	43.12152	26.83558	12.72784	5.587834	3.081596	4.616912	595.2027
65	6.697843	26.62014	60.55217	82.44101	72.52248	44.71751	21.53369	9.633984	5.312979	7.960017	1020.369
70	12.46998	48.21738	104.7234	137.6477	116.406	70.29182	34.99193	16.18303	8.924666	13.37112	1701.829
75	23.14886	87.13199	178.2389	223.8838	177.9113	103.6895	54.49633	26.37917	14.54767	21.79562	2761.104
80	42.55605	155.3766	297.0254	354.1495	258.2085	142.5646	81.1202	41.49382	22.88314	34.284	4357.797
85	78.10663	269.8265	480.8775	542.7681	355.0935	181.223	114.9823	62.5098	34.4731	51.64831	6693.03

5 γ_{ij}	Probability of death within the age interval conditional upon having lived to the start of that interval by BMI category									
Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45
20	0.000756	0.000686	0.000668	0.000699	0.000787	0.00095	0.001235	0.001677	0.002556	0.010317
25	0.000846	0.000768	0.000748	0.000782	0.000881	0.001064	0.001383	0.001878	0.002861	0.011549
30	0.000955	0.000867	0.000844	0.000882	0.000994	0.0012	0.00156	0.002118	0.003228	0.013031
35	0.001153	0.001047	0.00102	0.001066	0.001201	0.00145	0.001885	0.00256	0.0039	0.015743
40	0.001595	0.001448	0.00141	0.001474	0.001661	0.002005	0.002606	0.003539	0.005393	0.021771
45	0.002306	0.002093	0.002039	0.002131	0.002401	0.002898	0.003767	0.005116	0.007796	0.03147
50	0.003809	0.003457	0.003368	0.00352	0.003966	0.004788	0.006224	0.008452	0.012878	0.051988
55	0.005783	0.005249	0.005113	0.005344	0.006021	0.007269	0.009449	0.012832	0.019552	0.078927
60	0.009922	0.009006	0.008773	0.009169	0.010331	0.012473	0.016212	0.022017	0.033547	0.135427
65	0.015765	0.01431	0.013939	0.014569	0.016414	0.019818	0.025759	0.034982	0.053302	0.215174
70	0.025718	0.023344	0.02274	0.023767	0.026778	0.03233	0.042022	0.057068	0.086954	0.351023
75	0.044691	0.040567	0.039517	0.041302	0.046533	0.056182	0.073025	0.099172	0.151107	0.61
80	0.074405	0.067538	0.06579	0.068761	0.077472	0.093535	0.121576	0.165107	0.251571	1.015562
85	0.116794	0.106014	0.103272	0.107935	0.121608	0.146822	0.190839	0.25917	0.394893	1.594134

6 Probability of surviving interval

Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45
20	0.999244	0.999314	0.999332	0.999301	0.999213	0.99905	0.998765	0.998323	0.997444	0.989683
25	0.999154	0.999232	0.999252	0.999218	0.999119	0.998936	0.998617	0.998122	0.997139	0.988451
30	0.999045	0.999133	0.999156	0.999118	0.999006	0.9988	0.99844	0.997882	0.996772	0.986969
35	0.998847	0.998953	0.99898	0.998934	0.998799	0.99855	0.998115	0.99744	0.9961	0.984257
40	0.998405	0.998552	0.99859	0.998526	0.998339	0.997995	0.997394	0.996461	0.994607	0.978229
45	0.997694	0.997907	0.997961	0.997869	0.997599	0.997102	0.996233	0.994884	0.992204	0.96853
50	0.996191	0.996543	0.996632	0.99648	0.996034	0.995212	0.993776	0.991548	0.987122	0.948012
55	0.994217	0.994751	0.994887	0.994656	0.993979	0.992731	0.990551	0.987168	0.980448	0.921073
60	0.990078	0.990994	0.991227	0.990831	0.989669	0.987527	0.983788	0.977983	0.966453	0.864573
65	0.984235	0.98569	0.986061	0.985431	0.983586	0.980182	0.974241	0.965018	0.946698	0.784826
70	0.974282	0.976656	0.97726	0.976233	0.973222	0.96767	0.957978	0.942932	0.913046	0.648977
75	0.955309	0.959433	0.960483	0.958698	0.953467	0.943818	0.926975	0.900828	0.848893	0.39
80	0.925595	0.932462	0.93421	0.931239	0.922528	0.906465	0.878424	0.834893	0.748429	0
85	0.883206	0.893986	0.896728	0.892065	0.878392	0.853178	0.809161	0.74083	0.605107	0

7 Products to find 0.5

Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45
20	0.99795	0.99813	0.99818	0.99810	0.99786	0.99742	0.99664	0.99544	0.99306	0.97220
25	0.99406	0.99461	0.99475	0.99451	0.99382	0.99254	0.99031	0.98686	0.98004	0.92156
30	0.98980	0.99074	0.99098	0.99057	0.98938	0.98719	0.98338	0.97749	0.96590	0.86879
35	0.98458	0.98600	0.98636	0.98574	0.98395	0.98066	0.97493	0.96609	0.94877	0.80794
40	0.97782	0.97985	0.98036	0.97949	0.97692	0.97219	0.96400	0.95142	0.92688	0.73479
45	0.96808	0.97098	0.97172	0.97046	0.96678	0.96003	0.94835	0.93048	0.89595	0.63976
50	0.95273	0.95700	0.95809	0.95623	0.95082	0.94092	0.92387	0.89799	0.84863	0.51199
55	0.92946	0.93576	0.93737	0.93464	0.92666	0.91211	0.88723	0.84991	0.78018	0.36127
60	0.89321	0.90259	0.90499	0.90091	0.88905	0.86757	0.83126	0.77775	0.68109	0.20365
65	0.83539	0.84943	0.85303	0.84691	0.82920	0.79745	0.74480	0.66958	0.54113	0.07468
70	0.74960	0.76993	0.77518	0.76627	0.74068	0.69562	0.62315	0.52472	0.37136	0.01312
75	0.62279	0.65092	0.65826	0.64582	0.61061	0.55042	0.45862	0.34435	0.19247	0.00040
80	0.45351	0.48850	0.49780	0.48208	0.43867	0.36815	0.27008	0.16529	0.05988	0.00000
85	0.27066	0.30648	0.31629	0.29979	0.25598	0.19064	0.11271	0.04836	0.00793	0.00000

8 Expected Age of Death										
Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45
20	80	81	81	81	80	78	75	72	68	52
25	80	81	82	81	80	78	75	72	68	53
30	80	81	82	81	80	78	76	73	68	54
35	80	81	82	81	80	78	76	73	69	55
40	81	81	82	81	80	78	76	73	69	56
45	81	82	82	81	80	78	76	73	69	58
50	81	82	82	82	80	79	76	74	70	59
55	81	82	82	82	81	79	77	74	71	62
60	82	82	83	82	81	80	77	75	72	65
65	82	83	83	83	82	80	79	76	74	68
70	83	84	84	84	83	82	80	78	76	72
75	85	86	86	85	85	84	82	81	79	76
80	87	87	87	87	87	86	85	84	83	81
85	87	87	87	87	87	87	87	87	87	86

9 YLL (relative to a BMI of 24)										
Beginning of Age Interval	18	21	24	27	30	33	36	39	42	>=45
20	1	0	0	0	1	3	6	9	13	29
25	2	1	0	1	2	4	7	10	14	29
30	2	1	0	1	2	4	6	9	14	28
35	2	1	0	1	2	4	6	9	13	27
40	1	1	0	1	2	4	6	9	13	26
45	1	0	0	1	2	4	6	9	13	24
50	1	0	0	0	2	3	6	8	12	23
55	1	0	0	0	1	3	5	8	11	20
60	1	1	0	1	2	3	6	8	11	18
65	1	0	0	0	1	3	4	7	9	15
70	1	0	0	0	1	2	4	6	8	12
75	1	0	0	1	1	2	4	5	7	10
80	0	0	0	0	0	1	2	3	4	6
85	0	0	0	0	0	0	0	0	0	1

Average across age range	19	22	25	28	31	34	37	40	43	>=45
	1	0	0	1	1	3	5	7	11	20

Appendix 2

BMI Obesity = 33 kg/m^2							x_a	x
Age	q(x)	q(x_o)	P(x_o)	P(x_{no})	q(x_{no})	q(x_a)	survival probs multiplied	
18	0.000671	0.0008386	0.11836	0.88164	0.0006485	0.0006582	0.9993418	0.999329
19	0.000638	0.000796	0.12623	0.87377	0.0006152	0.0006251	0.9987171	0.9986914
20	0.000763	0.0009502	0.13431	0.86569	0.000734	0.0007466	0.9979714	0.9979294
21	0.000705	0.0008764	0.14252	0.85748	0.0006765	0.0006889	0.9972839	0.9972259
22	0.000827	0.0010262	0.15081	0.84919	0.0007916	0.0008071	0.996479	0.9964012
23	0.000802	0.0009933	0.15911	0.84089	0.0007658	0.0007817	0.9957	0.9956021
24	0.000761	0.0009408	0.16738	0.83262	0.0007249	0.0007408	0.9949625	0.9948444
25	0.000862	0.0010637	0.17556	0.82444	0.0008191	0.000838	0.9941287	0.9939869
26	0.000816	0.0010051	0.18361	0.81639	0.0007735	0.0007923	0.993341	0.9931758
27	0.000832	0.001023	0.19150	0.80850	0.0007868	0.0008068	0.9925396	0.9923494
28	0.000868	0.0010654	0.19921	0.80079	0.0008189	0.0008407	0.9917051	0.9914881
29	0.000902	0.0011053	0.20671	0.79329	0.000849	0.0008726	0.9908397	0.9905938
30	0.000981	0.0012001	0.21399	0.78601	0.0009213	0.000948	0.9899004	0.989622
31	0.000977	0.0011934	0.22103	0.77897	0.0009156	0.0009431	0.9889668	0.9886551
32	0.001088	0.0013269	0.22782	0.77218	0.0010175	0.0010492	0.9879293	0.9875795
33	0.001084	0.0013201	0.23436	0.76564	0.0010117	0.0010442	0.9868976	0.9865089
34	0.001109	0.0013486	0.24065	0.75935	0.0010331	0.0010673	0.9858443	0.9854149
35	0.001194	0.00145	0.24667	0.75333	0.0011102	0.001148	0.9847125	0.9842383
36	0.001260	0.0015281	0.25244	0.74756	0.0011695	0.0012104	0.9835206	0.9829982
37	0.001357	0.0016437	0.25794	0.74206	0.0012573	0.0013025	0.9822396	0.9816642
38	0.001347	0.0016297	0.26318	0.73682	0.001246	0.0012919	0.9809706	0.9803419
39	0.001532	0.0018514	0.26815	0.73185	0.001415	0.0014682	0.9795304	0.9788401
40	0.001661	0.0020051	0.27287	0.72713	0.0015319	0.0015907	0.9779722	0.9772142
41	0.001735	0.0020923	0.27732	0.72268	0.0015979	0.0016604	0.9763484	0.9755187
42	0.001870	0.0022529	0.28151	0.71849	0.00172	0.0017885	0.9746022	0.9736945
43	0.002215	0.0026661	0.28545	0.71455	0.0020348	0.0021172	0.9725388	0.9715378
44	0.002218	0.0026675	0.28913	0.71087	0.0020352	0.0021189	0.9704781	0.9693829
45	0.002412	0.0028985	0.29255	0.70745	0.0022108	0.002303	0.968243	0.9670448
46	0.002705	0.0032482	0.29571	0.70429	0.0024769	0.0025816	0.9657434	0.9644289
47	0.003050	0.00366	0.29862	0.70138	0.0027903	0.0029095	0.9629336	0.9614874
48	0.003290	0.0039455	0.30128	0.69872	0.0030074	0.0031372	0.9599126	0.9583241
49	0.003687	0.0044191	0.30367	0.69633	0.0033677	0.0035145	0.9565389	0.9547908
50	0.003997	0.0047882	0.30581	0.69419	0.0036484	0.0038088	0.9528957	0.9509745
51	0.004356	0.0052159	0.30769	0.69231	0.0039738	0.0041498	0.9489414	0.946832
52	0.004796	0.0057406	0.30932	0.69068	0.004373	0.0045678	0.9446068	0.942291
53	0.005142	0.0061527	0.31068	0.68932	0.0046865	0.0048963	0.9399817	0.9374458
54	0.005539	0.006626	0.31179	0.68821	0.0050465	0.0052735	0.9350247	0.9322532
55	0.006078	0.0072693	0.31263	0.68737	0.0055362	0.005786	0.9296147	0.926587
56	0.006598	0.0078902	0.31320	0.68680	0.0060087	0.0062804	0.9237763	0.9204734
57	0.007473	0.0089359	0.31351	0.68649	0.0068049	0.007113	0.9172055	0.9135947
58	0.008156	0.0097526	0.31355	0.68645	0.0074267	0.007763	0.9100852	0.9061434
59	0.008993	0.0107541	0.31332	0.68668	0.0081894	0.00856	0.9022949	0.8979945
60	0.010429	0.012473	0.31281	0.68719	0.0094986	0.0099276	0.8933372	0.8886293
61	0.011372	0.0136036	0.31202	0.68798	0.0103599	0.0108265	0.8836655	0.8785238
62	0.012913	0.0154513	0.31096	0.68904	0.0117675	0.0122955	0.8728004	0.8671794
63	0.013702	0.0164012	0.30961	0.69039	0.0124915	0.0130494	0.8614108	0.8552973
64	0.015267	0.0182823	0.30798	0.69202	0.0139251	0.0145434	0.8488829	0.8422395
65	0.016541	0.0198178	0.30606	0.69394	0.0150958	0.0157615	0.8355032	0.828308
66	0.018119	0.0217211	0.30385	0.69615	0.0165468	0.0172708	0.8210734	0.8132999

67	0.020123	0.0241394	0.30135	0.69865	0.0183906	0.0191882	0.8053185	0.7969339
68	0.022225	0.0266808	0.29856	0.70144	0.0203284	0.0212013	0.7882447	0.779222
69	0.024855	0.0298627	0.29548	0.70452	0.0227548	0.0237211	0.7695467	0.7598544
70	0.026884	0.0323298	0.29210	0.70790	0.0246369	0.0256704	0.7497921	0.7394265
71	0.030352	0.0365365	0.28844	0.71156	0.027845	0.0289977	0.7280499	0.7169834
72	0.033612	0.0405043	0.28449	0.71551	0.0308716	0.0321312	0.7046568	0.6928842
73	0.037206	0.0448874	0.28025	0.71975	0.0342151	0.0355894	0.6795785	0.6671047
74	0.041797	0.0504891	0.27573	0.72427	0.0384879	0.040008	0.6523899	0.6392218
75	0.046448	0.056182	0.27094	0.72906	0.0428306	0.0444919	0.6233639	0.6095312
76	0.051440	0.0623082	0.26587	0.73413	0.047504	0.0493111	0.5926251	0.5781769
77	0.057001	0.0691475	0.26055	0.73945	0.0527212	0.0546858	0.560217	0.5452202
78	0.062530	0.0759743	0.25497	0.74503	0.057929	0.0600406	0.5265812	0.5111276
79	0.069954	0.0851353	0.24915	0.75085	0.0649165	0.0672281	0.4911801	0.4753722
80	0.076723	0.0935349	0.24310	0.75690	0.0713234	0.0738009	0.4549306	0.4389002
81	0.084604	0.1033286	0.23683	0.76317	0.0787932	0.0814591	0.4178723	0.4017675
82	0.091956	0.1125174	0.23037	0.76963	0.0858014	0.0886249	0.3808384	0.3648226
83	0.098661	0.1209541	0.22372	0.77628	0.0922362	0.0951835	0.3445889	0.3288288
84	0.107752	0.1323606	0.21691	0.78309	0.1009357	0.1040625	0.3087301	0.2933969
85	0.119284	0.1468223	0.20995	0.79005	0.111966	0.1153227	0.2731265	0.2583993

Interpolating between ages 78 and 79 using the multiplied survival probabilities gives:

Median age of death, normal population = 78.75
Median age of death, adjusted for obesity = 78.31