Socioeconomic variation in the impact of obesity on life expectancy in Great Britain

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Abstract

Aims: (1) To investigate the impact of obesity on life expectancy in Great Britain. (2) To investigate whether and how this relationship varies by socioeconomic status (SES).

Methods: Data were taken from the British Health and Lifestyle Survey (1984-1985) and the longitudinal follow-up in June 2009 (n=4,062). Non-parametric, semi-parametric and parametric methods are used to estimate the impact of obesity (measured in three body mass index (BMI) categories) and SES (social class and education) on life expectancy. A range of diagnostic tests are used to guide the model selection. We run unadjusted models, models controlling for age and gender and models controlling for age, gender and additional household and individual characteristics likely to affect survival.

Results: Obesity has a negative impact on life expectancy. The negative impact varies by SES, and obese individuals in lower SES groups have lower life expectancy than normal weight individuals in high SES groups. Overweight has a non-significant positive impact on life expectancy compared to normal weight. We find similar results in all our models.

Conclusions: Our analysis show how the impact of obesity varies by SES. This emphasizes the importance of socioeconomic status and that it should be taken into consideration by governments when they promote healthy lifestyles to prevent premature death. It also has consequences for cost-effectiveness analyses of obesity interventions and could justify a subgroup analysis.

Introduction

Obesity is a rapidly increasing problem in the UK, and has been recognised as a priority by the NHS (NICE, 2006). In England in 2007, 24% of adults were classified as obese (body mass index (BMI) $\geq 30 kg/m^2$), which was a substantial increase compared with a prevalence of 15% in 1993 (NHS IC, 2009). There is a social gradient with respect to the prevalence of obesity; several British studies have found negative relationships between obesity and socioeconomic status (SES) in both men and women (see e.g., Wardle et al., 2002).

There is increasing evidence that obesity is associated with decreasing life expectancy both in the UK (Mayhew, Richardson, & Rickayzen, 2009) and elsewhere (Peeters et al., 2003). Although the evidence supports a negative relationship between obesity and life expectancy, the impact of overweight is currently debated. While there is an interest in socioeconomic inequalities in health (DH, 2007, Deaton, 2003), there has to our knowledge been no studies that have investigated socioeconomic variation in the relationship between obesity and life expectancy.

The aims of this study are to investigate the relationship between life expectancy and obesity, and to investigate whether or not this relationship varies by SES. We undertake the analysis using data from an individual level health survey and its longitudinal follow up, which includes nurse-measured height and weight, plus a set of individual and household characteristics that allows us to control for confounding factors that affect the relationship between obesity and life expectancy. We use a range of non-parametric, semi-parametric and parametric methods, including Kaplan-Meier survival curves, Cox Proportional Hazard models, and Weibull and generalised gamma survival models. We estimate unadjusted survival by obesity and SES, plus adjusted survival controlling for age and gender, plus also for additional covariates. We apply several diagnostic tests to guide model selection. We find that in the fully adjusted models the generalised gamma model is preferred, although the impact of obesity and SES shows little variation across the models used.

Methods

Data, sample and variables

The analysis is based on data from the first wave of the *Health and Lifestyle Survey* (HALS1) (1984-1985; *n*=9003) and the longitudinal follow up in June 2009. HALS1 surveys a representative sample of the population of Great Britain aged 18 years and over. Data for HALS1 were collected between Autumn 1984 and Summer 1985, in two home visits, the second by a research nurse during which a range of physiological measurements were taken. In the longitudinal follow up in June 2009 the original participants in HALS1 were flagged on the NHS Central Register (NHSCR) (now "The NHS Information Centre"), which is a computerised record of everyone registered with a GP in Great Britain that also collects demographic information, including mortality (http://www.ic.nhs.uk/). The linkage between HALS1 and NHSCR meant that it was possible to assess whether or not participants in HALS1 had died by June 2009 and if, so, their date of death. Ninety eight percent of participants in HALS1 were identified in the NHSCR (*n*=8808).

In our analysis we excluded pregnant women and individuals with missing BMI data; this reduced the sample from 9003 to 7,289. We then also excluded individuals under the age of 40 years at the time of HALS1. This was for two reasons. First, low mortality rates were observed among those below 40 years of age, which meant that a high proportion of the survival data were censored in this group. Second, there is some uncertainty about the SES of those under 40 years of age; our SES measures are based on educational and social class, which may change over time, especially among younger groups. We are unable to account for such changes in our analysis, which means that the observed impact of SES on survival could be biased. A similar approach has been taken in previous analyses of HALS data (Balia & Jones, 2008). This reduced the sample from 7,289 to 4,062.

Survival time is measured as the time to death or censoring in months from the date at which height and weight were measured in HALS1. Thus, the 'entry date' is the date of BMI measurement in HALS1 and the 'exit date' is either date of death or date last recorded alive (which is June 2009) if the respondent did not die during the follow-up period. Survival time is right censored because actual survival time is not observed for those who died beyond the censoring point. It is also left truncated because it observed only for those individuals who survived up to the HALS1 interview date.

Our obesity measure is based on body mass index (BMI), measured as weight in kilogrammes divided by height in metres squared (kg/m^2). BMI is computed from the height and weight measures obtained during the nurse visit; it is not based on self-reported height and weight, which means that the likelihood of systematic measurement error is reduced. Obesity is measured as a categorical variable based on three BMI categories: underweight/normal weight <25 kg/m^2 (hereafter referred to as normal weight); overweight 25-29.9 kg/m^2; and, obese $\geq$30 kg/m^2.

We measure SES based on social class and education. Social class is derived from the Registar General's Social Class classification system and is based on the occupation of the Head of Household. We aggregate the social classes into three groups, I & II (professionals, managers and intermediate workers), III (skilled workers and armed services), and IV & V (partly skilled and unskilled workers). Education is measured in HALS in 13 categories, which we aggregate into three groups, 'A' level and above, qualifications below 'A' level, and, no qualification. HALS does include data on income, but there is a high non-response rate so, as in other studies (Balia & Jones, 2008), we do not use this variable.

We also include covariates for the following individual and household characteristics: smoking status (yes/no), marital status (five categories), geographical area (ten categories), ethnicity (three categories), age (quadratic function) and gender.

Statistical analysis

We investigate SES variations in the relationship between obesity and life expectancy using a number of approaches. First, we use non-parametric Kaplan-Meier survival curves to investigate the impact of obesity on survival over time by SES group. We use log-rank tests to test for significant between-group differences.

Second, we model the hazard ratio of failure (death) for the predictors in our models using the semi-parametric Cox proportional hazard model. Third, we use fully parametric accelerated failure time models using both Weibull and generalised gamma survival distributions. The advantage of using the Cox proportional hazard model is that it leaves the baseline hazard function unspecified - it is treated as an unknown function - and so it is less vulnerable to problems caused by unobservable heterogeneity. However, it assumes that the hazard ratio is constant over time, which if not true can lead to biased results. While the parametric approaches assume a specific predefined survival distribution they do not assume that the hazard ratio is constant over time.

We use several diagnostic tests to identify the model that has the best 'fit' with our data. We use the Schoenfeld and scaled Schoenfeld residuals to test the proportionality of the Cox model, both as a whole and for each individual predictor. The null hypothesis is, effectively, that the log hazard ratio is constant over time; a rejection of the null hypothesis indicates that the proportional hazards assumption is violated and that alternative modelling choices, such as parametric methods are preferred. We compute Akaike Information Criterion to choose between the parametric models. We use LR-tests to test if we should include SES/BMI interactions.

In all the semi-parametric and parametric models we control for age at entry (and age squared) and gender. We also present models controlling for a wider range of individual and household characteristics

Using the model results we plot survival curves for selected BMI/SES groups in our data. We also calculate predicted survival time based on the preferred survival model. In both cases we fix the covariates at their sample mean values.

Results

After exclusions, our estimation sample consisted of 4,062 participants of whom 2075 (51%) were reported as deceased at the censoring point (Table 1). Comparable figures by BMI were 1017 of 2091 (49%) in the normal weight group, 779 of 1493 (52%) in the overweight group, and 279 of 478 (58%) in the obese group. Summary statistics on each of covariates in our model are in Table 2. Fifty one percent of participants were normal weight at measurement, 37% were overweight and 12% were obese.

Kaplan-Meier survival curves by social class and BMI and education and BMI are in Figures 1 and 2, respectively. In both cases the groups with the lowest survival curve are the low SES/obese groups. The groups with the highest survival curves are the high SES/normal weight groups.

The semi-parametric and parametric models are in Tables 3 and 4. In the models controlling for age and gender only (Table 3) we fail to reject proportional hazards, indicating that the assumption underpinning the Cox proportional hazard model is valid. This model shows that relative to normal weight, being obese, all other variables held constant, is associated with a higher hazard of failure (mortality) by around 24%. The effect of overweight is non-significant compared with normal weight. Low SES, measured both in terms of social class and education, is also associated with a higher hazard of failure (28% for social class IV & V relative to I & II, 42% for no qualifications relative to 'A' level and above). The results of the Weibull and generalised gamma models support the results of the Cox model, with obesity and low SES both having a negative impact on time to failure. Figure 3 shows survival probabilities based on the Cox model in Table 3 for 6 different combinations of SES and BMI. These results indicate that normal weight individuals with lower SES have a higher mortality rate than obese individuals with higher SES.

In the models presented in Table 4 we control for additional household and individuals characteristics as well as age and gender. While again the trends are similar in all three models, the Cox model fails the Schoenfeld test on two variables, suggesting that the proportional hazards assumption is violated, and the Aikake Information Criterion suggests that the generalised gamma model is preferred to the Weibull model. The results are consistent with those in Table 3, showing that after controlling for a more comprehensive set of covariates individuals who are obese have shorter survival time compared with those who are not obese and those in lower SES groups have shorter survival time compared with those in higher SES groups. We attempted to include SES/BMI interactions directly in each model but they were non-significant (all $p>0.1$)). We therefore modelled the extent to which impact obesity on survival varies by SES in terms of the main effects only.

In terms of the other covariates, males have shorter time to failure than women all else equal, smoking is associated with a shorter time to failure than not smoking, and being single is associated with a shorter time to failure than being married. Figure 3 shows the predicted hazard function based on the Cox model for 6 different combinations of SES and BMI. These results indicate that normal weight individuals with lower SES have a higher mortality rate than obese individuals with higher SES. Figure 4 shows survival probabilities based on the generalised gamma specification in Table 4.

Table 5 shows predicted times to failure (death) in months based on the estimated parameters of the generalised gamma model in Table 4 for selected combinations of values of the covariates. Older ages are associated with shorter times to failure compared with younger ages; men have shorter times to failure at all ages compared with women of similar ages; the obese have shorter times to failure than the overweight and those of normal weight; lower SES groups have shorter times to failure compared with higher SES groups; the impact of obesity on time to failure varies by SES.

Discussion

In this paper we use the *Health and Lifestyle survey* from 1984/1985 and its longitudinal follow up in 2009 to investigate the relationship between SES, obesity and life expectancy in Great Britain. We apply a variety of non-parametric, semi-parametric and parametric methods to investigate this relationship, using different combinations of covariates.

Previous studies have found a negative relationship between obesity and life expectancy using British and international data. However, to our knowledge no study has investigated how the impact of obesity on life expectancy varies by SES. We show that obesity has a negative effect on life expectancy after controlling for a range of household and individual characteristics. Mayhew, Richardson, & Rickayzen (2009) find similar results when they control for age and separate the population by gender and smoking status with BMI as a quadratic variable.

We also investigate the impact of overweight as well as obesity on life expectancy. We find an insignificant positive effect of overweight on life expectancy, which is contrary to some previous studies (see, e.g., Peeters et al., 2003; Adams et al., 2006), but not others (see, e.g., Felgal et al., 2005).

Our study shows how the impact of BMI on life expectancy varies by SES. Obese people in lower SES groups have lower life expectancy than those of normal weight in the same SES group, and have lower life expectancy than those in higher SES groups with the same weight. This trend is also observed after controlling for individual and household characteristics. We are not aware of any published studies that have stratified their analyses by SES groups to investigate whether or not the impact of obesity on life expectancy varies by SES. Some studies have shown that the impact of specific health problems on life expectancy does vary by SES, for example in individuals with HIV infection (Hogg et al., 1994).

Our findings have a number of implications. First, our study emphasise the importance of socioeconomic status in the relationship between obesity and life expectancy. Governments in many countries including the UK have recognised obesity as a critical issue and are making it a priority for health policy (Department of Health, 2008). The British government is also concerned with reducing health inequalities. For example, it has set national Public Service Agreement targets to reduce the gap in infant mortality across social groups, and raise life expectancy in the most disadvantaged areas faster than elsewhere. As noted in the recent report for the *Foresight Tackling Obesity: Future Choice Project*, these two issues are related: “[t]he greater prevalence of obesity among poorer social groups implies that efforts to counter health inequalities must take account of obesity; conversely, action on obesity must take account of socioeconomic factors” (Butland, 2007). This study provides an analysis of how these two factors (obesity and SES) relates to each other and affect health status (mortality). Second, given the use of survival analysis to implement time dependency in decision in cost-effectiveness analyses, our findings suggest that particular attention needs to be paid to the role of SES when undertaking economic evaluations of interventions to reduce obesity. The results show that normal weight lower SES individuals have a lower life expectancy than obese higher SES individuals. It is therefore important to possess knowledge about the SES of the target population. It also suggests that the cost-effectiveness of programmes to reduce obesity will vary by SES group, and that sub-group analyses by SES may be warranted.

Our findings have a number of limitations. First, our obesity data are measured in one period of time; it would be preferable to have repeated measures over time. Second, the relatively small sample size at higher BMI levels does not allow us to divide our sample into additional obesity categories. It is likely that the effect of obesity class III (BMI>40 kg/m^2) on life expectancy differs from the effect of obesity class I (30 kg/m^2>BMI>35 kg/m^2). Third, the data is based on measures from 1984/1985, when the prevalence of obesity is lower than it is today; the impact of obesity may change as population norms change. Fourth, our measure of obesity is BMI, which has been criticised, e.g., because it does not incorporate body fat, which is an independent predictor of ill health (Burkhauser & Cawley, 2008). Fifth, our models might underestimate the impact of obesity on survival in two ways. First, 'frailer' individuals (e.g. individuals with a bad health history) may be more likely to have a healthier diet and exercise more and then be less likely to be obese. The mix of frail and strong individuals might be equal to begin with, but over time frailer individuals will tend to die first and increase the hazard rate of the non-obese population. Second, as time passes the proportion of frail individuals will decrease and the overall hazard will decrease. As we have not controlled for the heterogeneity between the two types of individuals, this will give the appearance of decreasing duration dependence.

Nonetheless, we believe our study has a number of advantages over previous studies. We are the first study to investigate the relationship between BMI and life expectancy in the UK by including BMI as a categorical variable. This allows us to conclude that there is significant difference in the life expectancy of obese individuals compared to normal weight individuals. We are the first to apply the longitudinal follow up from June 2009. Our BMI measure is based height and weight measurements obtained during the interviewer visit, not on self-reported values. Thus, the likelihood of systematic measurement error is reduced. We apply several models in our estimation that all supports the same conclusion. Also, we have better information on individual and household characteristics and so can argue that it is less likely that the estimated effects of obesity on life expectancy in our models are due to their correlation with omitted variables.

To summarise, our study has shown that, as in previous studies, obesity is negatively correlated with life expectancy. In addition, we have shown that obese people in lower SES groups have lower life expectancy than those of normal weight in the same SES group, and that normal weight individuals in lower SES groups have lower life expectancy than obese individuals in higher SES groups.

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Table 1: Observations and failures by obesity and SES

	Whole sample		Normal weight		Overweight		Obese	
	Total	**Failures**	**Total**	**Failures**	**Total**	**Failures**	**Total**	**Failures**
N	4,062	2,075	2,091	1,017	1,493	779	478	279
Social class								
I & II	1,230	497	678	247	446	201	106	49
III	1,915	1,028	940	487	725	392	250	149
IV & V	917	550	473	283	322	186	122	81
Education								
‘A’ level and above	959	333	553	187	323	116	83	30
Qualification below ‘A’ level	566	234	306	115	200	87	60	32
No qualification	2,535	1,506	1,232	715	969	575	334	216

Table 2: Summary statistics

	Whole sample	Normal weight	Overweight	Obese
%	100	51	37	12
Social class				
I & II	30	32	30	22
III	47	45	49	52
IV & V	23	23	22	26
Education				
‘A’ level and above	24	26	22	17
Qualification below ‘A’ level	14	15	13	13
No qualification	62	59	65	70
Age	58	58	59	58
Gender				
Male	45	41	54	35
Female	55	59	46	65
Ethnicity				
White European	97	98	97	97
Other	2	2	2	2
Not answered	1	1	1	0
Smoking status				
Yes	30	36	24	22
No	70	64	76	78
Marital status				
Married	75	75	77	71
Single	14	13	14	18
Separated	4	4	3	5
Divorced	2	2	2	1
Widowed	6	6	4	5
Area				
London	10	11	9	7
Wales	5	5	5	8
North	6	6	7	7
North West	13	12	13	12
Yorks/Humber	9	9	9	10
West Midlands	8	8	8	8
East Midlands	8	8	7	8
East Anglia	4	4	4	4
South West	9	9	9	10
South East	18	19	18	14
Scotland	10	9	10	13

Table 3: Semi-parametric (Cox proportional hazards) and parametric (Weibull and generalised gamma) regression survival models controlling for age and gender

	Cox proportional hazards		Weibull		Generalised Gamma	
	Haz. ratio	**z**	**Coef.**	**z**	**Coef.**	**z**
BMI						
Normal weight	Base category		Base category		Base category	
Overweight	0.915	-1.9	0.055	1.8	0.046	1.7
Obese	1.239	3.2	-0.128	-3.0	-0.123	-3.1
Social Class						
I & II	Base category		Base category		Base category	
III	1.190	3.0	-0.105	-2.9	-0.102	-3.0
IV & V	1.277	3.7	-0.145	-3.5	-0.145	-3.7
Education						
‘A’ level and above	Base category		Base category		Base category	
Qualification below ‘A’ level	1.192	2.0	-0.110	-2.0	-0.090	-1.7
No qualification	1.419	5.3	-0.216	-5.2	-0.189	-4.7
Age	1.185	8.2	-0.106	-7.9	-0.113	-8.5
Age squared	0.999	-3.5	0.000	3.6	0.000	4.3
Gender						
Female	Base category		Base category		Base category	
Male	1.674	11.5	-0.310	-11.0	-0.296	-11.1
Constant			11.192	25.8	11.401	26.0
Schoenfeld residuals (Individual test) (p)	All p>0.14		-		-	
Schoenfeld residuals (global test) (p)	0.8861		-		-	

The number of observations in each model is 4062.

Table 4: Semi-parametric (Cox proportional hazards) and parametric (Weibull and generalised gamma) regression survival models controlling for age, gender and additional household and individual characteristics

	Cox proportional hazards		Weibull		Generalised Gamma	
	Haz. ratio	**z**	**Coef.**	**z**	**Coef.**	**z**
BMI						
Normal weight	Base category		Base category		Base category	
Overweight	0.991	-0.2	0.006	0.2	0.002	0.1
Obese	1.341	4.3	-0.175	-4.1	-0.166	-4.1
Social Class						
I & II	Base category		Base category		Base category	
III	1.148	2.4	-0.082	-2.3	-0.083	-2.4
IV & V	1.195	2.6	-0.102	-2.5	-0.106	-2.7
Education						
'A' level and above	Base category		Base category		Base category	
Qualification below 'A' level	1.141	1.5	-0.082	-1.5	-0.066	-1.3
No qualification	1.327	4.2	-0.172	-4.2	-0.152	-3.8
Age	1.189	8.2	-0.105	-7.9	-0.112	-8.4
Age squared	0.999	-3.4	0.000	3.5	0.000	4.1
Gender						
Female	Base category		Base category		Base category	
Male	1.670	11.1	-0.302	-10.6	-0.290	-10.7
Ethnicity						
White European	Base category		Base category		Base category	
Other	0.808	-1.0	0.127	1.0	0.118	0.9
Not answered	0.932	-0.3	0.046	0.3	0.038	0.3
Smoking status						
Yes	1.661	10.2	-0.303	-9.8	-0.285	-9.6
No	Base category		Base category		Base category	
Marital status						
Married	Base category		Base category		Base category	
Single	1.358	3.4	-0.177	-3.2	-0.170	-3.3
Separated	1.271	1.3	-0.132	-1.1	-0.140	-1.3
Divorced	0.874	-1.0	0.080	0.9	0.083	1.0
Widowed	1.100	1.6	-0.054	-1.4	-0.051	-1.5
Area						
London	Base category		Base category		Base category	
Wales	1.069	0.5	-0.034	-0.5	-0.043	-0.6
North	1.214	1.8	-0.115	-1.7	-0.104	-1.6
Northwest	1.084	0.9	-0.044	-0.8	-0.044	-0.8
Yorks/Humber	0.985	-0.2	0.017	0.3	0.003	0.1
West Midlands	1.183	1.6	-0.093	-1.5	-0.096	-1.6
East Midlands	1.022	0.2	-0.004	-0.1	-0.015	-0.2
East Anglia	0.849	-1.2	0.099	1.2	0.090	1.1
South West	1.103	1.0	-0.049	-0.8	-0.053	-0.9
South East	0.915	-1.0	0.057	1.1	0.051	1.0
Scotland	1.137	1.3	-0.074	-1.2	-0.078	-1.4
Constant	-	-	11.316	26.0	11.493	26.3
Schoenfeld residuals (Individual test) (p)	East Midlands p=0.0067, South East p=0.0225, rest p>0.1		-		-	
Schoenfeld residuals (global test) (p)	0.4642		-		-	

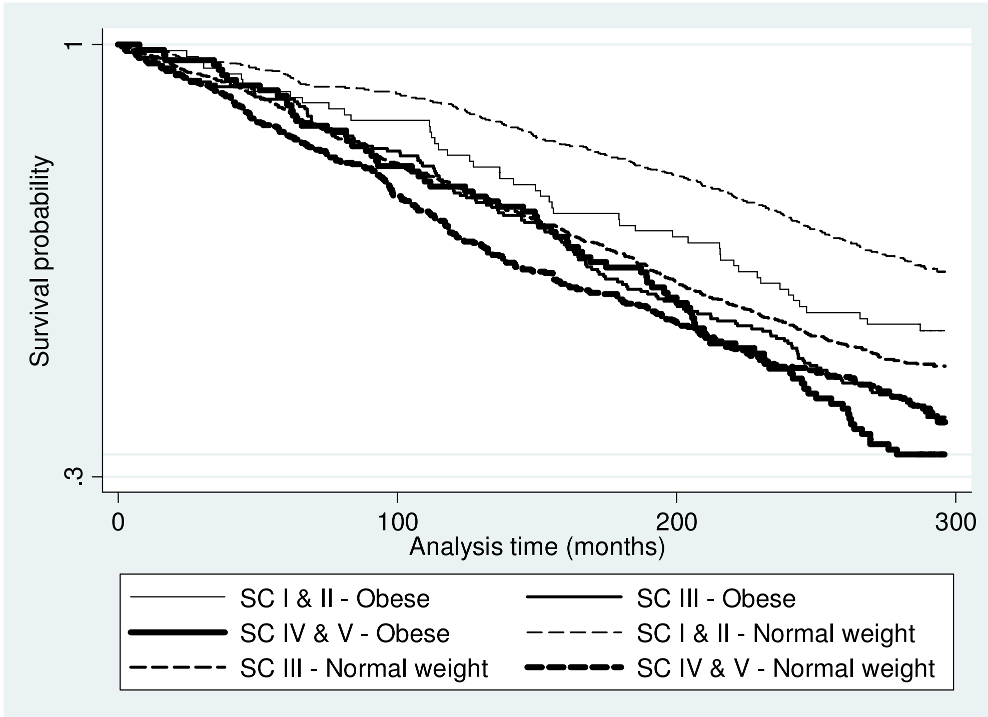
The number of observations in each model is 4061.

Table 5: Predicted survival time in months based on the generalised gamma parametric regression survival model controlling for age, gender and additional household and individual characteristics

	Age 55			Age 65			Age 75		
	Normal weight	**Overweight**	**Obese**	**Normal weight**	**Overweight**	**Obese**	**Normal weight**	**Overweight**	**Obese**
Men									
All	318	318	269	171	172	145	100	101	85
SES									
SC I & II + 'A' level and above	376	376	318	202	203	172	119	119	100
SC III + Qualification below 'A' level	324	324	274	174	175	148	102	102	87
SC IV & V + No qualification	290	291	246	156	157	133	92	92	78
Women									
All	425	425	360	229	229	194	134	134	114
SES									
SC I & II + 'A' level and above	502	503	425	270	271	229	158	159	134
SC III + Qualification below 'A' level	432	433	366	233	233	197	136	137	116
SC IV & V + No qualification	388	388	328	209	209	177	122	123	104

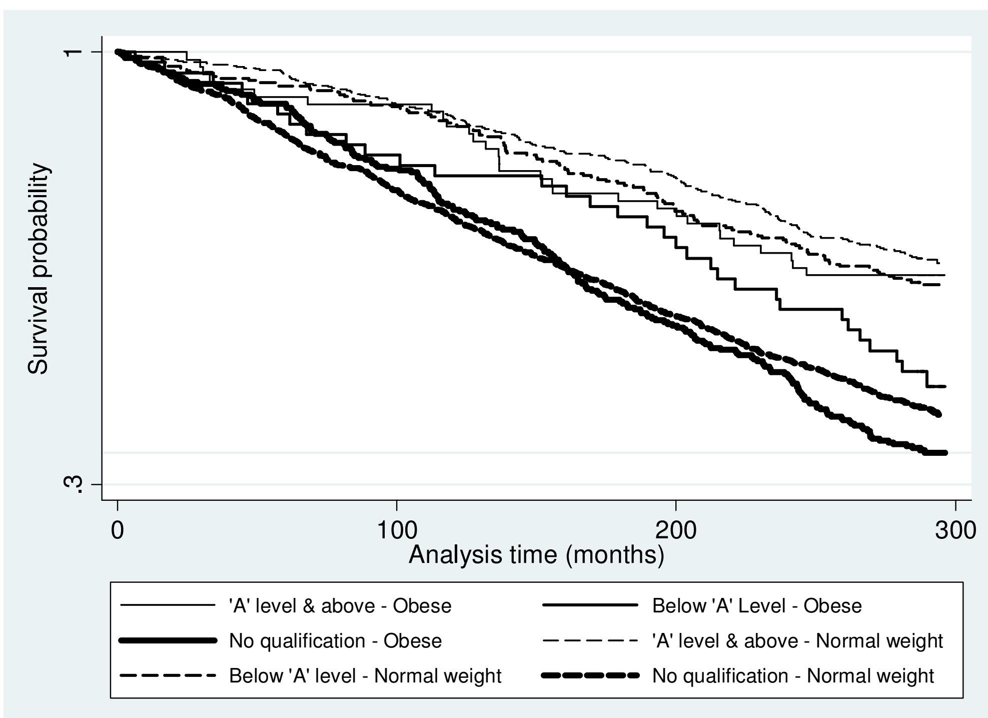
Covariates set at their sample mean value

Figure 1: Kaplan-Meier survival curves by social class and BMI



Log-rank test for equality of survivor functions: p<0.0001

Figure 2: Kaplan-Meier survival curves by education and BMI group



Log-rank test for equality of survivor functions: p<0.0001

Figure 3: Survival curves for selected SES and BMI groups based on Cox proportional hazards model controlling for age and gender

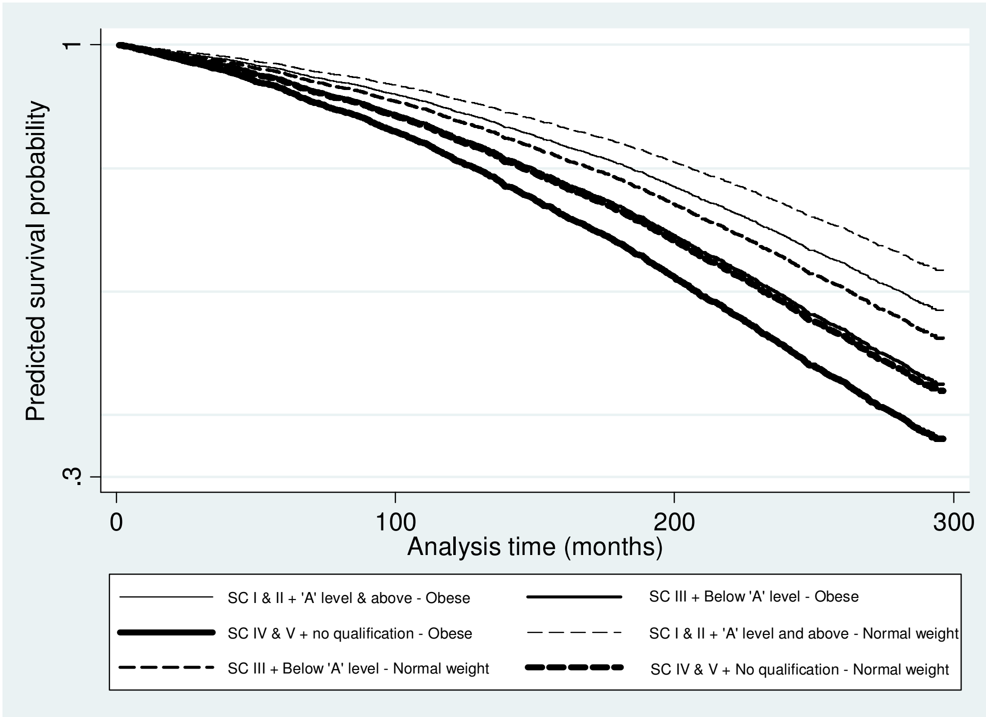


Figure 4: SES and BMI group combinations in the generalised gamma model controlling for age, gender and individual and household characteristics