Effect of body mass and physical activity on future long-term care use

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Keywords: long-term care; elderly people; formal care; social care; informal care; BMI; physical activity; obesity;

Abstract

Background: Obesity and physical activity rates are known predictors of disability and functional limitations, and, in turn, use of health care. In this study, we aim to explore whether obesity and physical inactivity also are significant risk factors for future long-term care needs (both informal and formal care).
Methods: We use multinomial logistic regression analysis on data from the English Longitudinal Study of Ageing (ELSA) respondents aged 65 and older between 2002 and 2011. Selection issues are tackled using the rich set of control variables, exploiting the data's longitudinal structure and accounting for loss to follow-up (including death). Control factors include functional limitations (related to ADLs, iADLs and mobility)) and specific existing health conditions, notably diabetes, high blood pressure and cardio-vascular diseases.
Results: We find that obese older people are 25% more likely to receive informal or privately paid care in two years' time, but this does not hold for formal care. People who are physically active are 38% less likely to be using any care in two years' time, with the strongest effect for formal care use. Sensitivity analysis suggests that the results are not driven by either prediabetes or any link between obesity and subjective health, depression, or unobserved heterogeneity.
Conclusions: This study indicates obesity's importance in future care costs and provides rationale for promoting a healthier weight for economic benefits, in relation not only to health care, but also long-term care.

1 Introduction

The widespread rise in obesity rates has become a worldwide health concern. In the UK, as in many other countries, obesity's prevalence is rising to epidemic proportions. About 40% of Britons are projected to be obese by 2025, and Britain is on track to become a largely obese society by 2050 (Foresight 2007). Obesity's high and still-rising prevalence creates major challenges for a society. In addition to being a debilitating condition in its own right, obesity is related to premature mortality [1] and is an important risk factor for several chronic conditions, including type II diabetes [2;3], cardiovascular diseases [4], cancer [5;6] and osteoarthritis [7]. It is also related to physical disabilities, impaired quality of life and decreased cognitive function and dementia among the elderly [8;9;10]. The upward shift in the age at which body fat and body mass index stop increasing due to the ageing process and current trends in population ageing suggest that obesity's prevalence in the elderly will rise as well [8; 14].

The increased burden of fatal and non-fatal conditions associated with obesity is likely to impose substantial financial costs on societies and governments [15; 16]. These costs are first monetary medical costs corresponding to an increased use of resources devoted to managing obesity-related diseases, such as ambulatory care, hospitalisation, drugs, tests and long-term care (including nursing homes) [17]. It is estimated that an extra £5.5 billion in such medical costs will be added to the NHS by 2050[18]. Moreover, indirect costs––including lost workdays, disability pensions, premature mortality, productivity reduction and decreases in disability-free life years––are likely to become even greater [17].

Although some recent evidence has surfaced concerning obesity's effects on health care utilisation and costs, not much is known about the relationship between obesity and long-term care utilisation. Our objective is to estimate obesity's effects on overall long-term care (LTC) use and, separately, on various forms of long-term care. We investigate how obesity's impact is transmitted, including its direct impact on the use of various modes of care in the future overall, as well as the indirect effect through changes in people's long-term conditions and functional abilities. An estimate of future LTC use that is attributable to obesity beyond currently known indicators of impairment will be useful information for decision making in both public health (PH) and social care. On the one hand, this allows us to incorporate a wider range of benefits from tackling obesity epidemics into decision-making and, thus, reach more socially optimal levels of investment in corresponding interventions. On the other hand, if obesity serves as a signal for impairment and future care needs, not yet diagnosed or assessed, accounting for increases of obesity prevalence in population could help improve planning and budgeting processes, and allow for better targeting of care-system resources in the future.

We also explore the effects of physical activity (PA), given people's health conditions, including diabetes, on LTC utilisation. Promoting physical activity is a potentially cost-effective public health intervention to tackle rising societal costs attributed to obesity. If an additional effect of physical activity exists on long-term care use that is not accounted for, we risk underestimating physical activity's benefits, thereby resulting in underinvestment in measures that promote PA.

This paper contributes to the literature in several ways. First, we focus on a country with moderate, but increasing, obesity levels compared with high-obesity-burdened countries, such as the US, which have been examined in previous literature. Second, we consider the whole spectrum of long-term care––informal, formal care (privately purchased and publicly supported) and institutional care (residential or nursing home)––while previous studies mostly focussed on nursing home admissions. Third, we address the problem of attrition due to non-response and death, which, in elderly populations, is likely to be related to health and care status. Finally, we investigate the pathways through which obesity leads to greater use of long-term care, within and beyond conventionally known risk factors.

In our analysis, we focus on people ages 65 and up, as this population group is most at risk of requiring long-term care and is more likely to be using expensive institutional care. We use the English Longitudinal Study of Ageing (ELSA) in a multinomial logit framework to estimate the impact of current obesity status and physical activity on the use of various modes of care two years in the future.

The remainder of the paper is organised as follows. Section 2 describes institutional and theoretical backgrounds on the matter, offering a literature review and formulating hypotheses. An econometric methodology is presented in Section 3, followed by a description of the data used in the analysis in Section 4. Section 5 provides a discussion of the results, while Section 6 concludes the paper.

2 Background

Long-term care support for adults with chronic health conditions and disabilities usually comprises nursing care, personal care and assistance with domestic tasks [19]. Care can be provided either informally by family members, friends and neighbours, or formally through professional services paid by individuals or local authorities [20]. The formal long-term care system in England is means-tested, providing a 'safety-net' for those in greater need [21], with unpaid carers providing most care 'informally'. Approximately 85 percent of all older people with a functional disability living in private households in England receive some informal care [19]. The number of informal care providers has increased over the years (11% between 2001 and 2011) and informal care itself has become more intensive [20]. According to some estimates, the total value of informal care to society in England totals £55 billion [20] .

A few US studies have tried to explore the direct relationship between BMI and long-term care utilisation. Elkins et al. [22] find some evidence that obesity in midlife is associated with a higher probability of nursing-home entry. Similarly, Zizza et al. [23] , Resnik et al. [24] and Yang and Zhang [25] show that obesity in older people increases the risk of nursing-home admissions, use of personal care assistance and LTC costs. Looking at physical activity's role, Demakakos et al. [26] demonstrate that any type of physical activity is associated with a reduced risk of type 2 diabetes in adults ages 70 and older, while vigorous or moderate activity reduces type 2 diabetes risk for adults ages 50 to 69.

Existent literature suggests that obesity is a risk factor for several long-term conditions, such as type 2 diabetes, cardiovascular disease, musculoskeletal diseases, some cancers, arthritis, hypertension, respiratory disease et al. [27]. These conditions lead to functional impairments and reduced cognitive and psychological well-being, generating the need for long-term care. This process is an indirect pathway for obesity's effect on the need for long-term care. Moreover, obesity also is directly associated with functional limitations (e.g., mobility) and disability in old age [8; 9; 10; 11]. We also can theorise that direct effects from obesity may exist on the use of care stemming from obesity status being used as a proxy for need, given that assessment of a need for long-term care is imperfect. In this way, an obese person might be regarded as having a need for long-term care, even if directly assessed indicators of impairment are accounted for in the analysis.

We hypothesise that obesity might affect the need for LTC in several ways, as summarised in Figure 1. First, obesity are well-known risk factors for a range of chronic diseases, and as such, will indirectly affect the need for care. In turn, these diseases lead to various functional impairments that generate LTC needs. We also distinguish between diagnosed and undiagnosed illnesses to emphasise that even after controlling for the health conditions covered in the data, we still may see an independent effect from obesity on future care use that would remain related to health. Second, obesity may cause some functional limitations directly, independent of specific health conditions, thereby reflecting impairment of physical activity resulting from excessive body weight, e.g., reduced mobility and self-care abilities. We also note in Figure 1 the potential for certain diseases and functional limitations to be *causes* of obesity, recognising issues with establishing causal effects from obesity on the need for care. Similar logic applies to physical activity both with regards of its effect on functional limitations [12] and chronic diseases [13].

We test the following hypotheses:

H1: Obesity among older individuals increases future use of long-term care.

H2: Greater future use of long-term care by obese older people is only partially explained by health conditions and functional limitations.

H3: Physical activity among older individuals reduces future use of long-term care.

H4: Lower future use of long-term care among older people who engage in physical activity is only partially explained by health conditions and functional limitations.

3 Methods and Data

3.1 Specification

We start with a (linear) model:

$$y_{itj} = \alpha_0 + \alpha_1 W_{it} + \alpha_2 x_{it}(W_{it}) + e_{it} \tag{1}$$

in which y_{itj} is the outcome that, in this case, is the utilisation of long-term care (of type j, e.g., informal care or formal home care) by person i at time t. In theory, utilisation is a function of a set of risk factors, including whether the person is (a) obese or (b) does physical activity (written as elements in the vector W_{it}), other needs-related risk factors (x_{it}), such as the prevalence of chronic conditions, as well as a set of 'other' factors (e_{it}). The α's are the coefficients that measure the size of risk factors' effects on care use. Moreover, we assume that the other needs-related risk factors for LTC use are also partly dependent on the person's obesity and physical activity, i.e., factors x_{it} are functions of W_{it}.

In practice, not all relevant risk factors are available in the data, as some are unobservable. Suppose we re-write (1) as:

$$y_{itj} = \alpha_0 + \alpha_1 W_{it} + \alpha_{21} X_{it}(W_{it}) + \alpha_{22} Z_{it}(W_{it}) + e_{it} \quad (2)$$

in which $\alpha_2 x_{it}(W_{it}) = \alpha_{21} X_{it}(W_{it}) + \alpha_{22} Z_{it}(W_{it})$, with X_{it} being observable risk factors, such as reported long-term conditions, and Z_{it} being unobservable risk factors (e.g., behavioural responses/preferences).

This specification presents several econometric challenges. First, we need to be clear about the different ways that obesity could affect LTC use, both as a direct effect captured by α_1 in (2) and indirectly, in which obesity status affects other factors that are included in the estimation, e.g., receiving a diabetes diagnosis or ADL limitations that stem from being obese (which are factors in X_{it}). The latter is captured partly in the coefficient vector α_{21}. Second, any unobserved risk factor that also is correlated with the person being obese or not will bias the estimated coefficients in a standard (OLS) estimation of y_{itj} on W_{it} and X_{it}. We cannot be certain that obesity's estimated effect is the actual causal effect or whether it also is capturing some effect from an unobserved factor that happens to be correlated with obesity's prevalence (e.g., the person's inherent self-confidence).

This problem can be addressed (to a certain extent) by exploiting the data's longitudinal nature and the persistence of conditions like obesity in affecting care use. Suppose that current obesity is a function of lagged obesity, plus the change in obesity between the lagged and current periods, e.g., $W_{it} = \Delta W_{it} + W_{it-1}$. Substituting for W_{it} in (2) (and also for X_{it} in the same way), we then estimate the model:

$$y_{itj} = \beta_0 + \beta_1 W_{it-1} + \beta_2 X_{it-1}(W_{it-1}) + \epsilon_{it}\big(Z_{it}\big(W_{it}(W_{it-1})\big), \Delta W_{it}, \Delta X_{it},\big) \quad (3)$$

The endogeneity problem likely would be reduced, depending on the extent of the correlation between current unobserved factors Z_{it} and lagged obesity. Where a subset of current unobserved variables, Z_{it}^{W}, causally affect current obesity (or physical activity rates), W_{it} and the need for long term care, this potential endogeneity problem is mitigated if lagged obesity/physical activity variables (W_{it-1}) are used. For example, if the person's current level of self-confidence is unobserved, and this leads to a need for care and also affects current obesity, then previous obesity rates are not endogenous. The problem remains if unobserved variables (e.g., self-confidence, stress, etc.) exert a historical effect on lagged obesity, in which this lagged effect also perpetuates direct impacts on current care use.

In short, potential endogeneity problems from any short-term (less than two years), unobserved, causal effects on obesity/physical activity are avoided. Where time-invariant factors are unobserved, this could cause bias. In theory, a fixed-effects approach also would reduce this endogeneity issue. The problem is that obesity rates also are largely time-invariant, providing relatively few cases (in which a change in obesity status has occurred) with which to work. Furthermore, with multinomial models, many observations will be predicted perfectly, again substantially limiting number of valid cases.

The feasible set of outcomes y_{itj} in the general (older) population includes the use of various types of long-term care support, no support, non-response and death. We estimate the model using multinomial logistic regression, which allows us to account for this range of outcomes simultaneously:

$$ln\left(\frac{p_{itj}}{p_{it1}}\right) = \beta_{0j} + W_{it-1}\beta_{1j} + X_{it-1}\beta_{xj} + \varepsilon_{it} \quad (4)$$

in which j refers to the category corresponding to the mode of care, and $p_{itj} = prob\left(y_{itj}|X_{it-1}, W_{it-1}\right)$ is the probability that the individual experiences outcome j. By focusing on future care use, we are relating current-wave obesity status to care use in two years' time.

3.1 Data and variables

ELSA is a longitudinal, bbiennial survey of individuals ages 50 and over with replacement. It was originally sampled from the pool of respondents to the Health Survey of England (1998, 1999, 2001). It collects a vast amount of data on individual and family circumstances and older people's quality of life. It explores the dynamic relationships between health and functioning, social networks and participation, and people's economic status during their pre-retirement and after-retirement periods. We pooled data from waves 1 to 5.

3.2 Variables

The dependent variable for the basic model is constructed based on responses to the set of questions on whether the person receives help from different sources for different reasons as a result of having difficulties with activities of daily living. The relevant questions differ between waves 1 and 2 and waves 3-5, which is reflected in Table 1. To avoid difficulties with correspondence and to ensure a reasonable share of cases per category, we aggregated to broader care categories, as shown in the table.

With respect to the future care use, we explored different specifications and decided to focus on two main specifications. The *basic* one categorises the dependent variable into four categories:

- respondent, no future care use (base category)
- respondent, any care used in the future
- non-respondent
- dead

The *extended* specification disaggregates future care use into several categories[1]:

- respondent, no future care use (base category)
- respondent, future informal care user
- respondent, future informal and privately purchased care user
- respondent, future formal care (care home and LA social care) user
- non-respondent
- dead

[1] We also tried the specification in which care home residents are placed into a separate category, but there was a small number of observations in this category per wave.

Keeping in line with existing literature, our main indicator for *obesity* is constructed from the body mass index (BMI). We classify respondents into four groups according to the World Health Organisation's (WHO) definition: underweight (BMI less than 18.5), normal weight (BMI 18.5 to 24.99), overweight (BMI 25 to 29.99) and obese (BMI of 30+). BMI was calculated directly for waves 2 and 4, and imputed for wave 1 (using wave 0 data). This was used as a risk factor for outcomes for waves 2, 3 and 5 [2] respectively.

The *physical activity* indicator in our analysis was based on the ELSA question about whether an individual is engaging in any of the following situations: (i) vigorous physical activity at least one to three times per month or more often; (ii) moderate physical activity at least once a week or more often; or (iii) light physical activity more than once per week.

Control factors included indicators of functional limitations and health conditions. We define *functional limitations* as a set of three variables operationalised as several limitations: (i) activities of daily living (ADLs), e.g., dressing, washing, transfer; (ii) instrumental activities of daily living (iADLs), e.g., shopping and meal preparation; and (iii) mobility, e.g., walking 100 yards .

A more extensive specification, in addition to the aforementioned variables, includes several controls for specific health conditions, such as high blood pressure, diabetes, cancer, lung disease, heart-related problems, stroke, psychiatric disorders and arthritis. Other control variables include respondents' ages, number of children, real-per-capita total household income and wealth, and indicators as to whether a respondent is female, has no educational qualifications, or is non-white, married, living alone, or owns his/her home, and time dummies [28-31].

[2] Excluding the data from waves 0/1 does not change the main results, buthowever it does prevent us from analysing heterogeneous effects due to the small sample size.

4 Results

4.1 Descriptive statistics

Table 2 presents summary statistics for the main sample used in the analysis, presented as a whole and by category. Overall, in the whole sample, 30% of respondents are receiving some type of care two years later, among which 1% are in nursing homes, 27% receive informal care, 3% receive formal care and 4% purchase care privately.

To gain insights into the nature of the relationship between care use and BMI, we initially conducted a simple (non-parametric) analysis using the LOWESS procedure (fitted using Stata 13). As could be seen from Figure 2, individuals with higher BMIs are far more likely to use care two years later across all forms, except for home care.

4.2 Any care specification

Table 3 shows the main results for the coefficients of interest from the estimation of (4), with standard errors clustered at the individual level (full estimation results are presented in Appendix Tables A1-A2). We estimate various specifications to explore the impact of the inclusion of additional controls on the magnitude of obesity and physical activity's effects on future care use. Relative Risk Ratios from the multinomial regressions are presented in sets of three columns, corresponding to the different main outcomes: care, non-response and death. These results are for the full sample of people ages 65 and up, with respondents who do not use any care being the base category.

As can be seen from column (1), obese people, compared with people at normal weights, are 1.75 times more likely to use some care two years later than not to use any care (controlling for death and non-response). If we add controls for health behaviours such as physical activity, smoking and drinking (column [2]), the effect's magnitude decreases somewhat, but still remains significant at 1.65.

Being physically active means that the person is 80% (100*[1-0.20]) less likely to use care. As we add demographic and socioeconomic controls, as well as ADL, iADL and mobility-limitation counts in the third specification (Table 3, column [3]), the effect from obesity and physical activity decreases further, but still remains statistically and economically significant: Obese individuals are 28% percent more likely to use care in the future, and those engaged in physical activity are 38% less likely.

Column (4) of Table 3 presents the specification that includes a full set of health risk factors, such as high blood pressure, diabetes, cancer, lung and heart problems, stroke, psychiatric problems and arthritis. As can be seen, the effect has decreased further, while still remaining at a significant magnitude: Being obese means that in two years, the person is around 25% more likely than the person at a normal weight to be using some form of care. Yet, those who are physically active are still 38% less likely to use care in the future.

In previous literature Flegal et al. [32] reported obesity as having some protective effect with respect to mortality. We find that overweight and obese individuals were ~20% less likely to be dead at follow-up. Yet those who are underweight are 2-2.5 times (depending on the specification) more likely to die in two years' time. With respect to our concerns of non-respondents, only being overweight is reducing the probability of being a non-respondent. Concerning other control variables, females are much more likely to use care in the future and are less likely to die. Those with no educational qualifications[3] are more likely to drop out of the survey or die, while exerting no effect on the probability of care among respondents. Married people and people with children are more likely and those living alone are less likely to use any care, which is expected, given that this is most likely driven by informal care.

[3] The ELSA educational qualification question lists the following options: (i) NVQ4/NVQ5/degree or equivalent; (ii) higher-education below a degree; (iii) NVQ3/GCE A-level equivalent; (iv) NVQ2/GCE O-level equivalent; (v) NVQ1/CSE other-grade equivalent; and (vi) Foreign/other qualification.

Neither home ownership, nor wealth or income exert any sizeable effect on any category. However, this may be because we control for limitations in (instrumental) activities of daily living, which are likely to be related to socioeconomic status [30]. As expected, indicators of impairment are positively related to the chance of using care. The health-condition controls also have the expected effects. Details on these estimates can be found in Appendix Tables A1 and A2.

4.3 Extended specifications

Rather than outcomes categorised as any care (or not), plus non-response and death, the analysis can be conducted using an extended set of outcomes. Columns (5)-(7) in Table 3 (panel A) show results in which care categories are defined as: (i) only informal care (IC); (ii) informal and privately purchased care (IC+PC); and (iii) formal care (both nursing homes and social care provided by Local Authorities) (FC). Respondents who receive the latter type of care are grouped in this category regardless of their use of informal or privately purchased care.

Obesity's impact on care use primarily is due to the effect on informal care, while the effect on privately purchased care or formal care is smaller (16% compared with 26%) and not statistically significant. However, the latter may be due to the relatively low number of cases in this category (see Table 1 for descriptive statistics). Simultaneously, physical activity's protective effect is large. Those engaged in physical activity are 36% less likely to use informal care, 27% less likely to use privately purchased/informal care and 64% less likely to use formal care (controlling for non-response and death).

Potentially, respondents' current care status may be driving the effect on future care use. To test this, we ran all the specifications on the sample, but restricted them to those who are currently not using any forms of care (see panel B in Table 3). We find almost no difference in the results between the two samples. If anything, the effect is larger in magnitude for the sample with no initial care use.

We also assess whether effect sizes regarding obesity and physical activity differ by gender. When estimating models with interaction terms on these variables, we find no statistically significant difference between genders with regards to obesity effects, but do find that physical activity is associated with a somewhat greater reduction in future care use for males than for females (any care model).

4.4 Sensitivity Analysis

To assess the results' robustness to different model specifications, we estimated a range of alternatives (see Table 4).

First, we investigated the use of the BMI-based obesity measures vs. an abdominal obesity measure. The abdominal obesity indicator is calculated as the waist-hip ratio (WHR) measurement, which was available in a sub-sample of the data. We found that WHR abdominal obesity was not significant when used alongside BMI-based measures. When only using WHR, the effect on informal care use was significant at the 10% level, with a relative risk of 1.12. While some suggestion exists in the literature about the abdominal obesity measure's superiority, this finding seems to show that, at least in the context of long-term care, the BMI-based obesity measure is of greater relevance.

Second, we considered pre-diabetes as an explanation for the obesity effect. ELSA also contains data on blood sugar levels for around a quarter of the sample, from which a 'pre-diabetes' indicator can be calculated using fasting blood glucose levels. This indicator can be used alongside an obesity measure as a likely immediate consequence of being obese. When both pre-diabetes and obesity indicators are used, both are insignificant, suggesting multi-collinearity.

Third, we explored subjective health and depression as explanations for the obesity effect. In the main analysis, we focussed mostly on the ADLs and iADLs as major determinants of care, plus health conditions that a doctor has diagnosed. We examine the effect of self-rated health state and the Centre for Epidemiologic Studies Depression scale as proxies for other yet-to-be-diagnosed health conditions. As reported in columns (3)-(4) in Table 4, when various combinations of these control factors were specified in the main model, we found no difference from the main result regarding effects from obesity and physical activity.

Column (5) reports the estimates from a regression in which counts of ADLs, iADLs and functional limitations two years later are included, i.e., not lagged with respect to the 'need care' outcome measure. Their inclusion reduces the significance and magnitude of obesity's effect. However, physical activity's effect remains significant. We might expect the current need for care to be highly correlated with current impairment rates (essentially by definition). Indeed, (lagged) obesity does not appear to affect care need beyond its effect on impairment rates. However, physical activity seems to exert a further distinct effect after controlling for current impairment rates. Column (6) tests for the interaction effect between obesity and several long-term health conditions. As can be seen, obesity's effect is again insignificant and reduced compared with the baseline specification, while the interaction terms are not statistically significant.

Although the indicator variables for obesity status in the main specification represented an obstacle to estimating the coefficients of interest, allowing for unobserved heterogeneity, we estimated an alternative specification with a quadratic function in BMI using the unobserved effect logit model. As Figure 3 shows, no statistically significant difference exists in the predictions from the two models.

One of the most discussed limitation of the multinomial logit modelis the assumption on the Independence of Irrelevant Alternatives (IIA). Several tests exist (most of which are incorporated into Stata routines), and we have implemented those that can be applied to the models with clustered standard errors: the Small-Hsiao Test and the one based on the Seemingly Unrelated Estimation (*suest* command in Stata). The results from the basic model with 'any care' category mostly supported the IIA assumption. The results for the extended model with several care categories turned out to be more problematic, as the tests in most specifications rejected the independence of other alternatives. We note that an agreement seems to exist in the literature, nonetheless, that both of the tests that we could apply perform rather poorly even in large samples [34-36]. Alternative estimators for the extended model specification that do not rely on IIA assumptions are computationally intensive and were not feasible, given the relatively low number of cases in the privately purchased and formal care categories, or else they require additional alternative specific information (e.g., distance to the nearest nursing home or prices of alternative modes of care), which was not available.

5 Discussion

5.1 Indicative Estimates of the Obesity Epidemic's Costs

Increasing obesity rates, among other things, imply greater care costs. An estimation of these costs can provide a sense of the obesity epidemic's full implications. In particular, we seek to calculate informal care's 'excess' costs that result from obesity. We start with a base year of 2009 – the last year of our sample with data on obesity – and consider the impact two years later (2011).

The proportion of people who are previously obese and need care is around 1.25 times greater than the proportion of previously non-obese people who need care, according to our estimates above. The excess number due to previous obesity can be determined as the difference between the number of people who previously were obese (but were not care users), assuming a 1.25

greater obesity effect and the number as though no such effect exists. The relative risk ratio (rrr) is:

$$rrr = \frac{\pi^1}{\pi^0} = \frac{\pi^0 \beta}{\pi^0} = \beta = 1.25 \tag{5}$$

in which $\pi^k = \frac{N_{1k}^t}{N_{1k}^t + N_{0k}^t}$, and N_{jk}^t is the population (at time t) who either have care needs or do not have any, denoted as $j = 0{,}1$ and obesity or not, denoted as $k = 0{,}1$. Accordingly, we can project the number of people at time $t + 1$ with care needs using the estimate of π^k and assuming that this rate remains unchanged over time:

$$N_{1k}^t = N_{0k}^t \left(\frac{\pi^k}{1 - \pi^k} \right) = N_{0k}^{t-1} \left(\frac{\pi^k}{1 - \pi^k} \right) \tag{6}$$

Moreover, the excess effect from obesity is the difference, Δ^t, between the projected number of people with care needs and (previous) obesity when (a) applying the estimated obesity effect rate π^1 and (b) assuming no obesity effect, i.e., applying π^0:

$$\begin{aligned} \Delta^t &= N_{11}^t - N_{11}^{t\pi^0} = N_{01}^{t-1} \left(\frac{\pi^1}{1 - \pi^1} \right) - N_{01}^{t-1} \left(\frac{\pi^0}{1 - \pi^0} \right) \\ &= N_{01}^{t-1} \pi^0 \left(\frac{\beta}{1 - \beta\pi^0} - \frac{1}{1 - \pi^0} \right) = N_{01}^{t-1} \pi^0 \frac{\beta - 1}{(1 - \beta\pi^0)(1 - \pi^0)} \end{aligned} \tag{7}$$

This calculation assumes no differential mortality rate between obese and non-obese people (as assumption that is largely consistent with our results above). The no-obesity-effect rate, π^0, is assumed to be the observed proportion of people in the ELSA sample in 2009 who used care, *but were not obese*, a rate of $\pi^0 = 0.175$. We use our estimation results of $\beta = 1.25$. The previous number of people who were obese and did not use care also is based on sample estimates from our data. In particular, we observe that around 20.78% of older people in the

2009 sample wave were obese, but not using care.[4] We apply this rate to England's population, giving N_{01}^{t-1} = 1.799 million people in this category, to calculate the excess effect in 2011.

This calculation also can be repeated for later pairs of years, e.g., 2013 compared with 2011. In this case, we uprate our starting value for the number of older people in 2011 who were obese, but not receiving care, using the projected changes in obesity rates as produced by Foresight (2007) (an average of 1.67% over a two-year period). We assume that this figure applies equally to all ages. Population change is based on the ONS population projections [37].

Table 5 shows this projection's results. We start with 20.78% of the age 65-and-up population who are obese and not using any care in row 4 for 2009 (a 1.67% biennial increase is applied to this number to obtain the corresponding share for 2013). Combining information from row 3 and row 4, we obtain the size of the obese population among those ages 65 and up who do not use any care in the current year (row 5).

Row 6 applies equation (7) to calculate Δ^t, i.e., the number of people who, over the two-year period, developed a need for informal care because they were obese, holding all other things constant. This 'excess' number of people in need of informal care corresponds to about 7.29% of the total number of informal care users.

We can estimate a cost associated with this excess effect by calculating a unit cost of informal care, as follows. First, we take estimates from our sample on the share of informal care users in the 65-and-up population, 21.90% in year 2009, and apply this share to the size of the older population and arrive at estimates of the numbers of informal care users in row 7. Second, we deflate the aforementioned estimate of the value of informal care: £55 billion in 2011 to £53.3

[4] The overall obesity rate, based on our sample, is 29.59%, slightly higher than the estimate of 27.88%, based on the 2009 Health Survey of England.

billion in 2009. Together, these figures provide the average value of informal care per care user in the amount of £28,410 per year (row 9).

Key financial results from the projections are provided in rows 10 and 12 in Table 5 (with corresponding percentages in rows 11 and 12). Applying the 2009 unit value of informal care to the numbers in row 6 (assuming no inflation and no wage growth) provides the estimate of the annual value of informal care linked to past obesity (row 10). In year 2011, it is calculated to be £3.9 billion, with a value of £4.3 billion in 2013. This amount can be interpreted as the excess use of informal care, which could have been avoided if obesity were addressed in people who did not use care two years ago. In other words, if the cost of addressing obesity via public health interventions among the 65-and-up population group was up to £3.9 billion in 2011, this would still represent an overall cost savings from a societal perspective.

For a comparison, Scarborough et al. [38] estimate the direct cost of both overweight and obesity to the NHS at £5.1 billion per year. Another comparison is made with the Public Health England budget: Programmes tackling obesity are funded from a ring-fenced, local authority grant, which in year 2015-2016 totalled £3.4 billion [39] and was not limited to obesity-focussed interventions or to the elderly population.

The second notable result is the additional cost of *increasing* obesity rates over time. All other things being equal, in 2009, obesity rates are associated with the excess number of informal care users is 137,000 in 2011. But starting in 2011, the equivalent figure is higher, at 151,000. This increase can be expressed in monetary terms (row 12), with the following interpretation: If obesity rates were halted at the 2009 level (for 2011), the cost of informal care would have been almost £400 million less two years later in 2011. In other words, halting further increases in obesity would have saved a projected £200 million per year in care costs.

These projections in cost terms are particularly sensitive to the assumed unit value of informal care. For example, using a value of half that in the tables would reduce all other financial figures by half. However, the results indicate the effect's considerable magnitude, given reasonable assumptions.

5.2 Study limitations

The study has several limitations. First, different types of long-term care exist, and effects might differ depending on type. Accordingly, we assessed the relationship between obesity and different types of long-term care, including formal and informal care. Second, unobserved control factors may exist that are associated with, but not caused by, obesity. Certain (pre-existing) conditions might cause obesity, as well as the disabilities that give rise to long-term care needs. Possible examples might include Vitamin D deficiency or psychological factors such as self-confidence/independence and willingness to cope. Where the analysis does not control for these pre-existing conditions, the observed impact from obesity on long-term care use might be somewhat biased. Using lagged obesity and physical activity measures should help mitigate (short-term) endogeneity issues. However, our test for the differences between the results with and without accounting for the unobserved factors reveals that the coefficients of interest are not affected.

6 Conclusions

The rising trend in the prevalence of obesity presents a challenge for future health care and social care needs. Although the impact on health care has received more attention, the implications from obesity in relation to long-term care utilisation and costs are not yet well understood. This paper explores the relationship between current obesity status and physical activity and future use of various modes of long-term care.

Using data from the English Longitudinal Study of Ageing and a cohort study design, we find a significant association between obesity indicators and future (two years hence) care use.

Control factors included various health conditions, ADLs, iADLs and mobility limitations, with the analysis also accounting for attrition due to non-response and death.

In line with existing literature, we expected obesity to be a risk factor for several long-term conditions (e.g., diabetes, arthritis, heart failure, etc.), as well as a cause of impaired functioning in everyday life through ADLs, iADLs and mobility limitations. Loss of functioning from either cause would increase the need for (and the benefits from) long-term care. Observed indicators of long-term conditions (e.g., reported/diagnosed chronic diseases) and impairment (e.g., reported failure to achieve ADLs) would be associated with increased use of services, all other things being equal.

We also hypothesised that obesity could be an independent, direct risk factor for future care use, even where these observed indicators were used in the estimation, for three reasons: First, because obesity is a proxy for undiagnosed/unobserved health conditions; second, because disability and 'need' are in part socially constructed so that being obese implies a need for care; and third, because assessment of need is imperfect and could put too much weight on overt indicators like obesity (although less so for physical activity). Similar arguments can be made about physical activity's effects, but in the opposite direction, reducing the need for long-term care.

Overall, we found a strong, significant association between obesity indicators and LTC use in the base model. This obesity effect on LTC use is almost entirely tied to the use of informal care, although as noted, we need to be aware of modelling limitations when estimating the effect on particular types of care. Regarding the different effects from obesity, with a full set of controls for other conditions and impairment, we also found a significant, but smaller, effect. With reference to (3), we found an overall effect: $\frac{\partial y_{it}}{\partial W_{it-1}} = \beta_1 + \beta_2 \frac{\partial X_{it-1}}{\partial W_{it-1}} > 0$. Controlling for other factors, X_{it}, we also found that $\frac{\partial y_{it}}{\partial W_{it-1}} > \beta_1 > 0$, which implies that part of the obesity effect lies in other factors, i.e., $\frac{\partial X_{it-1}}{\partial W_{it-1}} > 0$. The main, indirect obesity effect is picked up through changes in reported ADLs, iADLs and mobility limitations at the two-years-later stage. Exploring these effects' nature, we reach the conclusion that the additional development of problems with ADLs, iADLs and mobility limitations explains almost half the effect from obesity on future care use and about a quarter of the effect from physical activity. This is in line with current medical literature [40] that emphasises physical activity's protective effect against functional limitations, but also shows benefits from physical activity which reach beyong the improved health [41]. Although we find a significant 'direct' effect from obesity, we cannot rule out that this might impact the need for care via some unobserved factor ($\frac{\partial Z_{it-1}}{\partial W_{it-1}} > 0$). Nonetheless, we have included controls for the most theoretically likely factors and have taken some steps to address omitted variables.

In terms of the policy implications, we would argue that the 'direct' effects from obesity or physical activity are more likely to be influenced by the care system and local public policy. The indirect effects from obesity – especially as they work through impairment and chronic disease – fall more within the sphere of the health service.

Regarding the size of the direct effect from obesity, our main specification suggested that obese people are 25% more likely to use care. Simultaneously, those who engage in physical activity are 38% less likely to use care. These effect sizes concern the additional effects from obesity and physical activity after controlling for a range of health conditions that might themselves be caused or exacerbated, to some degree, by obesity or poor physical activity. The total effects are likely to be larger. Moreover, we have established the close association between long-term conditions and obesity (or physical activity) and the need for long-term care.

Applying our estimates from obesity's impact on future care use to the aforementioned value of informal care, at £55 billion in 2011, we find that the overall value of informal care linked to past obesity is around £3.9 billion per year, and that the increase in this cost, which is purely attributable to the upward trend in obesity, is almost £200 million per year. From an economic perspective, these numbers suggest that we could have invested up to these amounts to tackle obesity issues among the elderly. Both these figures, compared with the ring-fenced Public Health Budget (£3.4 billion in 2015-16), suggest a considerable underinvestment in measures addressing obesity epidemics from the societal perspective.

This study indicates obesity's importance in future care costs and provides rationale for promoting a healthier weight for economic benefits, in relation not only to health care, but also long-term care.

7 Declarations

7.1 Availability of Data and Materials

The datasets used and/or analysed during the current study is available from the UK Data Archive upon registration. All the information about the survey and how to access it is available at https://www.elsa-project.ac.uk/. The data were made available through the UK Data Archive. ELSA was developed by a team of researchers based at NatCen Social Research, University College London and the Institute for Fiscal Studies. The data were collected by NatCen Social Research. Funding was provided by the National Institute of Ageing in the United States and a consortium of UK government departments co-ordinated by the Office for National Statistics. The developers and funders of ELSA and the Archive do not bear any responsibility for the analyses or interpretations presented here.

7.2 Ethics declaration and consent to participate

ELSA was approved by the London Multicentre Research Ethics Committee (MREC/01/2/91), and informed consent was obtained from all participants.

7.3 Consent for publication

Not applicable.

7.4 Competing interests

The authors declare no competing interests.

7.5 Funding

This is independent research commissioned and funded by the NIHR/Policy Research Programme at the Department of Health and Social Care under the Quality and Outcomes of Person-Centred Care Research Unit (QORU) (Grant Number PRP 100/0001) – see www.qoru.ac.uk. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR, the Department of Health and Social Care or its arm's length bodies or other government departments.

7.6 Author's contributions

ON designed and managed the study, performed data analysis and drafted the manuscript. KG was responsible for the literature review and contributed to data analysis. JF contributed to the study design, interpretation of the results, manuscript preparation and finalisation. All authors read and approved the final manuscript.

7.7 Acknowledgements

Many thanks to the participants of the ILPN conference session on the Economics of Long-Term Care and the AUHE (University of Leeds) seminar's participants for their helpful comments and suggestions.

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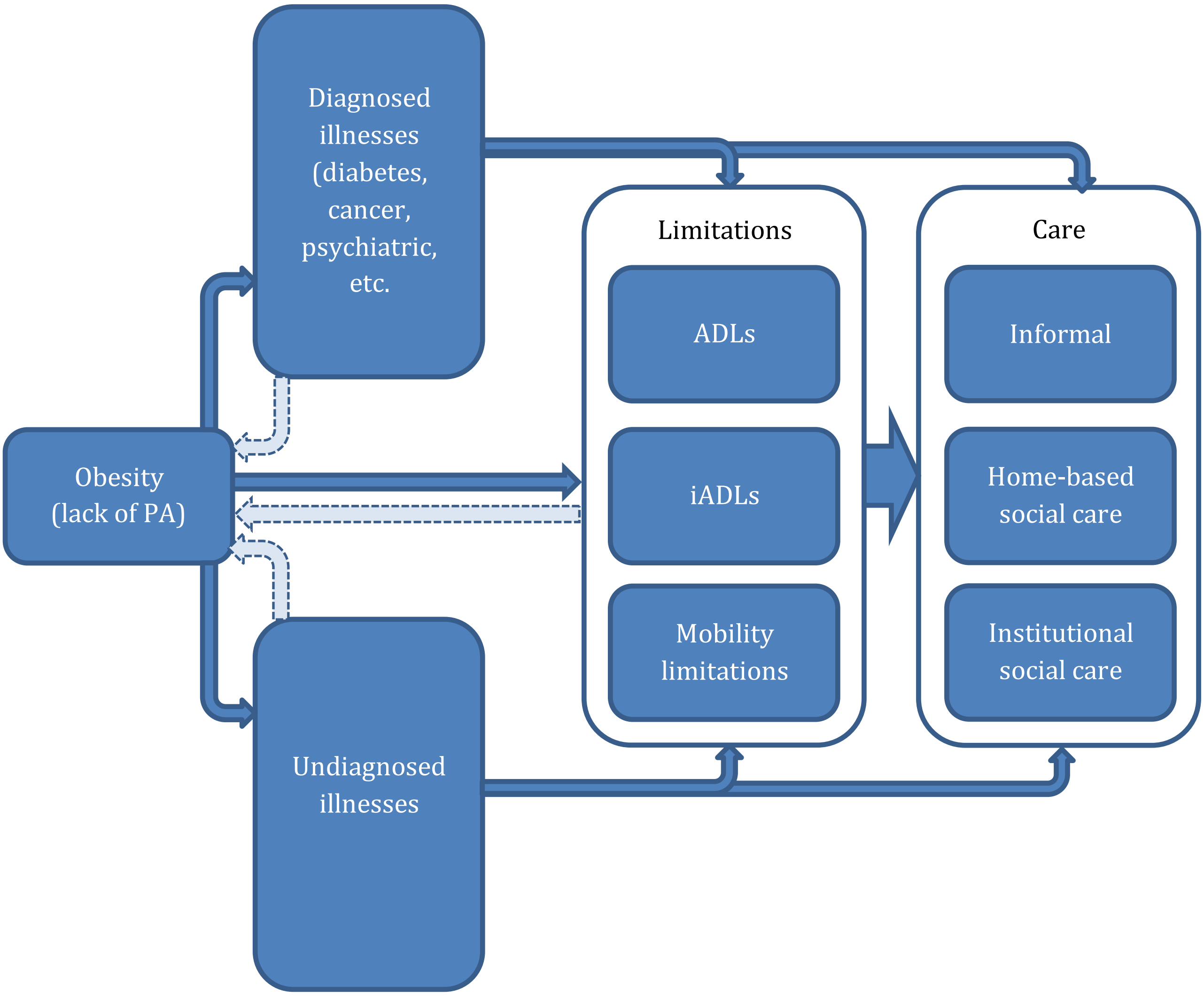

Figure 1 : Pathways of obesity's impact on future use of care.

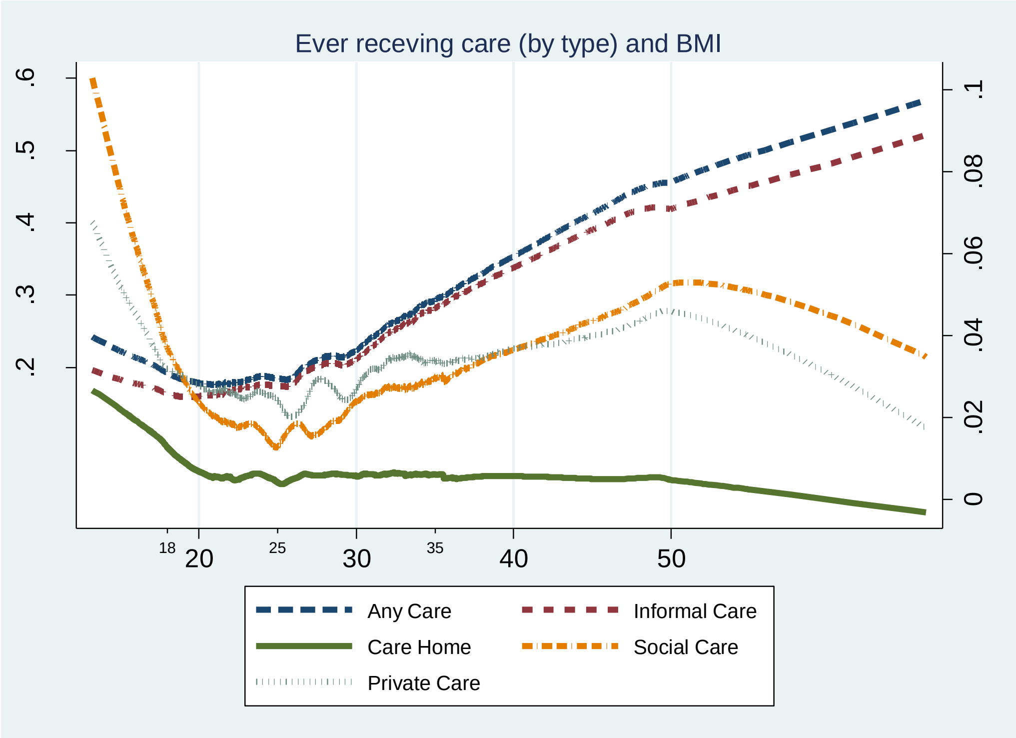

Figure 2 : Non-parametric relationship between care use and BMI 2 years ago.
Note: Any Care and Informal Care are on the scale of the left-hand y-axis, Care Home, Social Care and Private Care are on the scale of the right-hand y-axis.

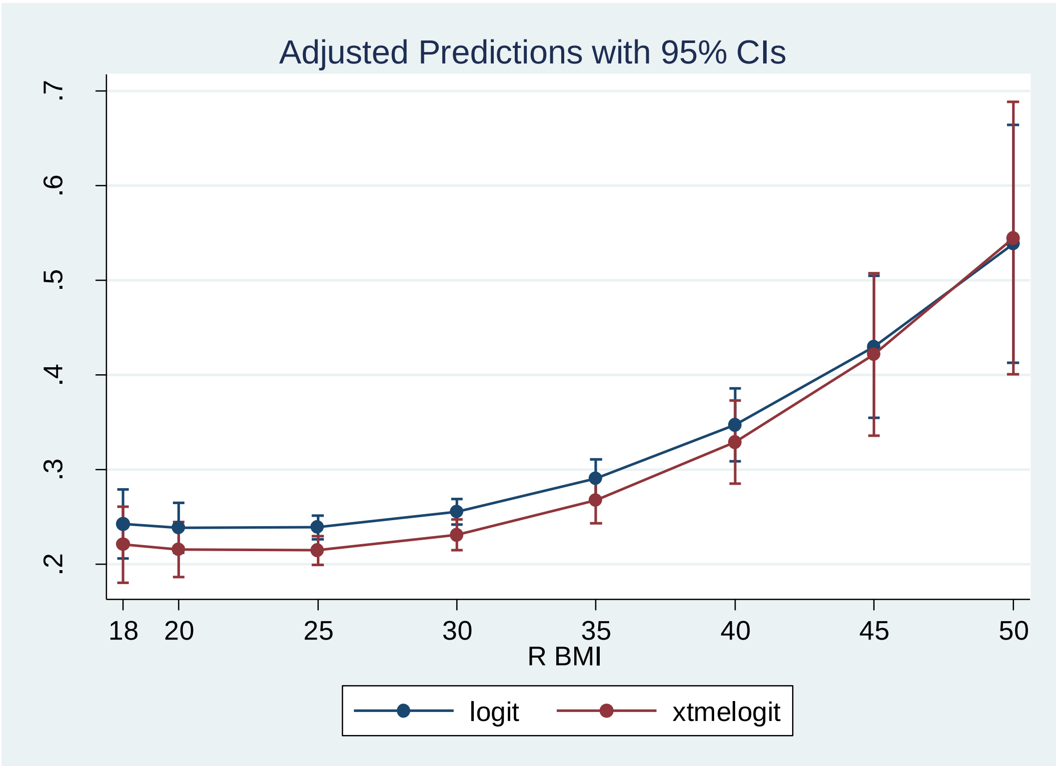

Figure 3 : Predicted probability of future care use from the model with and without unobserved effects.

Table 1: Wave Correspondence of Questions/Responses on Care Incidence.

Variable	Questions in waves 1-2	Questions in waves 3-5
	(1)	(2)
Any care received = 1 if answering 'yes' to at least one of the Qs	1. Individual outcome code (if in institution) 2. 'Thinking about the activities that you have problems with, does anyone ever help you with these activities (including your partner or other people in your household)?'	1. Individual outcome code (if in institution) 2. 'Functioning: whether ever has help with mobility, ADL, IADL'
	'Who helps you with these activities?'	'Whether receives help moving around house (wash/dress, preparing meals/eating, etc.) from…' asked individually
Informal care received	- husband/wife - mother/father - son - son-in-law - daughter - daughter-in-law - sister - brother - grandson - granddaughter - other relative - friend/neighbour - other person - unpaid volunteer	- spouse or partner - parent - son - son-in-law - daughter - daughter-in-law - sister - brother - grandson - granddaughter - other relative - friend/neighbour - other person - volunteer organisation
Formal care received	- social or health service worker	- social services/LA arranged care - nurse - other health or social services
Privately paid care	- privately paid employee	- privately arranged care
Nursing home care received	Derived from respondent's individual outcome code	Derived from respondent's individual outcome code

Table 2: Summary Statistics

	Whole sample	No care	Informal care (only)	Informal and privately paid care	Formal (care home/ LA care)	Non-response	Died
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
No. of observations	12323	7041	2504	347	187	1561	683
In care home	0.01				0.10**		
Any mode of care	0.30		1.00	1.00	1.00		
Informal care	0.27		1.00	0.31+	0.56**		
Formal care	0.02				0.95**		
Privately paid care	0.04			1.00	0.09**		
Underweight	0.01	0.01**	0.01	0.02	0.02	0.01	0.03**
Overweight	0.44	0.47**	0.39**	0.38*	0.36*	0.41*	0.40*
Obese	0.27	0.24**	0.36**	0.33*	0.32	0.27	0.23**
BMI	27.73	27.41**	28.81**	28.11	28.52*	27.61	26.87**
	[4.77]	[4.28]	[5.40]	[5.51]	[6.38]	[4.88]	[5.29]
Physical Exercise	0.84	0.93***	0.72***	0.71***	0.46***	0.79***	0.55***
Alcohol Drinking	0.86	0.89***	0.81***	0.84	0.64***	0.82***	0.77***
Smoked Ever	0.63	0.62***	0.65*	0.57**	0.63	0.65*	0.72***
R Smokes Now	0.11	0.10***	0.11	0.07**	0.13	0.13**	0.16***
Female	0.55	0.51**	0.64**	0.80**	0.73**	0.56	0.44**
No Educ Qualif	0.46	0.39**	0.54**	0.40*	0.59**	0.58**	0.59**
Non-white	0.01	0.01	0.01	0.01	0.01	0.03**	0.01
Age	73.87	72.37**	75.17**	78.57**	81.13**	74.20*	79.40**
	[6.91]	[5.87]	[6.99]	[6.92]	[9.22]	[7.21]	[8.74]
Married	0.57	0.59**	0.57	0.27**	0.17**	0.61**	0.45**
Number of Children	2.22	2.20*	2.42**	1.83**	1.89**	2.21	2.08*
	[1.53]	[1.45]	[1.61]	[1.48]	[1.77]	[1.59]	[1.69]
Living Alone	0.29	0.26**	0.28	0.55**	0.60**	0.27	0.40**
R Working	0.03	0.04**	0.01**	0.01*	0.00*	0.03	0.00**
Homeowner	0.73	0.78**	0.68**	0.75	0.51**	0.66**	0.61**
Real Per Capita Total HH Wealth 100K	149.45	177.05**	107.35**	167.42	83.09**	114.78**	107.47**
	[211.84]	[241.61]	[148.24]	[180.64]	[103.66]	[171.38]	[143.83]
Real Per Capita HH Total Income 1K	10.48	11.56**	8.91**	10.37	9.28*	8.90**	9.05**
	[8.49]	[9.53]	[6.22]	[6.60]	[4.67]	[6.75]	[7.80]
ADL count	0.46	0.18**	0.94**	0.89**	1.51**	0.56**	0.95**
	[0.99]	[0.54]	[1.29]	[1.30]	[1.52]	[1.13]	[1.38]
IADL count	0.43	0.14**	0.89**	0.96**	1.45**	0.51**	1.07**
	[0.88]	[0.44]	[1.14]	[0.99]	[1.20]	[0.96]	[1.30]
Mobility Limitations Count	2.32	1.39**	4.00**	4.35**	5.26**	2.45*	3.75**
	[2.48]	[1.79]	[2.58]	[2.56]	[2.58]	[2.60]	[2.71]

	Whole sample	No care	Informal care (only)	Informal and privately paid care	Formal (care home/ LA care)	Non-response	Died
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
High Blood Pressure	0.47	0.44**	0.54**	0.60**	0.63**	0.48	0.49
Diabetes	0.10	0.08**	0.13**	0.17**	0.14*	0.11	0.14**
Cancer	0.09	0.09**	0.09	0.11	0.12	0.08*	0.20**
Lung Disease	0.08	0.05**	0.11**	0.10	0.17**	0.08	0.16**
Heart Disease	0.26	0.20**	0.34**	0.36**	0.40**	0.27	0.40**
Stroke	0.06	0.04**	0.10**	0.11**	0.17**	0.07	0.12**
Psychiatric Problems	0.06	0.05**	0.07**	0.11**	0.06	0.05	0.05
Arthritis	0.42	0.34**	0.60**	0.64**	0.58**	0.41	0.43

Notes: ** indicates that the average for a specific category is statistically different from the average for the whole sample at a 1% level of significance, * - at the 5% level and + - at the 10% level.

Table 3: Simple vs. Extended Model Results

	Basic Model (Any Care)				Extended Model (Full controls)		
					IC	IC+PC	FC (NH+LA)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. All respondents ages 65 and up (N=12,323)							
Underweight	1.78*	1.57+	1.32	1.36	1.28	1.53	1.73
	(0.42)	(0.37)	(0.35)	(0.36)	(0.36)	(0.83)	(1.02)
Overweight	0.93	0.96	0.98	0.96	0.96	0.99	1.02
	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)	(0.15)	(0.20)
Obese	1.75**	1.65**	1.28**	1.25**	1.26**	1.27	1.16
	(0.12)	(0.11)	(0.09)	(0.09)	(0.10)	(0.21)	(0.26)
Physical Activity		0.20**	0.62**	0.62**	0.64**	0.73*	0.36**
		(0.01)	(0.05)	(0.05)	(0.05)	(0.11)	(0.07)
Panel B. Respondents age 65 and up with no care initially (N=8,770)							
Underweight	1.77+	1.66	1.41	1.44	1.42	1.16	1.90
	(0.58)	(0.54)	(0.47)	(0.49)	(0.53)	(1.09)	(2.13)
Overweight	0.99	0.99	0.97	0.93	0.92	1.20	0.68
	(0.08)	(0.08)	(0.08)	(0.08)	(0.09)	(0.27)	(0.25)
Obese	1.71**	1.65**	1.34**	1.27*	1.30*	1.32	0.80
	(0.15)	(0.14)	(0.13)	(0.12)	(0.13)	(0.34)	(0.35)
Physical Activity	1.77+	0.40**	0.65**	0.66**	0.66**	0.82	0.47*
	(0.58)	(0.04)	(0.08)	(0.08)	(0.08)	(0.23)	(0.18)
Controls:							
Health behaviours	No	Yes	Yes	Yes	Yes		
Socio-demographic _ functional limitations	No	No	Yes	Yes	Yes		
Diagnosed health conditions	No	No	No	Yes	Yes		

Table 4: Relative Risk Ratios From Multinomial Logit--Sensitivity Check With Basic Model

	Basic Model (Any Care)					
	(1)	(2)	(3)	(4)	(5)	(6)
Underweight	1.36	1.39	1.28	1.25	2.03*	1.43
	(0.36)	(0.36)	(0.34)	(0.33)	(0.63)	(0.59)
Overweight	0.96	0.96	0.97	0.97	0.95	1.06
	(0.06)	(0.06)	(0.06)	(0.07)	(0.08)	(0.12)
Obese	1.25**	1.25**	1.24**	1.24**	1.15	1.14
	(0.09)	(0.09)	(0.09)	(0.09)	(0.11)	(0.15)
Physical Activity	0.62**	0.62**	0.65**	0.65**	0.74**	0.62**
	(0.05)	(0.05)	(0.05)	(0.05)	(0.08)	(0.05)
Added/excluded controls						
Full controls for health and health behaviours	Yes	No alcohol	Yes	Yes	Yes	Yes
Self-rated health good			0.60**	0.59**		
or better			(0.04)	(0.04)		
CESD score				1.00		
				(0.02)		
Concurrent characteristics						
N ADLs					1.08	
					(0.07)	
N iADLs					4.09**	
					(0.31)	
N of mobility					1.41**	
limitations					(0.03)	
Underweight						0.98
*N(comorbidities)						(0.25)
Overweight						0.94
*N(comorbidities)						(0.05)
Obese						1.04
*N(comorbidities)						(0.06)

Table 5: Estimates of obesity epidemics' future costs in terms of informal care's value

		2009	2011	2013
1	Total population, 000	52,640	53,110	53,870
2	% 65 plus	16.27%	16.44%	17.27%
3	Population 65 plus, 000	8,565	8,731	9,303
4	% obese among 65 plus, no care use	20.78%	22.45%	24.12%
5	Obese population 65 plus, no care use (N_{01}^{t-1})	1,779,917	1,960,386	2,244,194
6	Excess number of informal care users due to obesity, compared with previous period		136,671	150,528
7	Informal care users 65 plus (2009)	1,875,970	7.29%	8.02%
8	Value of informal care per year, 000 GBP	53,300,000		
9	Average annual value of informal care per care user, GBP	28410		
10	Value of informal care per year linked to past obesity, 000 GBP		£3,882,813	£4,276,497
11	Value of informal care linked to past obesity, % of total		7.28%	8.02%
12	Annual increase in value of informal care per year linked to obesity epidemic, 000 GBP			£393,684
13	Annual increase in value of informal care per year linked to obesity epidemic, % total			0.74%

Appendix

Table A1: Relative Risk Ratios from Multinomial Logit – No controls, Partial Controls A

	No controls			Partial controls A		
	Any care	Non-response	Died	Any care	Non-response	Died
	(1)	(2)	(3)	(4)	(5)	(6)
Underweight	1.78*	1.37	3.05**	1.57+	1.21	2.45**
	(0.42)	-0.41	-0.87	-0.37	-0.37	-0.73
Overweight	0.93	0.82**	0.68**	0.96	0.85*	0.73**
	(0.06)	-0.06	-0.06	-0.06	-0.06	-0.07
Obese	**1.75****	1.13	0.80*	**1.65****	1.1	0.75*
	(0.12)	-0.09	-0.09	-0.11	-0.09	-0.09
Physical Activity				**0.20****	0.31**	0.10**
				-0.01	-0.02	-0.01
Drink				0.53**	0.57**	0.48**
				-0.04	-0.05	-0.05
Smoked ever				1.11+	1.15*	1.59**
				-0.06	-0.07	-0.15
Smoke now				0.87	1.02	1.01
				-0.08	-0.1	-0.13
Wave=2	0.57**	0.47**	0.40**	0.60**	0.49**	0.43**
	-0.03	-0.03	-0.04	-0.03	-0.03	-0.05
Wave=4	0.53**	0.25**	0.42**	0.55**	0.26**	0.45**
	-0.03	-0.02	-0.04	-0.03	-0.02	-0.05
Observations	12,323			12,323		
Pseudo R2	0.0267			0.0737		

Notes: All regressions include time dummies, and standard errors are clustered at individual levels. ** indicates significance at 1% level, * at 5% level and + at 10% level.

Table A2: Relative Risk Ratios From Multinomial Logit – Partial Controls B, Full Controls

	Partial controls B			Full controls		
	Any care	Non-response	Died	Any care	Non-response	Died
	(1)	(2)	(3)	(4)	(5)	(6)
Underweight	1.32	1.2	2.50**	1.36	1.18	2.33*
	-0.35	-0.38	-0.82	-0.36	-0.38	-0.78
Overweight	0.98	0.84*	0.77*	0.96	0.83*	0.77*
	-0.06	-0.06	-0.08	-0.06	-0.06	-0.08
Obese	**1.28****	0.94	0.79+	**1.25****	0.93	0.79+
	-0.09	-0.08	-0.1	-0.09	-0.08	-0.1
Physical Activity	**0.62****	0.57**	0.34**	**0.62****	0.58**	0.35**
	-0.05	-0.05	-0.04	-0.05	-0.05	-0.04
Drink	0.84*	0.75**	0.67**	0.86*	0.76**	0.70**
	-0.06	-0.06	-0.08	-0.07	-0.07	-0.08
Smoked ever	1.06	1.1	1.26*	1.04	1.09	1.18
	-0.06	-0.08	-0.13	-0.06	-0.07	-0.12
Smoke now	0.91	0.98	1.40*	0.93	0.99	1.42*
	-0.08	-0.1	-0.2	-0.09	-0.1	-0.2
Female	1.42**	1.15*	0.51**	1.44**	1.18*	0.55**
	-0.09	-0.08	-0.05	-0.09	-0.08	-0.06
No Educ Qualif	0.96	1.44**	1.26*	0.98	1.45**	1.30**
	-0.06	-0.1	-0.12	-0.06	-0.1	-0.13
Non-white	0.79	1.68*	0.87	0.81	1.69*	0.99
	-0.19	-0.38	-0.37	-0.19	-0.38	-0.42
Age	1.06**	1.04**	1.11**	1.06**	1.04**	1.11**
	0	-0.01	-0.01	0	-0.01	-0.01
Married	1.19*	1.43**	0.99	1.20*	1.43**	1.01
	-0.1	-0.14	-0.13	-0.1	-0.14	-0.14
Number of Children	1.04*	0.98	0.97	1.03+	0.98	0.96
	-0.02	-0.02	-0.03	-0.02	-0.02	-0.03
Living Alone	0.76**	0.78*	0.81	0.75**	0.77*	0.81
	-0.07	-0.08	-0.11	-0.07	-0.08	-0.11
Working	0.67+	1.29	0.45	0.72	1.32	0.51
	-0.14	-0.23	-0.27	-0.15	-0.24	-0.31
Homeowner	1.05	0.76**	0.84+	1.07	0.76**	0.82+
	-0.07	-0.06	-0.09	-0.07	-0.06	-0.09
Real per Capita Total HH Wealth	1.00**	1.00*	1.00	1.00	1.00+	1.00
100K	0.00	0.00	0.00	0.00	0.00	0.00
Real per Capita HH Total Income	1.00*	1.00+	1.00+	1	1.00*	1.00+
1K	0.00	0.00	0.00	0.00	0.00	0.00
ADL Count	1.15**	1.26**	1.14*	1.15**	1.26**	1.14*
	-0.05	-0.06	-0.06	-0.05	-0.06	-0.06
IADL Count	1.79**	1.62**	1.95**	1.76**	1.60**	1.89**
	-0.09	-0.08	-0.12	-0.09	-0.08	-0.11
Mobility limitations	1.38**	1.08**	1.24**	1.32**	1.06**	1.20**
Count	-0.02	-0.02	-0.03	-0.02	-0.02	-0.03

	Partial controls B			Full controls		
	Any care	Non-response	Died	Any care	Non-response	Died
	(1)	(2)	(3)	(4)	(5)	(6)
High blood pressure				1.12*	1.06	1.07
				-0.06	-0.07	-0.1
Diabetes				1.15	1.05	1.30+
				-0.10	-0.11	-0.18
Cancer				1.04	1.01	2.82**
				-0.09	-0.11	-0.35
Lung disease				1.31*	1.15	1.75**
				-0.14	-0.14	-0.26
Heart disease				1.30**	1.24**	1.64**
				-0.08	-0.09	-0.16
Stroke				1.44**	1.28+	1.35+
				-0.17	-0.17	-0.22
Psychiatric disorders				1.23+	1.03	0.97
				-0.15	-0.15	-0.21
Arthritis				1.41**	1.07	0.93
				-0.08	-0.07	-0.09
Wave=2	1.83**	3.38**	2.23**	1.98**	3.46**	2.50**
	-0.12	-0.29	-0.26	-0.13	-0.3	-0.3
Wave=4	0.93	1.65**	0.85	0.95	1.66**	0.9
	-0.06	-0.15	-0.11	-0.07	-0.15	-0.12
Observations	12,323			12,323		
Pseudo R2	0.1786			0.1841		

Notes: All regressions include time dummies, and standard errors are clustered at the individual level. ** indicates significance at 1% level, * at 5% level and + at 10% level.