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Article

Social determinants of multimorbidity and multiple functional limitations among the ageing population of England, 2002–2015

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ABSTRACT

This study explores longitudinal relationships between material, psycho-social and behavioural social determinants of health and multimorbidity of people aged 50 years or older in England. We used data from the English Longitudinal Study of Ageing collected biannually between 2002 and 2015. Apart from the basic measure of multimorbidity (two or more diseases within a person) we constructed two distinct measures of health in order to take into account the biology of ageing (complex multimorbidity and multiple functional limitations).

We found that the likelihood of multimorbidity and multiple functional limitations was consistently associated with the levels of household wealth, sense of control over one's life, physical activity and loneliness. Larger health inequalities were observed when health was measured as complex multimorbidity and multiple functional limitations than basic multimorbidity. Compared to the population group with the highest wealth, those with the lowest wealth had 47% higher odds of basic multimorbidity (95% C.I. 1.34-1.61), 73% higher odds of complex multimorbidity (95% C.I. 1.52-1.96) and 90% higher odds of having 10 or more functional limitations (95% C.I. 1.59-2.26). We did not find a dose-response relationship between alcohol consumption, smoking and multimorbidity but rather evidence of people in ill health actively moderating their health behaviour.

We suggest that materialist models of multimorbidity and functional limitation at older age can not, on their own, explain the health inequalities as the behavioural and psycho-social factors play an important role. Policies aiming to reduce the risk of multimorbidity and functional limitation should address the issue at these three levels simultaneously, using the existing national infrastructure of General Practices.

1. Introduction

Multimorbidity, the co-occurrence of two or more diseases within a person, affects over a quarter of primary care patients older than 18 years of age in England (Cassell et al., 2018). Individuals with multimorbidity have higher rates of GP consultations, prescriptions, and hospitalisations compared to people without multimorbidity (Salisbury, Johnson, Purdy, Valderas, & Montgomery, 2011; Cassell et al., 2018). Multimorbidity also leads to lower health-related quality of life (Bayliss et al., 2012; Peters et al., 2018) and decline in physical functioning (Jindai et al., 2016). Multimorbidity among people older than 65 years in England is set to rise with prevalence projected to increase from 54% in 2015 to 67.8% in 2035 (Kingston et al., 2018). People will live longer lives in worse health and this will increase the utilization of health services and the costs of health care (Cassell et al., 2018; Kingston et al., 2018).

While current studies of multimorbidity focus on the impact of biomedical and socio-demographic characteristics on patients' individual risk (Northwood, Ploeg, Markle-Reid, & Sherifali, 2018), we also need to understand the extra-individual factors contributing to the increase of multiple health problems in the ageing population. Only a few studies have examined simultaneously longitudinal trends in multimorbidity and their relationship with extra-individual factors such as society and environment (Dhalwani et al., 2017; Jackson, Dobson, Tooth, & Mishra, 2015; Mounce et al., 2018; Schäfer et al., 2012). None of them referred to any theoretical framework that would justify the choice of the contextual characteristics. This leads to the risk of omitting relevant factors which might explain more of the outcome variance and to exaggerating effects of the observed characteristics (Frohlich, Corin, & Potvin, 2001). Choosing an appropriate measure should be

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backed by theory too. For instance, education and income reflect different mechanisms through which socio-economic status operates (Demakakos, Nazroo, Breeze, & Marmot, 2008). We argue that multimorbidity should be studied with the help of the theories of *social determinants of health* (SDoH). These refer to the social, cultural, economic, and political conditions that influence the health of individuals and populations (De Maio, Mazzeo, & Ritchie, 2013; Lucyk & McLaren, 2017).

Multimorbidity in older people may have a different profile than that found in younger people. For example the prevalence of cardiovascular and neurological patterns (including dementia and Alzheimer's disease) in England increases with age while mental health disorders are more common among younger people (Public Health England, 2018). Further, we suggest that measuring multiple health problems of older people should be consistent with our knowledge of biological ageing. The concept of multimorbidity should reflect the build-up of damage within cells (Austad, 2009; Barnes, 2015; Kirkwood, 2008) that accumulates during the life course and leads to a chronic dysregulation of multiple body systems (Fabbri et al., 2015; Li et al., 2015). Accumulation of diseases is a milestone for system dysregulation, loss of resilience and accelerated ageing (Fabbri et al., 2015). The role of body systems in development of multimorbidity is beginning to receive some attention (Yarnall et al., 2017).

Our study seeks to address these gaps in understanding multimorbidity of ageing people. Along the basic definition of multimorbidity (Van den Akker, Buntinx, Metsemakers, Roos, & Knottnerus, 1998) we propose two measures of health which in our view better reflect the biological process of ageing: *complex multimorbidity* (Harrison, Britt & Henderson, 2014) and *multiple functional limitations*. These outcomes should not be omitted when studying multimorbidity as they have implications for quality of life, need for health care and residential care, and premature mortality of old people (Jindai, Nielson, Vorderstrasse, & Quiñones, 2016; Zulman, Pal & Wagner, 2015). Our approach is also novel in that it brings together new measures of multimorbidity and functional limitation with social theory of SDoH in a longitudinal design. The aim of our study is to explore the association of material, psycho-social and behavioural determinants to the probability of developing basic multimorbidity, complex multimorbidity and multiple functional limitations in the ageing population of England over a 14 year period.

1.1. Theoretical framework

Our starting point is the centrality of dysfunction in several body systems that is conducive to multiple impairment, limitation and disease. We postulate that if we can identify diverse social determinants that simultaneously affect an individual, changes could be observed across a number of body systems that will be involved in generating compound health outcomes. Here we follow the Generalized Health Impact model by White, O'Campo, Moineddin, and Matheson (2013) that showed how a combination of social determinants (stress, poverty or quality of housing) generated a range of host responses encompassing more than one health condition. This model informed our approach to the choice of social determinants and for measuring multimorbidity and multiple functional limitations.

1.2. Measuring multimorbidity and multiple functional limitations

Multimorbidity has been measured by a range of methods. In primary care settings, indices based on diagnostic or pharmaceutical data have been used such as Charlson Index, Adjusted Clinical Groups System or Cumulative Illness Index Rating Scale (Diederichs, Berger, & Bartels, 2011). Multimorbidity estimates in general populations are based on a simple unweighted enumeration of the number of diseases. The most common definition is "the co-occurrence of two or more diseases within a person" (Van den Akker et al., 1998) but different cut-off points have been used too (Marengoni et al., 2011). In our study this measure will be called *basic multimorbidity* in order to distinguish it from two other measures. The limitation of the concept of basic multimorbidity is that it leads to very high estimates among old people (55% to 98% between studies) which may be less informative than other definitions (Marengoni et al., 2011). Neither does it differentiate between the co-occurrence developing within one body system and two or more systems. Multimorbidity may have a larger impact on overall health if it arises out of disparate conditions (such as physical and mental health) rather than closely related comorbidities (Piette & Kerr, 2006; Yarnall et al., 2017).

The construct of complex multimorbidity addresses these issues. It has been defined as "the co-occurrence of three or more chronic conditions affecting three or more different body systems within one person without an index chronic condition" (Harrison, Britt, Miller, & Henderson, 2014, p. 8). Individuals with chronic conditions in 3 + body systems may require more complex care, as chronic conditions in different body systems are likely to compete for treatment, while conditions within the same system are more likely to be complementary (Piette & Kerr, 2006). With regard to the theories of ageing based on dysregulation of body systems described earlier, we argue that complex multimorbidity might be a more appropriate measure for ageing people than basic multimorbidity.

Finally, the measure of multiple functional limitations provides an idea of the impact of multimorbidity on the ageing population. Functional limitations are defined as restrictions in performing vital situation-free physical actions needed in everyday life (Verbrugge & Jette, 1994). This aspect is important as some morbidities (e.g. high blood pressure) may have less of an impact on the quality of life than others (e.g. arthritis). The measure of multiple functional limitations reflects the knowledge that the proportion of old people with physical impairments and limitations in multiple body systems increases with age (Burden of Disease Network Project, 2004; Jindai et al., 2016). Most studies have explored prevalence and effects of single impairments or functional limitations but we know less about the relationships between combined burden of impairments and functional limitations and social determinants (Burden of Disease Network Project, 2004).

1.3. Social determinants

The theoretical approach to health inequalities and the role of SDoH in the UK was shaped by the publication of the Black Report in 1980 that concluded that material conditions were the major determinant of health and premature mortality (Black, 1992). This led to discussions between proponents of the materialist explanations and those who claimed that health inequalities are result of culturally mediated choices and behaviours (Bartley, 2004; Cockerham, 2007). The debate has been enriched by a third perspective, the role of psycho-social factors highlighted in the Whitehall II Study (Marmot et al., 1991). The current approach is to understand these hypotheses as complimentary rather than mutually exclusive and to assess their effects in one model with three groups of determinants (Robertson, Benzeval, Whitley, & Popham, 2015; Van Oort, Van Lenthe, & Mackenbach, 2005).

Material determinants refer to the distribution of income and wealth in society and to resources that allow people to secure goods and services needed for a healthy life, e.g. housing, healthcare (Bartley, 2004; Cockerham, 2007). Attained education can be interpreted as another type of material resource as it mediates health risks on the pathway between childhood conditions and occupational level, income and accumulated wealth in later life (Northwood, Ploeg, Markle-Reid, & Sherifali, 2018). Studies of the ageing population in England and the UK found disparities by socio-economic status (SES) for a range of health outcomes (Nazroo, Zaninotto, and Gjonca, 2008). The few longitudinal studies of multimorbidity showed associations with low education, low household income, difficulties managing on income and total household wealth (Jackson et al., 2015; Mounce et al., 2018;

Table 1
Health data used in the analysis.

	Morbidities	Body systems		Functional limitations
1	High blood pressure	**1. Eye disorders**		**General mobility**
2	Angina	1.1. Glaucoma	1	Walking 100 yards
3	Congested heart failure	1.2. Macular degeneration	2	Sitting for 2 hrs
4	Heart murmur	1.4. Cataracts	3	Getting up from chair
5	Abnormal heart rhythm	**2. Circulatory disorders**	4	Climbing several flights of stairs
6	Heart attack	2.1. High blood pressure	5	Climbing one flight of stairs
7	Diabetes	2.2. Angina	6	Stooping, kneeling or crouching
8	Stroke	2.3. Heart attack	7	Reaching arms above shoulders
9	Lung disease	2.4. Congestive heart failure	8	Pulling or pushing a chair
10	Asthma	2.5. Heart murmur	9	Lifting/carrying weights over 10 pounds
11	Arthritis	2.6. Abnormal heart rhythm	10	Picking up a 5p coin
12	Osteoporosis	2.7. Stroke		**Activities of daily living**
13	Cancer	**3. Endocrine, nutritional and metabolic**	11	Dressing, including putting on shoes and socks
14	Parkinson's disease	3.1 Diabetic eye disease	12	Walking across a room
15	Dementia	3.2. Diabetes	13	Bathing or showering
16	Alzheimer's disease	**4. Musculoskeletal and connective system**	14	Eating, such as cutting up your food
17	Hallucinations	4.1. Osteoporosis	15	Getting in or out of bed
18	Anxiety	4.2. Arthritis	16	Using the toilet, including getting up or down
19	Depression	**5. Respiratory**	17	Using a map to figure out how to get around
20	Emotional problems	5.1. Lung disease	18	Preparing a hot meal
21	Mood swings	5.2. Asthma	19	Shopping for groceries
22	Glaucoma	**6. Neoplasms**	20	Making telephone calls
23	Diabetic eye disease	6.1. Cancers	21	Taking medications
24	Macular degeneration	**7. Nervous disorders**	22	Doing work around the house or garden
25	Cataracts	7.1. Parkinson's disease	23	Managing money (paying bills, track of expenses)
		7.2. Alzheimer's disease		**Symptoms**
		7.3. Hallucinations	24	Difficulty walking 0.25 mile
		8. Mental and behavioural	25	Pain in general
		8.1. Anxiety	26	Problems with eyesight
		8.2. Depression	27	Problems with hearing
		8.3. Emotional problems	28	Balance on level surface
		8.4. Mood swings	29	Dizzy walking on level surface

Schäfer et al., 2012). Lower level of education, manual occupation and poor social network predicted higher number of functional limitations in the Swedish population older than 60 years of age (Calderón-Larrañaga et al., 2018). Subjective social status (SSS) has been referred to as a subjective measure of SES as it reflects individual's *perceived* standing in a social hierarchy and hence can be included in the group of material determinants (Singh-Manoux, Marmot, & Adler, 2005). SSS also reflects perceptions of stress and the sense of social inequality (Charonis et al., 2017). To our knowledge there are no studies of how SSS is related to multimorbidity and only one study examined its association with functional decline (Chen, Covinsky, Cenzer, Adler, & Williams, 2012).

Psycho-social determinants, such as leisure and social activities and social networks and contacts, are increasingly more relevant to older people's idea of healthy ageing (Bowling, 2008; Cosco, Prina, & Perales, 2013). Social networks affect health via pathways such as provision of social support, social influence, social engagement and attachment, and access to resources and goods (Berkman & et al., 2010). Living as a couple, in a family, having a large social network and having a sense of control over one's life were all protective factors reducing the risk of multimorbidity (Marengoni et al., 2011; Melis, Marengoni, Angleman, & Fratiglioni, 2014). Older multimorbid people with a supportive social network have longer survival time compared to those without social support (Olaya et al., 2017). Loneliness has been found positively associated with multimorbidity in England, although the relationship was stronger for people younger than 44 than for people older than 65 (Stickley & Koyanagi, 2018). The stress-buffering hypothesis suggests that social relationships can provide resources that buffer the effect of stress on health (Gellert et al., 2018; Uchino, 2009). The direct effects' model says that social networks can facilitate positive health behaviours and access to health care by providing resources such as material assistance or transportation (Olaya et al., 2017).

Behavioural determinants describe different types of consumption and leisure activities that directly affect health and are, to some extent, subject to individual choice and decision-making (Bartley, 2004). Multimorbidity is associated with levels of physical activity, fruit and alcohol consumption, smoking tobacco and Body Mass Index (Dhalwani et al., 2017). However, while sociology of health has began to describe an interplay between human agency and social structure (Cockerham, 2007), health behaviours are still treated in isolation from other social determinants (Moor, Spallek, & Richter, 2016).

Each type of social determinant can work through any or several of the body systems (Blane, Kelly-Irving, D'Errico, Bartley, & Montgomery, 2013). For instance, occupation can affect respiratory, endocrine or cardiovascular system through toxins at work (Agency for Toxic Substances & Disease Registry, 2018) or nervous system and immune system through stress (Marmot et al., 1991). Smoking tobacco can affect nervous, respiratory, cardiovascular or digestive systems through both inhaled carcinogens and lower self-esteem (Bartley, 2004). These examples illustrate our assumption that the combined long-term impact of material, psycho-social and behavioural determinants should be sufficiently wide to be observable across a range of body systems through our measures of complex multimorbidity and multiple functional limitations.

2. Material and methods

2.1. Data

The English Longitudinal Study of Ageing (ELSA) is a multidisciplinary panel study of a representative sample of men and women aged 50 years and over living in England. ELSA explores the dynamics between ageing and demographic, socio-economic, psychological and health factors. The study began in 2002 with 12,099 participants and the sample is re-examined every two years. It was replenished at waves 3, 4, 6 and 7 with new participants to maintain the size and

representativeness of the study (Steptoe et al., 2013). We used data from the core members. ELSA defines core members as individuals who met the following survey criteria: they fit the age eligibility criteria (aged 50 years or older), took part in the original HSE survey that served as the basis for ELSA, and participated in wave 1 of ELSA or joined later as part of the refreshment samples. The cohabiting partners or household members are not included. Data on psycho-social characteristics come from self-completion interviews and all other data from personal interviews.

2.2. Dependent variables: measures of health

We used data on 25 physical and mental health conditions that were consistently recorded at each wave (Table 1). Respondents were asked whether they still had any of the medically diagnosed conditions or whether they had a new condition. This was coded as a binary variable with the value of 1 meaning the presence of a condition and 0 for its absence. The data were grouped into three categories: individual morbidities, groups representing body systems and functional limitations, a decision based on Verbrugge and Jette's Disablement Process Framework (1994). We decided to enlarge their category 'functional limitations' by including instances of impairment (dysfunction and abnormalities in body systems) and disability (difficulty with daily activities) (Table 1).

2.2.1. Measure 1: basic multimorbidity (MM)

A binary variable was created in order to identify participants at each wave who had two or more morbidities. At each wave this variable was composed of the data fed forward from the previous wave and the data on newly reported morbidities.

2.2.2. Measure 2: complex multimorbidity (CMM)

Individuals with three or more body systems affected by disease were considered as having CMM. Body systems were represented by the Chapters of the International Classification of Diseases 10th Revision (ICD-10) (Table 1). A patient with CMM had one or more chronic conditions within each of three or more different ICD-10 Chapters.

We also checked for potential biases between the basic measure of MM with CMM given that the cutpoint of two morbidities is used in the former while the latter uses three morbidities in distinct body systems. We created a version of basic MM with a cutpoint for 3 morbidities for fairer comparisons and re-ran all of our analyses (see Appendix).

2.2.3. Measure 3: multiple functional limitations (MFLs)

We derived the measure of MFLs from the combination of general mobility variables, Activities of Daily Living (ADL) variables, and data on symptoms of chronic conditions (Table 1). ADL is a common measure of the abilities necessary for basic functioning and for living in a community (Chatterji, Byles, Cutler, & et al., 2015). We counted the number of functional limitations per individual. The frequencies of MFLs per individual were high, reflecting the older age of participants and the large list of 30 limitations. Therefore we decided to specify the measure of MFLs as the presence of 10 or more functional limitations within the same person (MFL10+). This cut-off point allowed us to identify a group of participants with a total high functional limitation, compared to a cut-off point of three or five limitations.

2.3. Explanatory variables

Material SDoH were represented by variables: net household wealth (high, medium, low), subjective social status (high, medium, low), the last occupation (managerial/professional, intermediate, semi/routine), education (A-level or higher, O-level or equivalent and less than O-level). Psycho-social SDoH reflected aspects of social engagement, social support and individual sense of control. Social engagement was measured through individual participation in community organizations. A person was defined as very active if they took part in 3 or more community organizations and active if participated in 1 or 2. Perception of loneliness was a binary variable (yes/no). Social support was represented by variables supportive children (very/some, a little/not at all, no children), supportive friends (very/some, a little/not at all, no friends) and supportive partner (very/some, a little/not at all, no partner). The individual sense of control was measured by how often the respondent felt that what happened to them was out of their control. Four options (never, not often, sometimes, often) were grouped to three categories (never, not often/sometimes, often). Behavioural SDoH were represented by variables physical activity (vigorous, moderate, mild, none), alcohol consumption (never, monthly or less, weekly, daily) and tobacco smoking (never, ex-smoker, current smoker). Confounding variables were: wave (with values 1 to 7), age (categorized in 5-year bands and 90 + years age band) and a binary variable for sex.

3. Methods

To assess the relationships between multimorbidity and material, psycho-social and behavioural factors, we estimate a logistic panel data regression model which captures the temporal sequencing of events and accounts for temporal within-individual correlation. We favour an population-averaged regression model over subject-specific regression model, because these models are more appropriate for estimating the average influence of predictors on outcomes which is our focus: to estimate differences in the risk of multimorbidity between population groups and not between individuals (Muller & MacLehose, 2014). Additionally, population-averaged model do not require assumptions to be made about the distribution of the residuals (Liang & Zeger, 1986). The estimated model is:

$$logit\ \Pr(y_{it} = 1|x_{it}) = \beta_0 + \beta_1 x_{it} + e_{it} \quad (1)$$

where y_{it} is a binary dependent variable with 1 indicating an individual i experience a MM, CMM or FLM event at time t; 0 otherwise; β_0 is the regression constant; x_{it} is a matrix of individual time-varying factors; β_1 is a matrix of coefficients capturing the estimated strength of association between a multimorbidity event and an explanatory variable; e_{it} is a vector of residuals.

To estimate Equation (1), we use Generalized Estimating Equations (GEEs). GEEs represent an extension of standard regression estimation procedures to allow for autocorrelation (Liang & Zeger, 1986). By allowing correlation for repeated observations on individuals over time, GEEs produce robust estimation of standard errors which are derived from the observed variability in the data, rather than variability predicted by an underlying probability model (Twisk, 2013). GEEs is a two-stage method. The first stage involves specifying and estimating an appropriate correlation structure, and the second stage using the estimated correlations structure to adjust the estimates of the logistic model parameters and standard errors for autocorrelation (Liang & Zeger, 1986). We analysed the correlation structure for each of our three multimorbidity measures and they show a decreasing correlation over time, which justified the choice of an autoregressive correlation structure (Twisk, 2013).

We separately estimate regression models for each of our three multimorbidity measures and also control for confounding factors of time (wave of measurement), age (varying between waves) and sex. Confounding factors and explanatory factors are included as covariates in our regression models. The associations were measured in odds ratios and it is a common measure of health inequalities in large population-based studies (Di Lorenzo et al., 2014). In order to give additional effect to those who dropped out of the analysis, we used longitudinal weights. They calculated the inverse predicted probability of response among respondents who responded to all previous waves and multiplied that weight by the previous wave's longitudinal weight (Banks et al., 2018). Analyses were conducted in Stata version 13.

Table 2
Descriptive sample characteristics.

	N	%		N	%
Measurement occasions	56,202		Sense of control		
Participants 15,046	26,179	46.6	High	15,513	27.6
Basic MM					
Complex MM	9,663	17.19	Some	35,708	63.54
MFL10+	6,319	11.24	Low	3,608	6.42
Mean age (SD)	66(10.9)		Partner support		
Age group (years)			A lot/some	37,399	66.54
50-54	5,576	9.92	A little/not at all	1,549	2.76
55-59	10,074	17.92	No partner	16,953	30.16
60-64	10,434	18.57			
65-69	9,569	17.03	Children support		
70-74	8,166	14.53	A lot/some	43,693	77.74
75-79	6,233	11.09	A little/not at all	4,230	7.53
80-84	3,791	6.75	No children	7,895	14.05
85-89	1,789	3.18			
90 plus	570	3.18	Friends' support		
			A lot/some	42,705	75.98
Females	31,106	55.3	A little/not at all	9,076	16.15
			No friends	3,946	7.02
Physical Activity					
Vigorous	16,327	29.05	Loneliness		
Moderate	27,124	48.26	Yes	6,720	11.96
Mild	8,319	14.8			
No	4,416	7.86	Household wealth		
			Top	12,244	21.79
Alcohol consumption			Medium	32,358	57.57
Never	6,635	11.81	Low	10,490	18.66
Monthly or less	15,661	27.87			
Weekly	14,111	25.11	Subjective social status		
Daily	18,661	33.2	Top	9,080	16.16
			Medium	38,025	67.66
Smoking			Low	6,756	12.02
Never	21,041	37.44			
Ex-smoker	27,526	48.98	Occupational level		
Smoker	7,564	13.46	Managers/ professionals	18,555	33.01
			Intermediate	13,895	24.72
Participation			Semi/routine	22,334	39.74
Very active	11,162	19.86			
Active	26,940	47.93	Educational level		
Not active	15,142	26.94	A-level+	18,418	32.77
			O-level or equiv.	14,436	25.69
			Less than O-level	23,088	41.08

4. Results

The general characteristics of the studied population are presented in Table 2. The number of participants decreased from 10,331 (wave 1) to 7,130 (wave 7). The retained population are those who remained in the study and took part in the self-completion interviews. The mean age was 66 years (SD 10.9). The proportion of women was 55.3%. All longitudinal studies are subject to problems with non-response and attrition and these problems are starker in studies of ageing where rates of attrition tend to be higher (Banks et al., 2016). In our study respondents who took part in all waves of measurements were different to those who dropped out or refused to fill in the self-completion interview. The retained cohort was slightly older (mean age 67 years compared to 66.2 years), more female (56.2% versus 54.9%) and more affluent (23.3% in the top wealth tertile compared to 21.6%). The core cohort was also more active, with a third conducting vigorous physical activity compared to 27% of those who dropped out at one or more occasions. A quarter of them was very active in their community compared to 17%. The problem of the differences between the two populations was less relevant for our analysis because we focused on all core members rather than those who took part in all waves of measurements.

The following results in Table 3 – 6 were extracted from three logistic regression analyses, one per each health outcome, using the GEE method. Each model took account of all explanatory and confounding variables. The probability of people aged 50 or older in England to develop multimorbidity, complex multimorbidity and 10 or more functional limitations has increased between 2002 and 2014–15 (Table 3). Compared to 2002/03, the odds of having multimorbidity in 2014/15 were 2.33 times larger (95% CI 2.14–2.54), the odds of having complex multimorbidity 2.57 times larger (95% CI 2.29-2.88) and the odds of having ten or more MFLs twice larger (95% CI 1.77-2.31). The probability of having multimorbidity increases with age across the three measures. The increase peaked in multimorbidity at the age 85-89 years and in complex multimorbidity at the age 80-84 years. Female respondents were more likely to have basic MM (OR 1.31, 95% CI 1.21 – 1.41), complex MM (OR 1.26, 95% CI 1.14 – 1.38) and MFL10+ (OR 1.27, 95% CI 1.14-1.41).

4.1. Material determinants

We observed a health gradient across the three levels of household wealth in basic multimorbidity, complex multimorbidity and multiple functional limitations (Table 4). Compared to the population group with the highest wealth, those with the lowest wealth had 47% higher odds of basic MM, 73% higher odds of complex MM and 90% higher odds of 10 + functional limitations (Table 4). Low subjective social status was associated with higher odds of having all three outcomes compared to reporting high SSS, with odds ratios at 1.14 (95% CI 1.04-1.24), 1.2 (95% CI 1.07-1.35) and 1.37 (95% CI 1.26-1.70) respectively. People in routine or semi-routine occupations had higher odds of having basic multimorbidity and MFL10 + than people in the managerial and professional group, with odds ratios at 1.07 (95% CI 1.04-1.24) and 1.28 (95% CI 1.14-1.46) respectively. People with basic education had higher odds of having MFL10 + than people with at least A-levels (OR 1.12, 95% CI 1.01-1.22).

4.2. Psycho-social determinants

The relationship between the predictors of social support and our outcomes was mixed (Table 5). We observed that on average people without friends had 14% higher odds of basic multimorbidity than people whose friends were very supportive or supportive to some degree. Similarly people with no partner had odds of having basic multimorbidity higher than those who reported having supportive partner, with OR 1.15 (95% CI 1.06-1.26). The perception of loneliness was positively associated with all three outcomes: for basic MM OR 1.18 (95% CI 1.10-1.26), for complex multimorbidity OR 1.21 (95% CI 1.11-1.32) and for MFL10 + OR 1.32 (95% CI 1.20-1.46). The relationship between the sense of control and the probability of having each of our health outcomes was graded by the degree of the perceived control. The odds ratios were higher for MFL10 + than for the other two outcomes. Participation in community was not associated with multimorbidity and complex multimorbidity (Table 5). The odds of having MFL10 + increased the less people participated, with those not active in community having 25% higher odds (95% CI 1.10-1.42) than those who were very active.

4.3. Behavioural determinants

The relationship between physical activity and the probability of having each of our health measures was graded by the level of intensity of physical activity (Table 6). Compared to those who exercised vigorously, people who were physically inactive had 1.6 times larger odds of having basic MM (95% CI 1.21 – 1.41), twice larger odds of having complex MM (95% CI 1.78-2.27) and 8 times larger odds of having MFL10+ (95% CI 7.00-9.43). The frequency of alcohol consumption was associated with our health outcomes but not in the expected way.

Table 3
Basic multimorbidity, complex multimorbidity and functional limitation by year of measurement, age and sex.

	Basic MM		Complex MM		MFL10+	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Year						
2002/03	1		1		1	
2004/05	0.87	0.82-0.92	1.06	0.96-1.17	1.34	1.17-1.52
2006/07	1.07	1.01-1.13	1.17	1.05-1.29	1.63	1.43-1.84
2008/09	1.42	1.33-1.52	1.79	1.62-1.99	1.33	1.15-1.49
2010/11	1.61	1.51-1.73	2.07	1.86-2.29	1.47	1.28-1.67
2012/13	1.69	1.56-1.82	2.26	2.03-2.52	1.35	1.18-1.54
2014/15	2.33	2.14-2.54	2.57	2.29-2.88	2.02	1.77-2.31
Age group (years)						
50-54	1		1		1	
55-59	1.23	1.11-1.37	1.36	1.09-1.68	1.15	0.99-1.33
60-64	1.61	1.43-1.81	1.97	1.57-2.48	1.27	1.07-1.50
65-69	2.16	1.90-2.45	2.63	2.08-3.33	1.31	1.10-1.57
70-74	2.95	2.59-3.38	3.52	2.76-4.48	1.52	1.27-1.83
75-79	4.14	3.59-4.79	4.37	3.41-5.60	1.72	1.48-2.16
80-84	4.98	4.24-5.86	5.41	4.19-7.01	2.23	1.82-2.71
85-89	5.89	4.81-7.23	4.56	3.42-6.00	2.86	2.27-3.59
90 plus	4.70	3.40-6.51	3.33	2.33-4.75	3.62	2.65-4.91
Females	1.31	1.21-1.41	1.26	1.14-1.38	1.27	1.14-1.41

The probability of developing each of our health outcomes increased with decreasing frequency of drinking (Table 6). A history of smoking was related to the health outcomes. Ex-smokers had higher odds ratios compared to people who never smoked: 1.27 (95% CI 1.17 – 1.37) for basic MM, OR 1.29 (95% CI 1.17 – 1.42) for complex MM and OR 1.37 (95% CI 1.23-1.54) for ten or more multiple functional limitations.

4.4. Sensitivity analysis

In a separate sensitivity analysis we explored how the alternative measure of three or more diseases (MM3+) reflected the health inequalities compared to CMM. The results in the Appendix show that the magnitude of the odds ratios using MM3+ lay for most of the variables between the ORs of basic MM and CMM. We conclude that although the differences in risk between CMM and basic MM with the higher cut-point are narrower, the former measure still indicates the highest inequality which we believe justifies its use.

5. Discussion

5.1. Main results

Our results originate from a representative sample of an English population, hence they can be generalized for England. We have explored longitudinal association between the material, psycho-social and behavioural determinants and measures of multimorbidity and multiple functional limitation in an English population of people aged 50 years or older. We found a consistent association between the outcome measures and the levels of household wealth, the sense of control over one's life, physical activity and loneliness. The relationship with smoking and alcohol consumption indicated possible health selection, where individuals were actively regulating their health behaviours. Multiple functional limitation and complex multimorbidity captured larger inequalities than basic multimorbidity.

Table 4
Basic multimorbidity, complex multimorbidity, functional limitation and material determinants.

	Basic MM		Complex MM		MFL10+	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Household wealth						
High	1		1		1	
Medium	1.13	1.10-1.19	1.20	1.09-1.31	1.28	1.12-1.47
Low	1.47	1.34-1.61	1.73	1.52-1.96	1.90	1.59-2.26
Subjective social status						
High	1		1		1	
Medium	1.04	0.98-1.10	1.11	1.00-1.20	1.15	1.02-1.29
Low	1.14	1.04-1.24	1.21	1.07-1.35	1.37	1.26-1.70
Occupation						
Manager/prof.	1		1		1	
Intermediate	0.93	0.85-1.01	0.92	0.81-1.03	1.04	0.91-1.20
Semi/routine	1.07	1.04-1.24	1.03	0.92-1.15	1.28	1.14-1.46
Education						
A-level+	1		1		1	
0-Level or equiv.	0.93	0.86-1.00	0.92	0.81-1.03	0.89	0.80-1.02
Less than 0-Level	1.02	0.97-1.07	1.04	0.92-1.16	1.12	1.01-1.22

Table 5
Basic multimorbidity, complex multimorbidity, functional limitation and psycho-social determinants.

	Basic MM		Complex MM		MFL10+	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Participation						
Very active	1		1		1	
Active	0.97	0.92-1.03	1.03	0.95-1.12	1.12	1.01-1.27
Not active	1.04	0.96-1.12	1.01	0.91-1.12	1.25	1.10-1.42
Sense of control						
High	1		1		1	
Some	1.21	1.16-1.27	1.28	1.20-1.37	1.79	1.63-1.96
Low	1.57	1.41-1.74	1.70	1.51-1.91	3.29	2.87-3.76
Supportive children						
Very/some	1		1		1	
A little/not at all	1.02	0.94-1.11	1.02	0.90-1.15	1.14	1.00-1.28
No children	0.96	0.86-1.07	0.98	0.86-1.11	0.98	0.86-1.12
Supportive friends						
Very/some	1		1		1	
A little/not at all	0.99	0.94-1.06	0.96	0.89-1.04	1.04	0.95-1.14
No friends	1.14	1.02-1.26	1.07	0.95-1.2	1.05	0.92-1.19
Supportive partner						
Very/some	1		1		1	
A little/not at all	0.93	0.81-1.07	0.98	0.81-1.18	0.99	0.79-1.22
No partner	1.15	1.06-1.26	1.03	0.94-1.14	1.04	0.94-1.16
Loneliness						
Yes	1.19	1.11-1.28	1.22	1.12-1.33	1.32	1.20-1.46

5.2. Interpretation

We present evidence that a variety of material, psycho-social and behavioural determinants are to varying extents related to basic multimorbidity, complex multimorbidity and multiple functional limitations. We found consistent inequalities in multimorbidity and multiple functional limitation across the levels of household wealth, the sense of control over one's life, physical activity and loneliness. These inequalities appeared larger when measured as multiple functional limitation and complex multimorbidity than basic multimorbidity. Our results suggest that solely materialist models of multimorbidity at older age are insufficient as behavioural and psycho-social factors play an important role. Behavioural patterns in smoking and alcohol consumption suggest that while health inequality accumulates during the life course, psycho-social resources and active human agency also contribute to shaping the population health profiles.

Among material determinants the strongest health disparities were captured by household wealth. Compared to the population group with the highest wealth, those with the lowest wealth had 47% higher odds of basic MM, 73% higher odds of complex MM and 90% higher odds of ten or more functional limitations. The stark disparities support the evidence that the amount of available household wealth or assets constrains individuals' consumption choices on quality of housing, usable outdoor space, type of residential area or quality of health care (Joseph Rowntree Foundation, 2014). Savings also act as a buffer against unexpected loss of income due to ill health in later life thus reducing the exposure to stress. We observed that individuals with the lowest subjective social status had 14% larger odds of having basic MM, 20% larger odds of having complex MM and 37% larger odds of having ten or more functional limitations than those with the top SSS. These differences might reflect two-way effects: a very low subjective perception of one's status contributes to worse health but having more complex issues (with simultaneously affected body systems and limited in everyday lives) additionally reinforces the negative rating of individual status (O'Brien, Wyke, & Watt, 2014).

Occupational status was weakly associated with basic MM and MFL10 + and educational qualifications were weakly related to MFL10+. In comparison to the measure of household wealth which reflects a process of life-long accumulation, the indicators of education and occupation reflect periods of time from a more distant past. This might explain stronger and more consistent effect of household wealth and suggest that it is a better indicator of an older person's status

Table 6
Basic multimorbidity, complex multimorbidity, functional limitation and behavioural determinants.

	Basic MM		Complex MM		MFL10+	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Physical activity						
Vigorous	1		1		1	
Moderate	1.22	1.16-1.28	1.32	1.22-1.42	1.83	1.64-2.04
Mild	1.57	1.46-1.68	1.92	1.75-2.12	4.26	3.73-4.86
None	1.60	1.45-1.76	2.01	1.78-2.27	8.13	7.00-9.43
Alcohol consumption						
Don't drink	1		1		1	
Monthly or less	0.90	0.83-0.99	0.79	0.71-0.87	0.67	0.60-0.75
Weekly	0.82	0.75-0.91	0.68	0.61-0.77	0.51	0.45-0.58
Daily	0.81	0.73-0.88	0.65	0.58-0.74	0.47	0.40-0.53
Smoking						
Never	1		1		1	
Ex-smoker	1.27	1.17-1.37	1.29	1.17-1.42	1.37	1.23-1.54
Current	1.03	0.91-1.14	1.04	0.90-1.21	1.46	1.26-1.70

(Adena & Myck, 2014; McGovern & Nazroo, 2015).

Psycho-social determinants produced mixed results. We found a clear gradient between individuals with the strongest and the weakest sense of control over their lives. The more people felt in charge of their lives the less likely they were to develop ill health. Low control beliefs can affect health in several ways. They may lead to anxiety and aggression which facilitates chronic stress response, smoking and drinking. Feeling low control over destiny can also lead to passive responses such as low self-esteem which induce depression (Whitehead et al., 2016). Loneliness was the other factor consistently related to all of our measures. The feeling of being socially isolated is relatively common among the elderly because some relationships are lost as people get older (Singh & Misra, 2009).

Participation in community groups was associated to a reduced probability of developing 10 or more functional limitations but not to reduced multimorbidity. Participating in at least three community groups presupposes certain level of health and physical functioning which acts as a clear barrier for those with at least 10 functional limitations. This health selection process might explain why we can see a social gradient for multiple functional limitations but not for multimorbidities. Other measures of social support showed either no significant relationship or a limited relationship. We found an association with friendship among people with basic MM. The effects of support on health of older people depend on the source of support and the quality of relationship. For example relationships with friends can be beneficial to one's health while relationship with family members not (Huxhold, Miche, & Schüz, 2014).

In the group of behavioural determinants we found a dose-response relationship between all levels of physical activity and probability of the three health outcomes. This may suggest that lack of physical activity is an important factor increasing probability of chronic and complex health problems and limitations in the ageing population (Cimarras-Otal et al., 2014; Dhalwani et al., 2017). However, reverse causation is also very likely so that worse health outcomes were driving reduced physical activity. Both possibilities could operate together leading to a positive feedback loop of deteriorating health and reduced physical activity. Increasing frequency of alcohol consumption seems to be associated to reduced odds of multimorbidity and multiple functional limitation. Evidence has indicated that moderate alcohol consumption brings benefits to health and mortality reduction but the discussion is biased by the common problem of the inclusion of ex-drinkers with life-time abstainers in the same category (Stockwell et al., 2016). Part of this discussion explores the role of human agency in regulating alcohol consumption, thus balancing the negative health effects with experiences of social inclusion beneficial for mental health (Kelly, Olanrewaju, Cowan, Brayne, & Lafortune, 2018). Holdsworth, Mendonça, Pikhart et al. (2016) found that older people with good or improving self-reported health were increasing their drinking over time while people with bad or worsening health moderated their drinking.

The relationship between smoking and both types of multimorbidity is ambiguous. Compared to people who never smoked, ex-smokers were more likely to develop any one of the three outcomes but there was no relationship between current smokers and those who never smoked for basic or complex MM. Cross-tabulating smoking, age and prevalence of multimorbidity, we found that ex-smokers were more prevalent among older age groups with higher morbidities and current smokers were younger and healthier. The explanation of similar findings by Nazroo et al. (2008) is that when people become ill they might stop smoking. Unlike morbidities, the odds ratios between people with multiple functional limitation formed a consistent gradient. This difference might be related to the fact that the prevalence of current smokers was higher and the prevalence of non-smokers smaller among people with MFL10 + than among people with MM and CMM. The results for alcohol consumption and smoking exemplify how people in later life continue making active choices within their social context (Elder, 1994).

Comparing health inequalities between our three outcomes deserves a note of caution. Whilst the odds ratios for complex MM and multiple functional limitation show bigger associations with SES than basic MM, the latter is more common and this may to some degree limit the increase across categories, as it starts off at a higher level. This fact still allows us to make the claim that multiple functional limitation and complex multimorbidity captured larger inequalities than basic multimorbidity. Working with only the basic measure of multimorbidity might limit our ability to see the social heterogeneity of ageing population. But apart from improving the measure we also need to try to explain why different measures lead to different inequalities. Functional limitation and decline in the elderly is a consequence of chronic disease, with a greater effect among people with a higher number of morbidities (Jindai et al., 2016; Ryan, Wallace, O'Hara, & Smith, 2015). Complex multimorbidity results from dysfunction in three or more body systems. Both outcomes demand complex and long-term care but we know that patients' responses are socially differentiated (Bartley, 2004; Cockerham, 2007). People from higher social backgrounds are capable to use resources such as power, money, knowledge, prestige or social support to protect themselves from health risks or mitigate the consequences of multimorbidity (Link & Phelan, 1995). Taking into account this socially patterned human agency might help to explain why inequalities in complex multimorbidity and multiple functional limitations are stronger than in basic MM.

5.3. Limitations

There are several limitations to our study related to methodology and the scope of analyses. Our study was exploratory and based on GEE method with population-averaged data. It allowed us to observe averaged distribution of certain characteristics between individuals. However this study design does not enable building explanatory analyses or drawing conclusions on both within-individual and between-individual variance or change in outcomes.

Recent studies reported that social determinants do not only influence health simultaneously but also influence each other (Moor et al., 2016; Short & Mollborn, 2015). For instance, social support can mitigate the effect of stress on people with low social status (Gellert et al., 2018). We have not examined these interaction effects but they could lead to modification of some effects.

We constrained our classification to a generic count of single diseases, ICD-10 chapters and functional limitations without identifying the most frequent combinations. These have been studied either as pairs and triplets or as clusters with the highest degree of association and due to their synergistic effects are of special interest to clinicians (Ng et al., 2018). Unpacking the associational heterogeneity might shed some light on the relationships between these patterns of multimorbidity and specific determinants or groups of determinants.

6. Conclusions

Our study was the first study to comprehensively explore materialist, psycho-social and behavioural determinants of health in relation to multimorbidity and multiple functional limitations. Policies aiming to reduce the risk of multimorbidity and functional limitation should address the issue at several levels, as a socio-economic and behavioural intervention. Behavioural and therapeutic approaches in the community can help to compensate for social isolation, reduced self-esteem or to regain more sense of control over people's lives (Public Health England and UCL Institute of Health Equity, 2015). This strategy should be based around local primary care centres. They could be provided with additional resources to spend more time as the frontline assessors of multimorbidity and consistent coordinators acting as a link between patients and the specialist health care services (World Health Organization, 2016).

Ethical statement

Ethical approval was not required for the analysis of anonymised secondary data, which is made available to all researchers freely.

Declarations of interest

None.

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Appendix. Different definitions of MM and social determinants

Table A1
Basic multimorbidity, complex multimorbidity, MM3+ and material determinants

	Basic MM	95% CI	Complex MM	95% CI	MM3+	95% CI
	Odds ratio		Odds ratio		Odds ratio	
Household wealth						
High	1		1		1	
Medium	1.13	1.10-1.19	1.20	1.09-1.31	1.18	1.1-1.28
Low	1.47	1.34-1.61	1.73	1.52-1.96	1.66	1.49-1.86
Subjective social status						
High	1		1		1	
Medium	1.04	0.98-1.10	1.11	1.00-1.20	1.06	0.98-1.14
Low	1.14	1.04-1.24	1.21	1.07-1.35	1.16	1.04-1.28
Occupation						
Manager/prof.	1		1		1	
Intermediate	0.93	0.85-1.01	0.92	0.81-1.03	0.93	0.84-1.04
Semi/routine	1.07	1.04-1.24	1.03	0.92-1.15	1.05	0.95-1.16
Education						
A-level+	1		1		1	
0-Level or equiv.	0.93	0.86-1.00	0.92	0.81-1.03	0.94	0.86-1.05
Less than 0-Level	1.02	0.97-1.07	1.04	0.92-1.16	1.01	0.95-1.09

Table A2
Basic multimorbidity, complex multimorbidity, MM3+ and psycho-social determinants

	Basic MM		Complex MM		MM3+	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Participation						
Very active	1		1		1	
Active	0.97	0.92-1.03	1.03	0.95-1.12	1.03	0.96-1.11
Not active	1.04	0.96-1.12	1.01	0.91-1.12	1.04	0.99-1.24
Sense of control						
High	1		1		1	
Some	1.21	1.16-1.27	1.28	1.20-1.37	1.28	1.21-1.35
Low	1.57	1.41-1.74	1.70	1.51-1.91	1.62	1.44-1.92
Supportive children						
Very/some	1		1		1	
A little/not at all	1.02	0.94-1.11	1.02	0.90-1.15	1.05	0.95-1.16
No children	0.96	0.86-1.07	0.98	0.86-1.11	0.98	0.87-1.09
Supportive friends						
Very/some	1		1		1	
A little/not at all	0.99	0.94-1.06	0.96	0.89-1.04	0.99	0.93-1.06
No friends	1.14	1.02-1.26	1.07	0.95-1.2	1.06	0.95-1.18
Supportive partner						
Very/some	1		1		1	
A little/not at all	0.93	0.81-1.07	0.98	0.81-1.18	0.91	0.78-1.07
No partner	1.15	1.06-1.26	1.03	0.94-1.14	1.11	1.02-1.21
Loneliness						
Yes	1.19	1.11-1.28	1.22	1.12-1.33	1.20	1.14-1.33

Table A3
Basic multimorbidity, complex multimorbidity, MM3+ and behavioural determinants

	Basic MM		Complex MM		MM3+	
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI
Physical activity						
Vigorous	1		1		1	
Moderate	1.22	1.16-1.28	1.32	1.22-1.42	1.29	1.21-1.37
Mild	1.57	1.46-1.68	1.92	1.75-2.12	1.79	1.65-1.94
None	1.60	1.45-1.76	2.01	1.78-2.27	1.78	1.60-1.99
Alcohol consumption						
Don't drink	1		1		1	
Monthly or less	0.90	0.83-0.99	0.79	0.71-0.87	0.80	0.73-0.87
Weekly	0.82	0.75-0.91	0.68	0.61-0.77	0.73	0.65-0.81
Daily	0.81	0.73-0.88	0.65	0.58-0.74	0.69	0.62-0.77
Smoking						
Never	1		1		1	
Ex-smoker	1.27	1.17-1.37	1.29	1.17-1.42	1.31	1.20-1.44
Current	1.03	0.91-1.14	1.04	0.90-1.21	1.11	0.97-1.26

Table A4
Correspondence between CMM and MFL10 if MM = 1

	MFL10+		
CMM	0	1	Total
0	14,276	2,246	16,522
1	6,638	3,018	9,656
Total	20,914	5,264	26,178

Chi-square(1) = 1.200, p = .000.

Table A5
Correspondence between CMM and MFL10 if MM = 0

	MFL10+		
CMM	0	1	Total
0	28,965	1,051	30,016
1	2	3	5
Total	28,967	1,054	30,021

Chi-square(1) = 47.106, p = .000.

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