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ORIGINAL RESEARCH ARTICLE

Decomposition of Quality-Adjusted Life Expectancy Inequalities by Mortality and Health-Related Quality of Life Dimensions

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Abstract

Background Quality-adjusted life expectancy (QALE) combines mortality risk and multidimensional health-related quality of life (HRQoL) information to measure healthy life expectancy in terms of quality-adjusted life years (QALYs). This paper estimates the relative importance of individual quality of life dimensions in explaining inequalities in QALE.

Methods We combined EQ-5D-5L data from the Health Survey for England for 2017 and 2018 ($N = 14{,}412$) with full population mortality data from the Office for National Statistics to calculate QALE by age, sex and deprivation quintile. The effect of HRQoL dimensions on the socioeconomic gradient in QALE was decomposed using an iterative imputation approach, in which inequalities associated with socioeconomic status in each domain were removed by imputing the response distribution of the richest quintile for all participants. Sampling uncertainty in the HRQoL data was evaluated using bootstrapping.

Results People in the least deprived fifth of neighbourhoods in England can expect to live 7.0 years longer and experience 11.1 more QALYs than those in the most deprived fifth. Inequalities in HRQoL accounted for 28.0% and 45.7% of QALE inequalities for males and females, respectively. Pain/discomfort, anxiety/depression and mobility were the most influential HRQoL domains.

Discussion Our results identify the extent of inequalities associated with socioeconomic status in lifetime health and the relative importance of inequalities by mortality and HRQoL. The contributions of the individual dimensions of HRQoL towards lifetime inequalities vary substantially by sex. Our findings can help to identify the types of interventions most likely to alleviate health inequalities, which may be different for males and females.

1 Introduction

Systematic inequalities in lifetime health exist across individuals with different education attainment, occupations, income or wealth [1–3]. Socioeconomic status is both a determinant of how long an individual can expect to live [4–6] and of how much health-related quality-of-life (HRQoL) they can expect to enjoy throughout their lifetime [7–12]. Differences in healthy life expectancy are often perceived as unfair [13] and some health care systems, such as the English National Health Service (NHS), have explicit legal obligations to give regard to health inequalities in resource allocation decisions [14].

The metric of quality-adjusted life expectancy (QALE) is a useful indicator for tracking population health inequalities [9, 15]. QALE combines mortality risk information in life tables with HRQoL instruments collected as part of national, representative population health surveys. This allows measurement of healthy life expectancy in terms of the sum of quality-adjusted life years (QALYs) that a person can expect to experience. By accounting for HRQoL, QALE contains more information on health experience than life expectancy and is more sensitive than other adjusted measures like disease-free life expectancy, which crudely deduct the years lived with ill health or disability [16]. Despite this, the use of QALE as a population health inequality indicator has been

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Key Points for Decision Makers

Inequalities in quality-adjusted life expectancy (QALE) are a useful summary measure of population health inequalities. This study provides new estimates of QALE inequalities and decomposes the relative importance of mortality and individual quality of life dimensions in explaining the differences.

We find that life expectancy for people in the least deprived fifth of neighbourhoods in England is 7.0 years longer than those in the most deprived fifth. For QALE, the equivalent figure is 11.1 quality-adjusted life years. Mortality accounts for 63% of inequalities. Pain/discomfort was the most influential health-related quality of life domain. Anxiety/depression explains more inequality for females, whereas mobility was more influential for males.

The results illustrate how inequalities in lifetime health metrics are comprised in terms of mortality and quality of life, and how these vary substantially by sex. The results can help inform debate on how socioeconomic inequalities can be most effectively approached.

limited. In England, Love-Koh et al. [9] estimated that over the period 2010–2012, people in the richest fifth of neighbourhoods in England could expect 75.1 QALYs over their lifetime compared to 63.2 QALYs in the poorest fifth of neighbourhoods. Approximately 45% of this 11.9 QALY gap arose because of differences in self-reported HRQoL, with the remainder due to differences in life expectancy.

HRQoL is a multidimensional concept and reflects physical, mental and social well-being. For example, the EQ-5D-5L instrument, one of the most widely used measures of HRQoL, asks patients to report their level of problems across five dimensions [17]: mobility, self-care, usual activities, pain and discomfort, and anxiety and depression. Inequalities associated with socioeconomic status may be more pronounced on some of these dimensions of HRQoL than on others, and their impact on inequalities may be disproportionate to their overall impact on quality of life (for example, self-care issues may be relatively uncommon in the population but follow a strong socioeconomic gradient). However, the relative importance of each domain in explaining overall inequalities in QALE has not been established empirically.

The aims of this paper are twofold: First, we decompose inequalities associated with socioeconomic status in QALE in the English population due to differences in dimensions of HRQoL as captured by the descriptive system of the EQ-5D-5L. This could provide important information for policymakers on the kinds of interventions most likely to be effective in reducing health inequalities. Second, we provide updated estimates of inequalities associated with socioeconomic status in QALE for the English population in 2017–2018, drawing on more recent life tables and a more sensitive measure of HRQoL than that used in previous studies (i.e. the EQ-5D-3L) [9]. These up-to-date estimates can serve as inputs into distributional cost-effectiveness analysis conducted to allocate resources within public health systems [18].

2 Methods

2.1 Data

We pooled data from the 2017 and 2018 Health Survey for England (HSE), a long-running annual survey of a random sample of the English population [19, 20]. HRQoL is recorded using the EQ-5D-5L instrument, a standardised measure that has been designed and validated for use in population health surveys [17]. The EQ-5D-5L captures five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Participants report the level of problems they were experiencing at the time of the survey for each dimension on a 5-point scale, ranging from no problems to extreme problems. For each individual in the HSE, the reported dimension responses were used to generate a health state profile that is assigned an HRQoL score. The scores are taken from a value set derived from a preference study of the UK general population by Hernandez Alava et al. [21]. Summary scores range from 1 (indicating full health) to − 0.6, with 0 being equivalent to being dead and negative scores indicating health states considered worse than being dead. Participants with missing responses on any of the EQ-5D-5L dimensions were excluded from analysis.

Average EQ-5D-5L index values were calculated for age, sex and socioeconomic deprivation subgroups. To account for non-response bias in the survey, we applied individual sampling weights provided in the HSE. These weights are calibrated to make the sample nationally representative in terms of age, sex and geography. The HSE does not collect EQ-5D-5L responses for children and adolescents younger than 16 years. We therefore restricted our analysis of HRQoL to participants aged 16 or over at the time of the survey.

For these individuals, age at the time of the survey was recorded through 16 5-year age bands (with the exception of bands for 16–17, 18–19 and 85+ years of age). Socioeconomic deprivation was measured using the 2015 index of multiple deprivation (IMD), which combines information on multiple dimensions of social deprivation (e.g.

employment, income, education and housing, among other aspects) into a single score [22]. The IMD is defined at the level of small geographical areas (Lower-Layer Super Output Areas [LSOAs]) containing a median of approximately 1500 residents. Participants were linked to LSOAs on the basis of their postcode of residence and were assigned to one of five socioeconomic groups based on the IMD quintile of their respective LSOA.

Population and death data by age, sex and socioeconomic deprivation group for the years 2017 and 2018 were obtained from the UK national statistics authority, the Office for National Statistics (ONS), and subsequently pooled. These were available by single year of age and with socioeconomic deprivation again measured using IMD quintiles as defined above [23, 24].

2.2 Analysis

2.2.1 Life Tables

QALE was estimated by combining age-specific mortality and HRQoL information in life tables. Chiang II life tables [25] were used to calculate life expectancy, which were then adjusted for HRQoL using the Sullivan method [26]. This approach multiplies the person years lived in each year of age using the respective HRQoL score. The life tables incorporated the population and death information by single year of age in order to obtain the most accurate estimates of life expectancy. However, because HRQoL was only available according to the grouped age variable in the HSE, we assumed that the HRQoL weight was constant across all years within each age band. For years of age under 16 for whom HRQoL information was not available in the HSE, we assumed their HRQoL weights were equal to those of the youngest age group (16–17). The life tables also incorporated the standard assumption that individuals dying at a given year of age had an average survival of 6 months. Life tables by deprivation group were produced for the general population stratified by sex, and using three different annual discount rates of 0%, 1.5% and 3.5%. We extracted four quantities from each table: QALE at birth and at ages 16, 40 and 65.

2.2.2 QALE Inequality

Inequalities associated with socioeconomic status were assessed for the general population and by sex. Two simple measures were used to summarise inequalities between the most (IMD1) and least deprived (IMD5) deprivation quintiles: the absolute difference (IMD5 − IMD1) and the relative difference (IMD5/IMD1 − 1). The Atkinson index [27] was also used to estimate the health-related social welfare of the QALE distribution. This combines information on average health and health inequality to yield the 'equally distributed equivalent' (EDE) health of a given distribution. The difference between mean health and EDE can be interpreted as the amount of QALE society would be willing to trade-off in order to eliminate inequality. This trade-off requires specifying an 'inequality aversion' value—a parameter (ε) within the Atkinson index that reflects social concern towards inequality. At $\varepsilon = 0$ there is no concern for inequality (i.e. EDE = average health); at $\varepsilon = \infty$, the index only attaches weight to the least healthy group—the so-called 'maximin' principle [28]. As there is no consensus around what the societal inequality aversion parameter should be [13], we estimated EDE across a conservative value range of 0–10. However, we focused on two values when reporting our results: $\varepsilon = 3$ (low aversion) and $\varepsilon = 10$ (high aversion). Lastly, we calculated the change in EDE when applying a hypothetical health gain to IMD quintiles 1–4, relative to an identical gain in IMD5. This yields a set of implied equity weights for each IMD quintile specific to a particular value of ε.

2.2.3 Inequality Decomposition

The differences in QALE between the most and least deprived IMD quintiles can be directly decomposed into mortality and HRQoL components by comparing them with the respective difference in life expectancy. For example, a QALE difference of 10 QALYs and a life expectancy difference of 5 years would indicate that mortality and HRQoL contribute equally to overall QALE inequalities.

We developed a standardisation procedure to further decompose the QALE inequalities attributable to HRQoL into the separate contributions of each of the EQ-5D-5L health domains. The logic underlying the procedure is that if socioeconomic variation in a single health domain is removed and QALE re-estimated using this different set of domain responses, then we can compare the original QALE distribution with the standardised one to estimate how much QALE inequality is attributable to that health domain. For example, if the HRQoL component of QALE inequality is 5 QALYs but only 4 QALYs after removing socioeconomic variation in the pain/discomfort domain, the difference of 1 QALY can then be attributable to those inequalities in pain/discomfort.

The procedure can be summarised as follows and is repeated for each health domain:

1. Calculate the probability distribution of responses by age and sex for the least deprived group (IMD5).
2. Randomly impute a new domain response for all individuals in IMD1–IMD4 based on the respective probability distribution from IMD5 according to their age and sex.

3. Re-estimate QALE and QALE inequalities between IMD1 and IMD5.
4. Repeat steps 1–3 a further four times to generate five estimates of QALE inequalities.
5. Take the average across these estimates and calculate the proportion of QALE inequality that has been removed by eliminating socioeconomic variation in the domain.

The creation of multiple datasets described in step 4 accounts for the variation that results from randomly assigning domain responses, and mirrors the approach undertaken during the multiple imputation of missing data [29].

To assess whether the contributions of the HRQoL domains to inequality were disproportionate, we compared them with a separate decomposition that estimated how the domains contributed to average QALE. If for example, pain/discomfort accounted for 10% of mean lifetime HRQoL loss but 20% of inequalities, we could conclude that inequalities in this dimension are disproportionately high relative to other domains.

Lastly, to evaluate whether the contributions of mortality and the HRQoL domains change over time, we repeat our decompositions at four points: at birth and ages 16, 40 and 65.

2.2.4 Uncertainty

As the population and death data are for the whole of England, they are not subject to sampling error. This leaves the HRQoL information from the HSE as the sole source of uncertainty in the quality-adjusted life tables. Standard errors and confidence intervals (CIs) for the QALE estimates and decomposition analysis were calculated by conducting 1000 bootstrap replications of the HSE data. Whilst the proportion of participants over 16 with missing EQ-5D-5L data was approximately 10%, we elected not to use multiple imputation techniques to impute missing data. This was justified on the results of a previous analysis of HSE data from 2010 to 2012 by Love-Koh et al. [9], who found that imputation resulted in average absolute differences in the predicted QALY weights of < 0.003.

All analyses were conducted in R version 4.1.0 or later.

3 Results

A total of 16,175 participants aged 16 or over took part in the HSE waves of 2017 and 2018. We excluded 1763 participants (10.9%) because they provided incomplete EQ-5D-5L responses. The final sample available for analysis was 14,412 participants ($n = 7168$ for 2017 and $n = 7244$ for 2018). Table 1 presents descriptive statistics of the sample. There are clear age and deprivation gradients in HRQoL, with older and more deprived participants reporting, on average, lower summary scores.

Cumulative mortality by age, sex and IMD are illustrated in Fig. 1. Mortality rates increase monotonically with age and deprivation level for both males and females, with a larger spread (i.e. greater inequality) across IMD quintiles for males.

3.1 Inequalities in QALE

Life expectancy and QALE estimates by age, sex and IMD quintile are presented in Table 2. The lifetime QALY loss due to HRQoL, shown by the difference between life expectancy and QALE, ranged from 15.2 QALYs in the most deprived group to 11.1 QALYs in the least deprived group. QALE estimates were higher in groups with less social deprivation: 62.19 (95% CI 61.34–63.03) QALYs in IMD1 up to 73.27 (95% CI 72.47–74.07) QALYs in IMD5. This yielded an absolute difference in QALE at birth of 11.08 QALYs (95% CI 9.91–12.25) and a relative difference of 0.18 (95% CI 0.16–0.2).

The relative differences increased with age, from 0.22 (95% CI 0.2–0.24) at age 25 to 0.43 (95% CI 0.37–0.5) at age 65. The relative difference in QALE inequality is approximately twice the difference observed for life expectancy at all ages. At age 65, the life expectancy of those in the least deprived group is 24% higher than those in the most deprived; the respective figure for QALE is 43%. Discounted results are shown in Table S1 in the Electronic Supplementary Material.

Whilst life expectancy at birth was on average 3.6 years greater for females than males, lower HRQoL for females meant that this difference was largely offset when calculating QALE at birth, shrinking to 0.2 QALYs. However, at ages 40 and 65, the gap increases to approximately 1 QALY.

The results from the health-related social welfare analysis are shown in Figure S1 in the Electronic Supplementary Material. Due to greater socioeconomic inequality in QALE in females, the difference between mean QALE and EDE QALE was greater, indicating that more average health would need to be traded-off in order to eliminate inequalities. This is shown by the steeper gradient of the female curve in Figure S1 in the Electronic Supplementary Material. For males, mean QALE was 68.1 QALYs ($\varepsilon = 0$) and EDE QALE was 67.77 and 66.98 QALYs at $\varepsilon = 3$ and $\varepsilon = 10$, respectively. For females, the corresponding values were 68.3, 67.93 and 67.02.

The set of implied equity weights for each IMD quintile and inequality aversion parameter value are given in Table 3. These show that when the same health gain is added to IMD1 and IMD5, the EDE improvement (at $\varepsilon = 3$) to IMD1 is 1.63 times higher than that of IMD5. This weight increases as inequality aversion increases, rising to 5.22 when $\varepsilon = 10$.

Table 1 Descriptive statistics of the pooled 2017–2018 Health Survey for England samples ($N = 14{,}412$)

Variable	*N* (%)	EQ-5D-5L score (SD)
Age		
16–19	529 (3.67%)	0.891 (0.156)
20–24	668 (4.64%)	0.872 (0.179)
25–29	881 (6.11%)	0.877 (0.188)
30–34	1119 (7.76%)	0.889 (0.166)
35–39	1187 (8.24%)	0.862 (0.194)
40–44	1166 (8.09%)	0.859 (0.204)
45–49	1220 (8.47%)	0.817 (0.246)
50–54	1258 (8.73%)	0.814 (0.24)
55–59	1312 (9.1%)	0.804 (0.251)
60–64	1139 (7.9%)	0.793 (0.25)
65–69	1187 (8.24%)	0.787 (0.245)
70–74	1124 (7.8%)	0.793 (0.212)
75–79	734 (5.09%)	0.76 (0.231)
80–84	501 (3.48%)	0.743 (0.239)
85	387 (2.69%)	0.68 (0.259)
Sex		
Female	8093 (56.15%)	0.812 (0.231)
Male	6319 (43.85%)	0.835 (0.219)
IMD quintile		
1 (most deprived)	2638 (18.3%)	0.779 (0.273)
2	2916 (20.23%)	0.796 (0.250)
3	2877 (19.96%)	0.828 (0.213)
4	3094 (21.47%)	0.842 (0.199)
5 (least deprived)	2887 (20.03%)	0.858 (0.180)

IMD index of multiple deprivation, *SD* standard deviation

3.2 Decomposition of QALE Inequalities

The breakdown of the QALE inequalities at birth between IMD1 and IMD5 is displayed in Fig. 2 (top panel) and reported in Table S2 in the Electronic Supplementary Material. These differ substantially by sex, with mortality risk contributing relatively more to QALE inequality than HRQoL in males (72%) than females (54.3%). The contribution of each EQ-5D-5L domain to QALE inequality also differed by sex. Pain/discomfort (20.1%) and anxiety/depression (10.8%) were more influential for females than males (10.7% and 2.8%, respectively). Conversely, for males, inequalities in mobility (8%) were more influential than for females (5.1%).

The contributions of mortality and HRQoL domains are relatively stable across QALE at birth and at ages 16 and 40 (Fig. 2, lower panel, and Table S3 in the Electronic Supplementary Material), with mortality generating between 73% and 74% of QALE inequality. At age 65, the proportion of inequality attributable to mortality increases substantially for both males and females. Inequalities attributable to HRQoL fall from 26.1% at age 40 to 10.3% at age 65 in males and from 43.9% at age 40 to 27% at age 65 in females.

The contributions of HRQoL domains to average QALE HRQoL loss and QALE inequality are shown in Table S4 in the Electronic Supplementary Material. We find different patterns by sex. For females, there is broad agreement across both measures, with the biggest drivers of HRQoL loss (pain/discomfort and anxiety/depression) also being the biggest drivers of inequality. However, for males, we find stark differences. Anxiety/depression accounts for 26.4% of HRQoL loss, on average, but just 10.3% of inequalities. This suggests that anxiety/depression has a large impact on the average person's QALE, but there is little inequality in its impact across socioeconomic groups. Conversely, self-care accounts for 5.6% of average HRQoL loss but 19.5% of inequalities.

4 Discussion

4.1 Principal Findings

This study provides further evidence of inequalities associated with socioeconomic status in QALE in England. We find people in the most deprived quintile of neighbourhoods (IMD1) in the country can expect to die 7.0 years earlier and experience 11.1 fewer QALYs in their lifetime than people who live in the least deprived fifth of neighbourhoods (IMD5). These patterns are consistent at different points in the life course, with relative inequalities between most and least deprived quintile groups higher at 65 than at birth. Most of the gap (63%) in QALE at birth between the IMD1 and IMD5 is attributable to differences in mortality, with the remainder a function of inequalities in HRQoL. All five dimensions of the EQ-5D-5L contribute positively to inequalities in QALE. Of these, 'pain/discomfort' was the largest contributor to the overall inequality (15.6% of total), whilst the 'usual activities' dimension was the smallest (2.3% of total).

Separating the analysis by sex demonstrates two key points. First, adjusting for quality of life almost eliminates the gap in life expectancy between males and females for every deprivation quintile. Second, there are clear differences in the relative importance of HRQoL for inequalities associated with socioeconomic status in QALE for males and females. In females, HRQoL accounts for nearly half (45.7%) of inequalities in QALE, whilst in males, it accounts for just over a quarter (27.9%). These patterns are broadly consistent until later years of life, when mortality becomes a much larger driver for both males and females. These differences between males and females emerge because of inequalities in different HRQoL domains as captured by the

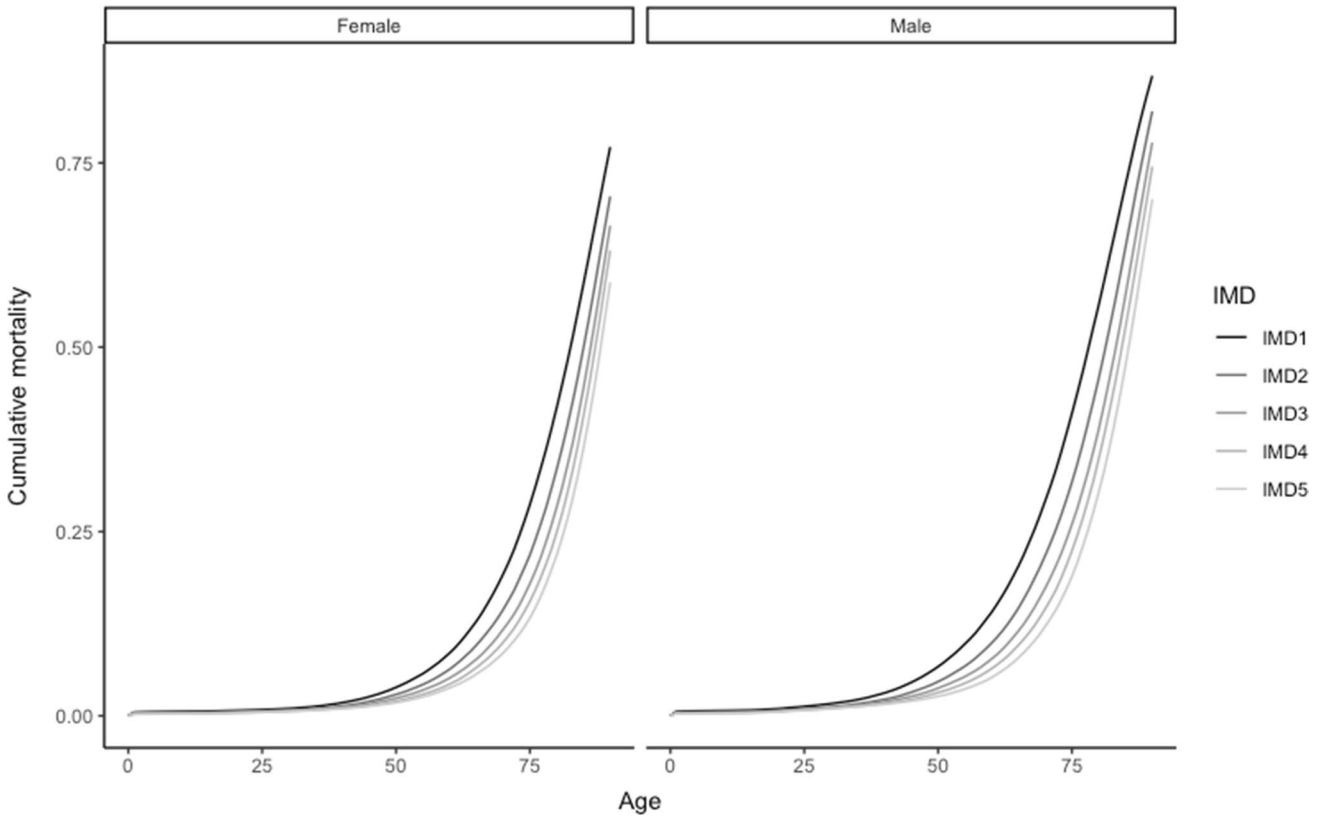

Fig. 1 Cumulative mortality in England for 2017–2018 by age, sex and index of multiple deprivation (IMD) quintile. Note: IMD1 = most deprived; IMD5 = least deprived

EQ-5D-5L instrument. For example, the anxiety/depression and pain/discomfort dimensions of the EQ-5D-5L account for 2.8% and 10.7% of the overall inequality in QALE between males and 10.8% and 20.1% of inequalities in QALE in females, respectively.

Conversely, we find mobility is a relatively important driver of inequalities in QALE in males, with 8% of the total, compared to 5.1% in females. While our data do not permit us to explore the reasons for these differences in greater detail, previous epidemiological and experimental studies suggest some plausible mechanisms. For example, females are consistently found to be at greater risk of chronic pain conditions than males [30, 31], and females may also be more sensitive to a range of pain stimuli, although evidence on this is less clear and is complicated by multiple factors, including hormonal interactions with nociceptive pathways, social expectations relating to reporting and tolerating pain, and the probability of receiving and responding to analgesia [32]. Additionally, financial hardship is associated with vulnerability to, and perception of, pain [33], which suggests that pain is likely to be a more important determinant of inequalities in HRQoL in females compared with males, and this is consistent with our findings.

Comparing the contributions of each of the HRQoL domains to QALE inequalities with their contribution to average HRQoL loss provides some insight on whether the decomposition results would be expected based on how common problems are in each domain. We find broad agreement in females, suggesting that inequalities are proportionate across domains. This does not hold for males, for whom anxiety/depression has a disproportionately small effect on inequality and self-care has a disproportionately large effect, indicating very different patterns of inequality across domains.

Our estimates of inequality in QALE are comparable, albeit lower, than those derived by Love-Koh et al. [9]. That study used EQ-5D-3L data from HSE and mortality information for the period 2010–2012, resulting in an estimated QALE gap of 11.9 QALYs for those in the most and least deprived quintiles in England. We find marginally higher

Table 2 Life expectancy and quality-adjusted life expectancy by index of multiple deprivation quintile (IMD) and sex

	IMD quintile group					Absolute difference	Relative difference
	1	2	3	4	5		
Females							
Life expectancy							
At birth	79.67	82.15	83.57	84.62	85.76	6.09	0.08
Age 16	64.18	66.55	67.92	68.9	70.06	5.88	0.09
Age 40	40.74	42.99	44.34	45.29	46.41	5.67	0.14
Age 65	18.8	20.4	21.28	21.96	22.88	4.08	0.22
Quality-adjusted life expectancy							
At birth	62.17 (0.72)	65.28 (0.6)	69.55 (0.57)	71.59 (0.65)	73.42 (0.65)	11.25 (0.93)	0.18 (0.02)
Age 16	48.39 (0.42)	52.26 (0.4)	55.53 (0.38)	57.3 (0.35)	59.58 (0.35)	11.18 (0.62)	0.23 (0.01)
Age 40	28.49 (0.37)	32.05 (0.35)	34.86 (0.33)	36.47 (0.28)	38.59 (0.28)	10.1 (0.52)	0.35 (0.02)
Age 65	12.26 (0.29)	14.37 (0.31)	15.84 (0.24)	16.98 (0.25)	17.86 (0.25)	5.6 (0.45)	0.46 (0.05)
Males							
Life expectancy							
At birth	75.18	78.23	80.17	81.45	82.87	7.69	0.1
Age 16	59.76	62.71	64.56	65.82	67.21	7.45	0.12
Age 40	36.82	39.49	41.29	42.47	43.83	7.01	0.19
Age 65	16.3	17.84	18.97	19.72	20.68	4.37	0.27
Quality-adjusted life expectancy							
At birth	62.36 (0.68)	65.52 (0.58)	69.49 (0.62)	70.64 (0.51)	73.02 (0.51)	10.66 (0.78)	0.17 (0.01)
Age 16	48.22 (0.44)	51.07 (0.37)	55.08 (0.39)	56.73 (0.38)	58.45 (0.38)	10.23 (0.58)	0.21 (0.01)
Age 40	27.68 (0.4)	30.28 (0.3)	34.09 (0.29)	35.7 (0.31)	37.17 (0.31)	9.5 (0.52)	0.34 (0.02)
Age 65	12.05 (0.31)	13.17 (0.25)	14.78 (0.25)	15.76 (0.25)	16.85 (0.25)	4.8 (0.37)	0.4 (0.04)
Combined							
Life expectancy							
At birth	77.39	80.2	81.89	83.07	84.36	6.97	0.09
Age 16	61.94	64.64	66.27	67.39	68.68	6.74	0.11
Age 40	38.76	41.26	42.85	43.92	45.17	6.41	0.17
Age 65	17.59	19.17	20.18	20.89	21.84	4.25	0.24
Quality-adjusted life expectancy							
At birth	62.19 (0.43)	65.54 (0.49)	69.54 (0.42)	71.12 (0.44)	73.27 (0.41)	11.08 (0.6)	0.18 (0.01)
Age 16	48.26 (0.34)	51.66 (0.31)	55.32 (0.26)	57.05 (0.28)	59.05 (0.26)	10.79 (0.43)	0.22 (0.01)
Age 40	28.06 (0.3)	31.15 (0.28)	34.5 (0.23)	36.1 (0.22)	37.92 (0.21)	9.86 (0.36)	0.35 (0.02)
Age 65	12.15 (0.24)	13.76 (0.21)	15.35 (0.19)	16.4 (0.17)	17.4 (0.18)	5.25 (0.31)	0.43 (0.03)

Standard errors in parentheses. Uncertainty not quantified for life expectancy given national population data are used rather than a sample

inequalities in QALE in females (11.3 QALYs compared to 11.2 QALYs) but significantly lower inequalities in QALE in males (10.7 QALYs compared to 12.5 QALYs).

4.2 Implications

This study has important implications for policymakers and practitioners aiming to reduce health inequalities. First, it provides further evidence that measuring mortality gaps across social groups underestimates the extent of existing disparities, and that greater consideration needs to be given to the quality in addition to the quantity of life. Robust instruments for monitoring HRQoL, such as the EQ-5D-5L element of the HSE, will therefore be crucial in guiding the public health and policy response.

Second, it demonstrates that some dimensions of HRQoL are more important than others in explaining social inequalities in overall QALE, and their contribution varies substantially with sex. Although some interventions will address multiple dimensions, interventions that are demonstrably effective for—or that specifically target—key dimensions may need to be prioritised over others, and different approaches may be required for males and females. Although we have focused on inequalities in this paper, decisions will

Table 3 Implied equity weights derived from the Atkinson index and quality-adjusted life expectancy distribution by index of multiple deprivation (IMD) quintile and inequality aversion parameter value

Atkinson inequality aversion	Implied weight (relative to IMD5)				
	IMD1	IMD2	IMD3	IMD4	IMD5
0	1	1	1	1	1
0.5	1.08	1.06	1.03	1.01	1
1	1.18	1.12	1.05	1.03	1
1.5	1.28	1.18	1.08	1.05	1
2	1.39	1.25	1.11	1.06	1
2.5	1.5	1.32	1.14	1.08	1
3	1.63	1.4	1.17	1.09	1
3.5	1.77	1.48	1.2	1.11	1
4	1.93	1.56	1.23	1.13	1
4.5	2.09	1.65	1.26	1.14	1
5	2.27	1.75	1.3	1.16	1
5.5	2.47	1.85	1.33	1.18	1
6	2.68	1.95	1.37	1.2	1
6.5	2.91	2.07	1.4	1.21	1
7	3.16	2.18	1.44	1.23	1
7.5	3.44	2.31	1.48	1.25	1
8	3.74	2.44	1.52	1.27	1
8.5	4.06	2.59	1.56	1.29	1
9	4.42	2.74	1.6	1.31	1
9.5	4.8	2.89	1.64	1.33	1
10	5.22	3.06	1.69	1.35	1

also need to reflect the overall impact of different dimensions on population mortality and quality of life, as dimensions that are more equitably distributed may also make a greater contribution to overall shortfalls in life expectancy. The impact of policies will need to be monitored over time and the mix of interventions adapted; as inequalities in individual dimensions are tackled, other dimensions will come to explain more of the remaining inequality.

Our findings provide an updated set of inputs that can be used in distributional cost-effectiveness analyses that model the health inequality impacts of health programmes and interventions. An implication of our lower estimates of inequalities in QALE (compared with previous work in Love-Koh et al. [9]) is that the marginal value of reducing these inequalities will be lower. Smaller relative differences in baseline QALE mean that the value of gains to the most deprived relative to the least deprived are slightly lower. This is exemplified in the set of implicit weights provided in Table 3: the implied weight for IMD1 to IMD5, at an Atkinson $\varepsilon = 10$, drops from 5.66 in the older Love-Koh et al. distribution to 5.22 for the distribution we estimate in this work.

4.3 Strengths and Limitations

The main strength of our study is the use of robust information on HRQoL, derived through a survey of a large, representative sample of the general population in England, alongside mortality rates taken from an official national statistics agency. The large sample size in the HSE permit us to stratify analyses of HRQoL by age, sex and socioeconomic deprivation profile. Furthermore, the EQ-5D-5L instrument is one of the most widely used generic measures of HRQoL and is recommended for use in England by the National Institute for Health and Care Excellence. The instrument is able to capture the multidimensional nature of health and HRQoL better than single-item questions commonly used in many population surveys and provides QALY weights for sociodemographic groups.

There are a number of limitations to our work. First, it is possible that some of the observed inequalities in QALE reflect differences in reporting style between socioeconomic groups. However, detection of such reporting differences would require external, validated anchoring vignettes, which are not part of the HSE.

We were not able to analyse the inequalities associated with socioeconomic status by the seven different dimensions of deprivation that make up the IMD indicator. Although scores for each dimension are calculated for each small area of England, the data used in our analysis were only available by quintile of the composite IMD score. Were this to become available, further research could investigate how inequalities vary by aspects of socioeconomic deprivation.

Our calculation of QALE required assuming that HRQoL for those aged under 16 was equivalent to those aged 16–19. This could mean we are underestimating QALE for all subgroups if HRQoL were higher for those under 16.

Approximately 11% of participants did not complete the EQ-5D-5L questionnaire and were excluded from the study. Rates of missingness were higher for males and those living in the most deprived neighbourhoods. Missing values were not imputed based on a previous study indicating that imputation had at most a marginal impact on HRQoL scores by deprivation quintile group, finding that the difference between complete case and imputed datasets differed by less than 0.01 QALYs.

Our findings of inequality in QALE and the importance of each HRQoL domain are contingent on the coverage of the EQ-5D descriptive system and the value set employed to translate health profiles into summary scores. We note that the value set used in this study reflects the general population's average preferences over health states. Again, it may be that different socioeconomic groups value HRQoL domains differently. Our estimates therefore reflect

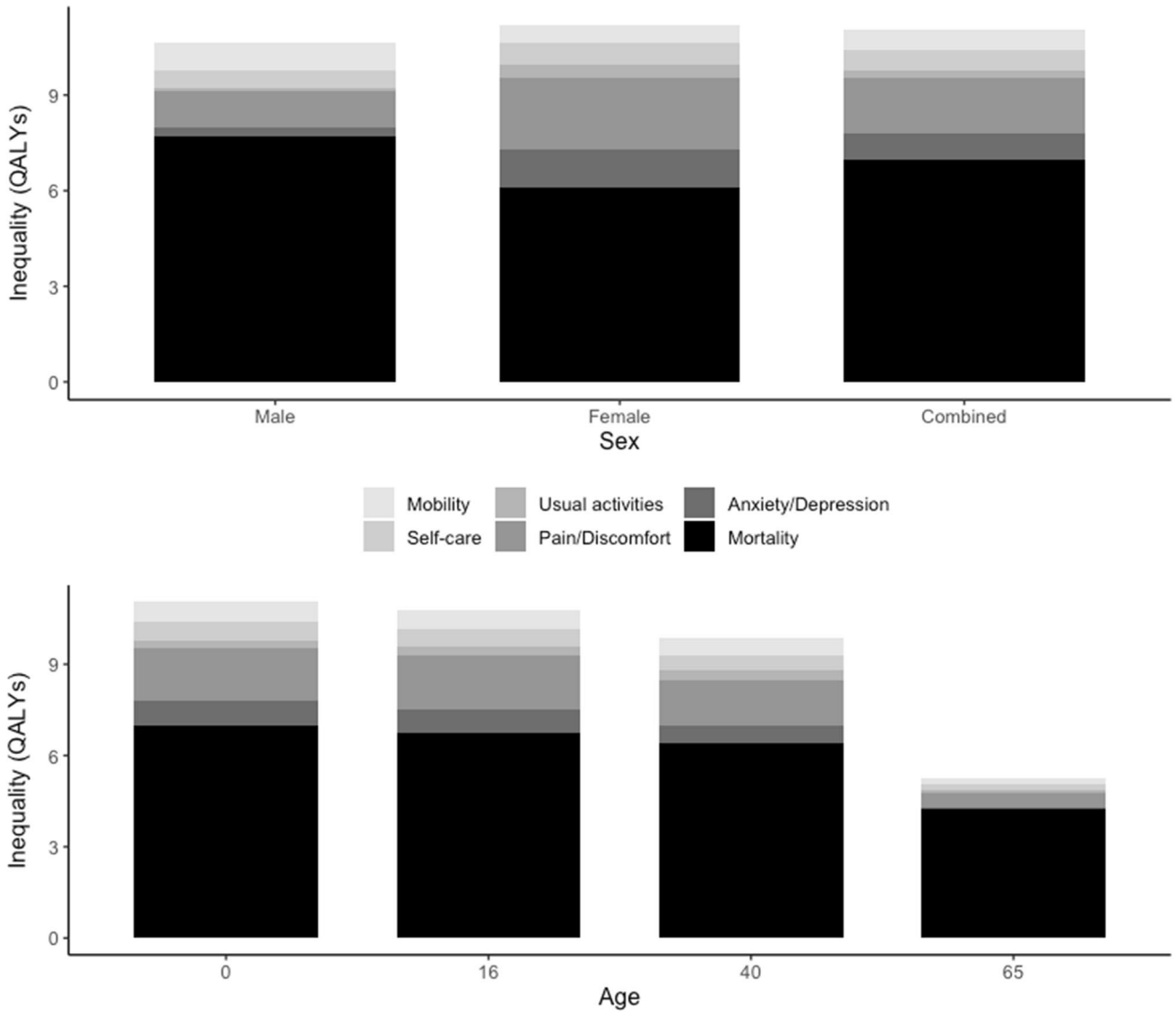

Fig. 2 Decomposition of quality-adjusted life expectancy differences between the most (IMD1) and least (IMD5) deprivation quintiles. Top panel: Decompositions at birth by sex. Lower panel: Decompositions at different ages. *IMD* index of multiple deprivation, *QALY* quality-adjusted life year

inequalities as perceived by the overall population, which may differ from the perception of the individual subgroups concerned.

Finally, because the EQ-5D-5L instrument was only used in the latest waves of the HSE (from 2017 onwards), our results are not directly comparable to previous estimates based on EQ-5D-3L data collected in earlier waves of the HSE [9]. Consequently, the HSE cannot be used to measure changes in inequalities in response to key relevant policies, such as Labour's Program for Action on health inequalities in the 2000s [34], or following major social and economic shocks, such as the 2008/2009 recession. However, we are not aware of other long-running representative surveys of the general population in England that include multi-attribute utility instruments required for the calculation of QALEs.

5 Conclusion

By combining information from a multi-dimensional HRQoL survey with national mortality data we have been able to generate new insights into the nature of social inequalities in health in England. Adjusting for HRQoL reduces the gaps in life expectancy between the sexes but increases the gaps between social groups; compared to the most affluent fifth, the most deprived fifth of people lose over a

decade of healthy life. For males, issues related to mobility are the biggest quality of life contributors to this gap, whereas for females, pain and anxiety are the key factors. Different, targeted approaches may therefore be necessary in order to make meaningful progress in tackling national health inequalities.

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Declarations

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Competing interests All authors have consulted the Springer Competing Interests policy and confirm that they have no relevant conflicts of interest to report.

Consent to participate/publish This study used only fully anonymised, publicly available data from the UK Office for National Statistics and the UK Data Service. No human subjects were involved in the study, and no consent to participate and publish was required.

Role of sponsor The funding agreements with the sponsors of this research ensured the authors' independence in designing the study, interpreting the data, writing and publishing the report.

Data availability All the data sets that were used for the analysis are publicly available: University College London Department of Epidemiology and Public Health and National Centre for Social Research (NatCen)—Health Survey for England, 2017 [19] and Health Survey for England, 2018 [20]; Office for National Statistics—National Life Tables, England, 1980–1982 to 2017–2019 [23] .

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Ethics Approval Not applicable.

Code Availability Available upon request.

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