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Erica I. Lubetkin
CUNY City College

Haomia Jia
Columbia University

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BMJ Open Burden of disease associated with lower levels of income among US adults aged 65 and older

Erica I Lubetkin,¹ Haomiao Jia²

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¹Department of Community Health and Social Medicine, CUNY School of Medicine, New York, New York, USA

²Department of Biostatistics, Mailman School of Public Health and School of Nursing, Columbia University, New York, New York, USA

Correspondence to

Dr Erica I Lubetkin;
lubetkin@med.cuny.edu

ABSTRACT

Background: Persons aged 65 years and older represent a heterogeneous group whose prevalence in the USA is expected to markedly increase. Few investigations have examined the total burden of disease attributable to lower levels of income in a single number that accounts for morbidity and mortality.

Methods: We ascertained respondents' health-related quality of life (HRQOL) scores and mortality status from the 2003 to 2004, 2005 to 2006, 2007 to 2008 and 2009 to 2010 cohorts of the National Health and Nutrition Examination Survey (NHANES) with mortality follow-up through 31 December 2011. A mapping algorithm based on respondents' age and answers to the 4 core Healthy Days questions was used to obtain values of a preference-based measure of HRQOL, the EuroQol five dimensions questionnaire (EQ-5D) index, which enables quality-adjusted life years (QALYs) to be calculated. We included only respondents aged 65 years and older at the baseline, yielding a total sample size of 4952. We estimated mean QALYs according to different categories of income based on the percentage of Federal Poverty Level (FPL).

Results: After adjusting for age, gender and education, the remaining QALYs decreased with each successive decrement of category of income, ranging from 18.4 QALY ($\geq 500\%$ FPL) to 8.6 QALY ($< 100\%$ FPL). Compared with participants with a mean income of $\geq 250\%$ FPL, participants with an income $< 250\%$ FPL had significant losses in QALY for most of the sociodemographic groups examined. In contrast, persons with a lower educational attainment did not show a corresponding loss in QALY according to income category.

Conclusions: This study confirmed the association between lower income category and greater burden of disease, as measured by QALYs lost, among the US population aged 65 years and older. Our findings provide additional evidence of the role played by other key determinants of health and how factors not traditionally addressed by the healthcare system impact the life cycle of individuals and communities.

INTRODUCTION

The USA has been experiencing a demographic shift in its age pyramid, as the

Strengths and limitations of this study

- Although numerous studies have examined the relationships between income and mortality and income and morbidity, fewer investigations have examined the total burden of disease attributable to lower levels of income in a single number.
- This is the first study that examines quality-adjusted life year (QALY) according to income category for the US population aged 65 years and older.
- Study limitations include (1) the sample size was too small to detect any difference in QALY loss due to low income within subgroups; (2) we were unable to determine if participants were still employed, a factor that would impact income and that would be expected to have an association with educational attainment and (3) although wealth may be more strongly associated with burden of disease than income, the National Health and Nutrition Examination Survey (NHANES) only included income-related items.
- A final limitation is that the NHANES did not include preference-based health-related quality of life (HRQOL) questions, so we used a mapping algorithm to obtain EuroQol five dimensions questionnaire (EQ-5D) index scores for respondents based on their answers to other HRQOL questions.

population aged 65 years and over is projected to nearly double between 2012 and 2050.¹ Although life expectancy for persons in the USA has been increasing, the income-mortality gradient has widened.^{2 3} Differences in life expectancy at age 50 based on lifetime earnings are projected to increase at least twofold. For example, among men born in the 1930 cohort, the highest income quartile have a life expectancy of 5.1 years longer than the lowest income quartile, and this gap has been projected to be 12.7 years for men born in the 1960 cohort.¹

A recent analysis of tax records and Social Security Administration death records found that the differences in life expectancy among

persons aged 40–76 years increased over the period from 2001 to 2014 across income groups.³ Not surprisingly, life expectancy was correlated with health behaviours both for persons in the top and bottom income quartiles.³ Regarding morbidity, Love-Koh *et al*⁴ adjusted for health-related quality of life (HRQOL) and found a substantial increase in the size of the socioeconomic health inequality as compared with life expectancy alone. Compared with wealthier persons, persons with a lower income are more likely to report fewer average healthy days and a greater number of chronic diseases and behavioural risk factors such as smoking.⁵ These inequalities according to income continue to persist after adjusting for comorbidities and health behaviours both for persons in the top and bottom income quartiles.^{3 6}

Although numerous studies have examined the relationships between income and mortality and income and morbidity, fewer investigations have examined the total burden of disease attributable to lower levels of income in a single number.^{7 8} In contrast, the vast majority of the literature examines the burden of disease due to diseases, injuries and behavioural risk factors.⁹ Although a recent investigation examining the burden of disease focused on risk factors across the age span, the investigators concluded that further analyses are needed to determine the underlying causes of health loss according to income, education and race/ethnicity as well.¹⁰

With regard to income, Muennig *et al*⁷ calculated that persons aged 18 years and older in the top 20% of households by earnings live 4.3 years and 6.4 health-adjusted life years (HALYs) longer than the remainder of the population, an annual difference of nearly 11 million years of prematurely lost life or 17.4 million HALYs. In another study, Muennig *et al*⁸ investigated the contribution of eight social and behavioural risk factors and discovered that living at <200% of the Federal Poverty Level (FPL) reduced quality-adjusted life expectancy more than any other risk factor, even after controlling for the effects of education. Yet the focus of this study was on the general population, not the elderly, and the mean age of the sample was 46.3 years of age.

Given that life expectancy is increasing and that the gap between the incomes of high earners compared with lower earners has increased in the elderly, understanding the relationship between the disparities in income on both mortality and morbidity (burden of disease) is critical in this population. Since income inequality adversely impacts population health, and has been increasing over the past three decades in many countries, policies might be enacted earlier in the life course in order to narrow the associated gap in health in later years.¹¹ Such policies might extend beyond the medical arenas by including social and economic decisions. This study sought to gain a better understanding of the association of income on persons aged 65 years and older on the remaining quality-adjusted life years (QALYs) at various levels of income as well as how

differences in educational attainment, race/ethnicity, marital status and number of comorbidities are related to levels of income, which in turn affects the remaining QALY.

MATERIALS AND METHODS

QALYs is a single value index that quantifies the burden of disease. It reflects all aspects of health, including non-fatal illness and mortality outcomes by weighting life-years lived with preference-based HRQOL scores.¹² Preference-based HRQOL, also called health utility value, is a summary score that assesses the preferences of one health state versus another state. The health utility value is anchored at 0 for death and 1 for perfect health,¹² so 1 year living in a reduced health state of utility value of 0.5 equals 0.5 QALYs, the same as living one half year in perfect health.

Data: This analysis used de-identified data produced by federal agencies in the public domain and therefore no ethics approval was required. Data were downloaded from the Centers for Disease Control and Prevention website (<ftp://ftp.cdc.gov/pub>). This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. We ascertained respondents' HRQOL scores and mortality status from the 2003 to 2004, 2005 to 2006, 2007 to 2008 and 2009 to 2010 cohorts of the National Health and Nutrition Examination Survey (NHANES) Linked Mortality File.^{13 14} The NHANES is an ongoing survey of random samples from the non-institutionalised civilian population of the USA.¹³ With the use of the design weight and adjustment for non-coverage and non-response, the distribution of respondents was representative of the US general population.¹³ The NHANES Linked Mortality File was created by the National Center for Health Statistics (NCHS) by linking the NHANES respondents to the National Death Index (NDI).¹⁴ The respondents in this analysis had mortality follow-up through 31 December 2011. We included only respondents aged 65 years and older at the baseline, yielding a total sample size of 4952.

The NHANES included a questionnaire which asks respondents to rank their general health from 1 (excellent) to 5 (poor) and to report numbers of their physically unhealthy days, mentally unhealthy days and days with activity limitation during the past 30 days.¹⁵ This study employs our previously published mapping algorithm based on respondents' age and answers to these four questions to obtain values of a frequently used preference-based HRQOL measurement, the EuroQol five dimensions questionnaire (EQ-5D) index, to calculate QALY.¹⁶ This algorithm provides valid estimates of EQ-5D scores for respondents and the bias of estimated QALY from these scores has been estimated to be <1% of that using the actual EQ-5D questions.¹⁷

The NHANES includes information on respondent sociodemographic characteristics and certain diseases at the baseline.¹³ These variables were included in the

analyses to assess potential associations with these variables and category of income. The analysis examined age, gender, race/ethnicity, educational attainment, income, marital status and number of comorbidities. The NHANES calculated income to the FPL ratio for respondents. Income initially was categorised into six levels based on the percentage of FPL—<100% FPL, 100 to <138% FPL, 138 to <250% FPL, 250 to <400% FPL, 400% to <500% FPL and $\geq 500\%$ FPL—but then was dichotomised into <250% FPL and $\geq 250\%$ FPL. The initial cut-off points were chosen because they are the basis of determining Medicaid eligibility and assist in determining eligibility for other non-healthcare-related assistance programmes.¹⁸

Statistical analysis: Since most of the participants are alive at the end of follow-up, we calculated mean QALY throughout the remaining lifetime by extrapolating quality-adjusted survival time beyond the end of follow-up using our newly developed QALY estimator.¹⁹ This study applied a hybrid method that calculated QALY from two parts: QALY during the follow-up period (to 31 December 2011) and QALY beyond the follow-up period (after 31 December 2011). Details of this method have been described previously.¹⁹ In summary, QALYs during the follow-up period were estimated based on the Kaplan-Meier method while QALYs beyond the follow-up period were estimated by extrapolating survival time beyond the end of follow-up using a Weibull model.²⁰

We calculated mean QALY according to different levels of income. A propensity score method was used to account for the systematic difference in participants' characteristics, such as age, sex and education, between persons of different income levels.²¹

RESULTS

The average age of participants was 73.5 years (SD=5.8 years) at the start of the study (table 1). Women comprised 55.4% of the population and non-Hispanic whites comprised 83.5% of the population. Only 7.9% were non-Hispanic blacks and 5.8% were Hispanics. About 16.6% of participants died during the follow-up, yielding a mortality rate of 3.83 deaths per 100 person-years (table 2). The mean EQ-5D score was 0.828 and the mean QALY throughout the remaining lifetime was 12.6 years.

Among US adults aged 65 years and older, EQ-5D scores increased and mortality decreased with each rise in the category of income. These patterns resulted in participants with a higher income category having a greater remaining QALY. After adjusting for age, gender and education, the total range of QALY remaining ranged from 8.6 years for persons in the lowest income category (<100% FPL) to 18.4 for persons in the highest income category, a difference of 9.8, or a loss of 53.3%.

After adjusting for age, gender and education, significant losses in QALY according to income category, <250% FPL as compared with $\geq 250\%$ FPL, were noted

Table 1 Baseline characteristics, 2003–2010 NHANES, US adults aged 65 years and older

	Total		
	N	Per cent	SE (%)
All	4952	100%	–
Age: mean (SD)	4952	73.5 (5.8)	
65–74	2605	57.4%	1.1
75–84	2058	38.2%	1.1
85+	289	4.4%	0.4
Sex			
Male	2505	44.6%	0.6
Female	2447	55.4%	0.6
Race			
Non-Hispanics white	3151	83.5%	1.3
Non-Hispanics black	772	7.9%	0.8
Hispanics	906	5.8%	0.8
Other	123	2.8%	0.4
Income			
<100% FPL	676	8.6%	0.6
100–138% FPL	712	12.0%	0.6
138–250% FPL	1369	30.5%	1.3
250–400% FPL	908	23.2%	1.0
400–500% FPL	334	9.0%	0.6
$\geq 500\%$ FPL	575	16.6%	1.1
Education			
<9th grade	1067	12.7%	0.8
9–11th grade	789	14.3%	0.9
High school graduate	1253	28.9%	1.0
Some college or higher	1831	44.1%	1.6
Married or with partner			
Yes	2778	60.3%	1.1
No	2173	39.7%	1.1
Comorbidities			
0	848	17.9%	0.9
1	1656	33.1%	1.0
2	1276	25.3%	0.7
3+	1172	23.7%	1.1

FPL, Federal Poverty Level; NHANES, National Health and Nutrition Examination Survey.

for men and women as well as for non-Hispanic whites, non-Hispanic blacks and Hispanics (figure 1). Although the QALY losses associated with <250% FPL were greater for women than for men and were greater for Hispanics than for non-Hispanic whites and non-Hispanic blacks, the differences were not significant. With regard to age, participants in the young-old age category (65–74 years) and the middle-old age category (75–84 years) who reported an income of <250% FPL had a significantly lower QALYs than their counterparts who reported an income of $\geq 250\%$ FPL. In contrast, no significant difference in QALYs according to income was noted in the old-old age category (85 years and older). In addition, significant losses in QALY by income category were noted for persons who were not married or living with a partner as well as persons with fewer (0–1) and more (2 or more) comorbid conditions.

Since education may act as an effect modifier for the relationship between income and burden of disease, we

Table 2 EQ-5D index, mortality rate and QALYs throughout the remainder of the lifetime by Income Category, US adults aged 65 years and older

Income	EQ-5D	SE	Decrease	SE	Mortality	SE	Increase	SE	QALY	SE	Decrease	SE
Total	0.828	0.004	–	–	3.83	0.15	–	–	12.6	0.8	–	–
Income												
≥500% FPL	0.858	0.015			2.39	0.73			18.4	8.5		
400–500% FPL	0.856	0.018	0.002	0.019	2.32	0.74	–0.07	0.82	15.7	3.5	2.7	5.2
250–400% FPL	0.828	0.011	0.030	0.012	3.75	0.40	1.37	0.54	12.9	2.1	5.4	3.8
138–250% FPL	0.829	0.008	0.029	0.010	4.17	0.32	1.78	0.48	10.7	1.3	7.7	3.8
100–138% FPL	0.801	0.013	0.056	0.014	4.89	0.46	2.51	0.59	9.0	1.3	9.4	4.2
<100% FPL	0.775	0.014	0.082	0.016	5.36	0.55	2.97	0.66	8.6	1.4	9.8	3.6
≥250% FPL	0.841	0.005			3.21	0.18			14.0	1.0		
<250% FPL	0.812	0.009	0.028	0.010	4.58	0.34	1.37	0.37	10.1	0.7	3.9	1.0

EQ-5D, mortality rate and QALY were adjusted for age, sex and education.

Mortality rate: deaths per 100 person-years of follow-up.

EQ-5D, EuroQol five dimensions questionnaire; FPL, Federal Poverty Level; QALY, quality-adjusted life years.

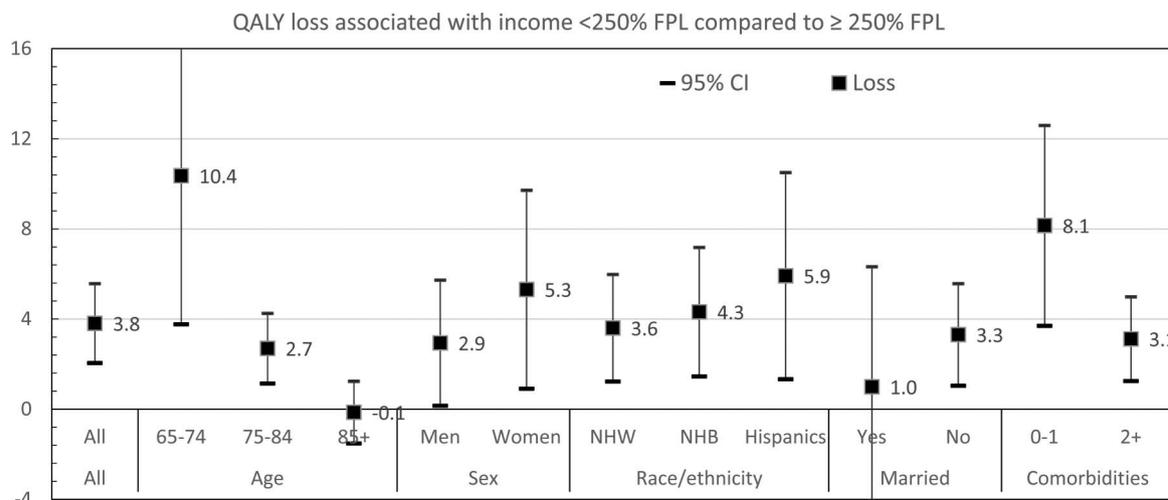
applied a stratified analysis to estimate the impact of income at different levels/categories of education (table 3). This analysis was conducted because participants reporting a higher level of educational attainment were more likely to be in a higher income category (OR=4.4, 95% CI 3.6 to 5.3). Among participants with a lower educational attainment, those who reported an income of <250% FPL had similar QALY remaining compared with those who reported an income of ≥250% FPL (10.6 and 10.1, respectively). In contrast, the remaining QALY loss proved to be statistically significant for participants with higher educational attainment who reported an income of <250% FPL compared with ≥250% FPL (11.3 vs 15.9, loss of 4.6 QALY; 28.7% loss).

Similarly, the impact of education on QALY differed according to category of income. Among participants

who reported an income of <250% FPL, those with a higher educational attainment had a similar QALY remaining compared with those with a lower educational attainment (11.3 vs 10.6). In contrast, the remaining QALY loss was statistically significant for participants reporting ≥250% FPL who had a low educational attainment compared with a higher educational attainment (10.1 vs 15.9, loss of 5.8 QALY).

DISCUSSION

To the best of our knowledge, this is the first study that examines the burden of disease due to differences in income for a representative sample of the US population aged 65 years and older. By linking the NHANES with the NDI, both morbidity and mortality could be



Adjusted for age, sex, and education.

Race/ethnicity: NHW=none-Hispanic Whites, NHB=non-Hispanic blacks

Married: Yes=married or with a partner, No=widowed, divorced, separated, or never married

FPL: Federal Poverty level

Figure 1 Quality-adjusted life years (QALYs) lost associated with income <250% Federal Poverty Level (FPL), as compared with ≥250% FPL, for all participants and according to age, sex, race/ethnicity, marital status and comorbidities.

Table 3 Stratified analysis of QALY by income category and level of education

Education	<250% FPL		≥250% FPL		Loss to low income	
	QALY	SE	QALY	SE	Loss	SE
High	11.3	1.0	15.9	1.1	4.6	1.2
Low	10.6	0.9	10.1	1.1	-0.5	1.2
Loss to low education	0.8	1.2	5.9	1.2		

Adjusted for age and sex.

Education: lower=less than high school, high=high school or higher.

FPL, Federal Poverty Level; QALY, quality-adjusted life years.

determined. Since the 1970s, the income gap in the USA has continued to widen and the income dispersion among this population also is greater compared with younger households.^{22 23} This is surprising, given that Social Security provides about half of the cash income for seniors.²³ On a parallel note, life expectancy has increased for persons earning more money but this increase is much less, or even declines, for lower earners.¹ Our results indicate that the association between income and burden of disease is present at all levels of income examined and, although the difference in QALY between different levels of income may not be statistically significant, the magnitude of change would be considered clinically important.

Investigators have noted that socioeconomic differences widen dramatically through middle age and early old age and then diminish in old age.²⁴ Our findings are consistent with the literature, as we noted that the percentage change in QALYs lost decreases when moving from young-old, middle-old, and old-old. There are multiple potential causes for a lack of impact of income level on burden of disease in the oldest age group but this topic has not been widely examined.²⁵ Interestingly, Hummer and colleagues examined data from the NCHS and found that among non-Hispanic blacks the mortality rates are 30–50% higher than for non-Hispanic whites at ages 65–79 but then converge at ages 80–84, eventually crossing over among persons aged 85 years and older.²⁶

Our stratified analysis revealed a more complex relationship between category of educational attainment and income, as the gain in QALYs due to a higher category of income only was seen in persons with a higher educational attainment. Disparities have been noted with regard to quality-adjusted life expectancy and educational attainment for the Dutch population but these investigators did not examine the role of income. Specifically, Gheorghe *et al*²⁷ noted that 65-year-old men reporting a low educational level had 3.48 fewer QALYs than males reporting a high educational level and observed a similar pattern for 65-year-old women. When we examined the QALY loss due to educational

attainment, we found a QALY loss of 3.9 between the lowest category of educational attainment (<9th grade) and the highest category of educational attainment (some college or higher) (data not shown). Our findings indicate that the magnitude between the remaining QALYs for participants at our highest and lowest income categories is greater than that due to educational attainment. Even after adjusting for education, persons reporting an income of <100% FPL (bottom 9%) had 9.8 fewer QALYs remaining than persons reporting an income of ≥500% FPL (top 17%).

In our study, after adjusting for education, differences in the remaining QALY by income category were present for young-old and middle-old persons as well as for men and women, whites, non-Hispanic blacks and Hispanics, and according to marital status and number of comorbidities. The impact of income on the remaining QALY lessened among the group of persons with more comorbidities as compared with the groups who had fewer comorbid conditions. This may have been because the impact of the multimorbidity might play a more prominent role in the QALY remaining. Yet disparities persisted in QALY remaining between persons with the same number of comorbid conditions who differed according to category of income. Von dem Knesebeck *et al*⁶ also noted that disparities in HRQOL according to income existed among patients between the ages of 65 and 85 years with multiple comorbidities. However, these investigators did not examine disparities by age among this sample.

Our study has a number of limitations. First, although our study had nearly 5000 participants, enabling us to analyse and adjust for a number of sociodemographic factors, our sample size was too small to detect any difference in QALY loss due to low income within subgroups. Second, we were unable to determine if participants were still employed, a factor that would impact income and that would be expected to have an association with educational attainment. Third, while evidence exists that wealth may be a better indicator of socioeconomic well-being as compared with income, especially among persons aged 65 years and older, the NHANES only included income-related items.^{28 29} Wealth may be more strongly linked to health and mortality than income, and therefore our results might underestimate the true impact of wealth on the burden of disease in the USA. The association between wealth and health also has been shown to be stronger in the USA compared with many other countries with state-based healthcare systems.^{29 30}

Finally, the NHANES did not include the preference-based HRQOL questions. We used a mapping algorithm to obtain EQ-5D index scores for respondents based on their answers to other HRQOL questions. Estimates of QALY loss would also most likely be underestimated due to regression towards the mean.³¹ However, a previous study that examined the bias of QALY estimates showed that these underestimations were about 2.5% for QALY loss.³¹

In conclusion, this study estimated the burden of disease attributable to category of income by calculating QALY throughout the remainder of life. Although the literature has noted that the income disparities may decrease among persons aged 65 years and older, these disparities were of great magnitude among the young-old and middle-old. Our findings are significant in the context of a growing elderly population which represents an extremely heterogeneous group with regard to life expectancy and income dispersion. A greater understanding would enable long-term planning for the anticipated health needs of this growing population.

Contributors This study was conceived and designed by EIL and HJ. HJ acquired and analysed the data. Both EIL and HJ reviewed all analyses and drafted the manuscript. EIL and HJ are joint authors and both authors gave final approval of the version of the manuscript to be published. EIL is the guarantor.

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