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Estimating EQ-5D utility values for major health behavioural risk factors in England

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ABSTRACT

Background Major behavioural risk factors, namely obesity, alcohol consumption, smoking, lack of fruit and vegetable intake and physical inactivity negatively impact on self-reported quality of life. However, little is known about their impact on preference-based measures of health-related quality of life commonly used to inform economic evaluations.

Methods Preference-based health-related quality of life outcomes associated with major behavioural risk factors were estimated using the EuroQol EQ-5D responses of 14 117 participants, aged ≥16 years, in the 2008 Health Survey for England. Multivariable linear regression was used to model the relationship between the five risk factors and EQ-5D utility scores. In addition, logistic regression was used to model their relationship to dichotomous reports of problems for each of the five EQ-5D dimensions.

Results Only one-third of participants had a body mass index within normal range, never drank alcohol, consumed at least five portions of fruit or vegetable/day or exercised regularly, while nearly half of participants were smokers or ex-smokers. In the fully adjusted multivariable analyses, reductions in EQ-5D utility scores (95% CI) of 0.105 (0.072 to 0.137), 0.062 (0.042 to 0.082) and 0.142 (0.129 to 0.155) were estimated for a body mass index ≥40 kg/m^2, heavy smoking (≥20 cigarettes/day) and physical inactivity, respectively. Hazardous alcohol consumption (men >4 and ≤8 units/day; women >3 and ≤6 units/day) and daily fruit and vegetable intake between three and less than five portions were associated with small positive effects on EQ-5D utility scores ($p<0.05$).

Conclusions The high prevalence and substantial utility loss associated with obesity, smoking and physical inactivity highlight the potential impact that interventions aimed at their prevention or alleviation may have on population health.

INTRODUCTION

The adverse consequences of obesity,[1] excess alcohol consumption,[2] smoking,[3] poor diet[4] and lack of physical activity[5] on health outcomes are well documented. The high prevalence of these health behavioural risk factors at the population level,[6–9] their combined effects on mortality[10] and morbidity[11 12] as well as their potential economic consequences[13] highlight the need for effective interventions targeted at their prevention or alleviation. In developing such interventions, estimates of effectiveness will need to be complemented with economic evaluations to ensure efficient allocation of scarce public health resources.

Cost–utility analysis is a form of economic evaluation where health outcomes are commonly measured in quality-adjusted life years. It remains the preferred evaluative approach of regulatory agencies in England and Wales[14] and in other nations.[15 16] Quality-adjusted life years are a product of the gain in life years weighted by the health-related quality of life (HRQoL) of the health states experienced. The HRQoL weights should reflect the relative desirability of the health states under consideration and are often referred to as preference-based HRQoL weights. These preference-based HRQoL weights (or utility scores) are obtained either using a standardised instrument, such as the EuroQoL EQ-5D[17] or the Health Utilities Index,[18] or using a complex scaling technique such as the standard gamble approach or the time trade-off approach.[19]

Although previous research has sought to estimate preference-based HRQoL weights (or utility scores) associated with alcohol consumption, cardiometabolic risk factors and obesity,[20–22] no study to date has estimated utility scores for a broad range of health behavioural risk factors in a representative sample of the general population. The aim of this study was, first, to estimate the impact of major health behavioural risk factors, namely obesity, alcohol consumption, smoking, lack of fruit and vegetable intake and physical inactivity, on utility scores in a nationally representative population sample of adults in England, and, second, to investigate how these health behavioural risk factors impact on different aspects of HRQoL. In so doing, these findings may provide a significant new resource to inform the cost-effectiveness of interventions aimed at tackling these major public health concerns.

METHODS

Study population

The Health Survey for England (HSE) is a series of annual surveys of a nationally representative non-institutionalised population sample of England, of which the 2008 HSE survey was the 18th.[23] The 2008 survey comprised two main components: a core sample of adults aged 16 years or older and a boost sample of children aged 2–15 years. The survey adopted a multistage stratified probability sampling design with the Postcode Address File as the sampling frame. Of the 14 250 households selected, 64% had at least one respondent and a total of 15 102 adults participated in the survey.[23] Of these 15 102 adults, 985 had missing data on EQ-5D utility scores. For this analysis, data for the 14 117 adults aged 16 years or older who participated in the core survey and for whom EQ-5D utility scores were available were used. Further details about the 2008 HSE survey, its sampling procedures and methodology and response rates, are reported elsewhere.[23]

EQ-5D

The 2008 HSE survey used the EuroQol EQ-5D to measure HRQoL.[17] The EQ-5D consists of two principal measurement components. The first is a descriptive system that defines HRQoL in terms of five dimensions: 'mobility', 'self-care', 'usual activities', 'pain/discomfort' and 'anxiety/depression'.[17] Responses in each dimension are divided into three ordinal levels, coded: (1) no problems, (2) some or moderate problems and (3) severe or extreme problems. The second measurement component of the EQ-5D consists of a 20 cm vertical visual analogue scale ranging from 100 (best imaginable health state) to 0 (worst imaginable health state), which provides an indication of the subject's own assessment of their health status on the day of the survey.[17] The adults who participated in the 2008 HSE survey completed the EQ-5D descriptive system only. The potential responses to the descriptive system can theoretically generate 243 (3^5) different health states. For the purposes of this investigation, the York A1 tariff was applied to each set of responses to the descriptive system in order to generate an EQ-5D utility score for each subject.[24] The York A1 tariff set has been derived from a survey of the UK population (n=3337), which used the time trade-off valuation method to estimate utility scores for a subset of 45 EQ-5D health states, with the remainder of the EQ-5D health states subsequently valued through the estimation of a multivariable model.[24] Utility values in the York A1 tariff set range from no problems on any of the five dimensions in the EQ-5D descriptive system (value=1.0) to severe or extreme problems across all five dimensions (value=−0.594).[24]

Health behavioural risk factors

Body mass index (BMI), computed by dividing weight in kilograms by height in metres squared, was categorised according to WHO guidelines[25]; underweight, BMI <18.5 kg/m^2; normal weight, BMI 18.5–24.9 kg/m^2 (reference category); overweight, BMI 25–29.9 kg/m^2; class I obesity, BMI 30–34.9 kg/m^2; class II obesity, BMI 35–39.9 kg/m^2, or class III obesity BMI ≥40 kg/m^2. Class I and class II obesity categories were combined into one category to ensure adequate numbers, while class III obesity was kept as a separate category to allow for examination of the effects of extreme obesity.

Alcohol consumption was categorised in accordance with national guidelines[26] into whether study participants were never-drinkers (reference category), sensible drinkers (≤4 units/day for men or ≤3 units/day for women), hazardous drinkers (>4 and ≤8 units/day for men or >3 and ≤6 units/day for women), harmful drinkers (>8 units/day for men or >6 units/day for women) or ex-drinkers. Smoking habits were categorised in terms of whether study participants were never-smokers (reference category); light smokers, <10/day; moderate smokers, 10 to <20/day; heavy smokers, 20+ a day; or ex-smokers. Participants were classified as ex-smokers if they reported that they no longer smoked on the day that they were surveyed. Fruit and vegetable consumption was categorised in terms of whether study participants' daily intake was either five or more portions (reference category), three to less than five portions, one to less than three portions or less than one portion, based on current national and international guidelines.[27 28]

The 2008 HSE survey used a previously validated questionnaire to measure adults' physical activity during the 4 weeks prior to interview.[23] All physical activities including leisure, occupational and commuting time were measured and weekly average levels derived. The recommended level of physical activity, five episodes of 30 min of moderate physical activity a week,[29] was used as the reference category. Alternative categories of weekly physical activity included more than three episodes of vigorous activity and five episodes of moderate physical activity, three episodes of 30 min of vigorous activity, active but lower than the recommended levels or inactive. A detailed description of the measurement of health behavioural risk factors in the 2008 HSE survey is presented elsewhere.[23]

Socio-demographic characteristics

Sex, age, ethnicity, marital status, social class, educational attainment and income were reported by study participants. Previous analyses suggest that these socio-demographic characteristics may have an independent association with HRQoL[22] and, therefore, were considered potential confounders in multivariable analyses. For income, the annual household income reported by the study participant was used. Annual household income was subsequently deflated and equivalised using the McClements equivalence scale and categorised into quintiles because of the non-linear relationship between income and health often reported in the literature.[30]

Statistical analysis

Multivariable linear regression was used to investigate the relationship between the EQ-5D utility score (dependent variable) and health behavioural risk factors (BMI, alcohol consumption, smoking status, fruit and vegetable intake and physical activity). EQ-5D utility scores usually follow a non-normal distribution, negatively skewed and censored at 1.0 and, therefore, a variety of estimators for health utilities are advocated in the literature. Estimators commonly used include ordinary least squares (OLS), Tobit,[31] Fractional logit (Flogit),[32] censored least absolute deviations[33] and two-part models (2PM).[34] As the median EQ-5D score was censored, the censored least absolute deviations estimator could not be applied to the data.[35] There is no single empirical test to evaluate the performance of these alternative estimators, so an a priori plan was developed based on comparable studies.[36 37] The aim was to investigate whether one estimator provided consistently more accurate estimates. First, the homoscedasticity assumption was examined using the White test.[38] Second, observed utility scores were compared with the estimated scores conditional on the covariates. Third, the mean squared error (MSE) and mean absolute error (MAE) statistics were compared for the entire study population and for subgroups of the study population dependent on their observed utility score. Fourth, the bias in the coefficient estimates were investigated by comparing the differences between observed values and the mean value of the coefficients across 500 bootstrap replications.[39] Finally, the absolute differences between the coefficients derived from each estimator were compared. After selecting a preferred estimator, three regressions on the EQ-5D utility score were performed. The first model was unadjusted, the second adjusted for age and sex as well as for the health behavioural risk factors and the third additionally adjusted for the remaining socio-demographic covariates.

Logistic regressions were also performed in order to investigate and evaluate the impact of the lifestyle characteristics on dichotomous reports of problems (none versus some or severe) for each of the five EQ-5D dimensions. These models controlled for the full set of covariates described for the fully adjusted models for the EQ-5D utility score.

For all analyses, survey weights reported in the 2008 HSE survey were applied to account for the probability of being a responding individual within a responding household. Possible clustering was accounted for within primary sampling units using unique identifiers reported in the 2008 HSE survey to

Table 1 Unadjusted EQ-5D utility scores by health behavioural risk factors and socio-demographic characteristics

	N (%)	EQ-5D utility score, mean (95% CI)
Total	14 100	0.851 (0.847 to 0.855)
Body mass index (kg/m^2)		
<18.5	186 (1.3)	0.879 (0.851 to 0.907)
18.5 to <25	4367 (30.9)	0.896 (0.891 to 0.902)
25 to <30	4631 (32.8)	0.873 (0.867 to 0.879)
30 to <40	2849 (20.2)	0.818 (0.809 to 0.827)
40+	263 (1.9)	0.715 (0.676 to 0.753)
Missing	1804 (12.8)	0.757 (0.743 to 0.772)
Alcohol intake		
Never-drinker	4256 (30.2)	0.818 (0.810 to 0.826)
≤4 units/day (men) or ≤3 units/day (women)	4092 (29.0)	0.857 (0.850 to 0.864)
>4 and ≤8 (men) or >3 and ≤6 (women)	2363 (16.7)	0.887 (0.880 to 0.895)
>8 units/day (men) or >6 units/day (women)	2676 (19.0)	0.897 (0.890 to 0.904)
Ex-drinker	629 (4.5)	0.700 (0.673 to 0.728)
Missing	84 (0.6)	0.914 (0.877 to 0.951)
Smoking		
Never-smoker	7407 (52.5)	0.879 (0.874 to 0.883)
Light <10/day	955 (6.8)	0.863 (0.849 to 0.877)
Moderate 10−<20/day	1230 (8.7)	0.828 (0.813 to 0.843)
Heavy 20+/day	736 (5.2)	0.767 (0.745 to 0.789)
Ex-smoker	3735 (26.5)	0.818 (0.810 to 0.826)
Missing	37 (0.3)	0.872 (0.803 to 0.941)
Fruit and vegetable intake*		
5 or more portions/day	3914 (27.7)	0.862 (0.855 to 0.869)
3 to <5 portions/day	4539 (32.2)	0.857 (0.851 to 0.864)
1 <3 potions/day	4462 (31.6)	0.847 (0.840 to 0.854)
<1 portions/day	1187 (8.4)	0.811 (0.795 to 0.827)
Physical activity		
5 moderate 30 min episodes a week	3453 (24.5)	0.913 (0.908 to 0.918)
3 vigorous 30 min episodes and 5 moderate 30 min episodes a week	1101 (7.8)	0.940 (0.933 to 0.947)
3 vigorous 30 min episodes a week	285 (2.0)	0.945 (0.932 to 0.958)
Active but not meeting recommended levels	5870 (41.6)	0.883 (0.879 to 0.888)
Inactive	3346 (23.7)	0.694 (0.683 to 0.705)
Missing	45 (0.3)	0.918 (0.882 to 0.953)
Sex		
Male	6270 (44.4)	0.867 (0.861 to 0.872)
Female	7830 (55.5)	0.839 (0.833 to 0.844)
Age (years)		
16−24	1579 (11.2)	0.938 (0.932 to 0.944)
25−34	2048 (14.5)	0.918 (0.911 to 0.925)
35−44	2563 (18.2)	0.897 (0.890 to 0.904)
45−54	2324 (16.5)	0.856 (0.846 to 0.865)
55−64	2415 (17.1)	0.818 (0.808 to 0.829)
65−74	1740 (12.3)	0.779 (0.766 to 0.792)
75+	1431 (10.1)	0.715 (0.700 to 0.729)
Ethnic origin*		
White	12 842 (91.0)	0.850 (0.846 to 0.854)
Mixed	142 (1.0)	0.887 (0.855 to 0.919)
Indian	325 (2.3)	0.880 (0.856 to 0.905)
Pakistani	174 (1.2)	0.804 (0.759 to 0.849)
Black Caribbean	130 (0.9)	0.833 (0.787 to 0.879)
Black African	165 (1.2)	0.900 (0.872 to 0.928)
Other	322 (2.3)	0.861 (0.834 to 0.888)

Continued

Table 1 Continued

	N (%)	EQ-5D utility score, mean (95% CI)
Marital status		
Single	2679 (19.0)	0.897 (0.889 to 0.904)
Married/civil partnerships	7457 (52.8)	0.857 (0.852 to 0.862)
Separated	308 (2.2)	0.789 (0.755 to 0.823)
Divorced	963 (6.8)	0.776 (0.758 to 0.795)
Widowed	1102 (7.8)	0.717 (0.699 to 0.734)
Cohabitees	1591 (11.3)	0.899 (0.890 to 0.908)
Social class		
I	694 (4.9)	0.932 (0.923 to 0.942)
II	4253 (30.1)	0.882 (0.876 to 0.889)
IIN	3170 (22.5)	0.852 (0.845 to 0.860)
IIIM	2247 (15.9)	0.824 (0.814 to 0.835)
IV	2269 (16.1)	0.812 (0.801 to 0.823)
V	662 (4.7)	0.801 (0.779 to 0.822)
Armed forces	36 (0.3)	0.889 (0.819 to 0.959)
Missing	769 (5.5)	0.839 (0.820 to 0.858)
Highest educational qualification*		
NVQ4/NVQ5/degree or equivalent	2795 (19.8)	0.922 (0.916 to 0.927)
Higher education below degree	1596 (11.3)	0.868 (0.857 to 0.878)
NVQ3/GCE A level equivalent	2111 (15.0)	0.903 (0.896 to 0.911)
NVQ2/GCE O level equivalent	3123 (22.1)	0.866 (0.859 to 0.874)
NVQ1/CSE other grade equivalent	694 (4.9)	0.831 (0.812 to 0.850)
Foreign/other	242 (1.7)	0.816 (0.788 to 0.845)
No qualification	3539 (25.1)	0.750 (0.741 to 0.760)
Equivalised income		
Highest quintile	2533 (18.0)	0.927 (0.922 to 0.933)
2nd highest quintile	2382 (16.9)	0.902 (0.895 to 0.908)
Middle quintile	2262 (16.0)	0.855 (0.846 to 0.865)
2nd lowest quintile	2284 (16.2)	0.807 (0.796 to 0.818)
Lowest quintile	1944 (13.8)	0.763 (0.750 to 0.777)
Missing	2695 (19.1)	0.834 (0.825 to 0.843)
Limiting long-standing illness		
No	10 612 (75.2)	0.928 (0.925 to 0.930)
Yes	3488 (24.7)	0.618 (0.608 to 0.629)

*Missing cases omitted from the analysis (n<10).

produce Huber−White sandwich robust variance estimators that allow for within-group dependence.[40] For all covariates, missing values were coded as a separate category. As part of sensitivity analyses, all analyses were repeated in individuals who reported no limiting long-standing illnesses (n=10 612) and in individuals who reported limiting long-standing illnesses (n=3485). All analyses were conducted using Stata SE V.11 (StataCorp LP, 2009), and p values <0.05 were regarded as statistically significant and Bonferroni corrected for multiple comparisons.

RESULTS

Of the 14 117 participants for whom EQ-5D utility scores were available, there were complete data on 9551 (67.6%) participants. The characteristics of study participants with and without complete data for all covariates were compared, and significant differences across all socio-demographic variables were found (p<0.05). Consequently, in order to maximise sample size and avoid bias, missing values were coded as a separate category for each covariate. For fruit and vegetable intake, ethnic origin and educational attainment, there were missing data on 1, 9 and 7 participants, respectively; these cases were excluded in the baseline analysis. Sensitivity analyses used multiple imputation methods to handle missing data. The estimated regression coefficients from the multiple imputed data sets (online appendix F) were comparable to the reported results.

Table 1 presents descriptive statistics for the EQ-5D utility score by health behavioural risk factor and socio-demographic characteristic. Approximately one-third of the sample had a BMI within the normal range, was a never-drinker, consumed at least five portions of fruit or vegetable per day or exercised regularly, while one-half were never-smokers. Normal BMI, non-smoking, consumption of five or more portions of fruit and vegetables/day and regular exercise were each associated with higher mean unadjusted EQ-5D utility scores. Current drinkers had a higher mean unadjusted EQ-5D utility score than never-drinkers or ex-drinkers.

Model diagnostics comparing the different estimators (OLS, Tobit, Flogit and 2PM) are summarised in table 2 and online appendices A–C. For all estimators, the White test rejected the hypothesis of homoscedasticity in the error term ($p<0.001$). Table 2 presents the observed and predicted EQ-5D utility scores, along with the MSE and MAE statistics for all estimators. A lower MSE and MAE indicate a more efficient model. The MSE and MAE for the 2PM estimator were appreciably higher, and while the OLS estimator predictions did result in some EQ-5D utility scores above 1.0, the MSE and MAE values (0.042, 0.141) were comparable to the Tobit (0.041, 0.147) and Flogit (0.040, 0.140) estimators, even when looking at predictions for selected utility ranges (online appendix A). The median bootstrapped bias in the regression coefficients derived from the Tobit and Flogit estimators were 0.7% and 0.5%, respectively, and lower than for the OLS estimator (4.4%). Although the bootstrapped bias in some regression coefficients is high, as the absolute value is low, the impact on the predicted EQ-5D utility score will be minimal. The median absolute difference in the regression coefficients between the Tobit and Flogit estimates was 34.7%, while the median absolute difference in the regression coefficients between the OLS and Tobit estimates was 21.0% and the OLS and Flogit estimates 38.0% (online appendix B). It was therefore concluded that the OLS, Tobit and Flogit estimators yielded acceptable results with no one estimator clearly superior in terms of performance across empirical tests. In this paper, the results for the OLS estimator are reported. The analogous results for the other estimators are available from the authors upon request.

Table 3 summarises the findings for the OLS estimator for each of the three models; young age, male sex and high equivalised income were each significant predictors of an increased EQ-5D utility score ($p<0.05$), while having no formal educational qualification was independently associated with a reduced EQ-5D utility score ($p<0.001$). In the fully adjusted model (model 3), obesity, smoking and physical inactivity had negative impacts on EQ-5D utility scores ($p<0.001$). The largest adjusted reductions were associated with a BMI $\geq$40 kg/m^2, heavy smoking ($\geq$20 cigarettes/day) and being physically inactive. Compared with the reference category for each of these factors, the adjusted reductions in EQ-5D utility scores were 0.105 (95% CI 0.072 to 0.137, $p<0.001$), 0.062 (95% CI 0.042 to 0.082, $p<0.001$) and 0.142 (95% CI 0.129 to 0.155, $p<0.001$), respectively. Compared with never drinking, hazardous alcohol consumption was associated with an increase in EQ-5D utility score of 0.019 (95% CI 0.009 to 0.029, $p<0.001$), while being a former drinker was associated with a decrease of 0.074 (95% CI 0.048 to 0.099, $p<0.001$). For fruit and vegetable intake, daily consumption between three and less than five portions was associated with a small positive effect on EQ-5D utility scores ($p<0.05$).

Table 4 summarises the findings of the logistic regression analyses for reported problems in each of the five EQ-5D dimensions. Compared with those with normal BMI, participants who were severely obese (BMI $\geq$40 kg/m^2) had increased odds of reporting some or severe problems with mobility (OR 5.31, 95% CI 3.91 to 7.22, $p<0.001$), self-care (OR 2.69, 95% CI 1.76 to 4.12, $p<0.001$), pain (OR 2.58, 95% CI 2.03 to 3.29, $p<0.001$), usual activities (OR 2.14, 95% CI 1.56 to 2.92, $p<0.001$) and anxiety/depression (OR 1.59, 95% CI 1.18 to 2.13, $p<0.05$). Compared with those who had never consumed alcohol, hazardous alcohol drinkers had reduced odds of reporting problems with mobility, self-care or performing their usual activities ($p<0.05$), while ex-alcohol drinkers had increased odds of reporting problems with anxiety, mobility and self-care ($p<0.05$). Compared with never-smokers, participants who smoked or who were ex-smokers had increased odds of reporting some or severe problems across each of the five EQ-5D dimensions ($p<0.05$), with the exception of light and moderate smokers for the self-care dimension. Compared with consuming five portions of fruit and vegetables a day, participants consuming fewer portions had similar odds of reporting problems in each of the five EQ-5D dimensions. Compared with those who were physically active and meeting current recommendations, those who were physically inactive had increased odds of reporting some or severe problems with self-care (OR 11.62, 95% CI 8.08 to 16.73, $p<0.001$), usual activities (OR 5.81, 95% CI 4.89 to 6.90, $p<0.001$), mobility (OR 5.53, 95% CI 4.70 to 6.50, $p<0.001$), pain (OR 2.08, 95% CI 1.85 to 2.35, $p<0.001$) and anxiety/depression (OR 2.01, 95% CI 1.75 to 2.30, $p<0.001$).

Online appendices D and E show the findings of the linear and logistics regressions undertaken for those without limiting long-standing illnesses and for those with limiting long-standing illnesses, respectively. The impact of the health behavioural risk factors on EQ-5D utility scores and the odds of reporting problems in each of the five EQ-5D dimensions were generally smaller in those not reporting limiting long-standing illnesses and higher in those reporting limiting long-standing illnesses. In these subpopulations, the deleterious effects of extreme obesity, smoking and physical inactivity remained.

Table 2 Estimated predicted values compared with actual utility scores

	Model	Observed	Mean	Minimum	Maximum	MSE	MAE
	Observed	14 100	0.851	−0.594	1.000		
Model	OLS	14 100	0.851	0.451	1.083	0.042	0.141
	TOBIT	14 100	0.853	0.342	0.991	0.041	0.147
	FLOGIT	14 100	0.852	0.112	0.987	0.040	0.140
	2PM	14 100	0.850	0.740	0.958	0.060	0.177

2PM, two-part models; FLOGIT, Fractional logit; MAE, mean absolute error; MSE, mean squared error; OLS, ordinary least squares.

DISCUSSION

This study examined the independent effects of five major health behavioural risk factors (obesity, alcohol consumption, smoking, lack of fruit and vegetable intake and physical inactivity) on preference-based HRQoL weights (or utility scores) in a nationally representative sample of the English adult general population. As expected, smoking was associated with a significant reduction in EQ-5D utility scores, with increasing levels of smoking associated with increased deleterious effects. The results support previous findings suggesting that in comparison to never smoking, heavy smoking is associated with the greatest deleterious effects and smoking at moderate or light levels

Table 3 Results of ordinary least squares regressions exploring the relationship between health behavioural risk factors and EQ-5D utility scores

	Model 1 unadjusted B (95% CI)	Model 2 partially adjusted B (95% CI)	Model 3 fully adjusted B (95% CI)
Body mass index (kg/m^2)			
18.5 to <25	Ref	Ref	Ref
<18.5	0.010 (−0.015 to 0.034)	−0.005 (−0.029 to 0.019)	0.000 (−0.024 to 0.024)
25<30	−0.019 (−0.026 to −0.011)**	−0.006 (−0.013 to 0.002)	−0.005 (−0.013 to 0.002)
30 to <40	−0.048 (−0.057 to −0.038)**	−0.033 (−0.043 to −0.023)**	−0.031 (−0.041 to −0.020)**
40+	−0.124 (−0.158 to −0.090)**	−0.117 (−0.150 to −0.083)**	−0.105 (−0.137 to −0.072)**
Missing	−0.080 (−0.094 to −0.066)**	−0.066 (−0.080 to −0.052)**	−0.064 (−0.078 to −0.051)**
Alcohol intake			
Never-drinker	Ref	Ref	Ref
≤4/day (men) or ≤3/day (women)	0.018 (0.009 to 0.027)**	0.028 (0.019 to 0.037)**	0.013 (0.004 to 0.023)
>4 and ≤8(men) or >3 and ≤6(women)	0.034 (0.024 to 0.043)**	0.036 (0.026 to 0.046)**	0.019 (0.009 to 0.029)**
>8/day (men) or >6/day (women)	0.040 (0.030 to 0.050)**	0.026 (0.016 to 0.036)**	0.011 (0.001 to 0.021)
Ex-drinker	−0.084 (−0.110 to −0.057)**	−0.073 (−0.098 to −0.047)**	−0.074 (−0.099 to −0.048)**
Missing	0.042 (0.016 to 0.068)*	0.008 (−0.017 to 0.033)	0.003 (−0.023 to 0.029)
Smoking			
Never-smoker	Ref	Ref	Ref
Light <10/day	−0.034 (−0.048 to −0.021)**	−0.044 (−0.058 to −0.031)**	−0.031 (−0.045 to −0.018)**
Moderate 10−<20/day	−0.049 (−0.063 to −0.036)**	−0.055 (−0.068 to −0.041)**	−0.033 (−0.047 to −0.019)**
Heavy 20+/day	−0.084 (−0.105 to −0.064)**	−0.087 (−0.107 to −0.067)**	−0.062 (−0.082 to −0.042)**
Ex-smoker	−0.046 (−0.055 to −0.038)**	−0.027 (−0.036 to −0.019)**	−0.023 (−0.031 to 0.014)**
Missing	0.005 (−0.051 to 0.061)	−0.022 (−0.074 to 0.029)	0.008 (−0.060 to 0.043)
Fruit and vegetable intake†			
5 or more portions/day	Ref	Ref	Ref
3 to <5 portions/day	0.011 (0.002 to 0.019)	0.009 (0.001 to 0.018)	0.012 (0.004 to 0.021)*
1 to <3 potions/day	0.009 (0.000 to 0.018)	0.000 (−0.009 to 0.009)	0.008 (−0.001 to 0.017)
<1 portions/day	−0.008 (−0.024 to 0.009)	−0.023 (−0.039 to −0.007)*	−0.010 (−0.026 to 0.006)
Physical activity			
5 moderate 30 min episodes a week	Ref	Ref	Ref
3 vigorous 30 min and 5 moderate 30 min a week	0.017 (0.009 to 0.025)**	−0.003 (−0.012 to 0.006)	−0.008 (−0.017 to 0.000)
3 vigorous 30 min episodes a week	0.025 (0.011 to 0.038)**	0.008 (−0.005 to 0.022)	−0.001 (−0.014 to 0.013)
Active but not meeting recommended levels	−0.021 (−0.028 to −0.015)**	−0.014 (−0.020 to −0.007)**	−0.017 (−0.024 to −0.010)**
Inactive	−0.177 (−0.189 to −0.164)**	−0.147 (−0.161 to −0.134)**	−0.142 (−0.155 to −0.129)**
Missing	0.017 (−0.018 to 0.051)	0.019 (−0.013 to 0.052)	0.021 (−0.013 to 0.055)
Sex			
Male	–	Ref	Ref
Female	–	−0.016 (−0.023 to −0.009)**	−0.014 (−0.021 to −0.006)**
Age (years)			
16−24	–	Ref	Ref
25−34	–	−0.015 (−0.026 to −0.005)*	−0.033 (−0.046 to −0.021)**
35−44	–	−0.033 (−0.044 to −0.022)**	−0.046 (−0.061 to −0.032)**
45−54	–	−0.068 (−0.080 to −0.056)**	−0.080 (−0.095 to −0.065)**
55−64	–	−0.094 (−0.107 to −0.081)**	−0.100 (−0.115 to −0.084)**
65−74	–	−0.116 (−0.131 to −0.101)**	−0.107 (−0.125 to −0.088)**
75+	–	−0.138 (−0.155 to −0.122)**	−0.119 (−0.140 to −0.098)**
Ethnic origin†			
White	–	–	Ref
Mixed	–	–	0.004 (−0.023 to 0.032)
Indian	–	–	0.007 (−0.015 to 0.028)
Pakistani	–	–	−0.038 (−0.085 to 0.008)
Black Caribbean	–	–	−0.003 (−0.039 to 0.033)
Black African	–	–	0.042 (0.014 to 0.070)*
Other	–	–	−0.006 (−0.030 to 0.018)
Marital status			
Single	–	–	Ref
Married/civil partnerships	–	–	0.006 (−0.005 to 0.017)
Separated	–	–	−0.055 (−0.087 to −0.023)*
Divorced	–	–	−0.035 (−0.054 to −0.015)*
Widowed	–	–	−0.017 (−0.039 to 0.005)
Cohabitees	–	–	−0.005 (−0.017 to 0.007)

Continued

Table 3 Continued

	Model 1 unadjusted B (95% CI)	Model 2 partially adjusted B (95% CI)	Model 3 fully adjusted B (95% CI)
Social class			
I	–	–	Ref
II	–	–	−0.015 (−0.027 to −0.004)
IIN	–	–	−0.019 (−0.032 to −0.006)
IIIM	–	–	−0.031 (−0.046 to −0.017)**
IV	–	–	−0.033 (−0.048 to −0.018)**
V	–	–	−0.025 (−0.048 to −0.003)
Armed forces	–	–	−0.036 (−0.086 to 0.014)
Missing	–	–	−0.042 (−0.062 to −0.022)**
Highest educational qualification†			
NVQ4/NVQ5/degree or equivalent	–	–	Ref
Higher education below degree	–	–	−0.017 (−0.028 to −0.006)*
NVQ3/GCE A level equivalent	–	–	−0.005 (−0.015 to 0.005)
NVQ2/GCE O level equivalent	–	–	−0.006 (−0.015 to 0.004)
NVQ1/CSE other grade equivalent	–	–	−0.012 (−0.030 to 0.006)
Foreign/other	–	–	0.008 (−0.020 to 0.036)
No qualification	–	–	−0.032 (−0.046 to −0.019)**
Equivalised income			
Highest quintile	–	–	Ref
2nd highest quintile	–	–	−0.015 (−0.023 to −0.006)*
Middle quintile	–	–	−0.023 (−0.033 to −0.012)**
2nd lowest quintile	–	–	−0.051 (−0.063 to −0.038)**
Lowest quintile	–	–	−0.071 (−0.086 to −0.057)**
Missing	–	–	−0.027 (−0.038 to −0.017)**
Constant	0.937 (0.926 to 0.948)	0.987 (0.974 to 1.000)	1.057 (1.040 to 1.074)
Adjusted R^2	0.180	0.210	0.232

Model 1: unadjusted; model 2: partially adjusted for age and sex; model 3: fully adjusted for age, sex, ethnic origin, marital status, social class, educational attainment and equivalised income.
*Significant $p<0.05$ after Bonferroni adjustment (adjusted α 0.05/5 for model 1; 0.05/7 for model 2; 0.05/12 for model 3).
**Significant $p<0.001$ after Bonferroni adjustment (adjusted α 0.001/5 for model 1; 0.001/7 for model 2; 0.001/12 for model 3).
†Missing cases omitted from the analysis (n<10).

having lesser but comparable effects.[12] Compared with continued smoking, cessation of smoking had a positive effect on EQ-5D utility scores.[41] In this study, smokers also reported increased odds of problems across all five EQ-5D dimensions, supporting previous findings that smoking negatively impacts both physical and mental components of HRQoL.[12]

Consistent with previous findings, physical inactivity and obesity each negatively impacted on HRQoL outcomes,[11 22] with the greatest effect seen on the physical dimensions of HRQoL.[11 42] Previous research has suggested that individuals who are overweight or obese are less likely to meet recommended levels of physical activity,[43] and therefore, it is notable that physical inactivity has an independent impact on EQ-5D utility scores. It was noteworthy to find that approximately one in four participants were inactive and that this had a stronger independent association with lower EQ-5D utility scores than being obese (BMI 30 to <40 kg/m^2) or severely obese (BMI ≥ 40 kg/m^2). The study found that being overweight (BMI 25 to <30 kg/m^2) was not associated with a significant reduction in EQ-5D utility score, while being physically active, but not meeting recommended levels, was. Given that about 65% of study participants did not meet the recommended levels of physical activity, a common finding in national surveys,[43] interventions to promote physical activity, irrespective of the recipients' BMI, are urgently needed. A minimally important difference in EQ-5D utility score has previously been estimated at 0.07[44]; findings of reductions in EQ-5D utility scores of greater than this for severe obesity (BMI ≥ 40 kg/m^2) and physical inactivity suggest that the estimated differences are clinically important.

In the study, fruit and vegetable consumption had little impact on EQ-5D utility scores. Previous studies have found that a BMI <30 kg/m^2, not smoking, consuming moderate levels of alcohol and engaging in regular physical activity are all strong correlates of more frequent fruit and vegetable consumption.[45 46] Therefore, it is possible that the benefits of '5-a-day' could well be closely related to these other health behaviours.

This study found that, in comparison to never drinking, sensible or hazardous alcohol consumption was associated with a positive impact on HRQoL. This finding is generally in keeping with previous research.[47 48] The study found that frequent alcohol consumption of more than 8 units/day (men) or 6 units/day (women), defined by English national guidelines[26] as harmful alcohol consumption, is also associated with a positive impact on HRQoL. The latter finding lies in partial contrast to broader evidence of the health effects of harmful alcohol consumption,[48 49] although this may be explained by a lack of disentanglement of excessive and binge drinking patterns in the present survey. Our findings in this area should be interpreted with caution. First, after adjusting for socio-demographic and health-related confounders, the utility increments were not statistically significant for the sensible and harmful drinking categories. Second, the adjusted increase in EQ-5D utility score for the hazardous category was less than the 0.07 minimally important difference commonly referred to for EQ-5D utility scores.[44] Compared with those who had never drunk alcohol and those who currently drank alcohol, ex-drinkers had significantly lower adjusted EQ-5D utility scores and in excess of the 0.07 minimally important difference. While this association could partly be explained by the 'sick quitter' hypothesis,[50] the relationship persisted when only those without limiting long-standing illnesses were analysed.

The sensitivity analyses (online appendices D and E) did find weaker associations between obesity, smoking, alcohol

Table 4 Adjusted odds of experiencing 'some or severe' problems across EQ-5D dimensions

	Adjusted OR (95% CI)				
	Anxiety/depression	Mobility	Pain	Self-care	Usual activities
Body mass index (kg/m^2)					
18.5 to <25	Ref	Ref	Ref	Ref	Ref
<18.5	1.25 (0.85 to 1.83)	0.91 (0.52 to 1.60)	1.15 (0.77 to 1.71)	0.43 (0.13 to 1.47)	1.61 (0.94 to 2.76)
25 to <30	1.03 (0.92 to 1.16)	1.18 (1.02 to 1.38)	1.19 (1.08 to 1.33)*	0.89 (0.69 to 1.14)	1.08 (0.93 to 1.25)
30 to <40	1.06 (0.93 to 1.21)	2.00 (1.71 to 2.34)**	1.67 (1.48 to 1.89)**	1.27 (0.99 to 1.63)	1.48 (1.27 to 1.74)**
40+	1.59 (1.18 to 2.13)*	5.31 (3.91 to 7.22)**	2.58 (2.03 to 3.29)**	2.69 (1.76 to 4.12)**	2.14 (1.56 to 2.92)**
Missing	1.17 (1.01 to 1.36)	2.52 (2.12 to 2.99)**	1.57 (1.37 to 1.81)**	2.43 (1.89 to 3.13)**	2.05 (1.74 to 2.42)**
Alcohol consumption					
Never-drinker	Ref	Ref	Ref	Ref	Ref
≤4/day (men) or ≤3/day (women)	0.85 (0.75 to 0.96)	0.87 (0.76 to 1.00)	0.91 (0.81 to 1.02)	0.86 (0.70 to 1.06)	0.79 (0.69 to 0.91)*
>4 and ≤8(men) or >3 and ≤6 (women)	0.91 (0.78 to 1.06)	0.76 (0.64 to 0.91)*	0.89 (0.79 to 1.02)	0.59 (0.43 to 0.80)**	0.65 (0.54 to 0.77)**
>8/day (men) or >6/day (women)	0.93 (0.80 to 1.07)	0.88 (0.73 to 1.06)	0.92 (0.80 to 1.05)	0.73 (0.54 to 1.00)	0.71 (0.59 to 0.85)*
Ex-drinker	1.60 (1.31 to 1.96)**	1.49 (1.19 to 1.86)**	1.21 (1.01 to 1.46)	1.47 (1.10 to 1.96)*	1.31 (1.05 to 1.64)
Missing	0.84 (0.44 to 1.60)	0.67 (0.24 to 1.86)	1.21 (0.70 to 2.09)	0.83 (0.17 to 4.17)	0.39 (0.15 to 0.99)
Smoking					
Never-smoker	Ref	Ref	Ref	Ref	Ref
Light <10/day	1.44 (1.20 to 1.73)**	1.55 (1.21 to 1.98)**	1.49 (1.25 to 1.77)**	0.92 (0.60 to 1.41)	1.39 (1.09 to 1.76)
Moderate 10−<20/day	1.55 (1.31 to 1.83)**	1.69 (1.38 to 2.07)**	1.34 (1.15 to 1.55)**	1.30 (0.95 to 1.77)	1.46 (1.19 to 1.78)**
Heavy 20+/day	1.82 (1.48 to 2.24)**	1.87 (1.49 to 2.34)**	1.54 (1.29 to 1.85)**	1.94 (1.40 to 2.69)**	1.76 (1.41 to 2.20)**
Ex-smoker	1.18 (1.06 to 1.33)*	1.40 (1.23 to 1.58)**	1.28 (1.16 to 1.40)**	1.37 (1.13 to 1.66)*	1.37 (1.21 to 1.55)**
Missing	1.60 (0.75 to 3.45)	2.30 (0.92 to 5.76)	0.98 (0.44 to 2.18)	1.02 (0.16 to 6.58)	0.95 (0.37 to 2.41)
Fruit and vegetable intake					
5 or more portions/day	Ref	Ref	Ref	Ref	Ref
3 to <5 portions/day	0.99 (0.87 to 1.11)	0.88 (0.77 to 1.02)	0.88 (0.80 to 0.98)	0.84 (0.68 to 1.05)	0.89 (0.78 to 1.02)
1 to <3 potions/day	1.02 (0.90 to 1.17)	0.91 (0.79 to 1.05)	0.91 (0.82 to 1.01)	0.74 (0.58 to 0.93)	0.94 (0.81 to 1.09)
<1 portions/day	1.17 (0.97 to 1.40)	1.03 (0.83 to 1.28)	1.01 (0.85 to 1.20)	0.98 (0.73 to 1.33)	1.01 (0.81 to 1.26)
Physical activity					
5 moderate 30 min episodes a week	Ref	Ref	Ref	Ref	Ref
3 vigorous 30 min and 5 moderate 30 min a week	1.15 (0.93 to 1.42)	0.81 (0.55 to 1.19)	0.86 (0.71 to 1.05)	0.93 (0.32 to 2.67)	0.66 (0.45 to 0.98)
3 vigorous 30 min episodes a week	1.09 (0.75 to 1.58)	0.56 (0.26 to 1.20)	0.64 (0.44 to 0.94)	1.88 (0.51 to 6.89)	0.78 (0.39 to 1.56)
Active but not meeting recommended levels	1.27 (1.12 to 1.44)**	1.69 (1.43 to 1.99)**	1.12 (1.01 to 1.25)	1.85 (1.25 to 2.73)*	1.62 (1.37 to 1.92)**
Inactive	2.01 (1.75 to 2.30)**	5.53 (4.70 to 6.50)**	2.08 (1.85 to 2.35)**	11.62 (8.08 to 16.73)**	5.81 (4.89 to 6.90)**
Missing	1.32 (0.59 to 2.96)	1.47 (0.57 to 3.78)	0.79 (0.39 to 1.57)	(omitted)	1.14 (0.41 to 3.22)

Fully adjusted for age, sex, ethnic origin, marital status, social class, educational attainment and equivalised income.
*Significant $p<0.05$ after Bonferroni adjustment (adjusted α 0.05/12).
**Significant $p<0.001$ after Bonferroni adjustment (adjusted α 0.001/12).

consumption and physical inactivity and EQ-5D utility scores when only those who did not report limiting long-standing illnesses were included. However, the patterns for reporting some or severe problems across EQ-5D dimensions in this subpopulation often remained. Stronger associations were found between smoking and physical inactivity and EQ-5D utility scores when only those who did report limiting long-standing illnesses were included. Caution must be placed on the use of the EQ-5D utility scores derived from these subpopulations. The survey weights applied to the total study population allowed the sample to more closely reflect a nationally representative population living in non-institutionalised settings in England. In contrast, there were no survey weights available to apply to these subgroups.

This study is not without limitations, many of which are related to the data used. Although this specific HSE survey provided a detailed assessment of health behavioural risk factors, apart from BMI, the measures were self-reported and therefore open to biases as a consequence of potential under- or over-reporting. Cotinine levels were measured in about two-thirds of participants and, like previous research,[51] there was good correlation between self-reported cigarette smoking and cotinine levels (Pearson's r=0.760, p<0.001). The 2008 HSE survey used accelerometry to collect objective measurements of physical activity in approximately 15% of adult participants. As with previous findings, self-reported physical activity was over-reported as compared with accelerometer measurements[52] and showed relatively low levels of correlation (Pearson's r=0.110, p<0.001). Reflecting this in the analysis would have restricted the sample size, and while not doing so is a potential limitation of the findings, interventions tackling physical activity will in the majority be based upon self-reported measures of physical activity. BMI was used as the measure of overweight/obesity; however, waist circumference or waist−hip ratio is increasingly being recognised as a more accurate measure of obesity and a stronger predictor of health outcomes than elevated BMI.[53] There was a moderate correlation between BMI and waist−hip ratio (Pearson's r=0.4484, p<0.001), and while both had large amounts of missing data, BMI had fewer. Although a range of estimators was investigated, no one estimator was clearly superior and like previous studies all lacked some efficiency when restricted to those with lower observed EQ-5D utility scores.[54] However, precision was high in those with higher

What is already known on this subject

- Health behavioural risk factors, namely obesity, alcohol consumption, smoking, lack of fruit and vegetable and physical inactivity, increase the risk of premature mortality and have a negative impact on self-reported quality of life.
- Regulatory agencies that provide guidance to policy makers require evidence on the cost-effectiveness of public health interventions. However, data on the impact of these major health behavioural risk factors on preference-based measures of HRQoL are lacking.

What this study adds

- The present study provides population-based evidence on the impact of these health behavioural risk factors on preference-based measures of HRQoL in England.
- The data presented here could be used to inform economic evaluations aimed at tackling these major public health concerns.

observed EQ-5D utility scores, which accounted for the majority of the sample. The 2008 HSE data set is cross sectional; therefore, the findings cannot establish the temporality of the observed associations, and there is potential for reverse causality. Moreover, the consequences of adaptation to health states impacting on EQ-5D scores cannot be excluded. These factors, along with the well-documented limitations of the EQ-5D in its ability to discriminate between mild health states,[55] have the potential to limit the findings and should be taken into account if the data presented are used to inform economic evaluations.

Despite these limitations, a nationally representative population was used,[36] a nationally derived EQ-5D tariff set determined the EQ-5D utility scores,[36 56] a range of sociodemographic variables were accounted for[22 36 56] reducing the likelihood of residual confounding and an additional set of EQ-5D utility scores in those without and with limiting longstanding illnesses is provided (online appendices E and F). The consistency between the findings and those of comparable studies add credibility to the estimated EQ-5D utility scores. Moreover, the similarity of approaches used to estimate EQ-5D utility scores with published studies[36 56] in other areas of healthcare adds to the growing methodologically consistent catalogues of EQ-5D utility scores that will allow a continuing standardised approach to cost-effectiveness analysis.

SUMMARY

Interventions are urgently needed to tackle major health behavioural risk factors, including obesity, alcohol consumption, smoking, lack of fruit and vegetable intake and physical inactivity, which independently and in combination pose significant burdens on individuals and health services. This study provides a set of EQ-5D utility scores that can inform economic evaluations of interventions aimed at tackling these major public health concerns; however, further research is needed to estimate the longitudinal effects of these concerns on utility scores.

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Competing interests None.

Patient consent Analysis of data accessed from UK Data Archive.

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