Lifestyle behaviours and quality-adjusted life years in middle and older age

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Introduction

Life expectancy in populations across the world has risen considerably over the last century [1]. However, this increase in life expectancy may not necessarily equate with the prolongation of health expectancy. It is therefore increasingly important to establish what factors may be associated with a healthy life.

Assessment of ‘health expectancy’ is increasingly undertaken through the use of health-related quality-of-life (HRQL) measures, of which the Short-Form 36 (SF-36) [2] has become one of the most widely used and validated. The relationship between modifiable lifestyle factors and health has been previously investigated [3–6]. There is also a substantial body of evidence with regard to these lifestyle behaviours and HRQL [7–13]. We have previously reported the relationship between SF-36 and mortality [14, 15].

However, measures such as the SF-36 are limited in their ability to be utilized within economic evaluations. The health status profile that is produced does not allow an unambiguous assessment of the improvement or deterioration of the quality-of-life unless all elements of the profile move in the same direction. It also does not provide the single index score required to derive a quality-adjusted life year (QALY) [16, 17]. To redress this, Brazier et al. [18] derived such a single index measure from the SF-36; termed the Short-Form Six Dimension (SF-6D) [18].

We have previously reported the effect of the combined health behaviours, including smoking, physical activity, alcohol consumption and fruit and vegetable consumption on total and cause-specific mortality in the European Prospective Investigation into Cancer (EPIC)-Norfolk cohort [19]. In this paper, we are interested in establishing whether there is a relationship between QALYs, as a proxy for health expectancy, and these lifestyle behaviours in a general population setting in middle and older age.

Methods

The participants were 13,358 men and women, aged 40–79 years at baseline, drawn from the Norfolk, UK component of the EPIC-Norfolk. EPIC-Norfolk participants were first surveyed in 1993–97 (99.5% white Caucasian) [20]. Briefly, the participants were recruited from age-sex registers of general practices. The cohort was comparable with national population samples, with a lower prevalence of current smokers [20].

At the 1993–97 baseline survey, participants completed a detailed health and lifestyle questionnaire. They were asked about medical history with the question ‘Has a doctor ever told you that you have any of the following?’ followed by a list of conditions that included heart attack, stroke and cancer.

Smoking history was derived from a yes/no response to the questions ‘Have you ever smoked as much as one cigarette a day for as long as a year?’ and ‘Do you smoke cigarettes now?’ Alcohol consumption was derived from the question ‘How many alcoholic drinks do you have each week?’ with four separate categories of drinks. A unit of alcohol (8 g) was defined as a half pint of beer, cider, or lager; a glass of wine; a single unit of spirits (whisky, gin, brandy or vodka); or a glass of sherry, port, vermouth or liqueurs. Total alcohol consumption was estimated as the
total units of drinks consumed in a week. For these analyses, a moderate drinker was defined as someone who drank between 1 and 14 units a week (inclusive).

Habitual physical activity was assessed using two questions referring to activity during the past year. The detailed description of this physical activity questionnaire has been previously reported [21, 22]. For the purposes of the current study, we dichotomised the population into physically inactive (sedentary job and no recreational activity) and physically not inactive (any category with activity levels above the latter).

Non-fasting blood samples were also taken and plasma vitamin C measured. Because humans do not manufacture vitamin C and have to rely on exogenous sources, plasma vitamin C is a good biomarker of plant food intake; previous studies have reported that a blood value of 50 μmol/l or more indicates an intake of at least five servings of fruit and vegetables daily [22, 23]. We have previously reported that high plasma vitamin C level is inversely associated with mortality from all causes [24].

Body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in metres: weight (kg)/{height (m)}^2. Both height and weight were measured by a trained study nurse using a standardised manual. Participants’ educational status was based on the highest qualification attained from the baseline questionnaire. The education level was categorised as lower than A level and at least A level education. Social class was classified according to the Registrar General’s occupation-based classification [25] and categorised as non-manual (I, II and III non-manual) and manual (III manual, IV and V) [26].

We constructed a simple pragmatic health behaviour score [19]. Participants scored one point for each of the following health behaviours: current non-smoking, physically not inactive, moderate alcohol intake (1–14 units a week) and plasma vitamin C level \( \geq 50 \) μmol/l, indicating fruit and vegetable intake of at least five servings a day. Participants could therefore have a total health behaviour score ranging from 0 to 4 (Table 1).

Eighteen months later, the surviving participants, then aged 41–80 years, were asked to complete a detailed health and life experiences questionnaire (HLEQ), which included the anglicised version of Short Form 36 version 1.0 (UK SF-36) [27, 28]. From the individual items of the SF-36, mapping to the SF-6D was performed for participants who responded to the HLEQ, using software provided by the Sheffield Health Economics and Decision Science, University of Sheffield. A total of 19,498 participants, from a total of 20,921 who responded to SF-36, had adequate data for this conversion.

The construction of SF-6D from SF-36 has been reported by Brazier et al. [18]. Briefly, the developers of the SF-6D selected items from SF-36 to define health states and constructed a simplified health state classification. They used standard gamble technique [18]. They applied three criteria in construction of SF-6D from SF-36. First, where two or more items described the same aspect of health and were closely correlated, only one of them was selected to avoid redundancy in the selection of items. Second, preferences to negative items were given because they were judged to be more relevant to health service provision. Third, people’s preferences were used where available [18].

All individuals were flagged for death certification at the UK Office of National Statistics (ONS), with vital status ascertained for the whole cohort. ONS reported deaths in the cohort via a regular record linkage system. We present results for mortality up to the end of July 2007.

The QALY was calculated based on the assumption that: (i) SF-6D value remained constant for those who remained alive at the follow-up; and (ii) SF-6D value decreased in linear fashion and reached to 0 in those at the time of death. As SF-36 was introduced 18 months after the baseline, we constructed two models. The first model (model A) presumed that SF-36 value at the baseline was the same as the time of completion of SF-36 (i.e. 18 months later) and the follow-up period was defined from the study commencement to follow-up date and the second model (model B) the follow-up period was defined as a period from the date of SF-36 completion to the follow-up date. QALYs were calculated by projecting of baseline SF-6D scores using the assumption described for both models (see Box 1 below).

Table 1. Health behaviour score: score one point for each of the health behaviours below for a total score of zero to four

<table>
<thead>
<tr>
<th>Health behaviour</th>
<th>How scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking habit</td>
<td>Non-smoker = 1</td>
</tr>
<tr>
<td>Physical activity</td>
<td>Not inactive = 1; i.e. if sedentary occupation, at last half an hour of leisure time activity a day; e.g. cycling, swimming; or else a non-sedentary occupation with or without leisure time activity</td>
</tr>
<tr>
<td>Alcohol intake</td>
<td>One or more but &lt;14 units/week = 1; 1 unit = 8 g of alcohol; i.e. one glass of wine, one small glass of sherry, one single shot of spirits or one half pint of beer</td>
</tr>
<tr>
<td>Fruit and vegetable intake</td>
<td>Five servings or more as indicated by blood vitamin C level ( \geq 50 ) μmol/l/1 = 1</td>
</tr>
</tbody>
</table>

Adapted from Khaw et al. (2008).

Box 1. Calculation of QALYs

Assumption 1 (for those who remained alive at follow-up—July 2007)

Model A: SF-6D x Duration of follow-up in years (begins at enrolment)

Model B: SF-6D x Duration of follow-up in years (begins at SF-36 completion date)

Assumption 2 (for those who died during follow-up)

Model A: SF-6D x Duration of follow-up in years (begins at enrolment)/2

Model B: SF-6D x Duration of follow-up in years (begins at SF-36 completion date)/2
Data were analysed using SPSS for Windows 14.0 (SPSS, Inc., Chicago, IL, USA). Data were presented descriptively using mean and standard deviation values of SF-6D by number of health lifestyle behaviours. Either unpaired Student’s *t*-test or Chi-squared tests were used for continuous and categorical data. For group comparison *P* values for general linear model were presented.

**Results**

Of 30,445 EPIC-Norfolk participants, a total of 20,921 responded to HLEQ which included UK SF-36. Of them, SF-36 scores were imputable for 19,535 participants (64.2% of total EPIC-Norfolk sample). Not all participants who completed the HLEQ questionnaire attended the baseline health examination, or vice versa. There were a total of 13,358 men and women included in the study after excluding those with prevalent stroke (n = 455), cancer (1,642), myocardial infarction (n = 977) and those who did not complete SF-36 (n = 10,910). There were no significant differences in sample characteristics such as age, sex and BMI between those who responded SF-36 and those who did not. Percentage of participants who were current-smokers were significantly less in those who responded to SF-36 compared with those who did not respond to SF-36 (0.09 versus 0.19%). The mean follow-up periods were 11.5 years (total person-years = 154,723) from enrolment and 9.5 year (total person-years = 124,133) from the completion of the SF-36.

Table 2 shows the sex-specific sample characteristics. Although SF-6D values were statistically significantly different between men and women with large sample size, the actual mean difference is minimal (0.78 versus 0.76 for men and women). At follow-up only 4.4% of men and 2.4% of women were dead.

Table 3 shows the mean (SD) QALYs for those who died (n = 437) versus those who remained alive (n = 12,921) at follow-up by health behaviour score. The total person-years of follow-up were 1,660 and 117,784 years, respectively. For those who died, the crude mortality rates were also presented. Consistent with our previous reports, the death rate was 6.5 times higher in people with 0 score compared with those who scored 4 (crude rates—8.4 versus 1.3%). The QALYs were not significantly different among those who died. Interestingly, the QALYs, although statistically significantly different, again do not demonstrate a very large absolute difference in people who remained alive at the follow-up. However, the observed cumulative mean difference is substantial. The overall QALY gained by those who died during the follow-up and those who remained alive at the follow-up shows largely similar effects (see Supplementary data available in *Age and Ageing* online, Tables).

**Discussion**

This is the first study to report on the effect of health behaviours on QALYs in an apparently healthy general population. Although the difference between the increase in number of health behaviours and QALYs gained was not very large, there were strong relationships between individual health behaviours and SF-36 [9, 10]. This may be partly due to the fact that we dichotomised the health behaviours and therefore failed to demonstrate the maximum benefit obtainable for adapting optimal health behaviour.

We combined non-drinkers and heavier drinkers (>14 units per week) in the same category for two major reasons. First, the relationship between alcohol consumption and
Table 3. Mean (SD) quality-adjusted life years lived to death or follow-up time by number of combined health behaviours by respective models using two follow-up methods investigated in 13,358 men and women of EPIC-Norfolk (1993–2007) stratified by survival status at follow-up

<table>
<thead>
<tr>
<th>Health behaviour score</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>P (trend)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>131</td>
<td>1,044</td>
<td>3,266</td>
<td>5,284</td>
<td>3,633</td>
<td></td>
</tr>
<tr>
<td>Number (crude rate)</td>
<td>11 (8.4%)</td>
<td>77 (7.4%)</td>
<td>132 (4.0%)</td>
<td>169 (3.2%)</td>
<td>48 (1.3%)</td>
<td></td>
</tr>
<tr>
<td>Model A</td>
<td>1.8 (0.8)</td>
<td>1.8 (0.7)</td>
<td>1.9 (0.7)</td>
<td>1.9 (0.7)</td>
<td>2.1 (0.7)</td>
<td>0.09</td>
</tr>
<tr>
<td>Model B</td>
<td>1.0 (0.6)</td>
<td>1.0 (0.6)</td>
<td>1.1 (0.6)</td>
<td>1.0 (0.7)</td>
<td>1.2 (0.6)</td>
<td>0.20</td>
</tr>
<tr>
<td>Those who died ($n = 437$, total person-years = 1,660 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>120</td>
<td>967</td>
<td>3,134</td>
<td>5,115</td>
<td>3,585</td>
<td></td>
</tr>
<tr>
<td>Model A</td>
<td>8.3 (2.1)</td>
<td>8.6 (1.9)</td>
<td>8.9 (1.8)</td>
<td>9.2 (1.7)</td>
<td>9.3 (1.6)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Model B</td>
<td>6.7 (1.8)</td>
<td>6.9 (1.7)</td>
<td>7.2 (1.6)</td>
<td>7.4 (1.5)</td>
<td>7.5 (1.4)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Those who remained alive ($n = 12,921$, total person-years = 117,784 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model A</td>
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<tr>
<td>Model B</td>
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</tbody>
</table>

Model A: QALY calculated from enrolment to death or follow-up; Model B: QALY calculated from completion of SF-36 to death or follow-up. For those who died both models assume that SF-6D value decline with time and reaches to 0 at the time of death and for those who remained alive at follow-up, both models assume that SF-6D value remained constant throughout the follow-up.

Heart outcome is not straight forward; there is a 'J' shape relationship between amount of alcohol consumption and health outcomes. Non-drinkers and heavy drinkers were consistently shown to have poorer health outcomes compared with moderate drinkers. Second, we are trying to convey a simple and straightforward message for clinicians, policy makers and most importantly for the general public. Although we are not able to differentiate regular moderate alcohol consumption from binge drinking in this study, the message is clear that moderation in alcohol consumption is beneficial in terms of QALYs whatever the mechanism behind this phenomenon. Our finding is consistent with many other studies examining the relationship between alcohol and health outcomes.

We used vitamin C concentrations as a marker of consumption of at least five portions of fruit and vegetables. In this cohort, 50% of men and 75% of women had vitamin C concentrations >50 µmol/l. This might have introduced healthy responder bias, attenuating the results. It is conceivable that the shifting the whole populations’ norms of fruit and vegetables consumption have huge potential in improving HRQL as well as QALYs.

Our analyses are based essentially upon cross-sectional analysis of baseline lifestyle behaviours and projection of baseline QALY data using certain assumptions. Therefore, the results of the study should be interpreted with caution. The assumption that SF-6D (and QALY) remains constant over the follow-up period implies that results may reflect more of the association between health behaviours and the quality-of-life after 18 months than QALYs until the end of study. Nevertheless, our results support the evidence of positive health outcomes associated with these lifestyle behaviours examined which are generally accepted as healthy lifestyle behaviours.

There are, of course, other limitations. For instance, reverse causality is a potential issue. It is possible that people who are already ill may be more likely to be physically inactive and change their diet as a result of prevalent disease. To address this, we excluded those with prevalent stroke and myocardial infarction, and cancer. Nonetheless, there appears to be a linear dose–response relationship between the behaviours undertaken and the level of outcome expressed as QALYS, achievable regardless of age, sex, social class or education level.

Furthermore, we regarded each of the four health behaviours is equal in terms of its impact on health and HRQL. It may be that some health behaviours e.g. smoking has more harmful effect compared from not having high vitamin C levels indicating lower level of fruit and vegetables consumption. We have adopted this approach for simplicity and to match with current recommendations on health behaviours. We used the same alcohol consumption category for both men and women for two reasons: first to be consistent with previous work [19, 29] and second because the average alcohol consumption in the whole cohort is not high in both men and women.

Although mean differences seem small, there is a substantial impact on the health of the population as a whole. Moreover, the differences in QALY appear to be higher in older men and women indicating that these health behaviours can have a substantial population impact in ageing populations across the world. Furthermore, Prieto and Sacristán [30] cautioned the use of QALY due to the potential problem associated with numerical nature of its constituent parts, i.e. two components of QALY are not measured in same units of measurement. This may explain the seemingly modest effect seen in QALY gain in this study associated with higher health behaviour score, hence suggesting actual benefit of adopting more health behaviours are likely to be bigger in real term.

This study therefore adds to our previous work as it demonstrates that the number of health behaviours is directly related to health expectancy not merely life expectancy [19] and incidence of chronic disease [29]. Der-Martirosian et al. [31] observed the decline in SF-6D score over a 5-year period hence the current study results should be interpreted in this context. Nevertheless, the current study findings suggest that people with higher
combined health behaviour scores not only live longer but also they are more likely to have a better HRQL. Whether this observed relationship between lifestyle behaviours and QALY is dependent on the presence of specific chronic condition should be investigated in the future studies.

While there is recent evidence that the adherence to healthy lifestyle behaviours in Western populations exemplified by the US adults may be declining [32], it is possible to prevent unfavourable changes in lifestyle through community-based public health programme [33]. The fact that the lifestyle behaviours examined in this study are achievable by the general population means that our findings are of relevance to middle and older populations worldwide. Our findings, therefore, should be regarded as an example of how substantial benefit could be potentially achieved in a population even with small difference in health behaviours.

**Key points**

- People with higher health behaviour score have higher survival.
- A linear dose–response relationship was observed between health behaviour score and QALY in middle and older age.
- Modifiable lifestyle factors are an important component in health improvement.

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**Conflict of interest**

None declared.

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**Ethical approval**

Norwich Local Research Ethics Committee approved the study. The corresponding address for the LREC is Clinical Governance Department, Aldwych House, 57 Bethel Street, Norwich.

**Contributors**

K.T.K. and N.J.W. are principal investigators in EPIC-Norfolk population study. P.G.S. is the principal investigator of EPIC-Norfolk HLEQ programme. R.N.L. is responsible for data management, computing and data linkages and PKM conducted analyses. P.K.M. and R.D.S. prepared the draft manuscript. All co-authors contributed to the writing of this paper. K.T.K. is the guarantor.

**Supplementary data**

Supplementary data mentioned in the text is available to subscribers in Age and Ageing online.

**References**


Ethnicity and falls in older men: low rate of falls in Italian-born men in Australia

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