Health planning for the future: comparative risk assessment of five major lifestyle risk factors: evidence from the Wirral, UK

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ABSTRACT

Background The aim of this study was to quantify and compare the burden of disease attributable to five major lifestyle-related risk factors in a UK Primary Care Trust (Wirral) using World Health Organizations’ (WHO) comparative risk assessment (CRA) methodology to demonstrate its practical utility for informing local policy initiatives.

Methods WHO CRA methodology was adopted using exposure data from a local lifestyle survey, disease risk factor relationships published by the WHO and local mortality data to calculate risk factor attributable deaths and years of life lost (YLL).

Results Smoking remains by far the leading cause of deaths followed by overweight and obesity and low fruit and vegetable intake. Alcohol ranked last by number of deaths, but second by YLL indicating its high contribution to deaths at younger ages.

Conclusions We have demonstrated the utility of WHO CRA methodology to influence health-related policy-making at a local level. Primary prevention should remain high on the agenda of government initiatives to reduce the future burden of ill health. Future research in this area could look at more in-depth national data to cover a wider range of risk factors addressing some of the methodological and data shortcomings identified in this study.

Keywords health intelligence, morbidity and mortality, public health

The recently published public health white paper puts lifestyle-related health problems at the heart of the government’s public health agenda, and local authorities will be given responsibility for the planning and delivering of initiatives to improve health and reduce inequalities in their communities.1 The World Health Organization (WHO) estimated 24 risk factors to be attributable for 44% of mortality globally and the leading 10 risk factors to contribute 33% of mortality.2 Lifestyle-related risk factors, in particular smoking, have been shown to contribute to health inequalities in England3 and a recent analysis of all-cause mortality showed an increase in the inequalities between North and South England which in part might also be explained by differences in lifestyle behaviours.4

Local policy-makers require evidence-based validated tools to guide local decision-making. Since the early 1990s WHO has dedicated large efforts into developing a uniform approach for the quantification of lifestyle-related and environmental risk factors.2,5,6 This methodology has found wide application at the global, regional and national levels for the comparison of different risk factors4,5—8 as well as for the quantification of single risk factors.9,10 In the UK there are a number of studies quantifying mortality and morbidity attributable to single risk factors,11,12 of which only one used...
the WHO burden of disease (BoD) methodology.13 Other studies have used the findings of the WHO BoD study for the European countries with very low child and very low adult mortality (WHO region EUR-A) to estimate the BoD due to risk factors and associated costs in the UK.14–18 The WHO EUR-A region consists of 27 countries with different population structures and lifestyle behaviours. The average of WHO EUR-A region might not be directly applicable to the UK and the true BoD might be different. As far as we know, no studies have been carried out to date comparing different risk factors using the WHO comparative risk assessment (CRA) methodology in England.

Against this background, Wirral Primary Care Trust (PCT) initiated a project to explore the usefulness of WHO CRA methodology to guide local decision-making in a practical application at the local level. In this study, using CRA methodology,5,6 we calculated the number of deaths and years of life lost (YLL) attributable to five major modifiable lifestyle risk factors (smoking, alcohol consumption, low fruit and vegetable intake, overweight and obesity and insufficient physical exercise) in Wirral PCT using a beta version of the WHO National Burden of Disease (NBD) toolkit CRA application. Wirral PCT serves a population of 312,000 in the North West of England and is characterized by areas with the highest levels of deprivation in England. The objectives of this study were (i) a practical application of the WHO CRA methodology using the WHO NBD CRA toolkit to quantify and compare the contribution of five risk factors to premature deaths and associated YLL in Wirral PCT; (ii) to explore the usefulness of such analysis at the local level and highlight methodological issues that occur in such undertaking at a local level and (iii) to derive recommendations for future work at the local and national levels in England.

Methods

We carried out a population-based CRA estimating the number of deaths and YLL that would be avoided in Wirral PCT if exposure to five risk factors (smoking, alcohol consumption, low fruit and vegetable intake, overweight and obesity and insufficient physical exercise) was shifted to (i) zero or an exposure level that is most beneficial to human health and (ii) an alternative scenario. These calculations are based on the formula for the population attributable fraction (PAF), described in detail by Murray et al.5 and require four input variables:

(i) the proportion of people exposed to the risk factor,
(ii) the strength of the association between exposure and risk factor,
(iii) the number of disease-specific deaths attributable to the risk factors and the remaining life expectancy at death,
(iv) an alternative exposure distribution.

The analysis was carried out using the WHO National BoD toolkit, which is currently available in a beta test mode for experimental use from the WHO upon request.19 This is a spreadsheet-based model, which was analysed using Microsoft Excel. Mortality data by disease and 5 year age bands was extracted using STATA10 software.20

Data

Mortality data for the latest 3-year period available at the time of the study (2005–07) by International Classification of Diseases 10th revision (ICD10)21 and 5 year age bands for Wirral PCT and life tables for England to calculate YLL were derived from the Office for National Statistics.22 Prevalence data on exposure to risk factors was taken from a local lifestyle survey (n = 4433, 53% females) which was commissioned by Wirral PCT. The survey was carried out in combination with a wider lifestyle survey for the North West of England.23 Population structure and risk factor prevalence by exposure categories are shown in the Supplementary data, Tables SA1–SA3. For the analysis, the sample was weighted by age, gender and deprivation quintile. For smoking we used lung cancer mortality data to estimate the smoking impact ratio (SIR),24 which is an indicator of historic smoking prevalence. The SIR is calculated as the lung cancer mortality in excess of that for never smokers relative to excess lung cancer mortality for a known reference group of smokers. The WHO model uses the cancer prevention study II cohort (CPSII) as a reference.25 Current smoking exposure data from the North West lifestyle survey25 was used in a separate analysis.

Risk factors and health outcomes

The health outcomes (see Supplementary data, Table SA4) and risk factor disease relationships used in this analysis were taken from the WHO BoD toolkit and have been described in detail elsewhere.6 For further analysis and comparison, the outcomes were grouped into the six categories: cardiovascular, cancers, diabetes, respiratory, other non-communicable diseases (NCDs) and injury.26

Calculations

The calculations are based on the formula for the PAF:5

$$\text{PAF} = \frac{\int_{x=0}^{\infty} RR(x)P(x)dx - \int_{x=0}^{\infty} RR(x)P'(x)dx}{\int_{x=0}^{\infty} RR(x)P(x)dx}$$
where \(RR(\alpha)\) is the relative risk at each exposure level, \(P(\alpha)\) is the proportion of population at each exposure level and \(P'(\alpha)\) is the alternative proportion of population at each exposure level and \(m\) is the maximum exposure.

If the exposure is dichotomous (exposed/non-exposed) and the alternative scenario is no exposure \((P'(\alpha) = 0)\), the formula reduces to the equation:

\[
PAF = \frac{P \cdot (RR - 1)}{P \cdot (RR - 1) + 1}
\]

where \(P\) is the prevalence of exposure and \(RR\) is the relative risk for exposed versus non-exposed.

The exposure categories used by the WHO model are outlined in Table 1.

The number of YLL for 5-year age bands was calculated using the formula:

\[
\sum_{\alpha=0}^{\infty} d_{\alpha} L_{\alpha}^c
\]

where \(d_{\alpha}\) is deaths at age \(\alpha\), \(L_{\alpha}\) is the last age group and \(L_{\alpha}^c\) is the estimated cohort life expectancy at each age. Life expectancy was taken from life tables for England.\(^{22}\)

### Alternative scenarios

Alternative scenarios were chosen to inform local public health programmes and primarily focused on the two major approaches of reducing risks of targeting high-risk people and targeting the entire population\(^2\) (Table 2). No alternative scenarios were defined for smoking as the SIR methodology gives an estimate of the current BoD attributable to historic smoking levels and hence is not suited for the definition of alternative scenarios. However, in a separate analysis we investigated the impact of using current smoking prevalence data to calculate smoking-attributable deaths. These calculations were based on the risk ratios for current smokers and ex-smokers used by the Centers for Disease Control and Prevention for the calculation of smoking-attributable mortality, morbidity and economic costs, which are also based on the CPSII study.\(^{25}\)

### Results

#### Mortality in Wirral

From 2005 to 07, 10,608 people died in Wirral PCT, 48% of these were males. The four most common causes of deaths were ischaemic heart disease (1715 deaths, 16.2%), cerebrovascular disease (1050 deaths, 9.9%), lung cancer (741 deaths, 7%) and chronic obstructive pulmonary disease (COPD; 584 deaths, 5.5%). The majority of all deaths (88%) occurred in the >60 year olds and the average age at deaths was 76.4.

#### Mortality due to risk factors

Tobacco smoking was the leading cause of deaths (828 deaths per year, 23.4%), followed by overweight and obesity (186 deaths, 5.3%) and low fruit and vegetable intake (164 deaths, 4.6%; Table 3). Insufficient exercise was estimated to have caused 133 deaths (3.8%) and alcohol consumption of 89 deaths (2.5%) per year. However, due to the positive effect of moderate alcohol consumption on cardiovascular diseases, 95 deaths were estimated to have been averted each year. Ranked by YLL, alcohol consumption was the second, indicating its high contribution to deaths at younger ages. Males and females contributed similar numbers of deaths for most risk factors except alcohol where men contributed about two-thirds of all cases, reflecting higher drinking prevalence in men.

#### Disease by risk factor

The following section relates to deaths as the proportions of deaths and YLL for the different disease categories and risk factors are largely similar. Cardiovascular diseases were the
Table 2  Alternative scenarios for alcohol consumption, low fruit and vegetable intake, overweight and obesity and insufficient physical exercise

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Scenario</th>
<th>Male Brief description</th>
<th>Female Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol consumption</td>
<td>1</td>
<td>Number of abstainers remain the same and all others drink &gt;0 to &lt;40 g/day</td>
<td>Number of abstainers remain the same and all others drink &gt;0 to &lt;20 g/day</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Number of abstainers and those drinking &gt;0 to &lt;40 g/day remain the same and all others drink &gt;40 to &lt;60 g/day</td>
<td>Number of abstainers and those drinking &gt;0 to &lt;20 g/day remain the same and all others drink &gt;20 to &lt;40 g/day</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>No abstainers, all men drink &gt;0 to &lt;40 g/day</td>
<td>No abstainers, all women drink &gt;0 to &lt;20 g/day</td>
</tr>
<tr>
<td>Low fruit and vegetable</td>
<td>1</td>
<td>Those who do not eat half the recommended amount of fruit and vegetable achieve this (300 g/day, standard deviation 25 g/day) in those age groups which consume 300 g/day or more already, nobody eats below 300 g/day</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Everyone eats one more piece of fruit and vegetable per day (standard deviation decreases to 50 g/day)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Everyone eats one more piece of fruit and vegetable a day and the standard deviation stays the same (mean: men = 184.5 g/day, women = 182 g/day)</td>
<td></td>
</tr>
<tr>
<td>Overweight and obesity</td>
<td>1</td>
<td>Reduction in standard deviation for all age groups to 1 unit from mean men = 2.96 units and mean women = 3.56</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Standard deviation of 1 and 1 unit decrease in average BMI per age group</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Decrease of 1 unit in average BMI per age group and standard deviation remains the same</td>
<td></td>
</tr>
<tr>
<td>Insufficient physical</td>
<td>1</td>
<td>All inactive people start doing some exercise</td>
<td></td>
</tr>
<tr>
<td>exercise</td>
<td>2</td>
<td>5% of inactive people are insufficient active and 5% of insufficient active are sufficiently active</td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>1</td>
<td>Prevalence of current smoker and ex-smoker used in calculation</td>
<td></td>
</tr>
</tbody>
</table>

Table 3  Average annual number of deaths and YLL attributable to risk factors for baseline and alternative scenarios, Wirral PCT 2005–07

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Scenario</th>
<th>Brief description</th>
<th>Deaths</th>
<th>YLL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Alcohol consumption</td>
<td>Baseline</td>
<td>All abstainers</td>
<td>55</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>All current drinkers drink within recommended limits</td>
<td>31</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Those with highest consumption reduce drinking to next lowest category</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Everyone drinks in moderation</td>
<td>49</td>
<td>81</td>
</tr>
<tr>
<td>Low fruit and vegetable</td>
<td>Baseline</td>
<td>Everyone eats 600 g (+ 50 g) of fruit and vegetable per day</td>
<td>94</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Everyone eats at least half of the recommended amount of fruit and vegetable per day</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Average fruit and vegetable intake increases and those who eat least increase their uptake</td>
<td>42</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Average fruit and vegetable intake increases by one portion</td>
<td>33</td>
<td>24</td>
</tr>
<tr>
<td>Overweight and obesity</td>
<td>Baseline</td>
<td>Average BMI of 21 ± 1</td>
<td>98</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Tackling people with high BMI</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Tackling people with high BMI and whole population</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Tackling whole population</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Insufficient physical</td>
<td>Baseline</td>
<td>Everyone does equivalent of 600 MET minutes exercise</td>
<td>59</td>
<td>74</td>
</tr>
<tr>
<td>exercise</td>
<td>1</td>
<td>Inactive start doing some exercise</td>
<td>21</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5% increase in activity levels</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Smoking</td>
<td>Baseline</td>
<td>SIR</td>
<td>425</td>
<td>403</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Current smoking prevalence used for calculations</td>
<td>325</td>
<td>250</td>
</tr>
</tbody>
</table>
leading cause of deaths due to obesity (73%, 135 deaths per year), insufficient physical exercise (84%, 111 deaths per year) and low fruit and vegetable intake (79%, 129 deaths per year) and the second leading cause of deaths due to smoking (31%, 258 deaths per year; Fig. 1). Cancers were the leading cause of smoking (40%, 335 deaths per year) and alcohol-attributable deaths (25%, 37 deaths per year) and contributed 21% of deaths (34 deaths per year) due to low fruit and vegetable intake and 13% of deaths due to insufficient physical exercise (18 deaths per year) and overweight and obesity (24 deaths per year). Liver cirrhosis was the single biggest cause of alcohol-related deaths (27 deaths per year) and injuries caused 10% (14 deaths per year) of alcohol-attributable deaths. Diabetes contributed the second largest number of deaths due to obesity (14%, 26 deaths per year) and 3% of deaths (4 deaths per year) due to insufficient physical exercise. Respiratory diseases contributed 229 deaths per year 28% of all smoking-attributable deaths.

Alternative scenarios
For all risk factors, except alcohol, the baseline scenario returned the largest number of lives and YLL saved. Accounting for the positive effect of alcohol on heart diseases, the highest benefits would be felt if everyone drank in moderation (Table 3). Measures tackling the population groups with the highest exposures could have the greatest impact (measured as lives/YLL saved per population at risk) if they were successful. Risk reductions of the population as a whole combined with those with the highest exposures avoided the largest number of deaths and YLL in our calculations. Using current smoking prevalence data for the calculation of smoking-attributable deaths resulted in a 31 and 25% decrease in smoking-attributable deaths and YLL, respectively. The decrease was more significant in women when compared with men.

Discussion
Main findings of this study
Even though smoking prevalence has been decreasing steadily over the past decades, smoking was still by far the biggest single risk factor, causing nearly one in four deaths. Overweight and obesity was the second biggest risk factor and low fruit and vegetable consumption and insufficient physical activity also contributed a large fraction of the BoD in Wirral PCT. Alcohol ranked last when ranked by number of attributable deaths, but second when ranked by YLL indicating its high contribution to deaths at younger ages. However, current levels of alcohol consumption were also estimated to avoid 95 deaths per year due to the positive effect on cardiovascular disease. Cardiovascular diseases and cancers were the leading disease categories related to the five risk factors included in our analysis.

What is already known on this topic
Lifestyle-related risk factors are known to contribute a large proportion of the burden of ill health. The ranking of risk factors by number of deaths found in this study were in line with the results of the 2009 update of the WHO CRA and those found by Danaei et al. for the USA. However, both other studies included a wider range of risk factors and high blood pressure ranked close second to smoking in these studies. The WHO study found alcohol consumption to be in second place when ranked by disability-adjusted life years, reflecting its high contribution to deaths at an early age and disability. This supports the finding of this study with...
alcohol having the highest YLL/deaths ratio contributing the second largest amount of YLL overall after smoking. Danaei et al. found a 17% difference in the number of smoking-attributable deaths using current prevalence data compared with the SIR methodology, the difference in this study was similar at 25%.

**What this study adds**

To our knowledge, this is the first CRA for modifiable lifestyle risk factors in England using the methodology established by the WHO. The key strength of this approach is that it allows comparison of different risk factors for priority setting and also allows comparison with other studies using an established and tested methodology. So far studies in England have mainly looked at single risk factors making it hard to compare the health impact of different risk factors due to using different methodologies, time periods or data sources. Our findings clearly show that smoking remains the leading risk factor. We demonstrated how the WHO BoD methodology can be applied for decision-making at the local level in England. The main constraints are the questionable reliability of exposure data. We also identified methodological shortcomings leading to recommendations for future work, which will be discussed in detail below. The results of our local assessment are in line with those for Europe and the USA, indicating that studies at higher geographical level could be used to guide local decision-making.

**Limitations of this study**

Our study was limited to five major lifestyle risk factors and was therefore not able to quantify the total burden attributable to risk factors in Wirral PCT. The BoD attributable to the five risk factors included in our analysis is likely to be less than the sum of all risk factors combined, as many diseases are caused by more than one risk factor. WHO estimated that the joint effect of the 10 leading risk factors contributes 28% of all deaths in high-income countries. However, when adding the sum of the single risk factors from this study they would add up to 71%. The greatest effect is seen for cardiovascular diseases, which are associated with 9 of the 10 leading causes of deaths in the WHO study and all five risk factors included in our study.

Exposure data were taken from a local lifestyle survey, which was weighted by age, sex and deprivation to adjust for the local population structure, but non-response bias had not been recorded. While this was the best exposure data available, the results from this survey indicate that people in Wirral lead a healthier lifestyle than the national average when comparing the findings with the Heath Survey for England. If these are true or due to response bias, needs further investigation.

As this study was intended to be explorative, we limited the analysis to the WHO NBD toolkit. While this allows for definition of alternative scenarios and modification of input parameters, it lacks the option of a detailed sensitivity analysis for all input parameters as recently demonstrated in the context of a smoking cessation measure by de Vocht et al. In a more detailed future analysis, it would be desirable to demonstrate the spread of results.

Smoking-attributable mortality was estimated using the SIR, which adjusts for the time lag between exposure and effect. This might overestimate the burden of cardiovascular deaths due to heart disease as the lag time between exposure and effect is shorter compared with that of smoking and cancers. The number of cardiovascular deaths using the SIR method compared with current smoking prevalence method was 1.6 times higher in men and 2.4 times higher in women. This significant difference in women is mainly due to the deaths in the age groups of >70. These age groups have low smoking prevalence, but high lung cancer mortality rates resulting in high SIR estimates and low attributable fractions using prevalence values for the calculation.

For alcohol, WHO methodology uses a J-shaped risk function accounting for the positive effects of moderate alcohol consumption on heart diseases and diabetes. However, reported positive health effects related to alcohol have been controversial and the biological mechanisms underlying the effect are not fully understood. Drinking pattern has also been reported to be an important impact on health with binge drinking having a negative effect on heart disease. This could not be adjusted for in this analysis. The uncertainties around alcohol suggest that the true burden due to alcohol could be greater.

**Conclusion**

The findings of this study clearly show that primary prevention should remain high on the agenda of government initiatives to reduce the future burden of ill health. Some of the risk factors included in our analysis are likely to become even greater problems in future due to changes in risk factor exposure and population structure. The greatest challenge might be increasing levels of obesity, with overweight and obesity already ranking in second place at the moment and obesity levels predicted to increase further. To tackle these risk factors and the associated health problems they have to be seen within the context of the wider determinates.
of health and particular attention should be paid to the most vulnerable groups.

While this practical application of WHO CRA methodology has proved useful to inform local planning, combining efforts into one comprehensive national study addressing the problems and shortcomings identified in this study would be a desirable future approach. Such a study could differentiate BoD by region and could look at a wider range of risk factors and their interactions identify the best sources for high-quality exposure data and highlight the spread of results in a sensitivity analysis.

**Supplementary data**

Supplementary data are available at the *Journal of Public Health* online.

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