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The potential contribution of increased vegetable and fruit consumption to health gain in the European Union

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Abstract

Background: The risk of many important diseases can be reduced by consuming a diet rich in vegetables and fruit. For this reason the World Health Organization (WHO) recommends a daily intake of more than 400 g person^{-1}. The pattern of both the supply and intake of vegetables and fruit and the potential health gain achieved by increasing intake in the European Union (EU) and three accession countries are presented in this paper.

Methods: Patterns of supply and dietary intake were assessed using (1) FAO food balance sheets, which allow comparison between the levels of supply in countries but do not reflect actual intake; and (2) survey data reflecting dietary intake. Using WHO mortality data for coronary heart and cerebrovascular disease and major cancers up to age 65 years, the number of preventable deaths is estimated, assuming vegetable and fruit consumption were levelled up to that of the highest consuming group, and assuming relative risks of 0.5, 0.7 or 0.9.

Results: Vegetable and fruit consumption varies considerably between EU Member States. The populations of about half (seven) of the EU Member States have a mean daily intake of less than 275 g. Using the best current estimates of relative risk, over 26,000 deaths before the age of 65 years would be prevented annually in the EU if intake was levelled up to the highest consumption levels (and about double this number of deaths before the age of 75 years).

Conclusion: Increasing the intake of vegetables and fruit is feasible and could result in considerable improvements in public health within the EU. Priority should be given to developing methods that demonstrate the burden of disease caused by too low intakes of vegetables and fruit. This would enable the appropriate social, cultural and economic policies to be developed within the EU.

Keywords
Health gain
Europe
Vegetables
Fruit
Nutrition policy

A diet rich in vegetables and fruits and low in saturated fats is protective against a large number of non-communicable diseases, such as cardiovascular diseases and certain cancers[1–3]. These diseases are the most important causes of premature death in countries of the European Union (EU). Biochemical studies have demonstrated the links between the nutrient and non-nutrient constituents of vegetables and fruit and related protective physiological pathways.

The World Health Organization (WHO) recommends a daily intake of more than 400 g of vegetables and fruit per person[4]. A large number of studies have confirmed that such a diet is associated with reduced all-cause mortality[5–7] as well as reduced mortality from cardiovascular diseases and cancer.

Reviews of the cancer literature provide convincing evidence that vegetable and fruit consumption is protective against certain common cancers[8–10]. The risk of gastric carcinoma is reduced among those who consume higher amounts of vegetables and fruit, the relative risk estimates tending to be approximately 0.7, with a fairly consistent dose–response relationship[9]. Oesophageal cancer is also inversely related to fruit and vegetable consumption, although the existing evidence may not be directly applicable to Europe[9]. The incidence of colorectal cancer is lower among higher consumers of vegetables and of fibre, with relative risk estimates generally between 0.9 and 0.5[9]. Breast cancer risk may be inversely related with the intake of vegetables (especially yellow/green vegetables), with relative risks

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of 0.83 and 0.86 in two cohort studies[9]. A lower risk of carcinoma of the lung is associated with the intake of vegetables and especially of fruit, with typical relative risk estimates in the region of 0.7[9].

Reviews of the relationship between ischaemic heart disease (IHD) and vegetable and fruit intake suggest a moderate protective effect[10–12]. One estimate of the relative risk is 0.85, comparing the 90th with the 10th centile of consumption[12]. Possible mechanisms include higher intakes of anti-oxidants, potassium, folate and fibre[12,13]. Dietary fibre has been shown to reduce the risk of death from coronary heart disease by 31% in a randomised controlled trial[14], and was associated with a 55% reduction in a cohort study[15]. In both studies, cereal fibre was more protective than that from fruit or vegetables, emphasising the health importance of a wide range of foods of plant origin. The protective effect of vegetables and fruit extends to stroke[11], and an inverse association has also been noted between nuts and IHD[16].

The association between a vegetarian diet and mortality from IHD has been established by a collaborative analysis of five prospective studies[17]. The principal finding was that vegetarians had a mortality rate that was 76% of that of non-vegetarians – 55% among those under 65 years – after adjustment for age, sex and smoking.

A randomised controlled trial found that dietary intervention achieved a strong protective effect. A 'Cretan' Mediterranean diet, given to men in Lyon who had survived a myocardial infarction, was well adhered to by participants[18]. It included higher intakes of vegetables, legumes, fruit and bread, and more fish, as well as substitution of types of fat and of types of meat (chicken for red meat). Results so far indicate that this total package, which goes considerably further than just increasing the vegetable and fruit intake, was associated with a fall in total mortality, in cardiac deaths and in incident cancers, all relative risks being in the range 0.35 to 0.44[18].

This paper has two purposes: first, to describe both the supply and intake levels of vegetable and fruit within the EU and three accession countries; and second, to estimate the potential health gain if vegetable and fruit intake were to increase substantially. As the dietary intake data available are insufficient to estimate the effect of an increase to the WHO recommended level, the impact of levelling up low intakes to the highest reported consumption levels is estimated.

The potential health gain is estimated by the number of premature deaths that could be prevented each year among those aged up to 65 years. Morbidity is not considered, as the data are not available, but the suffering, health care costs and total burden of disease implied by each death are immense. Until the necessary epidemiological data are available, estimates of potential health gain need to be based on premature mortality data and preventable deaths. These estimates can be revised as new evidence accumulates to provide better estimates of relative risk.

Methods

Sources of dietary data

Some EU Member States carry out surveys to assess dietary intake, including individual daily consumption of vegetables and fruit. However, national surveillance systems vary enormously in the different Member States. Some countries do not assess dietary intake, and where this is done, different methods are used to collect the data. Therefore current methods of assessing dietary intake are inadequate to allow good comparisons between the EU countries[19]. Most of the intake data cited in this paper were supplied by the national governmental nutrition counterparts to the WHO Regional Office for Europe. However, because not all countries have nationally representative dietary intake surveys, other data sources, from non-nationally representative surveys or data from the DAFNE study, which is derived from household budget surveys[20], have been used to estimate the mean national intakes of vegetables and fruit.

A major problem with comparing the intake figures from the different EU countries is that the intake data relate to different years, ranging from 1980 in Portugal to 1998 in Austria.

In contrast to the intake data, EU-wide comparisons can be made using the United Nations Food and Agriculture Organisation (FAO) food balance sheet data. They provide an estimate of the supply of vegetables and fruit available to the domestic market by:

1. adding the total quantities produced nationally and imported (adjusted for changes in stocks);
2. subtracting the quantities exported, fed to livestock, used in manufacture and lost during storage and transport; and
3. dividing this estimated national food supply by the population size to derive the per capita figure in kg per year with no breakdown of the distribution between genders or age groups.

The FAO figures only provide an estimate of the quantity of food available for human consumption. A substantial proportion of the available vegetables and fruit is destroyed or wasted and not consumed. By subtracting the existing intake data from the FAO supply data for each country, an estimate of the proportion of vegetables and fruit not consumed in each country can be calculated.

Potential health gain: statistical methods

Epidemiological studies of dietary intake generally present their findings in terms of the change in risk of death or disease when comparing equal divisions (quantiles) of the population, e.g. tertiles or quintiles, corresponding to different levels of consumption. The ideal way of drawing conclusions from this literature would be to construct a dose–response curve by plotting all component pieces of evidence on a single diagram. This would allow the distinction to be made between studies on populations with differing levels of consumption, which could be important if the dose–response relationship is far from linear.

Unfortunately, the data on actual intakes within each category are not consistently reported in the epidemiological literature. For example, some papers give the consumption of vegetables and fruit by each quantile in terms of the number of portions per day[21], week[22] or month[23]; others give values in grams for the median and/or mean and standard deviation[24]; while many give no information at all on consumption levels[25,26]. Among those studies for which information is available, the intake levels vary substantially. Therefore for the estimations carried out here it was decided to calculate the effect of levelling up the intake of the whole population to equal that of the highest consumers.

There are additional questions to consider in interpreting the observed relative risks, in addition to the considerations of data quality, selection effects and statistical power that are common to all epidemiological studies. One is the dispersion of consumption levels within the population: if there were no variation in intake, it would be impossible to demonstrate an association with disease rates. A second is the choice of the number of quantiles, as with smaller divisions the extremes are more widely separated and can therefore be expected to have a relative risk that is further from unity.

The method of calculation used in this paper quantifies the fall in the annual number of premature deaths that would result if the intake among all the lower quantiles were increased to equal that of the highest quantile. It assumes a similar relative risk and range of consumption in the EU Member States as in the populations where the research was done, or alternatively, a linear no-threshold dose–response relationship.

The proportion of deaths saved depends on the relative risk (RR) or death rate ratio, and was calculated using the formula for the Population Attributable Risk Proportion (see Appendix), applied to deaths rather than to incident cases (assuming therefore the same RR):

$$(1 - \mathrm{RR})/(1 + \mathrm{RR}).$$

The annual number of deaths saved was then obtained by multiplying the existing total number of annual deaths by this proportion. The disease-specific mortality figures occurring up to age 65 years, for each EU Member State and the three largest accession countries, were obtained from World Health Statistics, published annually by WHO[27,28]. Estimates were calculated based on three different levels of relative risk of the highest consuming group compared with the lowest, 0.5, 0.7 and 0.9, in the manner of a sensitivity analysis.

While unsophisticated in its assumption of levelling up low consumption to that of the group with the highest level, this method can provide an estimate of the potential health gain. Moreover, it allows re-interpretation of the data as further epidemiological evidence continues to accumulate.

Results

Dietary intake

The FAO figures show that the availability of vegetables and fruits varies greatly between EU Member States, from only 358 g per capita per day in Ireland to 1122 g in Greece (Table 1). This trend is mirrored in the intake data, with more vegetables and fruit being consumed in southern compared with northern Europe. Subtracting the intake figures from the FAO figures, it can be estimated that the average percentage of vegetables and fruits available but not consumed in the EU is around 30%. Moreover, according to the intake data, the mean consumption in about half (seven) of the Member States is less than 275 g of vegetables and fruit per person per day.

However, mean consumption of vegetable and fruit is a poor measure of the intake distribution within a population. Vegetable and fruit intake is not normally distributed but is highly skewed to the right[20]. Thus, both the FAO and mean intake values conceal the large proportion of the population within each country with low consumption levels of vegetables and fruit.

Table 1 Availability and intake of vegetables/fruit in the EU Member States

	Availability (FAO data, 1995) (g person^{-1} day^{-1})	Intake (g person^{-1} day^{-1})
UK	461	208 (1995)
Ireland	358	215 (1989)
Austria	576	235 (1998)
Netherlands	636	242 (1992)
Germany	514	250 (1990)
Sweden	418	265 (1989)
Denmark	415	273 (1995)
Belgium/Luxemburg	661	360 (1982)
Portugal	725	399 (1980)
Finland*	413	433 (1992)[37]
France	619	437 (1996)
Italy	755	480 (1995)
Greece	1122	511 (1995)
Spain	659	604 (1994)[29]
Czech	418	250 †
Poland	461	302 (1997)[20]
Hungary	368	360 (1997)[20]

* For Finland, the FAO availability data are from 1995 and do not include home produce, and intake data are from 1992 and refer to adults aged 24 to 65 years of age, whereas the FAO availability data cover the whole population including young and the old, who may consume less vegetables and fruit.

† Czech Republic: personal communication – not national data.

Table 2 Deaths (of people aged 15–64) from major diseases in the Member States and in the EU, and estimates of the number of deaths potentially preventable assuming different levels of relative risk

	Number of deaths year^{-1}	$D_{0.5}$*	$D_{0.7}$*	$D_{0.9}$*
UK 1995				
Ischaemic heart disease	21,941	7314	3872	1155
Cerebrovascular disease	5393	1798	952	284
Cancer of oesophagus & stomach	3123	1041	551	164
Colo-rectal cancer	3757	1252	663	198
Cancer of bronchus/lung	8354	2785	1474	400
Breast cancer	5362	1787	946	282
Ireland 1993				
Ischaemic heart disease	1382	461	244	73
Cerebrovascular disease	277	92	49	15
Cancer of oesophagus & stomach	161	54	28	8
Colo-rectal cancer	198	66	35	10
Cancer of bronchus/lung	410	137	72	22
Breast cancer	283	94	50	15
Austria 1995				
Ischaemic heart disease	2308	769	407	121
Cerebrovascular disease	788	263	139	41
Cancer of oesophagus & stomach	413	138	73	22
Colo-rectal cancer	552	184	97	29
Cancer of bronchus/lung	1074	358	190	57
Breast cancer	649	216	115	34
Netherlands 1995				
Ischaemic heart disease	3455	1152	610	182
Cerebrovascular disease	1112	371	196	59
Cancer of oesophagus & stomach	750	250	132	39
Colo-rectal cancer	974	325	172	51
Cancer of bronchus/lung	2609	870	460	137
Breast cancer	1384	461	244	73
Germany 1995				
Ischaemic heart disease	25,439	8480	4489	1339
Cerebrovascular disease	8051	2684	1421	424
Cancer of oesophagus & stomach	5610	1870	990	295
Colo-rectal cancer	6664	2221	1176	351
Cancer of bronchus/lung	13,751	4584	2427	724
Breast cancer	7437	2479	1312	391
Sweden 1995				
Ischaemic heart disease	2226	742	393	117
Cerebrovascular disease	569	190	100	30
Cancer of oesophagus & stomach	241	80	43	13
Colo-rectal cancer	439	146	77	23
Cancer of bronchus/lung	826	275	146	43
Breast cancer	556	185	98	29
Denmark 1993				
Ischaemic heart disease	1646	549	290	87
Cerebrovascular disease	508	169	90	27
Cancer of oesophagus & stomach	223	74	39	12
Colo-rectal cancer	413	138	73	22
Cancer of bronchus/lung	1012	338	179	53
Breast cancer	499	166	88	26
Belgium 1992/Luxemburg 1995				
Ischaemic heart disease	2086	695	368	110
Cerebrovascular disease	918	306	162	48
Cancer of oesophagus & stomach	467	156	82	25
Colo-rectal cancer	665	222	117	35
Cancer of bronchus/lung	2196	732	388	116
Breast cancer	1008	336	178	53
Portugal 1995				
Ischaemic heart disease	1775	592	313	93
Cerebrovascular disease	1894	631	334	100
Cancer of oesophagus & stomach	988	329	174	52
Colo-rectal cancer	628	209	111	33
Cancer of bronchus/lung	973	324	172	51
Breast cancer	692	231	122	36

Table 2. *continued*

	Number of deaths year^{-1}	$D_{0.5}$*	$D_{0.7}$*	$D_{0.9}$*
Finland 1995				
Ischaemic heart disease	1901	634	335	100
Cerebrovascular disease	625	208	110	33
Cancer of oesophagus & stomach	224	75	40	12
Colo-rectal cancer	222	74	39	12
Cancer of bronchus/lung	522	174	92	27
Breast cancer	369	123	65	19
France 1994				
Ischaemic heart disease	6430	2143	1135	338
Cerebrovascular disease	3685	1228	650	194
Cancer of oesophagus & stomach	3169	1056	559	167
Colo-rectal cancer	3019	1006	533	159
Cancer of bronchus/lung	8954	2985	1580	471
Breast cancer	4193	1398	740	221
Italy 1993				
Ischaemic heart disease	11,536	3845	2038	607
Cerebrovascular disease	5425	1808	957	286
Cancer of oesophagus & stomach	3751	1250	662	197
Colo-rectal cancer	3648	1216	644	192
Cancer of bronchus/lung	10,302	3434	1818	542
Breast cancer	4880	1627	861	257
Greece 1995				
Ischaemic heart disease	2928	976	517	154
Cerebrovascular disease	1332	444	235	70
Cancer of oesophagus & stomach	389	130	69	20
Colo-rectal cancer	335	112	59	18
Cancer of bronchus/lung	1770	590	312	93
Breast cancer	679	226	120	36
Spain 1994				
Ischaemic heart disease	6246	2082	1102	329
Cerebrovascular disease	3231	1077	570	170
Cancer of oesophagus & stomach	2592	864	457	136
Colo-rectal cancer	2281	760	403	120
Cancer of bronchus/lung	5649	1883	997	297
Breast cancer	2729	910	482	144
All EU Member States				
Ischaemic heart disease	91,299	30,433	16,112	**4805**
Cerebrovascular disease	33,808	11,269	5966	**1779**
Cancer of oesophagus & stomach	22,101	7367	**3900**	1163
Colo-rectal cancer	23,795	7932	**4199**	1252
Cancer of bronchus/lung	58,402	19,467	**10,306**	3074
Breast cancer	30,720	10,240	5421	**1617**
Czech Republic 1993				
Ischaemic heart disease	5994	1998	1058	315
Cerebrovascular disease	2094	698	370	110
Cancer of oesophagus & stomach	672	224	119	35
Colo-rectal cancer	1219	406	215	64
Cancer of bronchus/lung	2584	861	456	136
Breast cancer	828	276	146	44
Poland 1995				
Ischaemic heart disease	15,483	5161	2732	815
Cerebrovascular disease	6870	2290	1212	362
Cancer of oesophagus & stomach	2922	974	516	154
Colo-rectal cancer	2379	793	420	125
Cancer of bronchus/lung	9047	3016	1597	476
Breast cancer	2460	820	434	129
Hungary 1995				
Ischaemic heart disease	7373	2458	1301	388
Cerebrovascular disease	3719	1240	656	196
Cancer of oesophagus & stomach	1168	389	206	61
Colo-rectal cancer	1246	415	220	66
Cancer of bronchus/lung	3660	1220	646	193
Breast cancer	979	326	173	52

* For explanation, see text.
ICD-9 codes used were: ischaemic heart disease – 270 & 279; cerebrovascular disease – 29; cancer of oesophagus & stomach – 090 & 091; colo-rectal cancer – 093 & 094; cancer of bronchus/lung – 101; breast cancer – 113.

Potential health gain

Table 2 gives the estimated number of deaths occurring annually for the age group 15 to 64 years in each country, and in the EU as a whole, for each disease. The last three columns give the number of deaths potentially prevented, assuming a causal relative risk of 0.5, 0.7 and 0.9 ($D_{0.5}$, $D_{0.7}$ and $D_{0.9}$, respectively), by applying the above method to the country-disease-specific number of deaths. Any benefits from dietary change would occur after a lag of some years, which is specific to each disease.

For the EU as a whole, the overall estimate of numbers of deaths potentially preventable varies from 86,700 if a causal relative risk of 0.5 for each of the diseases is taken, to 45,900 and 13,700 assuming respectively 0.7 and 0.9. The epidemiological evidence currently available suggests that the relative risks may be 0.7, 0.7, 0.7, 0.9, 0.9 and 0.9 for oesophageal/stomach cancer, colo-rectal cancer, lung cancer, breast cancer, IHD and stroke, respectively. Using these figures (given in bold in the table), the potential health gain is over 26,000 deaths annually.

For the three candidate Member States, the numbers are greater (proportional to their population), owing to the higher mortality rates from these diseases.

Discussion

The data on both FAO food availability and dietary intake within the EU are subject to serious limitations. For example, the intake data, even if available, are based on different methods of collection (e.g. 24-hour recall, food records or household budget data) and in addition the data may not be based on nationally representative samples of the population. Moreover, the different years when the intake data were collected range from 1980 in Portugal to 1998 in Austria. In addition the years in which the two sets of data from FAO and intake surveys were collected are not the same. There may also be other problems, as is indicated by the data from Finland where the intake data appear to show that consumption is greater than the actual availability according to FAO statistics. This could be because (1) the data relate to different years (1995 and 1992); (2) the FAO data collected in Finland may not include home produce; and (3) the FAO statistics cover the whole population whereas the data from intake surveys refer only to adults aged 24 to 65 years. The intake and FAO statistics cited in this paper are therefore to be regarded as rough approximations until comparable data sets are available from improved dietary intake surveillance in the EU.

Despite these limitations, it is clear that a substantial proportion of the EU population is not consuming enough vegetables and fruit. In about half (seven) of the Member States, the mean recorded intake level is less than 70% of that recommended by WHO. Furthermore, even a country like Greece, which has a relatively high mean consumption (511 g), has a substantial proportion of the population (37%) who fall below the recommended level[20]. In many EU Member States, there is a social gradient with lower intake among the less prosperous and/or less educated, for example in Spain[29,30], the UK[9] and in Finnish children[31]. The three selected accession countries from central Europe also appear to have mean intakes well below the WHO recommended 400 g person^{-1} day^{-1}. There is evidence from former Socialist economies that low intake of fruits and vegetables is not only widespread but is responsible for a significant proportion of the health gap, contributing to the high mortality from non-communicable diseases[32,33].

The effect of levelling up to the highest consuming group shows that the potential health gain could result in some tens of thousands of deaths saved each year under the age of 65 years. If the age group 65–74 were also included, the estimates would roughly be doubled. Moreover, there are no known adverse health effects associated with increasing vegetable and fruit intake.

The assumed scenario of behaviour change would involve a radical change in the shape of the distribution of consumption. Rose believed that distributions shift in position without changing their shape[34], although there is no evidence for this. A more likely scenario is an upward shift in the whole distribution, with greater changes occurring at lower consumption levels where there is more scope for improvement. Whatever the exact nature of the change, the health gain could be achieved with a combination of both shifting and altering the shape of the distribution.

The analysis carried out in this paper could be more sophisticated in various ways. On the exposure side, the effect of raising consumption to a particular target, e.g. 400 g person^{-1} day^{-1}, could be estimated if valid dietary intake data were available from all Member States. In view of the potential that increasing vegetable and fruit intake has for reducing the burden of disease, it is highly desirable to improve nutritional surveillance and that the intake assessment methods are comparable. Data from such surveys could be used to quantify dietary intake more accurately, to identify low consumers and to monitor changes over time.

For the analysis of potential health gain, different outcome variables could be used in preference to the annual number of deaths saved. In EU countries, where life expectancy is already relatively high, the issue is not so much to add quantity to life but to add quality. The non-fatal consequences of disease may put an even greater burden on society than premature mortality. An indicator that combines mortality, morbidity and disability and measures the number of disability-adjusted life years (DALYs)[35] has been developed. The DALY extends the concept of premature death to include equivalent years of 'healthy' life lost because of illness and disability.

This method of analysis has been used in Sweden[36] where it was suggested that 4.5% of DALYs are lost in EU countries due to poor nutrition, with an additional 3.7% and 1.4% due to obesity and physical inactivity. The Swedish analysis is not as detailed as the Global Burden of Disease analysis[35] and is only for the EU. However, the Swedish study is one of the first to investigate the potential burden of disease coming from dietary risk factors. These were not included in the Global Burden of Disease report (GBD) published in 1996[35]. It is hoped that, by expanding the concepts of this paper, dietary risk factors and how they contribute to the global burden of disease will be included in the next GBD analysis, which will be published in 2001.

The Finnish authorities[37] demonstrate that a significant increase in mean vegetable and fruit intake is achievable over a reasonable time span. However, improved mean intake can mask a highly skewed distribution within a population. Before the appropriate public health policies can be implemented, it is crucial that the intake of vegetables and fruits is measured using valid methodologies. More attention should be focused on assessing the vegetable and fruit intake of vulnerable groups, notably low-income households, children and the EU accession countries.

A range of policies could be used to increase vegetable and fruit intake. Health education may be less important than lowering the price and improving the availability of vegetables and fruit. People on a low income tend to spend relatively more of it on food, and their first priority is to satisfy their energy needs. This means that there may very little money left for low-energy, but micronutrient-rich, and relatively expensive vegetables and fruits. Poor people also tend to have fewer transport options and may find it difficult to get to shops if they are not within walking distance. In many countries low-income groups are the people most in need of increasing their vegetable and fruit intake. Fiscal policies should therefore be considered to help these disadvantaged groups have easier access[38]. As agricultural products already receive subsidies, it would make sense to modulate these in accordance with the scientific evidence on health benefits.

Attempts to reduce social inequalities and food poverty are desirable and could be achieved using special measures to support low-income groups who are food-insecure. Measures could include: provision of small plots of land for the unemployed or ethnic minorities, including in large cities, to allow them to grow their own vegetables; protecting farmers' markets where local growers can sell their produce; community-supported agriculture schemes; co-operative bulk-buying initiatives within communities; and free or discounted school fruit. Some of these initiatives are discussed in more detail in the Urban Food and Nutrition Action Plan produced by the nutrition programme at the European Regional Office of WHO[39].

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Appendix – Population Attributable Risk Proportion

For a dichotomous situation, where the population can be divided into those who are exposed and those who are non-exposed, the Attributable Risk is given by:

$$\text{(incidence in the exposed group)} - \text{(incidence in the non-exposed group)},$$

or

$$I_E - I_0,$$

where the units are of the type cases/population/year.

The formula for the Attributable Risk Proportion is:

$$(I_E - I_0)/I_E,$$

where the units now cancel out, or (dividing by I_0):

$$(\mathrm{RR} - 1)/\mathrm{RR} \ \text{ or } \ 1 - (1/\mathrm{RR}),$$

which measures the proportionate change in risk *in the exposed group*. This would overestimate the change if applied to the whole population. For the latter purpose, it is necessary to use the Population Attributable Risk Proportion:

$$(I_E - I_0)/\text{(incidence rate in the whole population)}.$$

In the special case where the exposed and non-exposed groups are equal in size, this is equal to:

$$(I_E - I_0)/(I_E + I_0),$$

or (dividing by I_0):

$$(\mathrm{RR} - 1)/(\mathrm{RR} + 1).$$

For a protective factor, the signs are reversed:

$$(1 - \mathrm{RR})/(1 + \mathrm{RR}).$$

The dichotomous case is shown in Fig. A1 for RR = 0.5 and RR = 0.7 (first diagram in each case). From the figure, it can easily be seen that the same formula is generalisable to any number of equal-sized groups (tertiles, quartiles, quintiles, etc.) if the trend is monotonic, or even if non-monotonic but symmetrical.

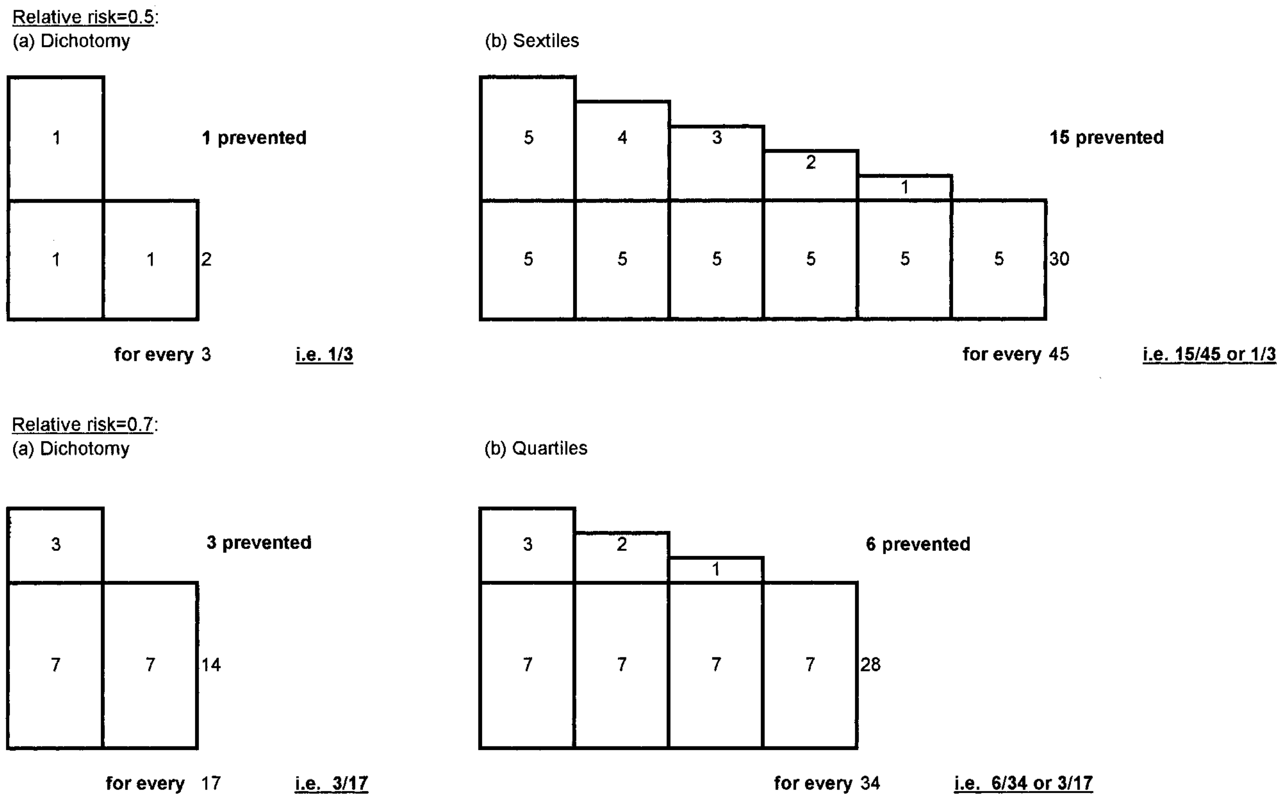

Fig. A1 Illustration of the Population Attributable Risk Proportion for a protective factor. The figure illustrates the relationship between the proportion of cases or deaths prevented and the relative risk. Thus, when the relative risk is 0.5, 1/3 are prevented; with a relative risk of 0.7, 3/17 are prevented. These are independent of the number of quantiles