The global burden of disease attributable to low consumption of fruit and vegetables: implications for the global strategy on diet

Karen Lock,[1] Joceline Pomerleau,[2] Louise Causer,[3] Dan R. Altmann,[4] & Martin McKee[5]

Objective We estimated the global burden of disease attributable to low consumption of fruit and vegetables, an increasingly recognized risk factor for cardiovascular disease and cancer, and compared its impact with that of other major risk factors for disease.

Methods The burden of disease attributable to suboptimal intake of fruit and vegetables was estimated using information on fruit and vegetable consumption in the population, and on its association with six health outcomes (ischaemic heart disease, stroke, stomach, oesophageal, colorectal and lung cancer). Data from both sources were stratified by sex, age and by 14 geographical regions.

Findings The total worldwide mortality currently attributable to inadequate consumption of fruit and vegetables is estimated to be up to 2.635 million deaths per year. Increasing individual fruit and vegetable consumption to up to 600 g per day (the baseline of choice) could reduce the total worldwide burden of disease by 1.8%, and reduce the burden of ischaemic heart disease and ischaemic stroke by 31% and 19% respectively. For stomach, oesophageal, lung and colorectal cancer, the potential reductions were 19%, 20%, 12% and 2%, respectively.

Conclusion This study shows the potentially large impact that increasing fruit and vegetable intake could have in reducing many noncommunicable diseases. It highlights the need for much greater emphasis on dietary risk factors in public health policy in order to tackle the rise in noncommunicable diseases worldwide, and suggests that the proposed intersectoral WHO/FAO fruit and vegetable promotion initiative is a crucial component in any global diet strategy.

Keywords Fruit; Vegetables; Cost of illness; Feeding behaviour; Diet; Health status; Gastrointestinal neoplasms/epidemiology; Lung neoplasms/epidemiology; Myocardial ischemia/epidemiology; Carebrovascular accident/epidemiology; Review literature; Meta-analysis (*source: MeSH, NLM*).

Mots clés Fruits; Plantes potagères; Coût maladie; Comportement alimentaire; Etat sanitaire; Tumeur gastro- intestinale; Tumeur poumon; Ischémie myocardique; Accident vasculaire cérébral; Revue de la littérature; Méta-analyse (*source: MeSH, INSERM*).

Palabras clave Frutas; Vegetales; Costo de la enfermedad; Conducta alimentaria; Estado de salud; Neoplasmas gastrointestinales; Neoplasmas pulmonares; Isquemia miocárdica; Accidente cerebrovascular; Literatura de revisión; Meta-análisis (*fuente: DeCS, BIREME*).

Arabic

Bulletin of the World Health Organization 2005;83:100-108.

Voir page 106 le résumé en français. En la página 106 figura un resumen en español.

Introduction

Chronic noncommunicable diseases are the leading causes of death and disability worldwide and are increasing rapidly in most regions of the world (*1*). *The world health report 2003* (*2*) estimated that cardiovascular disease accounted for 16.7 million deaths globally (29.2% of the total), while cancer contributed to 7.1 million deaths (12.5% of the total). Policies aimed at reducing these diseases have typically emphasized selected risk factors such as smoking, and, where diet is included, attention has focused on fat consumption. Less attention has been given to other dietary risk factors, specifically consumption of fruit and vegetables. This is of growing importance as the nutrition transition, occurring in all but the poorest countries of the world, is resulting in the replacement of traditional plant-based diets that are rich in fruit and vegetables with diets that are rich in calories provided by animal fats and sugar and are low in complex carbohydrates (*3*).

Although there is now increasingly good evidence that fruit and vegetables protect against cardiovascular diseases and some cancers (*4–6*), their precise contribution has been unclear.

[1] MRC Clinical Research Fellow, European Centre on Health of Societies in Transition, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, England. Correspondence should be sent to this author (email: Karen.Lock@lshtm.ac.uk).

[2] Lecturer, European Centre on Health of Societies in Transition, London School of Hygiene and Tropical Medicine, London, England.

[3] Research Fellow, European Centre on Health of Societies in Transition, London School of Hygiene and Tropical Medicine, London, England.

[4] Lecturer, Medical Statistics Unit, London School of Hygiene and Tropical Medicine, London, England.

[5] Professor, European Centre on Health of Societies in Transition, London School of Hygiene and Tropical Medicine, London, England.

Ref. No. **04-012674**

(*Submitted: 23 February 2004 – Final revised version received: 9 June 2004 – Accepted: 14 June 2004*)

It may be considerable: earlier national studies estimated that low consumption of fruit and vegetables was responsible for 2.4%, 2.8% and 3.5% of the burden of disease in New Zealand (*7*), Australia (*8*) and the European Union (*9*), respectively. Until now, however, there has been no attempt to estimate this contribution globally, particularly in developing countries.

The original global burden of disease (GBD) project (*10*) was the first study to calculate the worldwide burden of disability and mortality and the contribution of different diseases and risk factors in 1990. In the initial study, the number of risk factors examined was limited. Although it identified protein–energy malnutrition as the single greatest contributor to the overall disease burden, it did not look explicitly at the impact of dietary intake (*11*). In the updated analysis for 2000, WHO has expanded the study to include 26 risk factors assessed using a unified framework called comparative risk assessment (CRA) (*1*, *12*). For the first time this included "fruit and vegetable consumption" as a risk factor. This paper reports the research undertaken to estimate the global burden of disease attributable to low consumption of fruit and vegetables, and discusses its implications for policy development.

Methods

Two sources of information were combined to derive the burden of disease attributable to low intake of fruit and vegetables; first, information on the level and distribution of consumption in the population and a baseline level of intake that would yield the lowest overall population risk; and second, estimates of the association, in terms of relative risks (RR) between fruit and vegetable intake and selected health outcomes. Data on risk factor levels and relative risks were obtained for both sexes, eight age groups, and 14 geographical regions (Table 1). The detailed methods have been published elsewhere (*12–14*).

Estimates of fruit and vegetable consumption

In this study, the risk factor was an aggregate measure called "fruit and vegetable intake", which we defined as being total consumption of fruit and vegetables, excluding potatoes (*4*, *5*, *15*). Intake was treated as a continuous variable and expressed in grams (g) per person per day. Estimates were based primarily on national representative surveys of individual dietary intake identified through a comprehensive search of the literature and contact with experts worldwide. Surveys with individual-level dietary data provide information on intakes and their variability (standard deviations) in population subgroups (age and sex strata). Data were obtained for 26 countries (highlighted in bold in Table 1) within 9 regions (*16*, *17*). These included nationally representative surveys from some of the most populated countries in the world, including China, India, the Russian Federation and the United States of America (USA). Systematic extrapolations were made when the original data did not meet the age or sex categories. Data were then pooled statistically within each region to provide regional intakes. When no survey data were available in a region or when survey data were available from only one small country within a region, estimates of fruit and vegetable intakes were derived by the use of systematic extrapolations from per capita food supply statistics from the Food and Agriculture Organization of the United Nations (FAO) (*18*, *19*) in a model based on survey data from other regions. Data from FAO on the availability of fruit (excluding wine) and vegetables (excluding potatoes) and estimates of population size were used to calculate regional population-weighted average fruit and vegetable per capita availability for 1996–98. Complete details of the methods used for estimating fruit and vegetable intake have been published elsewhere (*16*, *17*).

Risk factor epidemiology

The health outcomes selected included ischaemic heart disease, cerebrovascular disease, and cancers of the lung, stomach, oesophagus, colon and rectum. The choice of outcomes was guided by previous reviews of the literature, which reported a consistent protective effect of fruit and vegetable intake on these health problems (*4*, *20*, *21*). There is growing evidence for an association with other outcomes, including cancers of the bladder, pharynx, larynx, and diabetes, which should be considered in future reviews.

Systematic reviews of the literature, using standardized methods, were conducted for each disease outcome (*17*). Considering the large variation in study design, study quality and measurement of both exposure and outcome among the studies identified, it was considered methodologically inappropriate and potentially misleading to pool statistically the results of all studies identified in the reviews. Thus, strict criteria were first applied to select only the best quality and most representative studies, which would allow fruit and vegetable intake to be treated as a continuous variable (to parallel exposure estimates).

When two or more studies were available, the results were pooled using meta-analysis (*22*), performed using log RR per consumption unit and corresponding standard errors, implemented in Stata 7 (Stata Corporation, USA; "meta" command). Where a study did not report RR per consumption unit, the method of Greenland & Longnecker (*23*) was used to estimate a weighted regression slope over the RR and consumption levels published by the study, thus obtaining an appropriate log RR. Heterogeneity between studies was tested using the chi-squared statistic. The random effects result was pre-specified conditional on evidence of heterogeneity. When only two studies were available, or when there was no evidence of heterogeneity, fixed effects meta-analysis was used. For stomach cancer, only one study met the selection criteria, and this was used (*24*). For oesophageal cancer, the results of a recent meta-analysis were used (*6*, *25*).

Because there is currently little evidence for significant variations in RR by age and sex, the RR estimates were applied to both sexes and to all groups of people aged between 15 and 70 years. Although studies of fruit and vegetable intake have not quantified this there is, however, evidence from other, presumably intermediate, risk factors like obesity and blood pressure. This suggests that age attenuation is likely in RR at both extremes of age (*7*). Approximate age attenuations were thus applied as follows: RRs were reduced by 25% for individuals aged 70–79 years and by 50% for those aged 80 years and over. Under the age of 15 years, a RR of 1 was applied (*7*).

The studies used to derive RR estimates came mainly from Japan, the USA and Western Europe. It is likely that differences in factors that interact with fruit and vegetables vary among populations. However, as these differences are not known, the same RR estimates were applied to all regions. While it is important to consider the issue of transferring RRs across populations, this is likely to be a smaller source of uncertainty than how we define and measure exposure in such epidemiological studies.

Table 1. **Estimated regional intake of fruit and vegetables**

Region[a]	Countries in region[b]	Regional population (%) covered by survey data[c]	Sex	Estimated regional mean intake of fruit and vegetables (grams per person per day) Age group (years) 0–4	5–14	15–29	30–44	45–59	60–69	70–79	≥80
Africa D	Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo	—	Male	144	296	288	413	419	439	446	476
			Female	140	279	302	345	305	355	349	382
Africa E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe	—	Male	94	193	192	278	294	325	333	380
			Female	91	181	201	236	214	257	244	245
America A	Canada, Cuba, **United States of America**	87.5	Male	278	247	257	305	338	369	387	364
			Female	262	236	234	261	307	335	346	348
America B	Antigua and Barbuda, **Argentina**, Bahamas, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, **Mexico**, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, Venezuela	32.0	Male	72	147	148	168	208	220	230	180
			Female	82	134	167	218	204	220	235	230
America D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru	—	Male	193	352	299	408	392	387	353	306
			Female	192	339	316	332	287	328	287	241
Eastern Mediter-ranean B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, **Kuwait**, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates	1.4	Male	218	335	296	368	374	392	350	334
			Female	218	327	323	362	346	392	336	319
Eastern Mediter-ranean D	Afghanistan, Djibouti, Egypt, Iraq, Morocco, Pakistan, Somalia, Sudan, Yemen	—	Male	174	342	312	388	409	446	442	420
			Female	174	333	348	352	319	385	372	409
Europe A	Andorra, Austria, **Belgium**, Croatia, Czech Republic, **Denmark**, **Finland**, **France**, **Germany**, Greece, Iceland, **Ireland**, **Israel**, **Italy**, Luxembourg, Malta, Monaco, Netherlands, **Norway**, Portugal, San Marino, Slovenia, Spain, Sweden, Switzerland, **United Kingdom**	71.3	Male	232	299	423	450	488	511	515	469
			Female	233	299	423	448	483	488	479	446
Europe B	Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, **Bulgaria**, Georgia, Kyrgyzstan, Poland, Romania, Slovakia, Tajikistan, The former Yugoslav Republic of Macedonia, Turkey, Turkmenistan, Uzbekistan, former Yugoslavia	3.8	Male	263	374	396	352	396	366	358	300
			Female	238	372	344	333	383	352	358	303
Europe C	Belarus, **Estonia**, Hungary, **Kazakhstan**, **Latvia**, **Lithuania**, Republic of Moldova, **Russian Federation**, Ukraine	69.2	Male	134	198	233	237	246	254	233	233
			Female	133	182	196	187	202	200	209	190
South-East Asia B	Indonesia, Sri Lanka, Thailand	—	Male	108	198	245	243	258	248	244	225
			Female	107	183	201	195	202	201	201	173

(Table 1, cont.)

Region[a]	Countries in region[b]	Regional population (%) covered by survey data[c]	Sex	Estimated regional mean intake of fruit and vegetables (grams per person per day) Age group (years): 0–4	5–14	15–29	30–44	45–59	60–69	70–79	⩾80
South-East Asia D	**Bangladesh**, Bhutan, Democratic People's Republic of Korea, **India**, Maldives, Myanmar, Nepal	93.7	Male	94	177	258	262	262	259	259	234
			Female	95	170	224	229	227	229	228	205
Western Pacific A	**Australia**, Brunei Darussalam, **Japan**, New Zealand, **Singapore**	97.6	Male	264	345	366	376	450	491	446	415
			Female	232	342	352	383	486	485	440	386
Western Pacific B	Cambodia, **China**, Cook Islands, Fiji, Kiribati, Lao People's Democratic Republic, Malaysia, Marshall Islands, Micronesia (Federated States of), Mongolia, Nauru, Niue, Palau, Papua New Guinea, Philippines, Republic of Korea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu, Viet Nam	84.0	Male	204	274	344	346	360	335	304	258
			Female	190	270	317	334	345	304	273	250

[a] Countries were grouped into five mortality strata on the basis of combinations of child (aged less than 5 years) and adult (aged 15–59 years) mortality. These mortality strata were then applied to the six main WHO regions (Africa, Americas, Eastern Mediterranean, Europe, South-East Asia, and Western Pacific) to produce the 14 epidemiological subregions: A. very low child and adult mortality; B. low child and adult mortality; C. low child and high adult mortality; D. high child and adult mortality; E. high child and very high adult mortality.

[b] Countries in each region included in the GBD study.

[c] Proportion of regional population covered by countries for which dietary survey data were obtained (in bold).

Estimating attributable burden

Population attributable fractions were estimated for each outcome (Fig. 1). The attributable fraction is the percentage reduction in disability and death that would occur if exposure to the risk factor was reduced to a defined level of exposure that yielded the theoretical lowest population risk (*14*). Hence, the attributable burden of disease is defined as the difference between the currently observed burden and the burden that would be observed if the distribution of exposure met this baseline of choice (*12*, *13*). Disability-adjusted life years (DALYs) are estimated in this project as a valid summary measure of the burden of disease in a defined population. They combine years of life lost and years lived with a disability (*1*).

Fruit and vegetable intake is an unusual risk factor in that there is an inverse disease–risk relationship, (i.e. it is the potential protective effect of fruit and vegetables that is considered). The theoretical minimum risk involves selecting a maximum consumption level at which the protective effect is maximized.

Fig. 1. **Potential impact fraction equation used to estimate population attributable fraction (PAF)**

$$PIF = \frac{\int_{x=0}^{m} RR(x)\,P(x) - \int_{x=0}^{m} RR(x)\,P'(x)}{\int_{x=0}^{m} RR(x)\,P(x)}$$

Where
RR(x) = relative risk at exposure level x.
P(x) = population distribution of exposure.
P′(x) = counterfactual distribution of exposure.
m = maximum exposure level.

WHO 04.205

As levels of intake that give the greatest protection remain unknown, the theoretical minimum risk level was chosen on the basis of knowledge of the highest achievable levels of current fruit and vegetable intake. Evidence of an association between fruit and vegetable intake and diseases comes mainly from studies performed in Europe and North America. Thus, the baseline of choice was selected based on the ranges of intakes observed in these populations (the maximum being 550 g per day in adults). The choice of optimal consumption was thus set at 600 g per day in adults. It reflects two factors: to what level do benefits continue, and what level of consumption can we assume (even in theory) to be achievable? Owing to uncertainty, the same threshold was assumed to apply equally to all health outcomes, and to all adult populations of both sexes worldwide.

Results

Consumption of fruit and vegetables

Estimates of mean regional intakes of fruit and vegetables by sex and age group are given in Table 1. Intakes were highest in Europe A and Western Pacific A, and lowest in America B, Europe C, South-East Asia regions B and D, and Africa E. As expected, intakes varied by age, with children and the elderly generally having lower intakes than middle-aged adults. Full details, including standard deviations, are published elsewhere (*16*).

Relative risks

RR estimates for the association of fruit and vegetable intake with the selected outcomes are shown in Table 2. They are expressed as the change in RR associated with an 80 g per day increase in intake (equivalent to the size of one standard serving) (*4*). The effect of an increase in fruit and vegetable consumption appears to be highest for coronary heart disease and ischaemic stroke. Significant RR ($P<0.05$) were estimated for coronary heart disease, ischaemic stroke, and lung cancer.

Attributable burden of disease

The results given in Table 3 show that increasing individual consumption of fruit and vegetables up to an optimal level of intake could reduce the worldwide burden of disease for ischaemic heart disease and ischaemic stroke by about 31% and 19%, respectively. For stomach and oesophageal cancer, the potential reduction in disease attributable to an increase in fruit and vegetable intake was 19% and 20%, respectively. Attributable risk fractions were lower for lung and colorectal cancer (12% and 2%). The total worldwide mortality attributable to inadequate consumption of fruit and vegetables was estimated to be approximately 2.6 million deaths in 2000. This is equivalent to approximately 1.8% of total global burden of disease (*13*). The regional analyses show that fruit and vegetable intake is a significant determinant of disease burden in both developed and developing regions (Table 4).

Discussion

An important finding of the GBD project for the year 2000 is the key role of nutrition in ill-health worldwide. About 15% of global disease is attributable to the effects of undernutrition and deficiencies in micronutrients, but a similar amount of disease can also be attributed to risk factors that have significant dietary components: overweight, high blood cholesterol, hypertension and low intake of fruit and vegetables (*12*).

Our work suggests that up to 2.6 million deaths worldwide and 31% of cardiovascular diseases may be attributed to inadequate consumption of fruit and vegetables (*1*). Considering the results for all 26 risk factors analysed as part of the GBD project, about 1.8% of the total burden of disease worldwide was estimated to be attributable to inadequate consumption of fruit and vegetables. This compares with 1.3% of the total global burden of disease for physical activity, 2.3% for overweight and obesity, 2.8% for high cholesterol and 4.1% for tobacco. This clearly indicates that fruit and vegetable intake is a significant determinant, particularly of cardiovascular diseases, in both developed and developing regions, although its impact is greater in developed regions.

For the diseases considered, diet is only one of many contributory factors (such as smoking or lack of physical activity), and even the dietary component may vary in different circumstances (such as the type and combination of fruit and vegetables, the frequency, and change in intake over the life course). Attempts need to be made to clarify these relationships. The CRA project has begun by estimating the joint population attributable fraction for some major worldwide diseases (*13*).

To estimate the impact of fruit and vegetable consumption on population health is a complex task: dietary exposure is difficult to measure, reflecting limitations of dietary ascertainment (*26*), there remains uncertainty as to which constituents are protective, and life-course exposure is complex. There is growing understanding of the complicated biological pathways through which fruit and vegetables act and of differences in the bioavailability of active components. Given the wide range of bioactive factors in fruit and vegetables, it is plausible that a varied diet has both generic (e.g. antioxidant) and disease-specific (e.g. tumour suppressor) effects. In addition, it is likely that there will be differences in genetic susceptibility, in particular because of different levels of activity of key metabolic pathways. This lack of understanding makes intervention studies of fruit and vegetable intake especially difficult to conduct, and also helps to explain the disappointing findings of trials of selected antioxidant and vitamin supplementation that have shown no effect on mortality, cardiovascular events or cancer (*27*, *28*). Nonetheless, there is now a growing body of evidence from well-designed cohort studies in a range of populations (*4*, *21*) and a small number of dietary intervention trials (*29*, *30*) that supports a protective effect of fruit and vegetables. Consequently, consumption of fruit and vegetables is increasingly being accepted as an important risk factor for a wide range of noncommunicable diseases.

Clearly the burden of disease estimates presented here are subject to the limitations imposed by the methods used, which have been designed to allow assessment of a wide range of diverse exposures across a variety of disciplines (*31*, *32*). Such quantitative risk assessment is inevitably subject to considerable uncertainty surrounding the estimation of exposure levels and

Table 2. **Relative risks (and 95% confidence intervals) associated with an increase in intake of fruit and vegetables[a] for selected health outcomes, by age group**

Outcome	Age group (years)							
	0–4	5–14	15–29	30–44	45–59	60–69	70–79	⩾80
Ischaemic heart disease	1.00	1.00	0.90 (0.82–0.99)	0.90 (0.82–0.99)	0.90 (0.82–0.99)	0.90 (0.82–0.99)	0.93 (0.85–1.01)	0.95 (0.87–1.03)
Ischaemic stroke	1.00	1.00	0.94 (0.89–0.99)	0.94 (0.89–0.99)	0.94 (0.89–0.99)	0.94 (0.89–0.99)	0.95 (0.91–1.00)	0.97 (0.92–1.02)
Lung cancer	1.00	1.00	0.96 (0.93–0.99)	0.96 (0.93–0.99)	0.96 (0.93–0.99)	0.96 (0.93–0.99)	0.97 (0.91–1.02)	0.98 (0.92–1.03)
Gastric cancer	1.00	1.00	0.94 (0.86–1.03)	0.94 (0.86–1.03)	0.94 (0.86–1.03)	0.94 (0.86–1.03)	0.95 (0.87–1.04)	0.97 (0.89–1.06)
Oesophageal cancer	1.00	1.00	0.94 (0.88–1.01)	0.94 (0.88– 1.01)	0.94 (0.88– 1.01)	0.94 (0.88– 1.01)	0.95 (0.89– 1.02)	0.97 (0.91–1.04)
Colorectal cancer	1.00	1.00	0.99 (0.97–1.02)	0.99 (0.97–1.02)	0.99 (0.97–1.02)	0.99 (0.97–1.02)	0.99 (0.97–1.02)	1.00 (0.97–1.02)

[a] Unit of change in risk = change per increase of 80 g per day in intake of fruit and vegetables (equivalent to the size of one standard serving).

Table 3. **The global burden of disease attributable to low intake of fruit and vegetables, by cause, 2000**

Outcome	Population attributable fraction[a] for low intake of fruit and vegetables (% of total DALYs[b] for each cause)	Mortality attributable to low intake of fruit and vegetables (000s)
Ischaemic heart disease	31	1800
Ischaemic stroke	19	474
Lung cancer	12	139
Stomach cancer	19	133
Oesophageal cancer	20	77
Colorectal cancer	2	12

[a] Population attributable fraction is the percentage reduction in disability and death that would occur if exposure to the risk factor was reduced to a defined level of exposure that yielded the theoretical lowest population.
[b] DALYs = disability-adjusted life years.

Table 4. **Mortality and DALYs[a] attributable to low intake of fruit and vegetables, by sex and regional level of development, in 2000 (% of total global burden of disease)** (*1*)

	Developing countries with high mortality (AFR-D, AFR-E, AMR-D, EMR-D, SEAR-D)		Developing countries with low mortality (AMR-B, EMR-B, SEAR-B, WPR-B)		Developed countries (AMR-A, EUR-A, EUR-B, EUR-C, WPR-A)	
	Male	Female	Male	Female	Male	Female
Attributable mortality	3.6%	3.5%	5.0%	4.8%	7.6%	7.4%
Attributable DALYs	1.3%	1.2%	2.0%	1.8%	4.3%	3.4%

[a] DALYs = disability-adjusted life years.
AFR = African Region; AMR = Region of the Americas; EMR = Eastern Mediterranean Region; EUR = European Region; SEAR = South-East Asia Region; WRP = Western Pacific Region.

exposure–outcome relationships, the selection of the baseline of choice, and the statistical methods used to obtain disease burden estimates. Sources of uncertainty include parameter uncertainty, which can sometimes be quantified (e.g. due to measurement error), and model uncertainty due to gaps in theory, measurement technology or simply lack of data (*14*). This uncertainty also includes the nature of the exposure–response relationship (e.g. whether there is a threshold effect for fruit and vegetables), the levels of bias in measurement, plus the extrapolation of exposure from one population to another. The last issue was a problem for estimating regional fruit and vegetable intake as in some regions of the world there are few studies reporting individual dietary intake. Given the limitations, there were two options for this global project; either exclude those regions without good representative intake survey data and RR estimates (meaning that the focus of diet as a risk factor would have been in developed countries, ignoring the rapid epidemiological and nutrition transition occurring worldwide (*3*)); or use clear assumptions and extrapolations, which may stimulate the need for more research on diet and noncommunicable disease in developing and transition countries with poor resources.

Two assumptions underpin the analysis of the burden of diet-related ill-health: that diet can be a primary determinant of disease; and that the extent of causation can be measured. Scientific evidence strongly supports a causal relationship between fruit and vegetable intake and cardiovascular disease and some cancers, but there were numerous problems encountered in estimating the hazard size. Estimates of hazard size in individual studies were adjusted for confounding as much as possible; however, it was not possible to estimate the uncertainty involved in extrapolating from a limited number of studies to a wide range of very different populations exposed to diverse dietary and other factors, any of which might interact. It is perhaps easier to confirm summary measures of relative risk for more proximal risk factors (such as blood pressure) compared with more distal factors such as intake of fruit and vegetables. The possible sources of uncertainty are discussed fully elsewhere (*17*). Nonetheless, the analyses presented here draw on the best evidence currently available and should be considered within the context of limited data as a first attempt to develop a tool that can be used to explain the worldwide burden of disease attributable to low consumption of fruit and vegetables, which also allows for comparisons between disease risk factors.

Despite the limitations of the GBD study, it is important to recognize the benefits that the presentation of comparable information can bring to health policy-makers. The CRA project provides timely objective information on the magnitude of 26 risk factors, obtained using uniform methods, for all world regions. The population health effects of dietary intake can thus be compared directly with the effects of other risk factors, including smoking, obesity, air pollution and unsafe sex, across the world. It is a means of stimulating decision-makers to consider a wider range of health determinants when formulating public policy. Our findings suggest that nutrition should be much higher on the policy agenda as we seek to address the increase in major noncommunicable diseases worldwide.

In Europe, the main emphasis of food policy continues to be on food safety, which is considerably less important in terms of disease burden. A number of national and international bodies advocate an increase in intake of fruit and vegetables to

400–500 g per day (excluding potatoes) (*4*, *15*). This has been translated into national health promotion campaigns, including the "5-a-day" programmes in the USA and the United Kingdom (*33*, *34*) and similar initiatives in other developed countries. The results presented here suggest that this target should be the minimum policy goal. However, this will require wide-ranging changes in many sectors as current preventive programmes have had limited success in increasing fruit and vegetable intake, owing to competing pressures such as intensive marketing of fast food. As dietary habits are embedded in cultural, economic and political structures, there should also be greater emphasis on promoting policies that target the determinants of fruit and vegetable consumption rather than simply targeting individual behavioural change. Policy should aim to remove obstacles and enhance people's ability to eat healthy diets, including action on agriculture, food labelling, nutritional claims, advertising, nutrition programmes, and differential food taxation.

To achieve these goals, WHO and FAO launched a new joint Fruit and Vegetable Promotion Initiative in 2003 (*35*, *36*) as part of the Global Strategy on Diet, Physical activity and Health endorsed by the World Health Assembly 2004 (*37*). This advocates the development and implementation of national fruit and vegetable promotion programmes that are sustainable, comprehensive and engage all sectors, particularly public health and agriculture. As food policy has been neglected as a key health determinant, such intersectoral policy approaches to food, nutrition and health appear to be an important new way forward for tackling the rise in obesity, cardiovascular disease and cancer worldwide. ■

Acknowledgements
The Stata program to implement the method of Greenland & Longnecker was written and tested by Ian R. White (MRC Biostatistics Unit, Cambridge). We thank Majid Ezzati (Harvard University) and Alan Lopez (WHO Geneva), Steve Van der Hoorn and Anthony Rogers (University of Auckland) for their advice during the GBD/CRA project. We also wish to thank the large number of people worldwide who helped in providing sources of data on fruit and vegetable intake. They are acknowledged in full in a forthcoming book (*17*).

This work was supported by a grant from the Department of Health, England. The Department of Health was not involved in study design, data collection, analysis or interpretation of data, report writing or paper submission. The Department of Health cannot accept responsibility for any information provided or views expressed.

Conflict of interest: none declared.

Résumé

Charge de morbidité attribuable à la faible consommation de fruits et de légumes dans le monde : conséquences pour la stratégie mondiale en matière de nutrition

Objectif Les auteurs ont estimé la charge mondiale de morbidité attribuable à la faible consommation de fruits et de légumes, facteur de plus en plus reconnu de maladie cardiovasculaire et de cancer, et ont comparé son impact à celui d'autres facteur de risque morbide majeurs.

Méthodes La charge de morbidité attribuable à une absorption sous-optimale de fruits et de légumes a été estimée à partir d'informations relatives à la consommation de fruits et de légumes dans la population et de son association à six événements affectant la santé (insuffisance coronarienne, accident vasculaire cérébral, cancer de l'estomac, de l'œsophage, du côlon/rectum et du poumon). Les données provenant de ces deux sources ont été stratifiées par sexe, âge et région géographique (14 régions).

Résultats On estime que la mortalité totale dans le monde actuellement attribuable à une consommation insuffisante de fruits et de légumes peut atteindre jusqu'à 2635 millions de décès par an. Amener la consommation individuelle de fruits et de légumes à 600 g par jour (niveau de référence de choix) pourrait permettre de réduire la charge de morbidité totale dans le monde de 1,8 % et la charge d'insuffisance coronarienne et d'accident vasculaire cérébral respectivement de 31 et 19 %. Pour les cancers de l'estomac, de l'œsophage, du poumon et du côlon/rectum, les réductions potentielles seraient respectivement de 19, 20, 12 et 2 %.

Conclusion La présente étude montre l'impact potentiellement important que pourrait avoir une consommation accrue de fruits et de légumes sur l'apparition de nombreuses maladies non transmissibles. Elle fait ressortir la nécessité d'accorder un poids beaucoup plus important aux facteurs de risque alimentaires dans les politiques de santé publique, afin de s'opposer à la prévalence grandissante des maladies non transmissibles dans le monde entier, et incite à penser que l'initiative intersectorielle OMS/FAO pour la promotion des fruits et légumes proposée constituerait une composante essentielle de toute stratégie alimentaire mondiale.

Resumen

Carga mundial de morbilidad atribuible al bajo consumo de frutas y verduras: implicaciones para la estrategia mundial sobre régimen alimentario

Objetivo Estimamos la carga mundial de morbilidad atribuible al consumo insuficiente de frutas y verduras, un factor de riesgo cada vez más reconocido de enfermedades cardiovasculares y cáncer, y comparamos su impacto con el de otros factores de riesgo de morbilidad importantes.

Métodos Se calculó la carga de morbilidad atribuible a una ingesta subóptima de frutas y verduras a partir de la información disponible sobre el consumo de esos productos en la población y sobre su asociación a seis resultados de salud (cardiopatía isquémica, accidente cerebrovascular, y cánceres de estómago, esófago, colon/recto y pulmón). Los datos de ambas fuentes se estratificaron por sexo, edad y 14 regiones geográficas.

Resultados La mortalidad mundial total atribuible a un bajo consumo de frutas y verduras se cifra actualmente en 2 635 000 defunciones anuales. El aumento del consumo individual de frutas y verduras hasta 600 g diarios (el punto de referencia de elección) podría reducir la carga mundial total de morbilidad en un 1,8%, y la carga de cardiopatía isquémica e ictus isquémico en un 31% y

19%, respectivamente. Para los cánceres de estómago, esófago, pulmón y colon/recto, las reducciones potenciales fueron del 19%, 20%, 12% y 2%, respectivamente.

Conclusión Este estudio muestra el enorme impacto potencial del aumento de la ingesta de frutas y verduras como medida de reducción de la incidencia de numerosas enfermedades no transmisibles. Subraya también la necesidad de hacer mucho más hincapié en los factores de riesgo alimentarios en las políticas de salud pública si se desea hacer frente al aumento de las enfermedades no transmisibles observado en todo el mundo, e indica que la iniciativa intersectorial OMS/FAO propuesta para promover el consumo de frutas y verduras es un componente crucial de cualquier estrategia mundial centrada en el régimen alimentario.

Arabic

References

1. World Health Organization. *The world health report 2002 – Reducing risks, promoting healthy life.* Geneva:WHO; 2002.
2. World Health Organization. *The world health report 2003 – Shaping the future.* Geneva:WHO; 2003.
3. Popkin B. The Bellagio Conference on the Nutrition Transition and its Implications for Health in the Developing World, Bellagio, Italy, August 20–24 2001. *Public Health and Nutrition* 2002;5:93-280.
4. World Cancer Research Fund, American Institute for Cancer Research. *Food, nutrition and the prevention of cancer: a global perspective.* Washington: American Institute for Cancer Research; 1997.
5. World Health Organization. *Diet, nutrition and the prevention of chronic diseases. Report of a Joint WHO/FAO Expert Consultation.* Geneva: WHO; 2003 (WHO Technical Report Series 916).
6. Ribioli E, Norat T. Epidemiologic evidence of the protective effect of fruit and vegetables on cancer risk. *American Journal of Clinical Nutrition* 2003;78 Suppl:559S-69S.
7. Tobias M. *The burden of disease and injury in New Zealand.* Wellington: New Zealand Ministry of Health; 2001.
8. Mathers C, Vos T, Stevenson C. *The burden of disease and injury in Australia.* Canberra: Australian Institute of Health and Welfare; 1999.
9. National Institute of Public Health. *Determinants of the burden of disease in the EU.* Stockholm: National Institute of Public Health; 1997.
10. The World Bank. *World development report 1993: investing in health.* Washington: The World Bank; 1993.
11. Murray C, Lopez, AD. Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. *Lancet* 1997;349:1436-42.
12. Ezzati M, Lopez A, Rogers A, Vander Hoorn S, Murray C, and the Comparative Risk Assessment Collaborating Group. Selected major risk factors and global and regional burden of disease. *Lancet* 2002;360:1347.
13. Ezzati M, Vander Hoorn S, Rogers A, Lopez A, Mathers C, Murray C, et al. Estimates of global and regional health gains from reducing multiple risk factors. *Lancet* 2003;362:271-9.
14. Ezzati M, Lopez AD, Rodgers A. Conceptual framework and methodological issues. In: Ezzati M, Lopez A, Rodgers A, Murray C, editors. *Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors.* Geneva: World Health Organization; 2004. In press.
15. World Health Organization. *Diet, nutrition and the prevention of chronic diseases.* Geneva: WHO; 1990.
16. Pomerleau J, Lock K, McKee M, Altman DG. The challenge of measuring global fruit and vegetable intake. *Journal of Nutrition* 2004;134:1175-80.
17. Lock K, Pomerleau J, Causer L, McKee M. Low fruit and vegetable intake. In: Ezzati M, Lopez A, Rodgers A, Murray C, editors. *Comparative quantification of health risks: global and regional burden of disease due to selected major risk factors.* Geneva: World Health Organization; 2004. In press.
18. Food and Agriculture Organization of the United Nations. FAOSTAT; 2001. Available from: http://apps.fao.org/
19. Kelly A, Becker W, Helsing E. Food balance sheets. In: Becker W, Helsing E, editors. *Food and health data. Their use in nutrition policy-making.* Copenhagen: World Health Organization Regional Publications, European Series; 1991.
20. Ness AR, Powles JW. Fruit and vegetables, and cardiovascular disease: a review. *International Journal of Epidemiology* 1997;26:1-13.
21. Klerk M, Jansen M, van't Veer P, Kok F. *Fruits and vegetables: chronic disease prevention.* Wageningen, Netherlands: Wageningen Agricultural University; 1998.
22. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Controlled Clinical Trials* 1986;7:177-88.
23. Greenland S, Longnecker MP. Methods for trend estimation from summarized dose–response data, with applications to meta-analysis. *American Journal of Epidemiology* 1992;135:1301-9.
24. Botterweck AA, van den Brandt P, Goldbohm R. A prospective cohort study on vegetable and fruit consumption and stomach cancer in the Netherlands. *American Journal of Epidemiology* 1998;148:842-53.
25. Fruit and vegetable consumption and risk of cancer of the digestive tract: meta-analysis of published case control and cohort studies. European Conference on Nutrition and Cancer 21–24 June 2001: abstracts book. Lyon, France: IARCPress. Available from: http://www.nutrition-cancer2001.com
26. Smith-Warner SA, Elmer PJ, Fosdick L, Tharp TM, Randall B. Reliability and comparability of three dietary assessment methods for estimating fruit and vegetable intakes. *Epidemiology* 1997;8:196-201.

27. Hennekens CH, Buring JE, Manson JE. Lack of effect of long-term supplementation with beta carotene on the incidence of malignant neoplasms and cardiovascular disease. *New England Journal of Medicine* 1996;334:1145-9.
28. Collins R, Peto R, Armitage J. The MRC/BHF Heart Protection Study: preliminary results. *International Journal of Clinical Practice* 2002;56:53-6.
29. Singh RB, Rastogi SS, Verma R, Laxmi B, Singh R, Ghosh S, et al. Randomised controlled trial of cardioprotective diet in patients with recent acute myocardial infarction: results of one year follow up. *BMJ* 1992;304:1015-9.
30. Conlin P, Chow D, Miller ER 3rd, Svetkey LP, Lin PH, Harsha DW, et al. The effect of dietary patterns on blood pressure control in hypertensive patients: results from the Dietary Approaches to Stop Hypertension (DASH) trial. *American Journal of Hypertension* 2000;13:949-55.
31. Murray C, Lopez AD. On the comparable quantification of health risks: lessons from the Global Burden of Disease Study. *Epidemiology* 1999;10:594-605.
32. Powles J, Day N. Interpreting the global burden of disease. *Lancet* 2002;360:1342-3.
33. Centre for Disease Control. National 5 A Day Partnership Plan 2001–2004. Atlanta (GA), USA: National Center for Chronic Disease Prevention and Health Promotion; 2002. Available from: http://www.cdc.gov/nccdphp/dnpa/5aday/
34. Department of Health. *The NHS Plan — a plan for investment. A plan for reform.* London: The Stationery Office; 2000.
35. World Health Organization. Fruit and vegetable promotion initiative. Geneva: WHO; 2003. Available from: http://www.who.int/hpr/NPH/fruit_and_vegetables/fruit_and_vegetable_report.pdf
36. World Health Organization. WHO and FAO announce a unified approach to promote fruit and vegetable consumption. November 2003. Geneva: WHO; 2003. Available from: http://www.who.int/hpr/
37. World Health Organization. Fifty-seventh World Health Assembly. Agenda item 12.6. Global Strategy on Diet, Physical Activity and Health, 22 May 2004. Available from: http://www.who.int/gb/ebwha/pdf_files/WHA57/A57_R17-en.pdf