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Cancers attributable to dietary factors in the UK in 2010

I. Low consumption of fruit and vegetables

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British Journal of Cancer (2011) 105, S19–S23; doi:10.1038/bjc.2011.477 www.bjcancer.com

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There is considerable controversy over the protective effect of diets rich in fruit, vegetables and fibre, and the respective roles of the different components (including micronutrients such as folate). The report of the Committee on Medical Aspects of Food Nutrition Policy (COMA) (Department of Health, 1998) recommended increasing consumption of all of them, an advice that seems to have motivated the Department of Health in promoting its '5-a-day' programme (Department of Health, 2005). The original consensus of the probable decrease in risk of several cancers of the gastrointestinal tract (oral cavity and pharynx, oesophagus, stomach and colorectum) associated with increased consumption of fruit and vegetables (WHO/FAO, 2003) was based on the results of multiple case-control studies and a few prospective studies. The IARC Handbook of Cancer Prevention (IARC, 2003) concludes its review of the evidence as follows:

There is *limited evidence* for cancer-preventive effect of consumption of fruit and vegetables for cancers of the mouth and pharynx, oesophagus, stomach, colorectum, larynx, lung, ovary (vegetables only), bladder (fruit only) and kidney.

There is *inadequate evidence* for a cancer-preventive effect of consumption of fruit and vegetables for all other sites.

More specifically, this evidence indicates that higher intake of fruit *probably* lowers the risk of cancers of the oesophagus, stomach and lung, while higher intake of vegetables *probably* lowers the risk of cancers of the oesophagus and colorectum.

Likewise a higher intake of fruit *possibly* lowers the risk of cancers of the mouth, pharynx, colorectum, larynx, kidney and urinary bladder. An increase in consumption of vegetables *possibly* reduces the risk of cancers of the mouth, pharynx, stomach, larynx, lung, ovary and kidney.

The conclusions of the WCRF report (2007) are more or less in line with these, except with respect to large-bowel cancer, for which the evidence for protective effects of both vegetables and fruit was considered 'limited' (in contrast to 'conclusive' or 'probable' – implying that a causative relationship is uncertain). More emphasis was placed on the importance of the protective

effects of consumption of foods containing dietary fibre than on vegetables *per se*. The summary conclusions were as follows:

Non-starchy vegetables probably protect against cancers of the mouth, pharynx, and larynx, and those of the oesophagus and stomach. There is limited evidence suggesting that they also protect against cancers of the nasopharynx, lung, colorectum, ovary, and endometrium.

Fruit in general probably protects against cancers of the mouth, pharynx, and larynx, and those of the oesophagus, lung, and stomach. There is limited evidence suggesting that fruit also protects against cancers of the nasopharynx, pancreas, liver, and colorectum.

In this analysis, we follow the WCRF in considering ONLY the effect of a deficit of fruit and vegetables on cancers of the mouth and pharynx, oesophagus, stomach and larynx, and of a deficit of fruit on cancers of the lung.

The advice from the Department of Health (2005) is to increase the average consumption of a variety of fruit and vegetables to at least five portions per day, corresponding to 5×80 or 400 g per day. In this section, we estimate the population-attributable fraction (PAF) of these five cancers (and of all cancer) that results from consumption of fruit and vegetables lower than this target.

METHODS

The risks associated with consumption of 1 g per day of fruit or of vegetables are shown in Table 1. As we are concerned with quantifying the effect of a deficit in consumption, they are presented as the risk associated with a decreased intake of 1 g per day.

These risks derive from the simple means of the values from three meta-analyses: those of Riboli and Norat (2003), WCRF (2007) and, except for laryngeal cancer, Soerjomataram *et al* (2010). (The value for the protective effect of vegetables on cancers of the oral cavity and pharynx in the meta-analysis of Soerjomataram *et al* (2010) was quite implausible, implying a reduction in risk of 1.4% per gram per day. We substituted the value for upper aero-digestive tract cancers from the multi-centre

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European prospective study (EPIC) of 0.29% per gram per day (Boeing *et al*, 2006)). The values from the latter were reported as relative risk per gram increase in daily consumption of fruit and vegetables. For the others, the excess relative risk for a decrease of 1 g of vegetables or fruit consumed was estimated by assuming a log-linear relationship between exposure and risk, so that:

$$\text{Risk per gram per day} = (\ln(1/RR_x))/x$$

where x is the exposure level (in grams per day) and RR_x the relative risk for x grams per day.

The latent period (or interval between 'exposure' to fruit and vegetables and the appropriate decrease in risk of these cancers) is not known. Prospective studies of diet and cancer (from which the estimates of relative risk are mostly drawn) involve follow-up periods (between estimated dietary intake and cancer onset) of several years. For the cohort studies contributing to the meta-

analyses of WCRF, 10 studies of lung cancer and 6 of stomach cancer reported the mean duration of follow-up; the simple means were 15.2 and 10.3 years, respectively. There are a few cohort studies on upper GI cancers: the follow-up periods in the EPIC study (González *et al*, 2006) and Japanese JPHC studies (Yamaji *et al*, 2008) were 6.5 and 7.7 years, respectively. For the purposes of estimating attributable fraction, we assume a mean latency of 10 years, and thus examine the effects on cancers occurring in 2010 of sub-optimal levels of fruit and vegetable consumption in 2000. Consumption of fruit and vegetables, in grams per week, by age group and sex, is available for 2000–2001 from the National Diet & Nutrition Survey (FSA, 2004; Table 2.1). The mean consumption, by age group, is shown in Table 2. The target consumption of 400 g per day was not achieved at any age, and the young, in particular, had a low consumption of such items.

Table 2 Mean consumption of fruit and non-starchy vegetables by sex and age group, Great Britain 2000–2001

Vegetables or fruit	Mean consumption (grams per day) by age group (years)				
	19–24	25–34	35–49	50–64	19–64
<i>Men</i>					
Vegetables	95	122	144	162	137
Fruit	27	61	99	122	87
<i>Women</i>					
Vegetables	89	130	139	143	132
Fruit	54	74	98	151	103
<i>Persons</i>					
Vegetables	92	126	141	153	135
Fruit	40	68	99	137	95

Table 1 Estimated risks associated with a decreased consumption of 1 g per day of fruits and non-starchy vegetables

Cancer type	Risks associated with 1 g per day decrease in consumption	
	Fruit	Vegetables ^a
Oral cavity and pharynx	0.00488	0.00416
Oesophagus	0.00504	0.00266
Stomach	0.00234	0.00320
Colon–rectum	0	0
Larynx	0.00322	0.00370
Lung	0.00146	0

^aNon-starchy vegetables.

Table 3 Proportions of the Great Britain population in seven categories of fruit and vegetable consumption in 2000–2001, and estimated deficit in consumption in each category from the recommended 400 g per day

Sex and age (years)	Consumption categories in 2000–2001						
	1	2	3	4	5	6	7
<i>Men 19–49</i>							
Proportion of the population	0.01	0.22	0.29	0.20	0.11	0.08	0.09
Vegetables (g per day)	0	27.8	83.3	138.8	194.3	249.8	305.3
Deficit from 256 g per day	256	228	172	117	61	6	0
Fruit (g per day)	0	15.8	47.3	78.8	110.3	141.8	173.3
Deficit from 144 g per day	144	129	97	66	34	3	0
<i>Men 50–64</i>							
Proportion of the population	0.01	0.06	0.22	0.16	0.15	0.16	0.24
Vegetables (g per day)	0	24.5	73.5	122.5	171.5	220.5	269.5
Deficit from 228 g per day	228	204	155	106	57	8	0
Fruit (g per day)	0	18.5	55.5	92.5	129.5	166.5	203.5
Deficit from 172 g per day	172	153	116	79	42	5	0
<i>Women 19–49</i>							
Proportion of the population	0.01	0.06	0.22	0.16	0.15	0.16	0.24
Vegetables (g per day)	0	25.8	77.3	128.8	180.3	231.8	283.3
Deficit from 242 g per day	242	217	165	114	62	11	0
Fruit (g per day)	0	16.8	50.3	83.8	117.3	150.8	184.3
Deficit from 158 g per day	158	141	107	74	40	7	0
<i>Women 50–64</i>							
Proportion of the population	0.01	0.19	0.26	0.21	0.12	0.08	0.12
Vegetables (g per day)	0	21	63	105	147	189	231
Deficit from 195 g per day	195	174	132	90	48	6	0
Fruit (g per day)	0	22.3	66.8	111.3	155.8	200.3	244.8
Deficit from 205 g per day	205	183	139	94	50	5	0

The National Diet & Nutrition Survey also provides the distribution of intake of fruit and vegetables in the British population, in terms of the cumulative percentage of individuals (by sex and age group) consuming 0, <1, <2, ..., >5 portions of fruit and vegetables daily (FSA, 2004; Table 2.3). The populations of each sex were dichotomised into two age groups (<50 and 50–64), and ‘portions’ were converted into grams (of fruit and vegetables), such that the mean daily intake corresponded to the values in Table 2. Table 3 shows the results in terms of the proportions of the population at seven different levels of consumption of fruit and vegetables.

To calculate the deficit in consumption of fruit and vegetables relative to a target of 400 g per day for both, the deficit in each sex and age group (19–49, 50–64) was calculated from Table 2. For example, the deficit in older men (50–64) was, on average, 216 g per day (400–(162+122)). The total deficit is partitioned into deficits of fruit and vegetables, so that the same ratio of vegetables to fruit that was being eaten in 2000–1 is maintained. Thus, the 400 g per day target for consumption in men in the age group of 50–64 years is partitioned in the ratio of 162:122 (Table 2); i.e., 228 g per day vegetables and 172 g per day fruit (Table 3). The deficit of each in the different consumption categories in men and women aged <50 years and in the age group of 50–64 is shown in Table 3.

For each cancer, the relative risk in 2010 in the four age–sex strata is calculated from the deficit in consumption 10 years earlier (2000–2001), with the risk for fruit and vegetables calculated separately according to the following formula:

$$RR = (\exp(R_g \times G_x))$$

where R_g is the relative risk for a deficit of 1 g per day of fruit or vegetables (Table 1) and G_x is the deficit in consumption (as shown in Table 3) in consumption category x .

The benefits of fruit and vegetables are considered to be multiplicative in their effect, so that

$$RR(f \text{ and } v) = RR(f) \times RR(v)$$

Population-attributable fractions were calculated for each of the four sex–age groups in Table 3 according to the following formula:

$$PAF = \frac{(p_1 \times ERR_1) + (p_2 \times ERR_2) + (p_3 \times ERR_3) + (p_4 \times ERR_4) + (p_5 \times ERR_5) + (p_6 \times ERR_6) + (p_7 \times ERR_7)}{1 + [(p_1 \times ERR_1) + (p_2 \times ERR_2) + (p_3 \times ERR_3) + (p_4 \times ERR_4) + (p_5 \times ERR_5) + (p_6 \times ERR_6) + (p_7 \times ERR_7)]}$$

where p_x is the proportion of population in consumption category x and ERR_x the excess relative risk ($RR(f \text{ and } v) - 1$) in consumption category x .

RESULTS

Table 4 shows the PAFs and the estimated number of cases ‘caused’ in 2010 by these deficits in consumption of fruit and vegetables 10 years earlier. The cancers for which the greatest proportion of cases may be related to low intake of fruit and vegetables are the oral cavity and pharynx (56%), oesophagus (46%) and larynx (45%). Although only 9% of lung cancer cases may be related to low intake of fruit (there is no excess risk of lung cancer from low intake of vegetables), the actual number of cases (3567) represents almost one-quarter of the total number of cancers attributable to low intake of fruit and vegetables (14 902; Table 5).

Table 5 sums the excess numbers of cases at the five sites, caused by low consumption of fruit and vegetables, and expresses these numbers as a fraction of the total burden of (incident) cancer. The estimate is 6.1% cancers in men and 3.4% in women, or 4.7% of cancers overall.

Table 4 Cancer cases in 2010 at six sites caused by deficient intake of fruit and vegetables in 2000–2001

At exposure	Age (years)	Oral cavity and pharynx			Oesophagus			Stomach			Colon–rectum			Larynx			Lung			
		At outcome (+10 years)	PAF	Obs.	Excess attributable cases	PAF	Obs.	Excess attributable cases	PAF	Obs.	Excess attributable cases	PAF	Obs.	Excess attributable cases	PAF	Obs.	Excess attributable cases	PAF	Obs.	
Men	19–49	29–59	0.65	1874	1223	0.56	1064	596	0.49	587	285	0	3410	0	0.56	443	249	0.11	2839	300
	50–64	≥60	0.52	2656	1393	0.45	4643	2067	0.35	3875	1367	0	18 643	0	0.43	1358	578	0.08	19 417	1584
	Total (%)			4571	2616 (57.2%)	5713	2663 (46.6%)	4467	1651 (37.0%)	22 127	0 (0.0%)	1803	827 (45.9%)	22 273	1884 (8.5%)					
Women	19–49	29–59	0.64	786	503	0.55	332	184	0.47	325	151	0	2791	0	0.54	113	61	0.11	2550	280
	50–64	≥60	0.50	1521	762	0.44	2482	1088	0.32	2243	722	0	14 926	0	0.40	269	106	0.09	15 562	1403
	Total (%)			2359	1265 (53.6%)	2819	1272 (45.1%)	2577	874 (33.9%)	17 787	0 (0.0%)	386	168 (43.5%)	18 132	1683 (9.3%)					
Persons	19–49	29–59		2660	1725	1396	779	912	436	6201	0	556	310	5389	579					
	50–64	≥60		4177	2155	7125	3155	6118	2089	33 569	0	1627	684	34 979	2987					
	Total (%)			6930	3881 (56.0%)	8532	3935 (46.1%)	7044	2525 (35.8%)	39 914	0 (0.0%)	2189	995 (45.4%)	40 405	3567 (8.8%)					

Abbreviations: Obs = observed cases; PAF = population-attributable fraction.

Table 5 Number of all cancer cases in 2010 caused by deficient intake of fruit and vegetables in 2000–2001

Age group (years)		All cancers ^a		
At exposure	At outcome (+10 years)	Observed cases	Excess attributable cases	PAF (%)
Men				
19–49	29–59	27 845	2651	9.5
50–64	60+	128 192	6990	5.5
Total		158 667	9641	6.1
Women				
19–49	29–59	42 499	1179	2.8
50–64	60+	110 403	4082	3.7
Total		155 584	5261	3.4
Persons				
19–49	29–59	70 344	3830	5.4
50–64	60+	238 595	11 071	4.6
Total		314 251	14 902	4.7

Abbreviations: PAF = population-attributable fraction. ^aExcluding non-melanoma skin cancer.

DISCUSSION

As we note in the Introduction, the protective role of the consumption of fruit and vegetables against cancer is controversial. The first report of the World Cancer Research Fund (WCRF)/AICR Panel (1997) considered that the evidence for a protective effect of fruit and/or vegetables against cancers of the upper aero-digestive tract, stomach and lung was ‘convincing’. As we describe, although the preventive recommendation remains to ‘eat at least five portions/servings (at least 400 g) of a variety of non-starchy vegetables and of fruits every day’, this evaluation had been downgraded to ‘probable’ in the latest report (WCRF, 2007). This is because of the subsequent publication of some cohort studies that failed to find statistically significant associations. Key (2011) suggests that, as all of the relevant cancers are also caused by smoking, and that smokers have a lower intake of fruit and vegetables than non-smokers, the observed associations could be due to residual confounding (failure to control adequately for this risk factor in the analysis, generally due to the use of rather broad groups for categorising smoking status). With respect to lung cancer (the malignancy with the strongest smoking-associated risk), for example, recent cohort studies show conflicting results: no association (Wright *et al*, 2008) or protective effects of fruit (and vegetables) in all subjects or in smokers only (Büchner *et al*, 2010). Miller *et al* (2004) have even suggested that the strength of the association between smoking and lung cancer can overwhelm a real, but much smaller, association with diet. Fruit and vegetables are the

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Table 6 Percentage of cancers in UK in 2002 attributable to low consumption of fruits and vegetables

	Oesophagus	Mouth, pharynx, larynx	Lung	Stomach
Non-starchy vegetables	21 (4–40)	34 (2–57)		21 (0–41)
Fruits	5 (2–9)	17 (0–43)	33 (17–51)	18 (3–33)

From WCRF/AICR (2009).

main dietary source of many micronutrients and other metabolically active chemicals. The types and quantities of these compounds vary between items, which may explain why most studies measuring cancer risk in relation to overall intake tend to show only a weak association (McCullough and Giovannucci, 2004).

In any case, in this section, we have followed the results of the current consensus reviews by WHO/FAO (2003), IARC (2003) and WRCF (2007) with respect to those cancers that might reasonably be caused, in part, by a deficient intake of these dietary elements. The latter report considered that the evidence for a protective effect of vegetables (and, even more so, fruit) on the risk of colon cancer was ‘limited’, and placed more emphasis on the importance of the protective effects of consumption of foods containing dietary fibre than on vegetables *per se*. This concurs with more recent reviews of the evidence from epidemiological studies (Koushik *et al*, 2007; Huxley *et al*, 2009), and in this section, therefore, we consider that no cases of colorectal cancer are attributable to sub-optimal consumption of vegetables or fruit.

An estimate of the fraction of cancer in UK attributable to low intake of fruit and vegetables was recently published by the WCRF (2009) (Table 6). There are several reasons for the differences in results from the current estimates. WCRF selected ‘representative’ studies from which to take the relative risks, rather than those from their own meta-analyses. Exposure prevalence was taken from data for the same year as outcome (2002). Finally, the baseline category (optimum consumption) varied by site – ≥ 160 g vegetables per day for oesophagus and stomach cancer; ≥ 120 g per day for upper aero-digestive cancers; ≥ 57.1 g fruit per day for stomach cancer; and ≥ 160 g fruit per day for lung cancer. Given the estimates by site in Table 6, the overall AF (for all cancers) due to low consumption of vegetables and fruits would be 7.1% – of which almost 60% are lung cancers, because of the large attributable fraction (33%) and high incidence of this cancer.

See acknowledgements on page Si.

Conflict of interest

The authors declare no conflict of interest.

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