Plasma vitamin C and food choice in the third Glasgow MONICA population survey

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Abstract

***Study objective*—To determine the contribution of different foods to the estimated intakes of vitamin C among those differing in plasma vitamin C levels, and thereby inform dietary strategies for correcting possible deficiency.**

***Design*—Cross sectional random population survey.**

***Setting*—North Glasgow, Scotland, 1992.**

***Participants*—632 men and 635 women, aged 25 to 74 years, not taking vitamin supplements, who participated in the third MONICA study (population survey monitoring trends and determinants of cardiovascular disease).**

***Measurements and main results*—Dietary and sociodemographic information was collected using a food frequency and lifestyle questionnaire. Plasma vitamin C was measured in non-fasted venous blood samples and subjects categorised by cut points of 11.4 and 22.7 µmol/l as being of low, marginal or optimal vitamin C status. Food sources of dietary vitamin C were identified for subjects in these categories. Plasma vitamin C concentrations were compared among groups classified according to intake of key foods. More men (26%) than women (14%) were in the low category for vitamin C status; as were a higher percentage of smokers and of those in the older age groups. Intake of vitamin C from potatoes and chips (fried potatoes) was uniform across categories; while the determinants of optimal versus low status were the intakes of citrus fruit, non-citrus fruit and fruit juice. Optimal status was achieved by a combined frequency of fruit, vegetables and/or fruit juice of three times a day or more except in older male smokers where a frequency greater than this was required even to reach a marginal plasma vitamin C level.**

***Conclusion*—Fruit, vegetables and/or fruit juice three or more times a day increases plasma vitamin C concentrations above the threshold for risk of deficiency.**

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The WHO MONICA Project (MONItoring trends and determinants of CArdiovascular disease) monitored rates of coronary heart disease (CHD), and trends in classic coronary risk factors by repeated population surveys, in defined populations worldwide over 10 years.[1] The Scottish MONICA population, Glasgow north of the River Clyde, had among the highest male CHD rates and the highest female rates of any MONICA population in 1985–87,[2] and ranked highly within Scotland for disease rates[3] and social deprivation.[4] Although not included in the core study, a multinational MONICA optional study on plasma antioxidant vitamins showed low concentrations of these in Scottish populations, and an inverse correlation with disease rates.[5] Within the limited data from Glasgow and Aberdeen there was a relation between estimated intake of vitamin C, derived from a food frequency questionnaire used for the Scottish Heart Health and MONICA surveys,[6 7] and non-fasting plasma concentrations of vitamin C, if smokers and non-smokers were separated.[8] Accordingly it was decided to measure plasma antioxidant vitamin concentrations more extensively in the third Glasgow MONICA population survey in 1992, and to relate these to demographic factors, to coronary risk factors and to self reported food frequency responses. This report is concerned with the relation of intakes of particular foods to plasma vitamin C concentrations, and the implication for dietary advice within the population. Given the poor life circumstances and high CHD rates of this population[3 4] the findings provide further evidence of the link between poor diet and disease.

The vitamin-antioxidant hypothesis relates sub-optimal levels of certain vitamins, short of frank deficiency, to increased risk of chronic diseases.[5 9–12] For example the relative risk for ischaemic heart disease of men with low plasma vitamin C (< 22.7 µmol/l) combined with low plasma carotene was almost twice, and that for stroke four times, that of those with higher values.[10] In addition, a persistent serum concentration of less than 5.7 µmol/l would be likely to lead to scurvy and signs of this deficiency disease have been observed at levels as high as 7.41 to 13.7 µmol/l.[13] For this analysis we have used common conventional cut points of 11.4 and 22.7 µmol/l[13–15] (equivalent to 0.2 mg/dl and 0.42 mg/dl) to categorise those with seriously low plasma concentrations from those with marginal and optimal values, albeit based on single non-fasting specimens.

Methods

SAMPLE

The design and conduct of the third Glasgow MONICA survey was based on that of earlier MONICA and Scottish Heart Health surveys,[1 3 12 16] but this survey involved sampling patients aged 25–74 years listed for 30 general practitioners and was conducted between January and August 1992. Participants were sent a detailed lifestyle and food frequency questionnaire[6 7] to complete, and were asked to attend a local survey clinic without fasting, where the questionnaire was checked by a survey nurse, and they underwent physical measurements and blood sampling.

MEASUREMENT OF PLASMA VITAMIN C

Venepuncture with minimum use of a tourniquet was followed by immediate separation of plasma using lithium/heparin as an anticoagulant. Plasma samples were rapidly frozen using dry ice and stored at −20°C for up to five days before transport to Dundee where they were stored at −80°C. Vitamin C was analysed using a fluorometric assay.[17]

Subjects were classified into three categories according to their plasma vitamin C concentration.[13–15] Less than 11.4 μmol/l was described as low, 11.4–22.7 μmol/l as marginal and above 22.7 μmol/l as optimal.

INTAKE OF VITAMIN C

The food frequency questionnaire was developed from one already validated against weighed intake in both a Welsh[6] and a Scottish population.[18] In the validation of the original questionnaire mean vitamin C intakes estimated from the food frequency questionnaire were slightly lower than from the weighed intake but overall intakes from the two methods were statistically significantly correlated. However, the questionnaire used in this study had been adapted to include a question on tomatoes and a better defined question on fruit juice. An attached lifestyle questionnaire provided information on supplement use but for this analysis it was the impact of food choice on plasma vitamin C that was being studied so supplement takers were excluded to avoid confusion. The food frequency questionnaire asked subjects about frequency of consumption (number of days each week, once a month, rarely or never) of over 65 different foods and drinks. Twenty seven of these were relevant to calculations of the intake of vitamin C—obtained by multiplying the food frequency by the standard portion sizes and then by the average vitamin C content obtained from the UK food composition tables.[19] For simplicity these foods were amalgamated into 11 food groups before calculation of their contribution to total intakes, and these contributions and totals were then calculated and averaged for each of the three plasma vitamin C categories.

STATISTICAL ANALYSIS

The percentage in each plasma vitamin C category, was calculated by gender, age, smoking habit and social class. The percentage of men and women who reported not eating the foods in the vitamin C rich food groups were compared across the plasma vitamin C categories. Proportions were compared using the χ^2 test.

Plasma vitamin C was compared in groups classified according to their consumption of certain foods or smoking habit. Before comparison, plasma vitamin C values were $\log_{10}$ transformed to normalise the distribution before testing the significance of differences between group means using Student's *t* test or analysis of variance with a test for linear trend. Means of these transformed values were back transformed to give the geometric mean for tabulation.

Untransformed means of vitamin C intake were used to show the contribution of each of the 11 food groups to vitamin C intake.

Table 1 Percentage of subjects in each plasma vitamin C group by gender, gender/age, gender/smoking habit and gender/social class

		Plasma vitamin C group			
	Number	*% Low*	*% Marginal*	*% Optimal*	χ^2
All	1267	20	24	56	
By gender					
Men	632	26	26	48	
Women	635	14	22	64	***
By age					
Men:					
25–34	101	15	19	66	
35–44	125	14	24	62	
45–54	129	31	30	39	
55–64	142	30	29	41	
65–74	135	36	25	38	***
Women:					
25–34	135	9	19	72	
35–44	127	11	26	62	
45–54	117	10	23	67	
55–64	125	15	27	58	
65–74	131	24	15	60	**
By smoking					
Men:					
smokers	321	36	30	34	
non-smokers	308	15	22	63	***
Women:					
smokers	271	23	30	48	
non-smokers (including ex)	361	8	16	76	***
By social class					
Men:					
manual	447	30	28	42	
non-manual	150	12	21	67	***
Women:					
manual	278	17	24	59	
non-manual	242	10	16	74	**

Plasma vitamin C groups are Low <11.4 μmol/l, Marginal 11.4–22.7 μmol/l, and Optimal 22.7 μmol/l and above. ***p<0.001, **p<0.01.

Results

There were 1958 participants in the MONICA survey, giving a corrected response rate of 65.1% for those approached. Of these, 96 were excluded for incomplete food frequency responses, 285 for taking, or not stating whether they took vitamin supplements, and in a further 310 blood samples were refused or were inadequate for both the core analytes and for plasma vitamin C. This left 1267 people with full data for this MONICA sub-study (632 men and 635 women), or 64.7% of all responding participants.

Table 1 shows the percentage of subjects in each plasma vitamin C category. Overall over half of the sample had "optimal" vitamin C status but 20% had plasma values indicative of a low status; 26% of men but only 14% of women fell into this category. Among men aged 45 and over, approximately one third were in the low and a further third in the marginal group. A higher percentage of older women than younger women were in the low category but at worst this was only 24%. Compared with non-smokers, among smokers a higher percentage were in the low or marginal categories.

Table 2 Percentage of subjects in each plasma vitamin C group not eating foods contributing to vitamin C intake

	Plasma vitamin C group			*Linear trend*
	% Low	*% Marginal*	*% Optimal*	
Men				
Citrus fruits	67	53	42	***
Fruit juice	63	49	31	***
Potatoes (other than chips)	4	2	2	
Chips (fried potatoes)	16	15	13	
Non-citrus fruit	42	34	17	***
Green vegetables and salads	20	10	7	***
Soft drinks	49	38	29	***
Other vegetables	9	1	3	*
Milk	7	6	5	
Tomatoes (fresh, tinned, pureed)	22	18	14	*
Other foods†	12	6	4	**
Women				
Citrus fruits	56	54	32	***
Fruit juice	54	46	23	***
Potatoes (other than chips)	7	2	2	**
Chips (fried potatoes)	13	10	16	
Non-citrus fruit	24	21	11	***
Green vegetables and salads	14	10	4	***
Soft drinks	33	34	26	
Other vegetables	3	4	1	
Milk	6	6	5	
Tomatoes (fresh, tinned, pureed)	19	14	8	**
Other foods†	7	5	3	

Plasma vitamin C groups are Low <11.4 μmol/l, Marginal 11.4–22.7 μmol/l, and Optimal 22.7 μmol/l and above. ***p<0.001, **p<0.001, *p<0.05. †Other foods are liver, fruit tarts and crumbles, fruit cake, tinned fruit, jellies, savoury snacks and sweet spreads.

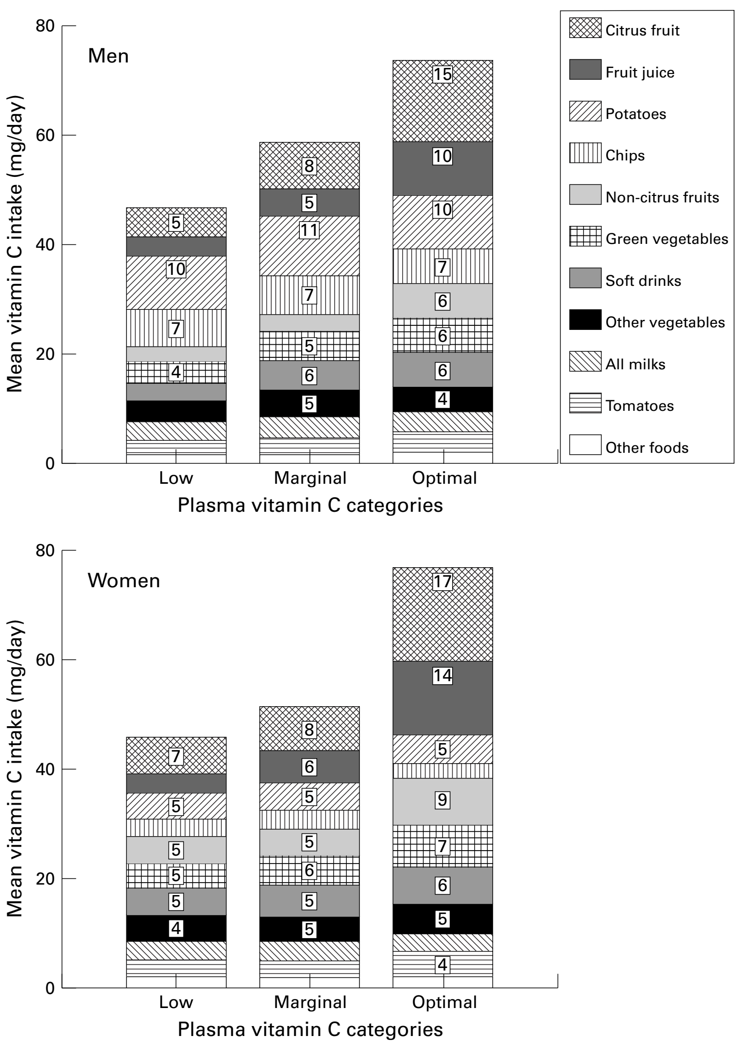

Figure 1 Contribution of foods to vitamin C intake by different plasma vitamin C categories. Unlabelled bands represent a mean contribution of less than 4 mg/day.

KEY POINTS

- In a deprived urban population half the men and one third of women had sub-optimal plasma vitamin C concentrations.
- Citrus fruit and fruit juice are the main dietary determinants of optimal vitamin C status but potatoes and chips (fried potatoes) are a major source for those with low status.
- Male smokers over 45 require over three portions of fruit, vegetables and fruit juice simply to reach a marginal to adequate plasma vitamin C concentration.
- Advice to lower intake of chips must ensure adequate replacement of their vitamin C contribution.
- Consumption of citrus fruit juice should be encouraged for those unwilling to eat fruit and vegetables.

Similarly the percentage of men in the low category among manual workers was twice that of those in this category among the non-manual social classes.

Table 2 gives the percentage of subjects not eating foods in the vitamin C rich food groups. Over half of subjects in the low category did not consume citrus fruits or fruit juice. These were two of the main contributors to vitamin C intake in the optimal category (fig 1). A significant positive trend existed between consumption of citrus fruits, fruit juice, potatoes (women only), non-citrus fruits, green vegetables and salads, soft drinks (men only), other vegetables (men only), tomatoes and increasing vitamin C status.

Figure 1 shows the mean intakes from each food group for men and women and illustrates the greater contribution in the optimal group compared with the other two from citrus fruit, fruit juices, non-citrus fruit and green vegetables. Citrus fruit, followed by fruit juice and potatoes were the highest contributors among men with optimal plasma concentrations. Citrus fruit, fruit juice and non-citrus fruit were the highest contributors to vitamin C among women with optimal plasma concentrations. Potatoes and chips (fried potatoes) contributed similar amounts of vitamin C across the plasma categories but comprised a higher percentage of vitamin C in the marginal and low categories because total vitamin C intake was lower.

Table 3 gives comparisons of mean plasma vitamin C in frequent versus infrequent consumers of each key food. The geometric means (antilogs of mean $\log_{10}$ plasma vitamin C) are given to allow comparison with the cut off values of plasma vitamin C defining the low and marginal categories. The definition of frequent intake varied according to the food involved to allow approximately equal numbers in the Frequent and Infrequent Groups. Means of plasma vitamin C were higher among the frequent (compared with infrequent) consumers of citrus fruit (except for young men), fruit juice, non-citrus fruit and green vegetables but

Table 3 Mean† (95% CI) plasma vitamin C concentrations (μmol/l) in frequent versus infrequent consumers of the vitamin C rich foods groups by age group and smoking habit

		25–44 years		*45–74 years*	
Food	*Frequent intake*	*Smokers*	*Never and ex-smokers*	*Smokers*	*Never and ex-smokers*
Men					
Citrus fruit	Yes (≥1)	24 (19.1 to 30.5)	37 (30.4 to 45.8)	17 (14.1 to 19.8)	31 (26.9 to 36.6)
	No	19 (15.6 to 22.6)	43 (36.3 to 50.14)	11 (8.9 to 12.9)***	16 (13.7 to 19.4)***
Fruit juice	Yes (≥1)	24 (18.9 to 30.7)	46 (38.7 to 53.9)	20 (16.7 to 24.7)	28 (24.0 to 33.7)
	No	19 (15.7 to 22.6)	33 (26.8 to 40.1)*	11 (9.3 to 12.8)***	21 (17.8 to 25.2)*
Potatoes	Yes (≥4)	22 (18.2 to 27.1)	42 (33.5 to 52.4)	14 (2.3 to 16.6)	23 (20.2 to 27.4)
	No	20 (16.2 to 24.7)	39 (33.7 to 45.9)	12 (9.5 to 15.0)	25 (20.1 to 30.5)
Chips (fried potatoes)	Yes (≥3)	20 (16.3 to 23.8)	35 (28.5 to 43.0)	12 (9.2 to 16.0)	22 (17.1 to 29.0)
	No	23 (17.0 to 29.9)	44 (36.4 to 52.6)	13 (11.4 to 16.1)	24 (20.7 to 28.2)
Non-citrus fruit	Yes (≥4)	28 (21.6 to 35.3)	46 (40.0 to 53.6)	17 (14.1 to 20.8)	30 (26.1 to 35.4)
	No	19 (15.9 to 22.5)*	34 (27.2 to 42.2)*	11 (9.6 to 13.4)**	17 (14.1 to 20.3)***
Green vegetables and salads	Yes (≥3)	24 (19.3 to 29.1)	48 (40.3 to 56.2)	17 (14.0 to 19.9)	30 (25.8 to 36.7)
	No	19 (15.6 to 23.3)	33 (27.6 to 40.3)**	11 (9.2 to 13.1)**	18 (15.2 to 21.6)***
Soft drinks	Yes (≥2)	23 (17.0 to 29.9)	39 (33.7 to 45.9)	17 (13.6 to 22.0)	26 (21.3 to 31.5)
	No	20 (16.3 to 23.8)	44 (33.9 to 57.4)	11 (9.7 to 13.5)**	23 (19.4 to 27.3)
Mean		21 (18.2 to 24.3)	40 (35.6 to 45.9)	13 (11.7 to 15.1)	24 (21.0 to 26.9)
Women					
Citrus fruit	Yes (≥1)	32 (25.8 to 39.8)	48 (43.1 to 54.3)	22 (18.2 to 27.4)	41 (36.3 to 46.0)
	No	19 (16.1 to 23.1)**	33 (27.1 to 41.4)**	18 (13.9 to 22.5)	27 (21.9 to 32.4)***
Fruit juice	Yes (≥1)	39 (32.6 to 47.4)	48 (42.5 to 53.9)	27 (21.7 to 33.4)	47 (42.1 to 53.0)
	No	16 (13.8 to 19.4)***	33 (26.5 to 41.2)**	16 (13.1 to 20.2)**	24 (20.5 to 29.1)***
Potatoes	Yes (≥4)	28 (23.0 to 33.8)	38 (32.2 to 45.0)	21 (17.4 to 25.8)	38 (33.0 to 43.0)
	No	23 (18.3 to 28.8)	48 (41.3 to 54.8)*	19 (15.1 to 24.7)	32 (27.1 to 38.2)
Chips (fried potatoes)	Yes (≥3)	20 (16.4 to 25.1)	39 (32.1 to 47.7)	20 (14.5 to 26.6)	27 (21.2 to 33.8)
	No	29 (23.6 to 35.8)	46 (40.5 to 53.2)	21 (17.7 to 25.8)	36 (32.0 to 41.7)
Non-citrus fruit	Yes (≥4)	31 (24.3 to 38.9)	49 (44.2 to 55.0)	22 (17.4 to 27.8)	39 (34.2 to 44.1)
	No	22 (18.7 to 26.7)*	30 (24.1 to 38.2)***	19 (15.4 to 22.9)	29 (24.1 to 34.7)**
Green vegetables and salads	Yes (≥3)	31 (25.3 to 38.2)	38 (30.7 to 46.1)	24 (20.3 to 29.1)	42 (37.6 to 47.5)
	No	21 (17.1 to 25.4)**	45 (39.2 to 50.9)	16 (12.4 to 20.7)**	25 (20.6 to 30.3)***
Soft drinks	Yes (≥2)	26 (22.1 to 31.4)	42 (36.4 to 47.4)	25 (20.1 to 31.0)	34 (29.0 to 40.5)
	No	24 (18.1 to 33.1)	43 (34.5 to 55.0)	16 (12.6 to 20.2)**	37 (31.4 to 42.6)
Mean		26 (22.2 to 29.7)	42 (38.1 to 47.4)	20 (17.4 to 23.6)	35 (31.7 to 39.2)

†Geometric mean from antilogarithm of mean $\log_{10}$plasma vitamin. Definition of Frequent intake allows approximately equal numbers in Frequent and Infrequent groups. ***p<0.001, **p<0.01, *p<0.01 significant of difference between frequent and infrequent consumers using the Student's *t* test.

there were some exceptions in particular groups. There was no evidence that frequent potato or chip consumption caused an increase in plasma concentrations of vitamin C and in some groups of women a significantly lower level was found in those who consumed potatoes or chips frequently. Also shown in table 3 is that mean plasma vitamin C was higher in the non-smokers compared with the smokers and this exceeded 22.7 μmol/l in the younger non-smoking men and both age groups of the non-smoking women. For older

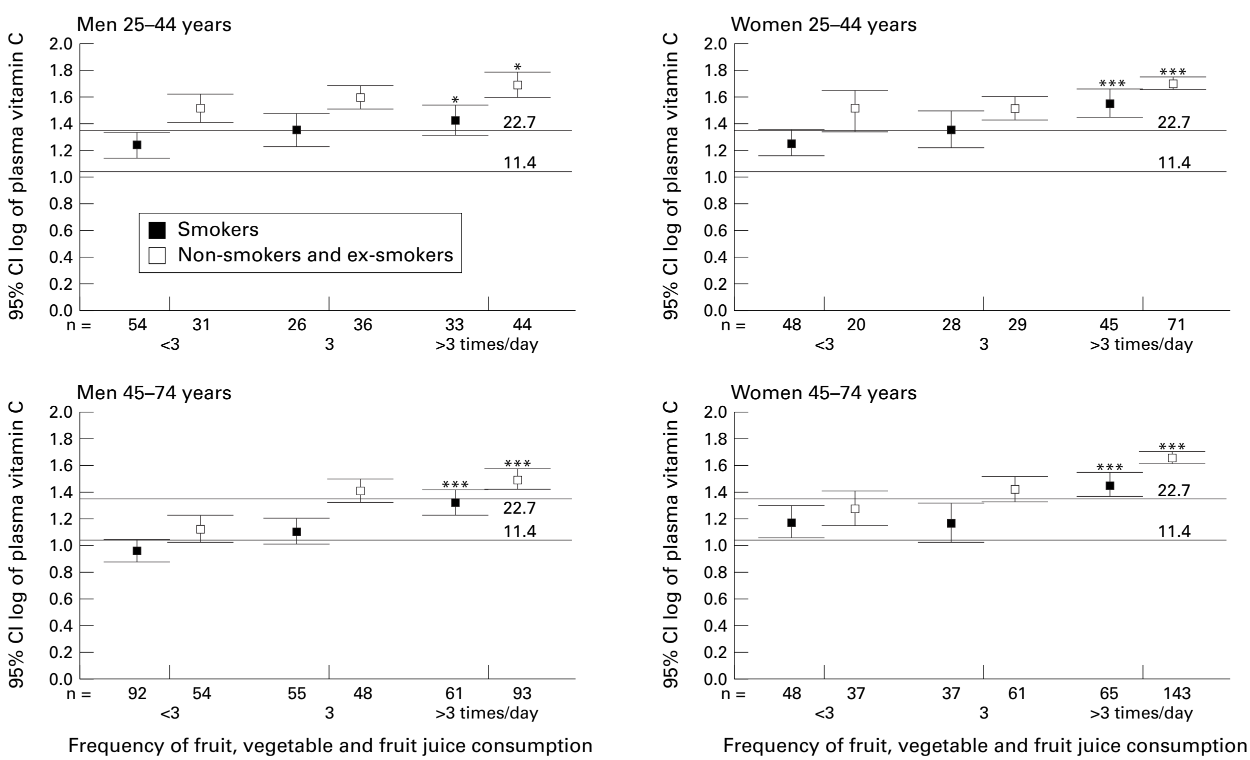

*Figure 2 Mean $\log_{10}$ plasma vitamin C for different frequencies of fruit, vegetable and fruit juice consumption by gender/age group. *p<0.05 and ***p<0.005 for linear trend in analysis of variance.*

male smokers the means for all consumption groups were below 22.7 μmol/l and only the frequent consumers of citrus fruit, fruit juice, non-citrus fruit, green vegetables, and soft drinks had confidence limits for the mean above 11.4 μmol/l.

Figure 2 shows the means (with 95% confidence limits) of $\log_{10}$ plasma vitamin C for groups of smokers and non-smokers by sex and age according to their combined consumption of fruit, vegetables (excluding potatoes) and fruit juice. Two reference lines are shown that are equivalent to 11.4 and 22.7 μmol/l vitamin C in plasma. Male and female non-smokers under 45 years had plasma vitamin C concentrations in the optimal range (above 22.7 μmol/l) even if combined consumption of fruit, vegetables and fruit juice was lower than three times a day. These values were significantly higher than for smokers taking an equivalent amount of fruit, vegetables and fruit juice. The young smokers in this consumption category had mean plasma concentrations in the marginal range. Mean $\log_{10}$ plasma vitamin C increased with increasing frequency of fruit, vegetables and fruit juice consumption in all groups but concentrations in smokers only exceeded the equivalent of 22.7 μmol/l when consumption was equivalent to three or more portions a day. Among the older male smokers mean $\log_{10}$ plasma vitamin C did not exceed levels equivalent to 22.7 μmol/l even when consumption was greater than three times a day. Female smokers 45–74 years had a higher mean for this consumption range that was equivalent to "optimal" status.

Discussion

The cut off points of 11.4 μmol/l and 22.7 μmol/l for low and marginal plasma vitamin C status have been used by various workers.[13–15] Only one of these studies claimed to use fasted blood samples[14] and significant correlations between dietary vitamin C and plasma vitamin C have been shown with both fasted[20] and non-fasted blood samples.[21] If it is assumed that the cut off points are based on fasting samples then it would be expected that non-fasting values might be slightly higher because of the effect of recent vitamin C intake. However, it must be noted that plasma vitamin C is a continuously distributed variable and risk of deficiency is probably also continuous. Nevertheless the categorisation into the three groups of low, marginal and optimal is useful to clarify the issues discussed here.

Over 20% (of which 70% were smokers) of this population sample had plasma vitamin C concentrations < 11.4 μmol/l and were therefore categorised as being of low vitamin C status[13–15] (table 1). However, the mean vitamin C intake of this 20% was above 40 mg (fig 1), the United Kingdom's Reference Nutrient Intake (RNI)[22] for vitamin C. The RNI is defined as "that amount of a nutrient sufficient for almost all the population" and would therefore be expected to be enough to maintain plasma vitamin C concentrations at an adequate level. Data presented here suggest that 40 mg/day is not adequate for a significant fraction of the population and that plasma vitamin C concentrations can be severely compromised by smoking and aging in men. This effect of age, sex and smoking on plasma ascorbate concentrations has been known for many years[23 24] and various attempts have been made to suggest the amount of vitamin C required for smokers to maintain similar body pools to non-smokers[25] and for men to maintain the same levels as women.[14] The Scottish Diet report[26] proposed a vitamin C intake twice that of the RNI (that is, 80 mg) to be derived from increasing fruit and vegetable consumption but it may be that even this amount is not sufficient to maintain optimal plasma concentrations in the older smokers. Consumption of the equivalent of fruit, vegetables and fruit juice three or more times a day by this group resulted in a plasma concentration of vitamin C twice that of the non or rare consumers but plasma values were still marginal. Despite a substantial intake of vitamin C from potatoes and chips in men it was the lack of fruit, green vegetables and fruit juice that characterised the low category for plasma vitamin C in both men and women (table 2 and fig 1). This provides yet further evidence that improvements in diet and cessation of smoking are required to increase plasma concentrations of vitamin C in the population.

To our knowledge this is the first report of the sources of vitamin C in the diet for those with plasma concentrations commensurate with a sub-optimal vitamin C status. However, the comparative contribution of different sources have been reported for men and women[27] smokers and non-smokers[28] and for those in non-manual and manual occupational groups.[26] No distinction was made between citrus and non-citrus fruit or non-fried potatoes and chips in these previously reported studies. Potatoes (including chips) contributed 13 mg/day of vitamin C in men and 8 mg/day in women in the survey of British adults.[27] National Food Survey data[30] from 1990 shows that potatoes contributed 8 mg and processed potato products 2 mg to vitamin C content of the daily diet but that the contribution from fresh potatoes has been steadily falling since 1975 and the contribution from the potato products increasing. These figures are comparable to those found in this study. Figure 1 shows that one third to one half of the contribution from potatoes is provided by chips. However, even if men eat two large portions of potatoes or chips per day, or both, the vitamin C contributed will not exceed 40 mg, which is unlikely to be sufficient for the older smokers. Advice to change from chips to pasta and rice could be counterproductive in the group with very low plasma vitamin C concentrations unless they embrace the positive message of increasing fruit and vegetable consumption. Our results are similar to those already reported that fresh fruit was the main source of vitamin C in non-smoking women.[29] Not surprisingly the contribution of fruits and fruit juice to intake of vitamin C in men with low plasma vitamin C is no greater than that from potatoes and chips. For citrus fruit and juice consumption this is equivalent to less than a fifth of an orange per day. Frequent consumption of potato and chips showed no positive effect on vitamin C status but this could be because these frequent consumers tended to be those who consumed chips and potatoes in preference to the less traditional foods associated with a healthy diet such as rice, pasta and a range of fruit and vegetables. If this low category is to improve vitamin C status there is a need to increase consumption of fruit, vegetables and fruit juice before decreasing chip consumption. Care must be taken such that those at risk of vitamin C deficiency, who are often those at risk of coronary heart disease, are not given advice to reduce fat intake (for example, cut out chips) that further compromises their vitamin C status. Encouraging people to eat fruits and vegetables that they find palatable must take precedence over reducing fatty, but relatively nutrient dense foods such as chips.

The Scottish Diet report[26] set behavioural targets for the year 2005. These targets represented a compromise between the World Health Organisation recommendation[31] to eat at least 400 g fruit and vegetables (not including potatoes), best translated as five a day[32] and the low average amount that the Scottish people were consuming at the time (181 g). Thus for young men and women the target was set at three or more portions of fruit and vegetables per day and for those 65–74 years at least two portions. Figure 2 shows that the three portions is less than ideal for those who continue to smoke and that two portions is not sufficient for older men even if they do not smoke. However, the incorporation of citrus fruit juice may be the solution for those unable for whatever reason to take more than two portions of solid fruit and vegetables a day.

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Conflicts of interest: none.

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