

Estimated prevalence and predictors of vitamin C deficiency within UK's low-income population

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ABSTRACT

Background Recent case reports of scurvy indicate that vitamin C deficiency may be more prevalent than generally assumed. The Low Income Diet and Nutrition Survey (2003–05) of a representative sample of the low-income/materially deprived UK population included a plasma vitamin C measurement.

Methods Adults aged ≥ 19 years from all countries/regions of UK were screened to identify low-income/materially deprived households. A valid plasma vitamin C measurement was made in 433 men and 876 women. The results were weighted for sampling probability and non-response.

Results An estimated 25% of men and 16% of women in the low-income/materially deprived population had plasma vitamin C concentrations indicative of deficiency ($<11 \mu\text{mol l}^{-1}$), and a further fifth of the population had levels in the depleted range ($11\text{--}28 \mu\text{mol l}^{-1}$). Being a man, reporting low-dietary vitamin C intake, not taking vitamin supplements and smoking were predictors of plasma vitamin C levels $\leq 28 \mu\text{mol l}^{-1}$ in mutually adjusted logistic regression models.

Conclusion Health professionals need to be aware that poor vitamin C status is relatively common among adults living on a low income.

Keywords low-income population, national survey, nutrient deficiency, vitamin C

Introduction

Vitamin deficiencies are considered unusual in Western populations, but recent case reports warn that scurvy is still present and may be misdiagnosed.^{1–3} Poor vitamin C status is associated with low socioeconomic status in developed countries.^{4,5} Vitamin C deficiency has also been reported in some disadvantaged groups,^{6,7} but there has been little concern that wider groups of the population may be at risk of clinical or sub-clinical deficiency. The Low-Income Diet and Nutrition Survey (LIDNS) provides representative data on the diet and nutritional status of low-income/materially deprived UK consumers in 2003–05.⁸ We report on the estimated prevalence of vitamin C deficiency (plasma vitamin C $<11 \mu\text{mol l}^{-1}$) and depletion ($11\text{--}28 \mu\text{mol l}^{-1}$)⁹ in this population and the predictors of low vitamin C status.

Methods

Study design and population

The target population was the 15% most deprived households in the UK. The LIDNS sample selection followed a

multi-stage clustered design, using wards, addresses, dwelling units, catering units and dietary respondents from all countries/regions of UK. Deprived wards were over-sampled to increase the screening-in rate. Participants were selected based on screening questions aimed at identifying low-income/materially deprived households. The sample was selected by scoring questions regarding, for instance, type of housing, car ownership, employment status, household income and receipt of benefits or pensions like Housing Benefit, Council Tax Benefit, Incapacity Benefit, Income Support, Jobseekers' Allowance or State Retirement Pension. In total, 68% of the sample lived in social housing and 70% had a gross household income below £200 per week.¹⁰

Up to two respondents (one adult and one child) were selected from a household, excluding pregnant women. Seventy-two percent of the screened-in households were

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willing to participate, and 92% of these completed the individual questionnaire and minimum three 24 h dietary recalls (55% of the persons in the screened-in households). Ninety-five percent of the sample was of self-defined European ethnicity.¹⁰ Participants aged ≥ 19 years consisted of 946 men and 1850 women, of which 81% were successfully revisited by a nurse and 51% (both sexes) provided a blood sample. A valid plasma vitamin C measurement was obtained for 433 men and 876 women (91% of the samples taken). Participants were not required to fast before blood sample collection. The survey was approved by the London Multi-Centre Research Ethics Committee and written informed consent was obtained.¹⁰

Blood collection and analysis

A lithium–heparin vacutainer of blood was delivered on ice to local laboratories within 2 h of collection and processed within 4 h. Five hundred microlitres of lithium–heparin plasma was mixed with 500 μl 6% metaphosphoric acid and stored at -30°C . Plasma ascorbic acid was measured by isocratic HPLC¹¹ at the Institute of Food Research, Norwich. The methods and protocol for quality control are further described in the report.^{8,10}

Covariates

Interviewers collected data on socio-demographic aspects (including sex, age, ethnicity and household composition) and health behaviours (including smoking and vitamin supplement use). Smoking levels were defined using the weighted average of reported number of cigarettes smoked on weekdays and weekends, respectively. Twenty-eight percent of the study sample had missing information in smoking habits and were included in the non-smoking group for the logistic regression analyses. Dietary vitamin C intakes were obtained from four 24 h recalls on random days (including at least one weekend day). Typically, the blood samples were collected 2 weeks after the dietary assessment.¹⁰

Statistical methods

The prevalence estimates were weighted to correct for unequal selection probabilities of wards and for non-response at the different stages of the survey.¹⁰ We used STATA 9.1 (StataCorp, College Station, TX, USA), applying the software's SVY series of commands to analyse proportions of deficiency and depletion with 95% confidence interval (CI). Simple and multiple logistic regression models were used to examine predictors of having plasma vitamin C levels $\leq 28 \mu\text{mol l}^{-1}$. Only predictors associated with low

vitamin C status at $P < 0.10$ were retained in logistic regression models. Analyses were repeated using plasma levels $< 11 \mu\text{mol l}^{-1}$ as the case definition, but results were similar to those presented.

Results

The weighted prevalence of plasma vitamin C concentrations indicative of deficiency ($< 11 \mu\text{mol l}^{-1}$) was 26% for men and 16% for women (Table 1). A further fifth of both men and women had levels in the depleted range ($11\text{--}28 \mu\text{mol l}^{-1}$). In total, 46% of men and 35% of women in the low-income/materially deprived population were estimated to have either deficient or depleted vitamin C status. The estimated prevalence of deficiency was highest in Wales (35% among men and 23% among women) and lowest in Scotland (15%) among men and in Northern Ireland (14%) among women (data not shown).

Table 2 presents crude and adjusted odds ratios (OR) for having plasma vitamin C levels $\leq 28 \mu\text{mol l}^{-1}$ by sex and associated risk factors. Low vitamin C status was not significantly associated with age (four groups), ethnic origin (White versus other ethnic groups) or household composition (single adult, ≥ 2 adults with no children, single adult with ≥ 1 child and ≥ 2 adults with ≥ 1 child) in bivariate analyses (data not shown). Being a man, reporting low-dietary vitamin C intake, not taking vitamin supplements and smoking status were associated with having plasma vitamin C levels $\leq 28 \mu\text{mol l}^{-1}$ separately and in the fully adjusted logistic regression models. Lower reported dietary vitamin C intake and heavier smoking were both associated with increasing risks of low vitamin C status. Participants living in Scotland were less likely (adjusted OR 0.46) to have

Table 1 Weighted^a proportion of the UK low-income population with plasma vitamin C levels indicative of deficiency ($< 11 \mu\text{mol l}^{-1}$) and depletion ($11\text{--}28 \mu\text{mol l}^{-1}$), by sex

Plasma vitamin C levels	%	(95% CI)	Cumulative %
Men ($n = 433$)			
$< 11 \mu\text{mol l}^{-1}$	25.3	(19.5, 31.1)	25.3
$11\text{--}28 \mu\text{mol l}^{-1}$	21.0	(16.0, 26.0)	46.3
$> 28 \mu\text{mol l}^{-1}$	53.7	(46.6, 60.8)	100.0
Women ($n = 876$)			
$< 11 \mu\text{mol l}^{-1}$	16.1	(12.9, 19.3)	16.1
$11\text{--}28 \mu\text{mol l}^{-1}$	18.5	(15.0, 22.1)	34.6
$> 28 \mu\text{mol l}^{-1}$	65.4	(61.1, 69.7)	100.0

^aEstimates weighted for unequal selection probabilities and non-response.

Table 2 Crude and adjusted^a odds ratios (OR) (95% confidence interval) of plasma vitamin C levels $\leq 28 \mu\text{mol l}^{-1}$ by sex and associated risk factors for adults (≥ 19 years) in the Low Income Diet and Nutrition Survey

Predictors	n	Crude		Adjusted	
		OR (95% CI)	P	OR (95% CI)	P
Sex			<0.001		<0.001
Men	433	Reference		Reference	
Women	876	0.61 (0.48, 0.78)		0.60 (0.47, 0.78)	
Country of residence			0.06		0.004
England	844	Reference		Reference	
Wales	135	1.35 (0.78, 2.32)		1.26 (0.72, 2.23)	
Scotland	130	0.60 (0.39, 0.93)		0.46 (0.29, 0.73)	
Northern Ireland	200	0.74 (0.35, 1.58)		0.65 (0.29, 1.44)	
Reported vitamin C intake from food ^b			<0.001 ^c		<0.001 ^c
Lowest (1–38 mg d ⁻¹)	436	Reference		Reference	
Middle (38–72 mg d ⁻¹)	437	0.70 (0.52, 0.94)		0.71 (0.52, 0.97)	
Highest (>72 mg d ⁻¹)	436	0.37 (0.27, 0.50)		0.38 (0.28, 0.53)	
Taking vitamin supplements			<0.001		<0.001
Yes	272	Reference		Reference	
No	1037	2.28 (1.67, 3.11)		1.93 (1.37, 2.66)	
Smoking status			<0.001 ^c		0.008 ^c
Non-smoker ^d	747	Reference		Reference	
<10 cigarettes/day	110	1.30 (0.84, 2.01)		1.14 (0.72, 1.80)	
10–19 cigarettes/day	242	1.59 (1.16, 2.18)		1.23 (0.88, 1.72)	
≥ 20 cigarettes/day	210	1.95 (1.37, 2.77)		1.48 (1.01, 2.16)	

^aAdjusted for all factors listed above.

^bIntakes in thirds.

^cTest for trend.

^dIncludes 380 persons with unknown smoking status.

depleted values than the reference group (participants living in England).

Discussion

Main findings

LIDNS provides the first nationally representative data on the nutritional status of Britain's low-income- and materially deprived households. It suggests that poor vitamin C status is considerably more common in this population than previously thought.

What is known already

In 2000–01, the estimated prevalence of vitamin C deficiency ($<11 \mu\text{mol l}^{-1}$) among British adults aged 19–64 years was 5% in men and 3% in women,¹² but higher prevalences of deficiency have been reported in selected population groups. In the third Glasgow MONICA survey,

26% of men and 14% of women aged 25–74 had plasma vitamin C levels $<11.4 \mu\text{mol l}^{-1}$.⁶ Among the older British population (65 years and over) surveyed in 1994–95, the estimated prevalence of deficiency ($<11 \mu\text{mol l}^{-1}$) was relatively high (men 14% and women 13%).^{13,14} Vitamin C deficiency is also likely to be common among the homeless.⁷

Data on the prevalence of scurvy in the studied population is not available. Plasma vitamin C levels may indicate the functional reserves of the vitamin, but the relationship between functional status and clinical manifestations of deficiency is not straightforward.¹⁵ However, plasma vitamin C in the depleted range indicate low dietary intakes of fruit and vegetables, juice, vitamin-fortified drinks or supplements over weeks or months. Such a diet is also likely to lack several other important nutrients such as folate, other antioxidants and fibre. Only 2% of men and 1% of women in the LIDNS reported vitamin C intakes $<10 \text{ mg day}^{-1}$,¹⁶ which is the threshold intake preventing the clinical signs of scurvy.¹⁷

Other studies indicate that plasma vitamin C concentrations may not rise above the level of deficiency ($<11 \mu\text{mol l}^{-1}$) on intakes between 10 and 30 mg day⁻¹.¹⁸ Demand for the vitamin may be higher during, for instance, disease and pregnancy.¹⁵ As confirmed by the analysis, the picture is also complicated by smoking. The dietary intake needed to maintain a similar body pool of the vitamin is estimated to be ~40% higher in smokers compared with non-smokers.¹⁹

Experimental induction of scurvy shows that the first signs of disease develop after ~60–90 days on a vitamin C-free diet. Vitamin C supplementation gives a rapid resolution of symptoms.¹⁷ Vitamin C plays a central role in the formation of mature collagen, and deficiency impairs the synthesis of connective tissue causing delayed wound healing and formation of fragile granulation tissue.²⁰ The vitamin is also an important antioxidant. Low plasma vitamin C levels have been associated with higher mortality,²¹ although controversy exists whether this is due to vitamin C *per se* or associations with a generally poorer diet and lifestyle.²²

What this study adds

This study calls for health practitioners to consider vitamin C deficiency when presented with purpuric rash, hyperplastic haemorrhagic gingival enlargement, limping or low-grade inflammation. Some patients with scurvy will only have vague symptoms such as aching muscles and fatigue.³

Limitations of this study

Vitamin status was measured once in non-fasting participants. Plasma vitamin C levels will be elevated if fruit, fruit juice or supplements are consumed in the hours before venepuncture, which may give underestimation of poor vitamin C status. Vitamin C is liable to oxidation, but considerable care was taken to stabilize vitamin C in the sample and the analytical procedures were tightly controlled. The procedures followed were similar to the protocol used in the NDNS of the general UK population in 2000–01¹² and the British population aged 65 years in 1994–95.^{13,14} Fifty-one percent of the study sample provided valid plasma vitamin C measurement. The blood samples were taken after dietary assessments at a separate visit by a nurse, and participants were asked to comply with several measurements in addition to giving blood. This may have contributed to the lower response rate. However, specific statistical weighting was used to correct for the non-response to each stage of the data collection.¹⁰ The lower prevalence of poor vitamin C status in Scotland and otherwise few geographical variations in vitamin C status were unexpected. Replication

of the estimates for vitamin C deficiency and depletion in this population is needed.

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Competing interests

We declare that we have no conflict of interest. Data analysis and interpretation was done by the authors independently of the funding sources based on the available data.

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