British Journal of Nutrition (2002), **87**, 605–613
DOI: 10.1079/BJN2002583

Intake and sources of phylloquinone (vitamin K_1): variation with socio-demographic and lifestyle factors in a national sample of British elderly people

C. W. Thane[1]*, A. A. Paul[1], C. J. Bates[1], C. Bolton-Smith[1], A. Prentice[1] and M. J. Shearer[2]

[1]*MRC Human Nutrition Research, Elsie Widdowson Laboratory, Fulbourn Road, Cambridge CB1 9NL, UK*
[2]*Vitamin K Research & Diagnostic Units, Haemophilia Centre, St Thomas' Hospital, London SE1 7EH, UK*

(Received 2 July 2001 – Revised 14 December 2001 – Accepted 30 January 2002)

Intake and sources of phylloquinone (vitamin K_1) were examined according to socio-demographic and lifestyle factors in free-living British people aged 65 years and over, from the 1994–5 National Diet and Nutrition Survey. Complete 4-d weighed dietary records were obtained from 1152 participants living in private households. Using newly-available, mainly UK-specific food content data, the weighted geometric mean intake of phylloquinone was estimated at 65 (95% CI 62, 67) μg/d for all participants, with higher intakes in men than in women (70 *v.* 61 μg/d respectively, $P<0{\cdot}01$). The mean nutrient densities of phylloquinone intake were 9·3 and 10·5 μg/MJ for men and women respectively ($P<0{\cdot}01$), after adjusting for age group, region and smoking status. Of all the participants, 59% had phylloquinone intakes below the current guideline for adequacy of 1 μg/kg body weight per d. Participants aged 85 years and over, formerly in manual occupations, or living in Scotland or in northern England reported lower phylloquinone intakes than their comparative groups. Overall, vegetables contributed 60% of total phylloquinone intake, with cooked green vegetables providing around 28% of the total. Dietary supplements contributed less than 0·5% of phylloquinone intake. Participants living in northern England or in Scotland, in particular, derived less phylloquinone from vegetables than those living in southern England.

Vitamin K intake: Food sources: Elderly

Vitamin K was originally described for its role in blood clotting, but it may also be important for maintaining bone (Szulc *et al.* 1993, 1996; Binkley & Suttie, 1995; Shearer, 1997) and cardiovascular health (Luo *et al.* 1997; Shearer, 2000; Schurgers *et al.* 2001). Both are relevant to elderly people, with postmenopausal women and older men vulnerable to deteriorating health in these areas. Vitamin K is present mainly as phylloquinone (vitamin K_1) in both the diet and in blood.

Dietary vitamin K requirements for health cannot be set without detailed assessment of usual population intakes in relation to measurable health outcomes (Shearer & Bolton-Smith, 2000). Currently, no recommended intakes exist for vitamin K in the UK, only a guideline of 1 μg/kg body weight per d (Department of Health, 1991) that is based on the estimated average daily requirement for its role in blood clotting. Estimates of phylloquinone intake are scarce and only relatively recent, in the USA (Booth *et al.* 1995, 1996; Institute of Medicine, 2001), Scotland (Price *et al.* 1996; Bolton-Smith *et al.* 2000*b*) and the Netherlands (Schurgers *et al.* 1999). Previous attempts have been hampered by a lack of reliable phylloquinone content data for a comprehensive range of foods.

The present study uses newly-available food content data (Bolton-Smith *et al.* 2000*a*) to estimate the intake and sources of phylloquinone in free-living British people aged 65 years and over, to assess variation in intake according to several socio-demographic and lifestyle factors, and to characterise those with potentially inadequate phylloquinone intakes.

Subjects and methods

The current analyses use data from a nationally-representative sample of older adults, living in mainland Britain, who participated in the 1994–5 National Diet and Nutrition Survey of people aged 65 years and over. Full details and methods are provided in the survey report (Finch *et al.* 1998), and so only a brief account is given here, together with details of procedures used for data analysis.

* **Corresponding author:** Mr C. W. Thane, fax +44 1223 437515, email Chris.Thane@mrc-hnr.cam.ac.uk

After obtaining ethical approval for the survey from the National Health Service Local Research Ethics Committees for each of the eighty postcode sectors involved, participants were selected by a random stratified selection procedure. The survey included both those living in private households ('free-living', 79 % of the total) and in institutions (i.e. residential and nursing homes (but not people in acute hospital beds), 21 % of the total), with participants from both types of domicile represented in each postcode sector. Only those participants living in private households are investigated in the present analysis. The survey fieldwork was conducted over a single calendar year (October 1994 to September 1995), in four 'waves' corresponding to the four seasons. For statistical adequacy, predetermined numbers of men and women were recruited from each of three age groups (65–74, 75–84 and 85+ years), requiring deliberate over-sampling of men, and of the older age groups. Socio-demographic information was obtained by trained fieldworkers on health and lifestyle, previous employment, occupational social class of head of household, household income, use of medications, food consumption, smoking and drinking habits.

Dietary assessment

Participants kept a 4-d weighed record of all food and drink consumed, both in and out of the home. For those unable or unwilling to keep a weighed record, a descriptive diary, with household measures and portion sizes, was kept by the participant or carer, with food weights later assigned by the survey nutritionists. Due to possible day-to-day variation in nutrient intakes, the start day of each diary was spread evenly between the days of the week. The quality of dietary recording was assessed afterwards, with questions concerning difficulties in keeping the dietary record and any circumstances which may have affected their eating habits, such as illness.

Of 2060 participants in the interview sample, 4-d weighed dietary records were obtained for 1310 from the free-living sample. Dietary records of all participants who were unwell, with eating habits affected, or who failed to provide a complete 4-d dietary record were excluded from analyses. After these exclusions, 1152 free-living participants remained.

Estimating phylloquinone intake

Phylloquinone intake, and the relative contributions of different food groups and dietary supplements, were estimated using both published (Bolton-Smith *et al.* 2000*a*) and unpublished (MJ Shearer and C Bolton-Smith, unpublished) phylloquinone food content data (UK-specific whenever possible). Since phylloquinone values were not available for each of over 4000 foods in the database, individual values were assigned only to the main contributors of phylloquinone, as identified in preliminary data analysis. These comprised vegetables (fifty-seven food items), fats and oils (twenty-eight food items), cereals and cereal products (eighty-four food items). Foods in the remaining eighty-seven food subgroups had lower phylloquinone content, varying little between items in the group, and so an average phylloquinone content value was assigned to each of these subgroups. Phylloquinone contents of nutritional supplements (tablets and capsules, oils and syrups, and liquid or powdered nutritionally-complete supplement drinks) were also used, as obtained by direct analysis (for example, cod-liver oil) or from the manufacturers. Phylloquinone intakes were expressed as μg/d, energy-adjusted intake (μg/MJ) and body weight-adjusted intake (μg/kg per d), with body weight measured by trained fieldworkers. Intakes were also compared with the guideline for vitamin K adequacy (1 μg/kg body weight per d) (Department of Health, 1991) and examined according to several socio-demographic and lifestyle factors.

Under-reporting and representativeness of phylloquinone intake data

The extent and impact of likely under-reporting in the weighed dietary records were investigated, as a possible source of error in assessing phylloquinone intake. The method based on the ratio of total energy intake to calculated basal metabolic rate (energy intake:BMR) (Schofield *et al.* 1985) was used, with values $\geq 1{\cdot}2$ considered acceptable or valid usual energy intakes (Goldberg *et al.* 1991). To assess the representativeness of results from participants included in the dietary analyses (i.e. well with eating habits unaffected and who provided a complete 4-d dietary record), socio-demographic characteristics were compared with those of participants excluded from the analyses (i.e. unwell with eating habits affected or who provided an incomplete dietary record).

Data analysis

Data reduction and analyses were carried out using Excel (Microsoft Corp., Redmond, WA, USA) and SPSS (SPSS Inc., Chicago, IL, USA) respectively. Data were weighted, using a population weighting factor, to correct for disproportionate sampling (Finch *et al.* 1998). The resulting weighted samples then had similar profiles for sex, age and region of habitation as those of the population aged 65 years and over from the 1991 census data.

Sex-specific analyses of phylloquinone intake were conducted, adjusted for age group (65–74 years; 75–84 years; 85+ years), region of habitation (Scotland and the North; Central, South West and Wales; London and South East), occupational social class of the head of household (non-manual; manual) and smoking status (no; yes). When phylloquinone intakes were related to body weight, sample size was reduced by 14 % due to missing weight values.

Where necessary, the normality of data was improved by natural logarithmic transformation before analysis. Due to the skewed distributions of estimated phylloquinone intakes, geometric means (with 95 %, CI) are given throughout. These were obtained by back-transformation of the $\log_e$-transformed values and represent better 'average' measures for such non-normally distributed data. Arithmetic means are also quoted occasionally, for comparison. ANOVA with Scheffé tests, multiple logistic regressions and χ^2-tests were performed, with $P<0{\cdot}01$ deemed significant.

Table 1. Phylloquinone intake in free-living British people aged 65 years and over, by sex*
(Geometric mean values and 95 % confidence intervals)

	Phylloquinone (vitamin K_1) intake								
	μg/d			μg/MJ energy intake			μg/kg body weight per d		
Domicile and sex	*n*	Geometric mean†	95 % CI†	*n*	Geometric mean†	95 % CI†	*n*	Geometric mean†	95 % CI†
Free-living sample	1091	65	62, 67	1091	10·0	9·6, 10·4	954	0·96	0·92, 1·01
Men	491	70[a]	66, 74	491	9·3[a]	8·8, 9·8	443	0·94	0·88, 1·00
Women	600	61[b]	57, 64	600	10·5[b]	9·9, 11·1	511	0·99	0·93, 1·05

[a,b]Mean values within a column for sexes with unlike superscript letters were significantly different ($P<0·01$ from ANOVA).
* Weighted sample sizes (*n*) and statistics are presented to correct for non-proportional sampling (see p. 606).
† Back-transformed from $\log_e$(phylloquinone intake) and adjusted for age group, region, occupational social class of head of household and smoking status.

Results

More women than men in the free-living sample (14 *v.* 8 %; $P=0·002$) failed to provide a complete dietary record and were excluded from the statistical analyses. Free-living participants aged 85 years and over (18 *v.* 11 %, $P=0·02$) and those living alone (15 *v.* 9 %, $P<0·001$) were also less likely to have been included.

The distribution of phylloquinone intake was positively-skewed. Geometric mean phylloquinone intake was 65 μg/d for all participants; 70 and 61 μg/d for men and women respectively (Table 1). These values were somewhat lower than their respective arithmetic means of 88 (SD 68, 95 % CI 82, 94) and 78 (SD 65, 95 % CI 73, 83) μg/d for men and women (not shown). The range of daily phylloquinone intake was wide (9–585 μg/d) and very similar for men and women. The inner 95 % range of values for phylloquinone intake was 17–244 μg/d.

Women had higher energy-adjusted phylloquinone intakes than men (Table 1). Geometric mean phylloquinone intakes, adjusted for body weight, were not significantly different between men and women (Table 1). Of the participants, 59 % (644/1091) had estimated daily phylloquinone intakes below 1 μg/kg body weight, with no significant difference by gender.

Impact of under-reporting

Of the participants, 44 % (420/947) were low energy reporters (energy intake:BMR $<1·2$), with significantly more women than men (54 *v.* 33 %; $P<0·001$). After exclusion of likely under-reporters, daily and body weight-adjusted phylloquinone intakes were significantly higher in the remaining participants. The overall geometric mean for daily phylloquinone intake was 75 μg; 78 and 71 μg for men and women respectively. Corresponding arithmetic means were 92 μg; 94 and 90 μg for men and women respectively. Phylloquinone intake, adjusted for body weight, increased to 1·10 μg/kg per d overall, with an arithmetic mean intake of 1·36 μg/kg per d. Conversely, energy-adjusted phylloquinone intakes were almost unchanged after excluding likely under-reporters (9·2 and 10·3 μg/MJ for men and women respectively). Of the free-living sample, 47 % had daily phylloquinone intakes <1 μg/kg body weight, with no gender difference.

Variation in phylloquinone intake by season, socio-demographic and lifestyle factors

Average daily phylloquinone intake varied significantly with region in men and women, with those living in Scotland and northern England having significantly lower intakes than those living elsewhere (Table 2). Male smokers also had lower daily phylloquinone intakes than non-smokers. Daily phylloquinone intake fell with age in both sexes, being of borderline significance in men ($P=0·04$) but very highly significant in women ($P<0·001$). Manual occupational social class was also associated with lower daily phylloquinone intakes in women but not in men. Phylloquinone intake did not vary significantly according to season, level of household income, household composition, educational attainment or drinking habits in either men or women.

Socio-demographic variation in phylloquinone intake was also adjusted for energy intake (Table 2) and body weight (Table 3). Age, region, occupational social class and smoking status continued to be associated with energy-adjusted phylloquinone intake (Table 2). As for daily phylloquinone intake, neither season, level of household income, household composition, educational attainment nor drinking habits was associated with energy-adjusted phylloquinone intake, in either men or women.

Body weight-adjusted phylloquinone intakes decreased significantly with age in women only, with a lower mean value observed in those aged 85 years and over compared with those aged 65–74 years (Table 3). Intakes in men did not differ significantly with age group or occupational social class, although women from manual backgrounds had lower body-weight adjusted intakes than those of non-manual status. Previously observed regional differences in phylloquinone intake in men and women remained after adjusting for body weight, while intakes ceased to be associated significantly with smoking status.

Proportions with daily phylloquinone intakes below 1 μg/kg body weight ('low') differed significantly with region in women, but not in men. A higher proportion of women living in Scotland and northern England had 'low' phylloquinone intakes compared with those in London and south-east England (Table 3). Higher proportions of women from manual households also had 'low' intakes ($P=0·001$), although this was only of border-

Table 2. Daily and energy-adjusted phylloquinone intake in free-living British people aged 65 years and over, by sex and selected socio-demographic and lifestyle factors*

	Men					Women				
		μg/d		μg/MJ			μg/d		μg/MJ	
Socio-demographic or lifestyle factor	*n*	Geometric mean†	95 % CI†	Geometric mean†	95 % CI†	*n*	Geometric mean†	95 % CI†	Geometric mean†	95 % CI†
Age group										
65–74 years	325	72	67, 77	9·0	8·4, 9·6	345	66[a]	61, 71	11·0[a]	10·2, 11·8
75–84 years	144	68	60, 77	8·9	7·8, 10·0	197	57[b]	52, 63	10·0[ab]	9·0, 10·9
85+ years	22	54	42, 71	7·7	5·9, 10·0	58	45[b]	38, 55	8·2[b]	6·8, 9·7
Region										
Scotland and North	171	59[a]	54, 65	7·9[a]	7·2, 8·6	195	49[a]	46, 53	8·5[a]	7·9, 9·2
Central, South-West and Wales	186	73[b]	66, 81	9·0[ab]	8·2, 10·0	208	61[b]	56, 66	10·2[b]	9·4, 11·2
London and South-East	134	80[b]	72, 89	10·0[b]	9·0, 11·2	197	74[c]	66, 83	12·6[c]	11·3, 14·0
Season										
Autumn (Oct–Dec)	131	65	58, 72	8·1	7·4, 9·0	148	61	55, 68	10·7	9·5, 11·9
Winter (Jan–Mar)	121	75	66, 84	9·3	8·2, 10·4	148	63	57, 71	10·4	9·4, 11·6
Spring (Apr–Jun)	99	68	60, 77	8·4	7·4, 9·6	133	57	50, 64	9·5	8·5, 10·7
Summer (Jul–Sep)	140	72	64, 81	9·6	8·6, 10·8	171	61	55, 68	10·6	9·5, 11·8
Social class of head of household										
Non-manual	223	74	68, 81	9·0	8·3, 9·8	283	69[a]	63, 75	11·4[a]	10·5, 12·3
Manual	268	66	61, 72	8·8	8·1, 9·5	317	54[b]	50, 58	9·5[b]	8·8, 10·2
Smoking status										
Non-smoker	397	73[a]	68, 78	9·2[a]	8·7, 9·8	514	62	58, 65	10·4	9·8, 11·0
Smoker	94	59[b]	52, 66	7·5[b]	6·6, 8·5	86	55	48, 63	9·8	8·5, 11·2

[a,b,c]Mean values for categories within respective socio-demographic or lifestyle factors within a column with unlike superscript letters were significantly different ($P<0·05$, Scheffé test following overall $P<0·01$ from ANOVA, adjusted for age group, region, social class of head of household and smoking status).

*Weighted sample sizes (*n*) and statistics are presented to correct for non-proportional sampling (see p. 606).

†Back-transformed from $\log_e$(phylloquinone intake) and adjusted for age group, region, occupational social class of head of household and smoking status.

Table 3. Phylloquinone intake relative to body weight (μg/kg body weight per d) in free-living British people aged 65 years and over, by sex and selected socio-demographic and lifestyle factors*

(Geometric mean values and 95 % confidence intervals)

	Men				Women			
Socio-demographic or lifestyle factor	*n*	Geometric mean†	95 % CI†	Low intake‡ (%)	*n*	Geometric mean†	95 % CI†	Low intake‡ (%)
Age group								
65–74 years	298	0·93	0·87, 1·00	55	295	1·07[a]	0·99, 1·16	49
75–84 years	126	0·99	0·86, 1·13	55	170	0·91[ab]	0·82, 1·01	59
85+ years	19	0·82	0·60, 1·10	68	46	0·79[b]	0·63, 0·99	67
Region								
Scotland and North	145	0·79[a]	0·71, 0·88	63	155	0·81[a]	0·75, 0·89	66[a]
Central, South-West and Wales	170	0·99[b]	0·89, 1·10	52	181	0·96[ab]	0·87, 1·06	54[ab]
London and South-East	128	1·09[b]	0·97, 1·22	52	175	1·20[b]	1·07, 1·35	43[b]
Season								
Autumn (Oct–Dec)	120	0·87	0·78, 0·98	62	127	0·97	0·87, 1·08	52
Winter (Jan–Mar)	107	0·99	0·87, 1·13	48	125	1·08	0·96, 1·23	50
Spring (Apr–Jun)	89	0·94	0·82, 1·08	64	121	0·89	0·78, 1·01	59
Summer (Jul–Sep)	127	0·97	0·85, 1·10	50	138	1·01	0·89, 1·15	55
Social class of head of household								
Non-manual	209	1·00	0·92, 1·09	49	246	1·11[a]	1·01, 1·21	46[a]
Manual	234	0·89	0·81, 0·98	61	265	0·89[b]	0·82, 0·96	62[b]
Smoking status								
Non-smoker	360	0·97	0·91, 1·04	53	438	0·98	0·92, 1·05	54
Smoker	83	0·83	0·71, 0·96	67	73	1·02	0·88, 1·18	56

[a,b]Mean values for categories within respective socio-demographic or lifestyle factors within a column with unlike superscript letters were significantly different ($P<0·05$). For phylloquinone intake expressed as μg/kg body weight per d, differences were determined by Scheffé test following overall $P<0·01$ from ANOVA; for percentages of participants with low phylloquinone intake, differences were determined by χ^2 test if $P<0·01$ from multiple logistic regression.

* Weighted sample sizes (*n*) and statistics are presented to correct for non-proportional sampling (see p. 606).

† Antilogs of $\log_e$(phylloquinone intake), adjusted for age group, region, occupational social class of head of household and smoking status.

‡ Phylloquinone intake < 1 μg/kg body weight per d.

Table 4. Percentage contribution of selected food groups to average daily intake of phylloquinone in free-living British people aged 65 years and over*
(Mean values)

	Men						Women					
Socio-demographic or lifestyle factor	*n*	Total veg.†	Cooked green veg.‡	Lettuce and salad veg.§	Total cereals‖	Soups¶	*n*	Total veg.†	Cooked green veg.‡	Lettuce and salad veg.§	Total cereals‖	Soups¶
Age group												
65–74 years	325	59	28	9	12[a]	3	345	64[a]	30[a]	11	11[a]	3[a]
75–84 years	143	57	28	6	15[ab]	3	197	58[b]	28[a]	9	13[b]	4[b]
85+ years	22	53	20	6	18[b]	3	58	50[b]	22[b]	6	16[b]	6[b]
Region												
Scotland and North	171	53[a]	23	6	14	6[a]	195	53[a]	21[a]	9	15[a]	5[a]
Central, South-West and Wales	186	60[b]	28	8	14	2[b]	208	62[b]	28[b]	10	11[b]	3[b]
London and South-East	134	64[b]	31	11	12	2[b]	197	66[b]	37[c]	11	10[b]	2[b]
Season												
Autumn (Oct–Dec)	131	56	27	6[a]	15	4[ab]	148	62	32[a]	7[a]	11	4
Winter (Jan–Mar)	121	60	33	5[a]	13	4[a]	148	58	33[a]	5[a]	13	5
Spring (Apr–Jun)	99	55	25	7[a]	14	4[a]	133	58	28[ab]	9[a]	13	4
Summer (Jul–Sep)	140	61	24	14[b]	12	1[b]	171	63	22[b]	18[b]	10	2
Social class of head of household												
Non–manual	223	58	26	10[a]	14[a]	3	283	63	31	12[a]	11	3
Manual	268	58	28	6[b]	12[b]	3	317	58	27	8[b]	13	4
Smoking status												
Non–smoker	397	59	29	8	13	3	514	60	29	10	12[a]	3
Smoker	94	54	22	8	13	4	86	62	27	10	19[b]	4

[a,b,c]Mean values for percentage contributions within respective socio-demographic or lifestyle factors within a column with unlike superscript letters for respective food types were significantly different ($P<0{\cdot}01$ ANOVA, or Scheffé test following $P<0{\cdot}01$ in ANOVA where more than two factor levels were present), after adjusting for age group, region, occupational social class of head of household and smoking status in ANOVA model.

* Weighted data are presented to correct for non-proportional sampling (see p. 606). Data exclude those unwell with eating affected and those who failed to provide a complete food diary during the 4-d period of dietary assessment. The main food groups not detailed (milk and milk products, eggs and egg dishes, fat spreads, meat and meat products, fish and fish dishes, fruit and nuts, sugar, preserves and confectionery, and beverages) contributed minor proportions to phylloquinone intake and did not vary significantly by socio-demographic or lifestyle factors in either men or women.

† Total veg., all vegetables and vegetable products (including potatoes and savoury snacks).

‡ Cooked green veg., broccoli, Brussels sprouts, cabbage and spinach (subgroup of Total veg.).

§ Lettuce and salad veg., lettuce and other salad vegetables (raw) (subgroup of Total veg.).

‖ Total cereals, cereals and cereal products (i.e. breads, breakfast cereals, buns, cakes, pastries, fruit pies and cereal-based puddings).

¶ Soups, vegetable and other soups.

line significance in men ($P=0{\cdot}04$). The prevalence of 'low' phylloquinone intake increased with age, with a trend in differences between the three age groups in women ($P=0{\cdot}03$) but not in men ($P=0{\cdot}29$). Smoking status was not associated with having 'low' phylloquinone intakes in women ($P=0{\cdot}92$), although more male smokers tended to have lower intakes compared with their non-smoking counterparts ($P=0{\cdot}03$).

Exclusion of the low energy reporters had little effect on the seasonal and socio-demographic differences. Regional differences remained, regardless of whether phylloquinone intake was expressed in terms of daily intake, or adjusted for energy intake or body weight. Male smokers also continued to have lower daily phylloquinone intakes than non-smokers, although the significance was reduced ($0{\cdot}01 < P < 0{\cdot}05$) after adjustment for energy intake and body weight respectively.

Sources of phylloquinone intake

Table 4 shows the sources of phylloquinone intake for the free-living sample. Vegetables and vegetable products contributed most to mean daily phylloquinone intake (60 % overall), with cooked green vegetables alone providing around 28 % (cabbage, 15 %; Brussels sprouts, 7 %; broccoli, 5 %; spinach, 1 %). The main food groups of cereals, meat and milk provided 12, 7 and 3 % respectively, while fat spreads contributed only 4 %. Dietary supplements *in toto* provided $<0{\cdot}5$ % (arithmetic mean 0·02 %) to phylloquinone intake.

Sources of phylloquinone intake did not vary significantly by gender although percentage contributions from some foods did vary with season, and other socio-demographic and lifestyle factors. Cereals and cereal products provided proportionately more phylloquinone with age in both sexes, while that from total vegetables and its subsidiary food group of cooked green vegetables declined significantly in women.

Regional differences in the sources of phylloquinone intake were also noted. Vegetables, and cooked green vegetables in particular, contributed least to phylloquinone intake in those living in Scotland and northern England. Percentage contributions from total vegetables in Scotland and in London and south-east England were 44 and 65 % respectively, with those in Scotland deriving only half as much of their phylloquinone intake from cooked green vegetables as those in London and south-east England (17 *v.* 35 %) (not shown). One other notable difference, in both sexes, was a significantly higher contribution to phylloquinone intake from soups in Scotland and northern England. A very high contribution in Scotland (11 *v.* 2–4 % elsewhere) accounted for much of this difference.

With regard to season, a higher contribution to phylloquinone intake was made by lettuce and salad vegetables during summer, while soups contributed less during summer than winter. Participants of non-manual occupational social class derived more phylloquinone from lettuce and salad vegetables than did those of manual occupational background, while female smokers had higher contributions from cereals and cereal products than non-smokers. Sources of phylloquinone intake did not vary significantly with household income, education, drinking habits or whether or not participants were likely to have under-reported their food consumption.

Discussion

Few estimates of phylloquinone intake are available for representative population groups, with this analysis being the first report of its type within the UK. Whilst errors inevitably exist in any assessment of population nutrient intakes, the results are likely to be broadly representative of this age group in the UK.

A 4-d, rather than a 7-d, dietary recording period was chosen for greater compliance, and as this was suggested to be of adequate duration to provide an accurate estimate of habitual food consumption (Smith & Lowe, 1998). The assigned phylloquinone content values of some foods are provisional (Bolton-Smith *et al.* 2000*a*), since phylloquinone contents vary according to the part of the food consumed (for example, cabbage contains 3–6 times more phylloquinone in outer compared with inner leaves), the type of oils in fat spreads and blended vegetable oils and the degree of hydrogenation of these oils (Davidson *et al.* 1996), as well as according to soil and growth conditions, geographical location and maturity (Ferland & Sadowski, 1992*a*), and by heating and ultraviolet light exposure (Ferland & Sadowski, 1992*b*).

Ranges of phylloquinone intake were wide, with over a 10-fold difference for the inner 95 % of values. The arithmetic mean phylloquinone intakes of 84 and 73 μg/d for men and women respectively were only slightly higher than values of 76 and 69 μg/d reported for sixty-five younger Scottish men and women, using repeated 7-d weighed dietary records (Price *et al.* 1996). In the USA, the 1990 Total Diet Study reported a mean phylloquinone intake of 80 μg/d in 1216 older adults aged 60 years and over (Booth *et al.* 1996), while another study with 362 post-menopausal women (41–71 years) reported a geometric mean phylloquinone intake of 89 μg/d (Booth *et al.* 1995). In a recent follow-up of 888 Americans aged 65 years and over from the Framingham cohort study, mean phylloquinone intake, by food frequency questionnaire, was around 155 μg/d, with median values of about 99 and 113 μg/d in men and women respectively (Booth *et al.* 2000). However, these authors acknowledged the likelihood of these values being over-estimates.

An even higher food frequency questionnaire-derived weighted mean phylloquinone intake of around 245 μg/d has been reported in a subset of 3156 adults aged 65 years and over from a population cohort study based in Rotterdam (Schurgers *et al.* 1999). Whilst different methods of dietary assessment and food composition data may account for some of these differences in reported intake, a higher phylloquinone intake in the Netherlands may be genuine, since a higher value was also reported in a different study of 113 Dutch post-menopausal women (mean age 66 years), with an estimated mean daily intake of around 227 (SD 15) μg (Jie *et al.* 1995). Higher phylloquinone intakes in the Netherlands may be attributable to higher consumption of spinach and broccoli among the Dutch.

In common with younger Scottish adults (Price *et al.* 1996), around one-half of the current sample had daily phylloquinone intakes below the Government guideline of 1 μg/kg body weight (Department of Health, 1991). This may be of particular concern in the elderly, as low phylloquinone intake increases undercarboxylated osteocalcin, which may impact negatively on bone health. Similarly, undercarboxylation of matrix γ-carboxyglutamic acid protein may contribute to vascular calcification and CHD (Schurgers *et al.* 2001). Recent findings suggest that substantially higher vitamin K intakes are needed to maximise carboxylation of bone γ-carboxyglutamic acid proteins than those for carboxylation of coagulation γ-carboxyglutamic acid proteins synthesised in the liver (Vermeer *et al.* 1995; Sokoll *et al.* 1997). Few data exist on the relationship between phylloquinone intake and undercarboxylated osteocalcin concentrations, although a recent study suggested that dietary phylloquinone intakes below 100 μg/d are inadequate for optimal carboxylation of osteocalcin (Booth *et al.* 1999). In this survey, two-thirds reported phylloquinone intakes below the equivalent values of 1·25 and 1·5 μg/kg body weight per d for men and women respectively, however no undercarboxylated osteocalcin data are available for comparison. The value of 100 μg/d is mid-way between the new US dietary reference intakes of 125 μg/d for men and 90 μg/d for women (Institute of Medicine, 2001).

Lower phylloquinone intakes were found in participants aged 85 years and over, those living in Scotland and northern England, and those of manual background, compared with their comparator groups. Smokers generally had lower intakes than non-smokers, particularly in men, while seasonal differences were not observed. Similarly, no sex or seasonal differences were reported by Price *et al.* (1996) or in 362 post-menopausal women (41–71 years) in the USA (Booth *et al.* 1995). The lower phylloquinone intake in those aged 85 years and over accords with a recent finding in Dutch men and women aged 84 years and over (Schurgers *et al.* 1999), while lower phylloquinone intakes in smokers than non-smokers have been reported in two samples of younger Scottish adults (Fenton *et al.* 1997; Bolton-Smith *et al.* 2000*b*), although this was not shown in Dutch elderly people (Schurgers *et al.* 1999).

With regard to sources of phylloquinone intake, a number of studies have also shown vegetables to contribute around one-half of total phylloquinone intake, with leafy green vegetables alone providing one-quarter to one-third of intake (Booth *et al.* 1995, 1996; Fenton *et al.* 1997). This accords with the findings from mainland Britain as a whole, while participants living in northern England and in Scotland, in particular, derived less phylloquinone from vegetables, especially cooked green vegetables (cabbage, Brussels sprouts and broccoli), than those in the south of England.

In summary, the present study has provided the first nationally representative estimates of phylloquinone (vitamin K_1) intake among British people aged 65 years and over who live in private housing. It has also provided a better understanding of the variability in phylloquinone intake and food sources according to socio-demographic and lifestyle factors. These data will enable associations to be explored between phylloquinone intake and biochemical measures of vitamin K status, and possibly contribute to a better understanding of the role of phylloquinone in bone and cardiovascular health in the future.

Acknowledgements

This study (NSD 20) was supported by the Department of Health. Dr Celia Prynne contributed to work on the phylloquinone content values of the food groupings used in this analysis. The Data Archive, University of Essex, Colchester CO4 3SQ provided an electronic copy of the survey data.

References

Binkley NC & Suttie JW (1995) Vitamin K nutrition and osteoporosis. *Journal of Nutrition* **125**, 1812–1821.

Bolton-Smith C, Price RJG, Fenton ST, Harrington DJ & Shearer MJ (2000*a*) Compilation of a provisional UK database for the phylloquinone (vitamin K_1) content of foods. *British Journal of Nutrition* **83**, 389–399.

Bolton-Smith C, Price RJG & Shearer MJ (2000*b*) Decreasing phylloquinone (vitamin K_1) and total fat intake in a 10-year longitudinal study of Scottish adults. *Proceedings of the Nutrition Society* **59**, 24A.

Booth SL, O'Brien-Morse ME, Dallal GE, Davidson KW & Gundberg CM (1999) Response of vitamin K status to different intakes and sources of phylloquinone-rich foods: comparison of younger and older adults. *American Journal of Clinical Nutrition* **70**, 368–377.

Booth SL, Pennington JAT & Sadowski JA (1996) Food sources and dietary intakes of vitamin K_1 (phylloquinone) in the American diet: Data from the FDA Total Diet Study. *Journal of the American Dietetic Association* **96**, 149–154.

Booth SL, Sokoll LJ, O'Brien ME, Tucker K, Dawson-Hughes B & Sadowski JA (1995) Assessment of dietary phylloquinone intake and vitamin K status in postmenopausal women. *European Journal of Clinical Nutrition* **49**, 832–841.

Booth SL, Tucker KL, Chen H, Hannan MT, Gagnon DR, Cupples LA, Wilson PWF, Ordovas J, Schaefer EJ, Dawson-Hughes B & Kiel DP (2000) Dietary vitamin K intakes are associated with hip fracture but not with bone mineral density in elderly men and women. *American Journal of Clinical Nutrition* **71**, 1201–1208.

Davidson KW, Booth SL, Dolnikowski GG & Sadowski JA (1996) The conversion of phylloquinone to 2,3-dihydro-vitamin K_1 during the hydrogenation of vegetable oils. *Journal of Agricultural and Food Chemistry* **44**, 980–983.

Department of Health (1991) *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*. Report on Health and Social Subjects, no. 41. London: HMSO.

Fenton ST, Price RJ, Bolton-Smith C, Harrington D & Shearer MJ (1997) Nutrient sources of phylloquinone (vitamin K_1) in Scottish men and women. *Proceedings of the Nutrition Society* **56**, 301A.

Ferland G & Sadowski JA (1992*a*) The vitamin K_1 (phylloquinone) content of green vegetables: effects of plant maturation and geographical growth location. *Journal of Agricultural and Food Chemistry* **40**, 1874–1877.

Ferland G & Sadowski JA (1992*b*) The vitamin K_1 (phylloquinone) content of edible oils: effects of heating and light

exposure. *Journal of Agricultural and Food Chemistry* **40**, 1869–1873.
Finch S, Doyle W, Lowe C, Bates CJ, Prentice A, Smithers G & Clarke PC (1998) *National Diet and Nutrition Survey: People Aged 65 Years and Over,* vol. 1. *Report of the Diet and Nutrition Survey*. London: The Stationery Office.
Goldberg GR, Black AE, Jebb SA, Cole TJ, Murgatroyd PR, Coward WA & Prentice AM (1991) Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-reporting. *European Journal of Clinical Nutrition* **45**, 569–581.
Institute of Medicine (2001) *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*, pp. 127–154. Washington, DC: National Academy Press.
Jie K-SG, Bots ML, Vermeer C, Witteman CM & Grobbee DE (1995) Vitamin K intake and osteocalcin levels in women with and without aortic atherosclerosis: a population-based study. *Atherosclerosis* **116**, 117–123.
Luo G, Ducy P, McKee MD, Pinero GJ, Loyer E, Behringer RR & Karsenty G (1997) Spontaneous calcification of arteries and cartilage in mice lacking matrix Gla protein. *Nature* **386**, 78–81.
Price R, Fenton S, Shearer MJ & Bolton-Smith C (1996) Daily and seasonal variation in phylloquinone (vitamin K_1) intake in Scotland. *Proceedings of the Nutrition Society* **55**, 244A.
Schofield WN, Schofield C & James WPT (1985) Basal metabolic rate. *Human Nutrition: Clinical Nutrition* **39C**, Suppl. 1, 1–96.
Schurgers LJ, Dissel PE, Spronk HM, Soute BA, Dhore CR, Cleutjens JP & Vermeer C (2001) Role of vitamin K and vitamin K-dependent proteins in vascular calcification. *Zeitschrift für Kardiologie* **90**, Suppl. 3, 57–63.
Schurgers LJ, Geleijnse JM, Grobbee DE, Pols HAP, Hofman A, Witteman JCM & Vermeer C (1999) Nutritional intake of vitamins K_1 (phylloquinone) and K_2 (menaquinone) in the Netherlands. *Journal of Nutritional and Environmental Medicine* **9**, 115–122.
Shearer MJ (1997) The roles of vitamins D and K in bone health and osteoporosis prevention. *Proceedings of the Nutrition Society* **56**, 915–937.
Shearer MJ (2000) Role of vitamin K and Gla proteins in the pathophysiology of osteoporosis and vascular calcification. *Current Opinion in Clinical Nutrition and Metabolic Care* **3**, 433–438.
Shearer MJ & Bolton-Smith C (2000) The UK food data-base for vitamin K and why we need it. *Food Chemistry* **68**, 213–218.
Smith P & Lowe C (1998) *National Diet and Nutrition Survey: People aged 65 Years and Over. A Report of the Feasibility Study (January–April 1994)*. London: Social and Community Planning Research.
Sokoll LJ, Booth SL, O'Brien ME, Davidson KW, Tsaioun KI & Sadowski JA (1997) Changes in serum osteocalcin, plasma phylloquinone, and urinary γ-carboxyglutamic acid in response to altered intakes of dietary phylloquinone in human subjects. *American Journal of Clinical Nutrition* **65**, 779–784.
Szulc P, Chapuy MC, Meunier PJ & Delmas PD (1993) Serum undercarboxylated osteocalcin is a marker of the risk of hip fracture in elderly women. *Journal of Clinical Investigation* **91**, 1769–1774.
Szulc P, Chapuy MC, Meunier PJ & Delmas PD (1996) Serum undercarboxylated osteocalcin is a marker of the risk of hip fracture: a three year follow-up study. *Bone* **18**, 487–488.
Vermeer C, Jie K-SG & Knapen MHJ (1995) Role of vitamin K in bone metabolism. *Annual Review of Nutrition* **15**, 1–22.