Public Health Nutrition: 8(2), 171–180 DOI: 10.1079/PHN2004674

Intake and sources of phylloquinone (vitamin K_1) in 4-year-old British children: comparison between 1950 and the 1990s

CJ Prynne[1,*], CW Thane[1], A Prentice[1] and MEJ Wadsworth[2]
[1]MRC Human Nutrition Research, Elsie Widdowson Laboratory, Fulbourn Road, Cambridge CB1 9NL, UK: [2]MRC National Survey of Health and Development, University College and Royal Free Medical School, 1–19 Torrington Place, London WC1E 6BT, UK

Submitted 10 February 2004: Accepted 7 September 2004

Abstract

Objectives: To compare dietary intake and sources of phylloquinone (vitamin K_1) in 4-year-old British children between 1950 and the 1990s, and report their variation by sociodemographic factors.
Design: Nationally representative samples of 4-year-olds from the longitudinal Medical Research Council National Survey of Health and Development (NSHD) (1950) and the cross-sectional National Diet and Nutrition Surveys (NDNS, 1992/93 and 1997).
Setting: Great Britain.
Subjects: Subjects were 4599 children born on 3–9 March 1946 (NSHD) and 307 children in the 1990s (NDNS).
Results: Geometric mean dietary phylloquinone intake was significantly higher in 1950 (39 μg day^{-1}, 95% confidence interval (CI) 37, 40) compared with the 1990s (24 μg day^{-1}, 95% CI 22, 25) ($P < 0.001$). This difference remained when intake was expressed per MJ energy intake and per kilogram body weight, and after accounting for sex, region and occupational social class of the family. In 1950, phylloquinone intake in Scotland was significantly lower than in the rest of Britain. By the 1990s these regional differences had disappeared. Food sources of phylloquinone intake changed significantly between 1950 and the 1990s, with fats and oils contributing more and vegetables less, although vegetables contributed most (60% and 48%, respectively) to phylloquinone intake in both surveys.
Conclusions: Phylloquinone intakes of children have decreased significantly since 1950. With the suggested need for adequate phylloquinone intake for optimal development and maintenance of bone and the cardiovascular system, the substantially lower phylloquinone intakes reported in children of the 1990s, compared with 1950, may have implications for the health of these two systems in later adulthood.

Keywords
Phylloquinone
Vitamin K
Intake
Food sources
Children
Great Britain

It is now recognised that the role of vitamin K goes beyond involvement in coagulation mechanisms. The proteins to which it confers functionality by acting as a cofactor in γ-carboxylation include osteocalcin and matrix Gla protein. Osteocalcin is considered to play a role in bone mineralisation and remodelling while matrix Gla protein may be involved in the prevention of vascular calcification[1,2]. Vitamin K occurs naturally in foods – mainly as phylloquinone (vitamin K_1) but also, to a much lesser extent and particularly in the UK diet, as menaquinone (vitamin K_2), which occurs in cheese, other fermented dairy foods, eggs and fermented soya-containing foods[3]. Vitamin K may also occur as dihydrophylloquinone, which is produced by hydrogenation of vegetable oils, although its biological activity is uncertain[4].

Both dietary and environmental factors in early life influence the bone mass achieved in young adulthood. Childhood growth rates have been related to risk of fracture in later adulthood[5] and it could be that strong bones laid down in childhood reduce the risk of osteoporosis and fracture in later life. There is also evidence that the first lesions of atherosclerosis are apparent in childhood[6] and so vitamin K intake at that time of life may have wider implications beyond bone health.

As more information on the phylloquinone content of foods has become available, phylloquinone intakes have been reported in children across a broad age range in the USA[4,7,8], and in adults in the USA[4,7,8], The Netherlands[3] and Great Britain[9–11]. Phylloquinone intakes in British adolescents have also been reported[12,13], as it is recognised that the risk of developing osteoporosis may

*Corresponding author: Email celia.greenberg@mrc-hnr.cam.ac.uk

be reduced by maximising peak bone mass in adolescence[14]. There is much less information on menaquinone intake owing to the limited quantity of food content data.

Discussion of vitamin K in younger children is usually confined to its role in the prevention of haemorrhagic disease of the newborn[15] or deficiency due to malabsorption in children with cystic fibrosis[16]. Its role in relation to bone and cardiovascular health in early childhood, with potential significance later in adulthood, has not been discussed and phylloquinone intakes in representative samples of younger British children have not been reported.

The 1946 Birth Cohort of the Medical Research Council (MRC) National Survey of Health and Development (NSHD) provides such an opportunity, by monitoring the possible consequences of childhood diet through to later life. Food consumption and nutrient intakes of this cohort when 4 years old have already been reported[17], but phylloquinone intake was not included as the necessary food content database was not then available. The present study thus investigates differences in phylloquinone intake by sex, socio-economic class and region of residence. As the cohort is still being studied and is reaching an age at which degenerative diseases of bone and the cardiovascular system may become apparent, it will be possible to relate these to childhood intakes of phylloquinone.

We have already shown that dietary patterns of 4-year-olds have changed substantially since 1950[17], together with the composition of food in relation to constituent fats and oils. Green vegetables are a primary source of phylloquinone but vegetable oils, used in spreading fats and hence many manufactured cereal foods, are also a very rich source. Thus, it was of interest to investigate the intake and food sources of phylloquinone in children of 1950, during food rationing, compared with children of the same age in the 1990s.

Subjects and methods

Children from 1950

Four thousand, seven hundred 4-year-old children living in mainland Britain were eligible for inclusion in the present study. This represented 88% of the 5362 children selected for the longitudinal NSHD (1946 Birth Cohort) as a class-stratified random sample of all legitimate singleton babies born in the week of 3–9 March 1946. Local health visitors collected information on health and socio-economic circumstances at a home visit when the children were 4 years old; during the same visit the health visitor measured the weight and height of the child. The majority of these visits were in June (73%) and July (19%) 1950, with most of the rest taking place during the winter of 1950/51. Twenty-four-hour recall dietary records were obtained by asking the mother or carer 'What did this child have for each meal yesterday?' and referring specifically to 'breakfast', 'dinner', 'tea or high tea' and 'last thing at night'. Usable dietary data were obtained for 4599 children. Of those whose dietary data were analysed, information on father's occupational social class and region of residence was obtained for 4411 children[17].

Coding and phylloquinone analysis

The dietary records were coded using the in-house program DIDO (Diet In Data Out)[18] and nutrient analysis performed using the in-house suite of programs originally based on data from *McCance & Widdowson's The Composition of Foods*[19] but adapted to include historically appropriate nutrient content data. Details of the dietary coding have been published previously[17]. Apart from the relatively few foods that were reported by weight, portion sizes suitable for 4-year-olds were allocated using the amounts of rationed foods available and contemporary recommendations on feeding young children[20]. Since neither of these two sources separated boys and girls, no distinction could be made in portion sizes for the two sexes in the present study.

The phylloquinone contents of a wide range of foods were assigned from published data[21,22] and a much more comprehensive range of unpublished data (C Bolton-Smith and M Shearer, unpublished results). However, as the phylloquinone content of cakes, biscuits and fried foods, for example, depends on the oils used in their preparation, these values had to be re-calculated according to the oils and fats in use in 1950. A contemporary report describing the oil and fat contents of margarines was used to estimate the phylloquinone content of an average margarine and thus the content of baked foods containing margarine[23].

Comparison between 1950 and the 1990s

Comparison was made between data from 1950 and data from the cross-sectional National Diet and Nutrition Surveys (NDNS) of 1992/93[24] and 1997[25]. The 1992/93 NDNS included 218 children aged 4 years, sampled from July 1992 to June 1993, while 89 4-year-olds were included from January to December 1997. Participants were selected from private households in 100 (1992/93) and 132 (1997) randomly selected postal code sectors around the whole of mainland Britain, with only one child eligible to participate from each household. Approximately equal numbers of participants were sampled for each of the four seasons in which the NDNS surveys were conducted.

Participation in the surveys was voluntary, while ethical permission for all parts of the surveys was obtained from the National Health Service's Local Research Ethics Committees for every location in which the surveys were conducted[24,25]. The surveys' design included a face-to-face interview, usually with the child's mother, to provide information about sociodemographic characteristics of the child's household. Trained fieldworkers measured height and weight of the 4-year-olds in the 1990s.

Phylloquinone intakes from the diet were estimated from 4-day (1992/93) and 7-day (1997) weighed dietary records of all foods and drinks consumed by participants, both in and out of the home, and were completed by their mother or other carer. To maximise the quality of the resulting dietary information, fieldworkers returned approximately 24 h after leaving the food diaries with respondents to check that items were being recorded correctly and with enough detail, and to provide encouragement where appropriate.

In common with the method used for data in 1950, dietary phylloquinone intake and the relative contribution of different food groups were estimated for each individual using content values for a comprehensive range of foods and drinks from published sources[21,22] plus unpublished data (C Bolton-Smith and M Shearer, unpublished results). Previous reports on phylloquinone intake in children aged 4–8 years in the USA[8] and in British elderly people[11] showed that dietary supplements (e.g. multivitamin tablets and cod-liver oil) made a negligible contribution overall. Thus although dietary phylloquinone has been reported in the present study, this can be assumed overall to be not dissimilar to total intake (diet plus supplements).

Sociodemographic comparisons

Occupational social class of the head of household (HoH) (father in 1950; father, mother or guardian in the 1990s) was categorised as non-manual (professional, managerial, technical and skilled non-manual occupations) or manual (skilled manual, partly-skilled and unskilled occupations) from standard categories derived from the Registrar General's *Standard Occupational Classification*[26] that were applicable in 1950 and the 1990s. Children whose HoH was in the armed forces (e.g. $n = 180$ in 1950) were omitted from the present analyses. Children in 1950 and the 1990s were also grouped into four broad regions of residence (Scotland; North; Midlands, Central South, South West and Wales; London and South East).

Data analysis

Data analysis was conducted using Excel (Microsoft Corp., Redmond, WA, USA) and SPSS 11.0 for Windows (SPSS Inc., Chicago, IL, USA). Data from 1992/93 and 1997 were pooled since no significant differences in anthropometric and sociodemographic characteristics or phylloquinone intakes and food sources were found in 4-year-olds between the two surveys. Similarly, data from all four seasons of the NDNS were used since, in agreement with studies involving British adults[9,11] and adolescents[13], phylloquinone intake did not vary significantly by season. Each season contained approximately equal numbers of participants. Using NDNS data from all four seasons and pooling them across the two surveys also helped to maximise the power of the statistical analyses and the reliability of subsequent findings.

Dietary phylloquinone intakes are expressed as $\mu g\,day^{-1}$ and as adjusted for energy intake from the diet ($\mu g\,MJ^{-1}$) and body weight ($\mu g\,kg^{-1}\,day^{-1}$). Intakes are also compared with the UK guideline for vitamin K adequacy ($1\,\mu g\,kg$ body weight^{-1} day^{-1})[27] and, for international comparison, with the recent Adequate Intake (AI) of $55\,\mu g\,day^{-1}$ for 4- to 8-year-olds suggested in the USA[8].

Where necessary, variables were transformed to give a normal distribution using natural logarithmic transformation. In this case, geometric means (95% confidence intervals (CIs)) are presented as better measures of central tendency than arithmetic means (standard deviations). However, the latter summary statistics are also sometimes presented for comparison, together with ranges of phylloquinone intake and reference (2.5–97.5 percentile) ranges – to give a better indication of the distribution of values when one or two extreme intakes were reported.

The analysis first compared the geometric means of dietary phylloquinone intake ($\mu g\,day^{-1}$, $\mu g\,MJ^{-1}$, $\mu g\,kg^{-1}\,day^{-1}$) after adjustment for sex, social class and region. Next, geometric means of intake were compared according to sex, social class and region. Finally, means of percentage contribution of food groups to phylloquinone intake and consumption of selected food groups were compared in the two populations in relation to sex, social class and region.

Fully factorial analysis of variance (ANOVA) with *post hoc* Bonferroni tests, unpaired Student's *t*-tests, multiple logistic regression and chi-square tests were performed. All statistical tests were two-tailed with $P < 0.05$ deemed significant throughout. *P*-values were adjusted for the other sociodemographic factors while, for ease of comparison with other studies and since they did not differ significantly from values adjusted for other sociodemographic factors, summary statistics presented in the tables are unadjusted. Crude odds ratios (ORs) are presented with 95% CI. Adjusted ORs (adjusted for each of the other sociodemographic factors) are not also presented since they did not differ significantly from crude ORs.

Results

Sociodemographic characteristics of 4-year-old children from 1950 and the 1990s were very similar, as shown in Table 1. In addition, their mean heights and weights were almost identical.

Phylloquinone intake

Table 2 shows summary statistics for dietary phylloquinone intake of children in 1950 and the 1990s. Geometric mean daily intake of phylloquinone from the diets of children in 1950 was significantly higher than that in the 1990s, whether expressed per day, per MJ energy intake or per kilogram of body weight. The latter difference in phylloquinone intake equated to significantly more

https://doi.org/10.1079/PHN2004674 Published online by Cambridge University Press

Table 1 Sociodemographic characteristics of 4-year-old children who provided dietary records from 1950 and the 1990s

	1950		1990s	
	n	Mean (SD) or %	*n*	Mean (SD) or %
Sex				
Boys	2404	52	147	48
Girls	2195	48	160	52
Anthropometry				
Height (m)	4239	1.03 (0.05)	300	1.04 (0.04)
Weight (kg)	4343	17.2 (2.2)	299	17.3 (2.3)
Occupational social class of HoH				
Non-manual	1794	41	136	47
Manual	2625	59	155	53
Region of residence				
Scotland	527	12	34	11
North	1119	25	79	26
Midlands, Central South, South West & Wales	1787	41	99	32
London & South East	978	22	95	31

SD – standard deviation; HoH – head of household.

children in the 1990s having intakes below 1 μg kg^{-1} day^{-1} (27% vs. 21%, $P = 0.04$; OR 1.33, 95% CI 1.06, 1.61). However, this overall difference was due to the girls (34% vs. 18% with intakes <1 μg kg^{-1} day^{-1} in the 1990s and 1950, respectively, $P < 0.001$; OR 2.31, 95% CI 1.95, 2.67) with no difference reported for boys (18% vs. 24%, $P = 0.13$). Geometric mean phylloquinone intake in 1950 was 71% of the US AI for 4- to 8-year-olds (55 μg day^{-1}) compared with 44% of the US AI in the 1990s ($P < 0.001$; OR 5.23, 95% CI 4.76, 5.70).

The ranges of dietary phylloquinone intake were wide at both time points, but substantially wider in 1950, even after excluding values at the extremes (<2.5 and >97.5 percentile). Regardless of how intake was expressed, minimum and 2.5 percentile values were comparable for 1950 and the 1990s, while higher values at the upper ends of the distributions explained the wider ranges of intake reported in 1950.

Table 3 shows dietary phylloquinone intake expressed per day and per MJ energy intake from the diet by sex, occupational social class of the HoH and region. Intakes in 1950 were consistently higher than those reported in the 1990s, across the range of sociodemographic factors. In 1950, children from a manual social class family had a significantly lower daily intake of phylloquinone than those from a non-manual social class family ($P = 0.006$). That intake was still higher than the phylloquinone intake of children in the 1990s. However, as there was a statistically significant interaction between social class and region, this difference in phylloquinone intake between social classes in 1950 was found in Scotland only and, when expressed per MJ energy, intake was not significantly different. In the 1990s, phylloquinone intake did not differ significantly by any of the sociodemographic factors, apart from occupational social class of the HoH when expressed per MJ energy intake (lower phylloquinone density reported in children from a manual compared with a non-manual social class family, $P = 0.02$).

In 1950, phylloquinone intake differed significantly by region. Daily phylloquinone intake in Scotland was significantly lower than all other regions, including the north of England – in which intakes were significantly lower than in the rest of England and Wales. When expressed per MJ of energy intake, phylloquinone densities in Scotland and the North were both significantly lower than in the other two regions. In the 1990s there were no significant differences in phylloquinone intake between regions, while phylloquinone intake in Scotland did not differ significantly between 1950 and the 1990s.

Table 4 shows the dietary phylloquinone intake of children in 1950 and the 1990s expressed relative to body weight and also the percentages with a 'low' intake (<1 μg kg^{-1} day^{-1}). In 1950 significantly more boys than girls had a low intake, although the converse was found in

Table 2 Dietary phylloquinone intake of 4-year-old children in 1950 and the 1990s

		Dietary phylloquinone intake					
		μg day^{-1}		μg MJ^{-1}		μg kg body weight^{-1} day^{-1}*	
Year	*n*	GM	95% CI	GM	95% CI	GM	95% CI
1950	4411	39	37, 40	6.6	6.4, 6.8	2.27	2.20, 2.34
1990s	291	24	22, 25	4.6	4.3, 4.9	1.40	1.31, 1.49
P-value†		<0.001		<0.001		<0.001	
		Mean	SD	Mean	SD	Mean	SD
1950	4411	68	85	11.6	14.9	4.03	5.07
1990s	291	28	16	5.2	2.9	1.62	0.94
		Range	$P_{2.5}$, $P_{97.5}$	Range	$P_{2.5}$, $P_{97.5}$	Range	$P_{2.5}$, $P_{97.5}$
1950	4411	2, 485	8, 283	0.8, 135.2	1.5, 53.9	0.16, 29.96	0.44, 17.83
1990s	291	3, 88	8, 73	1.4, 18.0	2.0, 14.3	0.21, 6.03	0.51, 4.18

GM – geometric mean; CI – confidence interval; SD – standard deviation; $P_{2.5}$ – 2.5 percentile; $P_{97.5}$ – 97.5 percentile.
* 1950, $n = 4176$; 1990s, $n = 283$.
† Adjusted for sex, region and occupational social class of the head of household (analysis of variance).

https://doi.org/10.1079/PHN2004674 Published online by Cambridge University Press

Table 3 Dietary phylloquinone intake (μg day^{-1} and μg MJ^{-1}) of 4-year-old children in 1950 and the 1990s by selected sociodemographic factors

Sociodemographic factor	n		μg day^{-1}			μg MJ^{-1}		
			GM (95% CI)			GM (95% CI)		
	1950	1990s	1950	1990s	P* (ANOVA)	1950	1990s	P* (ANOVA)
Sex								
Boys	2309	141	35 (34, 37)	25 (22, 27)	<0.001	6.0 (5.7, 6.3)	4.5 (4.1, 4.9)	0.003
Girls	2102	150	38 (37, 40)	22 (20, 25)	<0.001	6.6 (6.3, 7.0)	4.4 (4.1, 4.9)	<0.001
P (ANOVA)			0.02	0.13		0.003	0.92	
Occupational social class of HoH								
Non-manual	1791	136	39 (37, 41)	25 (22, 28)	<0.001	6.5 (6.1, 6.8)	4.8 (4.4, 5.3)	0.002
Manual	2620	155	35 (34, 37)	22 (20, 24)	<0.001	6.1 (5.9, 6.4)	4.1 (3.8, 4.4)	<0.001
P (ANOVA)			0.006	0.13		0.12	0.02	
Region								
Scotland	527	30	27[a] (25, 29)	21 (17, 26)	0.13	4.9[a] (4.5, 5.4)	3.9 (3.3, 4.6)	0.14
North	1119	74	35[b] (33, 38)	23 (20, 27)	0.001	5.9[a] (5.5, 6.3)	4.4 (3.9, 5.0)	0.02
Midlands, Central South, South West & Wales	1787	95	43[c] (41, 45)	26 (23, 29)	<0.001	7.2[b] (6.9, 7.6)	5.0 (4.5, 5.5)	0.001
London & South East	978	92	45[c] (42, 48)	24 (21, 29)	<0.001	7.6[b] (7.1, 8.0)	4.6 (4.2, 5.1)	<0.001
P (ANOVA)			<0.001	0.24		<0.001	0.08	

GM – geometric mean; CI – confidence interval; ANOVA – analysis of variance; HoH – head of household (father for 1950 data; father, mother or guardian for 1990s).
* 1950 vs. 1990s comparison (fully factorial ANOVA).
[a,b,c]Mean values for categories within the particular sociodemographic factor within a column with unlike superscript letters are significantly different ($P < 0.05$, Bonferroni test).

Table 4 Dietary phylloquinone intake (μg kg body weight^{-1} day^{-1} and percentage below 1 μg kg body weight^{-1} day^{-1}) of 4-year-old children in 1950 and the 1990s by selected sociodemographic factors

Sociodemographic factor	n		μg kg body weight^{-1} day^{-1}			<1 μg kg body weight day^{-1}		
			GM (95% CI)			%		
	1950	1990s	1950	1990s	P* (ANOVA)	1950	1990s	P* (MLR)
Sex								
Boys	2187	135	2.1 (2.0, 2.2)	1.5 (1.3, 1.6)	<0.001	24	18	0.23
Girls	1989	148	2.3 (2.2, 2.4)	1.3 (1.2, 1.4)	<0.001	18	34	<0.001
P (ANOVA/MLR)			0.005	0.19		<0.001	0.005	
Occupational social class of HoH								
Non-manual	1713	133	2.2 (2.1, 2.3)	1.4 (1.3, 1.6)	<0.001	19	23	0.20
Manual	2463	150	2.1 (2.0, 2.2)	1.3 (1.2, 1.4)	<0.001	23	30	0.04
P (ANOVA/MLR)			0.14	0.23		0.004	0.20	
Region								
Scotland	494	30	1.6[a] (1.5, 1.8)	1.2 (1.0, 1.4)	0.07	33[a]	43	0.18
North	1077	71	2.1[b] (2.0, 2.2)	1.4 (1.2, 1.5)	0.001	26[b]	30	0.40
Midlands, Central South, South West & Wales	1682	92	2.5[c] (2.4, 2.7)	1.5 (1.4, 1.7)	<0.001	19[c]	18	0.99
London & South East	923	90	2.6[c] (2.5, 2.8)	1.4 (1.3, 1.6)	<0.001	14[d]	27	0.004
P (ANOVA/MLR)			<0.001	0.17		<0.001	0.06	

GM – geometric mean; CI – confidence interval; ANOVA – fully factorial analysis of variance (used for μg kg body weight^{-1} day^{-1}); MLR – multiple logistic regression (used for percentage of intakes below 1 μg kg body weight^{-1} day^{-1}); HoH – head of household (father for 1950 data; father, mother or guardian for 1990s).
* 1950 vs. 1990s comparison.
[a,b,c,d]Mean values for categories within the particular sociodemographic factor within a column with unlike superscript letters are significantly different ($P < 0.05$, Bonferroni test for μg kg body weight^{-1} day^{-1}, chi-square test for percentage of intakes below 1 μg kg body weight^{-1} day^{-1}).

the 1990s. In 1950 the percentage with low intakes was significantly different between each of the four regions, with a trend of decreasing prevalence on moving from north to south. This trend was still apparent in the 1990s but was only of borderline significance.

Food sources of phylloquinone intake

The highest contribution to dietary phylloquinone intake at both time points came from vegetables, with a significantly higher contribution from this food group in 1950 compared with the 1990s (60% vs. 48%; $P < 0.001$)

Table 5 Mean daily consumption and percentage contribution of food groups to dietary phylloquinone intake of 4-year-old children in 1950 and the 1990s

Food group	Consumption (g day^{-1}) 1950 ($n = 4411$)	Consumption (g day^{-1}) 1990s ($n = 291$)	Contribution (%) 1950 ($n = 4411$)	Contribution (%) 1990s ($n = 291$)
Cereals and cereal products*	284[c]	179	14[c]	17
of which: bread	*118[c]*	*58*	*9*	*2*
biscuits	*4[c]*	*19*	*< 0.5*	*4*
buns, cakes, pastries and fruit pies	*43[c]*	*13*	*2*	*5*
breakfast cereals	*27*	*24*	*1*	*1*
Milk and milk products	312	313	7	7
Eggs and egg dishes	32[c]	9	<0.5	<0.5
Fat spreads	20[c]	9	5[b]	6
Meat, fish and products	55[c]	85	3[c]	8
of which: meat pies and pastries	*4[a]*	*7*	*< 0.5[c]*	*2*
Vegetables and vegetable products	148[c]	125	60[c]	48
of which: leafy green vegetables	*26[c]*	*4*	*33[c]*	*15*
peas and green beans	*16[c]*	*6*	*16[c]*	*6*
potatoes and potato products	*81[a]*	*75*	*5[c]*	*18*
Fruit and nuts	36[c]	67	4[b]	6
Sugar, preserves and confectionery	21[c]	33	<0.5[c]	2
Beverages	213[c]	854	2	2
Miscellaneous (mainly comprising soups)	16[c]	33	3	4

* In addition to the subsidiary food groups listed, cereals and cereal products also comprised pasta, rice, pizza, and cereal-based and sponge-type puddings.
[a,b,c]Statistically significant difference between 1950 and 1990s ($P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively; *t*-test) for mean daily consumption and percentage contribution of food groups to dietary phylloquinone intake, respectively.

(Table 5). This was due to the contribution from leafy green vegetables (mainly comprising cabbage and lettuce) in 1950 being twice that of the 1990s. Cabbage provided 20% of dietary phylloquinone intake in 1950 compared with only 6% in the 1990s ($P < 0.001$), while the contribution from lettuce was also significantly higher (11% vs. 2%; $P < 0.001$).

Children in the 1990s obtained a significantly higher percentage of their phylloquinone intake from potatoes and potato products (mainly chips and crisps) than children in 1950 ($P < 0.001$), despite similar mean daily consumption of this food group *in toto*. Children in the 1990s also obtained significantly more phylloquinone from cereals and cereal products ($P < 0.001$), despite consumption of this food group being significantly higher in 1950. This source of phylloquinone intake was derived mainly from biscuits, cakes and pastries, whereas in 1950 the highest contribution from this food group came from bread. The contribution from meat, fish and their products was also significantly higher in the 1990s ($P < 0.001$).

Table 6 shows the percentage contribution of major food sources to dietary phylloquinone intake by sex, occupational social class of the HoH and region. In 1950 the contribution from leafy green vegetables, and other

Table 6 Percentage contribution of selected food groups to dietary phylloquinone intake of 4-year-old children in 1950 and the 1990s, by selected sociodemographic factors

	n 1950	*n* 1990s	All vegetables 1950	All vegetables 1990s	Leafy green vegetables 1950	Leafy green vegetables 1990s	Peas & beans 1950	Peas & beans 1990s	Potatoes & potato products 1950	Potatoes & potato products 1990s	All cereal products 1950	All cereal products 1990s
Sex												
Boys	2309	141	59[c]	47	32[c]	16	16[c]	6	5[c]	18	15[a]	18
Girls	2102	150	62[c]	49	35[c]	15	17[c]	7	5[c]	19	13[b]	16
P (ANOVA)			0.004	0.34	0.15	0.85	0.14	0.28	0.65	0.61	<0.001	0.20
Occupational social class of HoH												
Non-manual	1791	136	62[c]	47	35[c]	18	16[c]	5	4[c]	14	13[c]	18
Manual	2620	155	59[b]	49	32[c]	13	16[c]	7	6[c]	22	14[a]	16
P (ANOVA)			0.02	0.67	0.11	0.09	0.29	0.57	<0.001	<0.001	<0.001	0.83
Region												
Scotland	527	30	39	46	17	9	9[a]	2	8[c]	26	17	16
North	1119	74	59[b]	47	32[c]	13	15[b]	6	6[c]	18	15	17
Midlands, Central South, South West & Wales	1787	95	64[c]	51	37[c]	16	17[b]	8	5[c]	18	13[b]	17
London & South East	978	92	66[c]	46	36[c]	18	20[c]	5	4[c]	16	12[c]	17
P (ANOVA)			<0.001	0.31	<0.001	0.45	<0.001	0.01	<0.001	0.02	<0.001	0.90

HoH – head of household (father for 1950 data; father, mother or guardian for 1990s).
[a,b,c]Statistically significant difference between 1950 and 1990s for respective food groups ($P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively; fully factorial analysis of variance).

https://doi.org/10.1079/PHN2004674 Published online by Cambridge University Press

major food groups, was significantly lower in children from manual class families but only in Scotland – as indicated, once again, by a significant interaction between social class and region in the fully factorial ANOVA model. However, by the 1990s the contribution from this source did not differ significantly by region or social class. One exception remained with the percentage contribution from potatoes and potato products to phylloquinone intake being significantly higher in the manual class and in Scotland in both 1950 and the 1990s.

The contribution of soups to phylloquinone intake differed significantly by region in 1950 ($P < 0.001$), while regional differences were of borderline significance in the 1990s ($P = 0.052$). In 1950, children living in Scotland derived 16% of their phylloquinone intake from the consumption of vegetable soup compared with only 1% from soup consumption in the rest of Britain. In the 1990s, soups also contributed most to phylloquinone intake in children living in Scotland (5% vs. 1–3% for the rest of Britain) although the contribution from soups in Scotland in the 1990s was significantly lower than that of 1950 (5% vs. 16%; $P = 0.02$, ANOVA).

Discussion

The present study is the first to report phylloquinone intake in representative samples of British children aged 4 years and was made possible using newly available, UK-specific phylloquinone food content data, both published[21,22] and to a greater extent unpublished (C Bolton-Smith and M Shearer, unpublished results), for a comprehensive range of foods and drinks. The main findings were:

1. Dietary phylloquinone intakes reported for 4-year-olds were substantially higher in 1950 than in the 1990s;
2. Intakes in 1950 were lowest in children living in Scotland, particularly among those whose HoH was of manual occupational social class;
3. Significant differences in phylloquinone intake by sex, region and occupational social class of the HoH were almost non-existent in the 1990s;
4. Vegetables, particularly leafy green vegetables, were the main contributors to phylloquinone intake at both time points;
5. Fats and oils made a significantly higher contribution to phylloquinone intake in the 1990s.

At present, there is no current Reference Nutrient Intake (RNI) or Lower Reference Nutrient Intake (LRNI) for vitamin K but, based on requirements for hepatic synthesis of the vitamin K-dependent coagulation factors, $1\,\mu g\,kg$ body weight^{-1} day^{-1} is considered to be a safe and adequate intake[27]. More recently, the USA has set an AI of $55\,\mu g$ day^{-1} for children aged 4–8 years[8], which is based on representative dietary data from healthy individuals. The current AI is considerably higher than the previous Recommended Dietary Allowance of $20\,\mu g$ day^{-1} for 4- to 10-year-olds[28], and is testimony to the greater appreciation gained in the last decade of the increasing importance of phylloquinone to optimal bone health in particular.

It is not known whether the vitamin K requirement of children (provided mainly as phylloquinone) is higher than that of adults because skeletal growth requires the deposition of hydroxyapatite, which is thought to be regulated by osteocalcin. Average phylloquinone intakes of children aged 2–5 years have been reported to be $2.1\,\mu g\,kg^{-1}$ day^{-1} in the USA[8]. This is higher than that estimated for the NDNS surveys ($1.6\,\mu g\,kg^{-1}$ day^{-1}) but around one-half that estimated for children in 1950 ($3.9\,\mu g\,kg^{-1}$ day^{-1}).

When phylloquinone intakes of children in 1950 are compared with those in the 1990s there are three factors to be considered: differences in methods of dietary assessment, changes in dietary patterns and changes in food composition. In 1950 dietary records were obtained by 24-hour recall, compared with 4- and 7-day weighed records in the 1990s. Twenty-four-hour recall relies on memory. There may also be reporting errors due to parents misrepresenting their child's diet to impress the interviewer and errors in estimating portion size. However, the reliability of the mean phylloquinone intake was improved by the very large sample size[17].

Vegetable consumption, particularly that of leafy green vegetables (including cabbage, spring greens, spinach and lettuce), by 4-year-olds in 1950 was much higher than in the 1990s. It was assumed that the phylloquinone content of vegetables has not changed over the years although the estimation could not take into account differences in the varieties of leafy green vegetables that may have been eaten or food preparation practices. For example, summer cabbage, which has a higher proportion of dark green leaves, would have predominated in diet records collected mainly in June and July. Moreover, it is unlikely that, at a time of food shortages, any outer leaves would have been discarded so a phylloquinone value at the higher end of the spectrum was chosen (C Bolton-Smith and M Shearer, unpublished results).

In 1950 vegetables were the main contributor to dietary phylloquinone intake. However, the higher contribution to phylloquinone intake from potatoes and their products in the 1990s does not reflect a higher consumption of potatoes but the consumption of potato products (e.g. chips and crisps) prepared with phylloquinone-rich vegetable oils. Bread also made a substantial contribution to phylloquinone intake in 1950. Not only was bread almost universally consumed but it was all made, by law, with 'national flour' of high extraction rate (85%) and higher phylloquinone content than that present in bread made with white flour (72% extraction rate). Children in the 1990s consumed much less bread and it was predominantly made from lower extraction flour[24,25]. Children in 1950 also consumed more spreading fats in conjunction with their higher consumption of bread[17]. Again it is assumed that the composition of butter has not changed. However, the phylloquinone content of margarine in 1950, composed of oils from groundnuts, coconut, palm and whale, was estimated to be 5.3 μg per 100 g compared with 12–78 μg per 100 g for blended margarines and fat spreads of the 1990s. Those spreading fats with a high content of rapeseed or soyabean oils are at the upper end of this spectrum. The phylloquinone content of cakes, biscuits and pastries reflects their content of fat since their other ingredients are not rich sources of phylloquinone. In 1950 food was fried in animal fat, lard or beef dripping, all comparatively low in phylloquinone. By the 1990s, vegetable oils were mainly used for frying and in the preparation of potato products such as crisps and other snack foods. During this period one-half of all the edible oil used in the UK was rapeseed oil, with one of the highest phylloquinone contents of all oils[21,29]. As a result of these changes in food composition, there has been a change in the sources of phylloquinone. If it is considered that the phylloquinone from cakes, biscuits and pastries, meat and fish dishes, and potato products originates predominantly from the fat in those foods, children in 1950 derived around 15% of their phylloquinone intake from fats and oil sources and 55% from vegetables (excluding potatoes) compared with 35% from fats and oils and 30% from vegetables in the 1990s.

There is some uncertainty about the bioavailability of phylloquinone from different sources. It has been reported that phylloquinone from oils or from vegetables cooked in oils was better absorbed[30,31], although this has not been reported by all[32]. If this is so, then the 1990s children may have achieved better phylloquinone status on a lower intake, although this was not assessed in the two contemporary surveys or in 1950.

Socio-economic differences in the intake of other nutrients by children in 1950 have been reported previously[33]. It was shown that children from the families of manual workers had significantly lower intakes of vitamin C and β-carotene, which was related to a lower consumption of fruit and vegetables. This included not only exotic, imported fruit of which the supply was very restricted but also the local seasonal vegetables such as cabbage and lettuce. This was reflected in the lower phylloquinone intake of the children from manual class families.

The lower dietary phylloquinone intake in Scotland in 1950 is in accordance with the finding that the Scottish diet was different in many respects to that in the rest of Great Britain. Vegetables were consumed less frequently but Scotland also had the lowest consumption frequency of fried foods, spreading fats and cakes. Despite this, these sources of phylloquinone were relatively more important in Scotland in the comparative absence of vegetable sources. A study of phylloquinone intakes in Great Britain among the present-day elderly found that there were clear regional differences, with the lowest intakes in Scotland – again attributable to lower consumption of leafy green vegetables[11]. However, these regional differences were reduced in the children of the 1990s, as intakes in all regions became closer to those found in Scotland. In terms of bone health, children in Scotland would be doubly disadvantaged because vitamin D synthesis in the skin from sunlight is much reduced in northern latitudes[34].

The low levels of vegetable consumption by children in Scotland are still of concern[35]. Evidence from adults who participated in the Scottish Heart Health Study[36] suggested that classical risk factors could not completely explain the Scottish situation with regard to cardiovascular disease, and that factors such as inadequate consumption of fruit and vegetables may possibly play a role. The antioxidant content of these foods was highlighted but the relative inadequacy of phylloquinone intake in Scotland may also be one of several factors (both dietary and non-dietary) contributing to the high prevalence of cardiovascular disease[37].

The lower intake of phylloquinone reported in children of the 1990s poses the question as to whether vitamin K adequacy is achieved by the modern diet. However, this cannot be answered without knowing more about the relative bioavailability of phylloquinone from different food sources. The results presented here do not take into account any possible contribution to total vitamin K intake from menaquinones, but as they are present in relatively few foods they are unlikely to make a substantial difference, particularly to the diets of children. With phylloquinone intake indicating the consumption level of (leafy) green vegetables, there is no doubt that children in the 1990s consumed substantially less than children in 1950. Vegetable consumption has also been related to bone health for reasons other than its phylloquinone content[38]. Even though children in the 1990s were obtaining more phylloquinone from fats and oils, the relatively low contribution of vegetables to phylloquinone intake in this sample should be a cause for concern; as should the finding that their diets are as low in phylloquinone as those of Scottish children in 1950. The long-term health outcome of the children born in 1946 is being measured in terms of both bone and cardiovascular health outcomes[39,40]. The results should provide an insight into the present and future health of both the 1946 cohort and of those children who are growing up today.

Acknowledgements

The National Survey of Health and Development (NSHD) is funded by the Medical Research Council (MRC). The National Diet and Nutrition Survey (NDNS) of children aged 1.5 to 4.5 years and the NDNS of young people aged 4 to 18 years were commissioned and funded jointly by the Ministry of Agriculture, Fisheries and Food and the Department of Health. Responsibility for the NDNS programme transferred to the Food Standards Agency on its establishment in April 2000. The surveys were conducted by the Social Survey Division of the Office for National Statistics in conjunction with the Micronutrient Status Research Section, formerly part of the MRC Dunn Nutrition Unit and now part of MRC Human Nutrition Research. We gratefully acknowledge the UK Data Archive, University of Essex, Colchester for providing electronic copies of the datasets for the NDNS and for granting permission for their further analyses. We also thank Dr Caroline Bolton-Smith and Dr Martin Shearer for allowing us to use their unpublished database of phylloquinone content of foods.

References

1 Shearer MJ. Role of vitamin K and Gla proteins in the pathophysiology of osteoporosis and vascular calcification. *Current Opinion in Clinical Nutrition and Metabolic Care* 2000; **3**: 433–8.
2 Schurgers LJ, Dissel PE, Spronk HM, Soute BA, Dhore CR, Cleutjens JP, *et al*. Role of vitamin K and vitamin K-dependent proteins in vascular calcification. *Zeitschrift für Kardiologie* 2001; **90**(Suppl. 3): 57–63.
3 Schurgers LJ, Geleijnse JM, Grobbee DE, Pols HAP, Hofman A, Witteman JCM, *et al*. Nutritional intake of vitamins K_1 (phylloquinone) and K_2 (menaquinone) in the Netherlands. *Journal of Nutritional and Environmental Medicine* 1999; **9**: 115–22.
4 Booth SL, Webb R, Peters JC. Assessment of phylloquinone and dihydrophylloquinone dietary intakes among a nationally representative sample of US consumers using 14-day food diaries. *Journal of the American Dietetic Association* 1999; **99**: 1072–6.
5 Cooper C, Eriksson JG, Forsen T, Osmond C, Tuomilehto J, Barker DJ. Maternal height, childhood growth and risk of hip fracture in later life: a longitudinal study. *Osteoporosis International* 2001; **12**: 623–9.
6 Stary H. Macrophages, macrophage foam cells, and eccentric intimal thickening in the coronary arteries of young children. *Atherosclerosis* 1987; **64**: 91–108.
7 Booth SL, Pennington JAT, Sadowski JA. 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* 1996; **96**: 149–54.
8 Institute of Medicine. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: National Academy Press, 2001.
9 Price R, Fenton S, Shearer MJ, Bolton-Smith C. Daily and seasonal variation in phylloquinone (vitamin K_1) intake in Scotland. *Proceedings of the Nutrition Society* 1996; **55**: 244A.
10 Bolton-Smith C, Price RJG, Shearer MJ. Decreasing phylloquinone (vitamin K_1) and total fat intake in a 10-year longitudinal study of Scottish adults. *Proceedings of the Nutrition Society* 2000; **59**: 24A.
11 Thane CW, Paul AA, Bates CJ, Bolton-Smith C, Prentice A, Shearer MJ. Intake and sources of phylloquinone (vitamin K_1): variation with socio-demographic and lifestyle factors in a national sample of British elderly people. *British Journal of Nutrition* 2002; **87**: 605–13.
12 Prynne CJ, Paul AA, Greenberg DC, Bolton-Smith C, Stear SJ, Jones SC, *et al*. Dietary intake and sources of phylloquinone (vitamin K_1) of a sample of adolescents in Cambridge, UK. *Proceedings of the Nutrition Society* 2001; **60**: 208A.
13 Thane CW, Prynne CJ, Ginty F, Bolton-Smith C, Stear SJ, Jones SC, *et al*. Dietary phylloquinone (vitamin K_1) intake: comparison between adolescents living in Cambridge and a national British sample. *Proceedings of the Nutrition Society* 2002; **61**: 146A.
14 Mora S, Gilsanz V. Establishment of peak bone mass. *Endocrinology and Metabolism Clinics of North America* 2003; **32**: 39–63.
15 Zipursky A. Prevention of vitamin K deficiency bleeding in newborns. *British Journal of Haematology* 1999; **104**: 430–7.
16 Rashid M, Durie P, Andrew M, Kalnins D, Shin J, Corey M, *et al*. Prevalence of vitamin K deficiency in cystic fibrosis. *American Journal of Clinical Nutrition* 1999; **70**: 378–82.
17 Prynne CJ, Paul AA, Price GM, Day KC, Hilder WS, Wadsworth MEJ. Food and nutrient intake of a national sample of 4-year-old children in 1950: comparison with the 1990s. *Public Health Nutrition* 1999; **2**: 537–47.
18 Price GM, Paul AA, Key FB, Harter A, Cole T, Day K, *et al*. Measurement of diet in a large national survey: comparison of computerised and manual coding in household measures. *Journal of Human Nutrition and Dietetics* 1995; **8**: 417–28.
19 Paul AA, Southgate DAT. *McCance & Widdowson's The Composition of Foods*, 4th ed. London: HMSO, 1978.
20 Ministry of Health. *The Feeding of Young Children from One to Five*. London: HMSO, 1949.
21 Bolton-Smith C, Price RJG, Fenton ST, Harrington DJ, Shearer MJ. Compilation of a provisional UK database for the phylloquinone (vitamin K_1) content of foods. *British Journal of Nutrition* 2000; **83**: 389–99.
22 Food Standards Agency. *McCance & Widdowson's The Composition of Foods*, 6th summary ed. Cambridge: Royal Society of Chemistry, 2002.
23 Ward R. The vitamin E content of margarine. *British Journal of Nutrition* 1958; **12**: 231–6.
24 Gregory JR, Collins DL, Davies PSW, Hughes JM, Clarke PC. *National Diet and Nutrition Survey: Children aged 1½ to 4½ years. Vol. 1: Report of the Diet and Nutrition Survey*. London: HMSO, 1995.
25 Gregory J, Lowe S, Bates CJ, Prentice A, Jackson LV, Smithers G, *et al. National Diet and Nutrition Survey: Young people aged 4 to 18 years. Vol. 1: Report of the Diet and Nutrition Survey*. London: The Stationery Office, 2000.
26 Great Britain Office of Population Censuses and Surveys. *Standard Occupational Classification, Vol. 3: Social Classifications and Coding Methodology*. London: HMSO, 1991.
27 Department of Health. *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom*. Report on Health and Social Subjects No. 41. London: HMSO, 1991.
28 Food and Nutrition Board. *Recommended Dietary Allowances*, 10th ed. Washington, DC: National Academy Press, 1989.
29 Food and Agriculture Organization of the United Nations. *Food Balance Sheets*. Available at www.fao.org.
30 Gijsbers BLM, Jie K-SG, Vermeer C. Effect of food composition on vitamin K absorption in human volunteers. *British Journal of Nutrition* 1996; **76**: 223–9.
31 Garber AK, Binkley NC, Krueger DC, Suttie JW. Comparison of phylloquinone bioavailability from food sources or a supplement in human subjects. *Journal of Nutrition* 1999; **129**: 1201–3.
32 Booth SL, O'Brien-Morse ME, Dallal GE, Davidson KW, Gundberg CM. 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* 1999; **70**: 368–77.
33 Prynne CJ, Paul AA, Mishra GD, Hardy RJ, Bolton-Smith C, Wadsworth MEJ. Sociodemographic inequalities in the diet

of young children in the 1946 British birth cohort. *Public Health Nutrition* 2002; **5**: 733–45.

34 Davies PSW, Bates CJ, Cole TJ, Prentice A, Clarke PC. Vitamin D: seasonal and regional differences in preschool children in Great Britain. *European Journal of Clinical Nutrition* 1999; **53**: 195–8.

35 Baxter I, Schroder M. Vegetable consumption among Scottish children: a review of the determinants and proposed strategies to overcome low consumption. *British Food Journal* 1997; **99**: 380–7.

36 Todd S, Woodward M, Tunstall-Pedoe H, Bolton-Smith C. Dietary antioxidant vitamin and fibre in the etiology of cardiovascular disease and all-causes mortality: results from the Scottish Heart Health Study. *American Journal of Epidemiology* 1999; **150**: 1073–80.

37 Department of Health. *Coronary Heart Disease in Scotland. Report of a Policy Review*. Edinburgh: The Scottish Office/Department of Health, 1996.

38 New SA. Intake of fruit and vegetables: implications for bone health. *Proceedings of the Nutrition Society* 2003; **62**: 889–99.

39 Hardy RJ, Wadsworth MEJ, Langenberg C, Kuh D. Birth weight, childhood growth and blood pressure at 43 years in a British birth cohort. *International Journal of Epidemiology* 2003; **33**: 1–9.

40 Aihie Sayer A, Poole J, Cox V, Kuh D, Hardy R, Wadsworth MEJ, *et al*. Weight from birth to 53 years; a longitudinal study of the influence on clinical hand osteoarthritis. *Arthritis & Rheumatism* 2003; **48**: 1030–3.