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An estimate of phytate intake and molar ratio of phytate to zinc in the diet of the people in the United Kingdom

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Abstract

Objective: To estimate the phytate intake and molar ratio of phytate to zinc in the diet of the people in the United Kingdom.
Design: Tables of the phytate content of foods were developed from twenty-eight published and unpublished studies. They were then applied to the nutrient databank of the National Diet and Nutrition Survey (NDNS). The study is a retrospective analysis of data on daily consumption of foods and drinks from the NDNS of children, adolescents, adults and the elderly based on 4–7 d weighed intakes.
Subjects: A total of 6786 British participants aged 1·5 years and above, who participated in the NDNS, 1992–2001.
Setting: England, Scotland and Wales.
Results: The median daily intakes of phytate for children, adolescents, adults and the elderly population were 496, 615, 809 and 629 mg/d, respectively. Although there were differences in phytate intakes between men and women, and for children, adolescents and elderly populations, after adjusting for differences in energy intake, there was no significant variation. The median phytate-to-zinc molar ratios for children, adolescents, adults and the elderly population were 11·8, 10·4, 9·7 and 8·7, respectively. Overall, the main sources of phytate were cereal and cereal products (e.g. breakfast cereals and breads), vegetables, potatoes and savoury snacks (e.g. chips and crisps), hot drinks and miscellaneous foods (e.g. commercial toddler foods and drinks, chocolate and soups), fruits and nuts.
Conclusions: The present study estimated the dietary intake of phytate and the phytate-to-zinc molar ratio of the diet of the UK population, which can be used for estimating the average requirement of zinc. Further research should focus on the completion and validation of the tables of phytate content of UK foods, to assess (and if necessary improve) the accuracy and precision of these findings.

Keywords
Phytate
Phytate-to-zinc molar ratio
Diet
The United Kingdom

To estimate the average zinc requirement, it is necessary to have an estimate of the physiologic zinc requirement together with an estimate of the proportion of zinc absorbed. The models of zinc absorption[1,2] predict the proportion of zinc absorption from the dietary intake of zinc and phytate. The extent to which phytate affects the absorption of zinc in the UK diet has been difficult to estimate because information on the phytate content of foods consumed in the United Kingdom has not been readily available.

There are many studies on the phytate content of various foods but these studies do not constitute an extensive database on the phytate content of foods. The development of such a database is difficult for several reasons.

First, there is no universally accepted method to assess the phytate content of foods. Large differences were found in direct comparisons of results obtained from a variety of methods; therefore, a large variation in the content of phytate has been reported[2,3]. Second, many factors such as growing conditions, maturity, type of soil, variety and mill fraction of grain, genetics, environmental changes, location, irrigation, year and application of fertilisers can affect the phytate content of foods[4,5], adding to the variability in the reported values. Finally, conducting a food survey that includes a representative sampling from all food groups is technically difficult.

In the United Kingdom, there have been very few and inconclusive data on the phytate content of the foods consumed[6–11], and data on the phytate intake of the UK population are scarce. The dietary intake of phytate and its meal distribution pattern were assessed in seventy-six students and staff at the Robert Gordon Institute of Technology[12]. Findings of that study cannot be generalised to the UK population because the study was conducted on a very limited number of participants more than 20 years ago. Dietary phytate intake of the UK

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population was also commented on in 1982, although details of the investigation were not published[13].

Thus, the aims of the present study were to: (i) generate a database on the phytate content of foods consumed in the United Kingdom; (ii) apply the database to the data of the National Diet and Nutrition Survey (NDNS) to evaluate the phytate intake of the UK population and to determine the variations associated with gender and age groups; and (iii) evaluate the dietary phytate-to-zinc molar ratio of the population and estimate the representative values for gender and age groups to be used for the calculation of zinc absorption. This will ultimately allow the revision of the Estimated Average Requirement of zinc for the population.

Materials and methods

Selection of data

This investigation was a retrospective study among the British population based on the data obtained in the NDNS programme. The four most recent surveys of the NDNS (i.e. children aged 1·5–4·5 years, young people aged 4–18 years, adults aged 19–64 years and people aged 65 years and above) were used. The design and sampling procedure of these surveys are described in the survey reports[14–21].

Phytate content of foods

Data on the phytate content of different foods are not available in the UK food composition tables[22]. Phytate values were therefore derived from published[3–5,7–11,23–35] and unpublished[6,36,37] data. As these values were to be used for analysing NDNS data, the tables were produced to reflect the food types and food groups used for the dietary assessments in the NDNS.

Foods were divided into twelve main food types including (i) cereal and cereal products, (ii) milk and milk products, (iii) eggs and egg dishes, (iv) fat spreads, (v) meat and meat products, (vi) fish and fish dishes, (vii) vegetables, potatoes and savoury snacks, (viii) fruit and nuts, (ix) sugar, preserves and confectionery, (x) total drinks, (xi) miscellaneous and (xii) dietary supplements and artificial sweeteners.

Each of the food types consisted of one or more food groups expressed as integers (e.g. 1 = main group of pasta, rice and other miscellaneous cereals). Foods consumed in the United Kingdom were classified into fifty-seven main groups. Food groups were then divided to 115 subsidiary groups that were expressed as integers with an alphabetical suffix (e.g. 1A = subsidiary food group of pasta).

A total of 300 foods commonly consumed in the United Kingdom were selected and numbered as examples of foods within the subsidiary food groups. Each of these foods was allocated to one of the 115 subsidiary food groups (e.g. 1A1 = noodles, dry form was allocated to subsidiary food group of 1A; pasta). The phytate content of these foods was then estimated from the published and unpublished data. These values in turn were aggregated into the phytate values for subsidiary food groups.

The phytate content of foods in the literature was usually a mean value from a number of different samples and studies; hence, there was considerable variability associated with most values. In these cases, the range of the values in the literature was mentioned, citing the references. However, the values were aggregated to a single value on the phytate content of the subsidiary food group.

A number of factors were considered when collating phytate content of the various sources. First, the data source and its applicability to UK foods were taken into account, and second, the analytical sample numbers and an analytical method were used. When there was insufficient information for evaluating the suitability of the phytate values, the mean of the values was used after excluding the obvious outliers. If there was doubt regarding specific foods, advice was sought from the researcher of the original investigation. This was the approach used in the development and modification of the meal-based intake assessment tool (MBIAT) software[38] in the Institute of Food Research (Norwich, UK) and endorsed by the experts in the field[36].

Table 1 is an example of estimates of the phytate content of foods for nuts and seeds. A complete table of the phytate content of subsidiary food groups, with examples of the phytate values of the foods included in each subsidiary food group, is available from the authors. Figure 1 illustrates the process used to estimate the phytate content of foods and the phytate intake of the individuals.

Phytate intake of the individuals

Information on the amount of subsidiary foods consumed over a 4 or 7 d period is available for the participants who completed food diaries during the NDNS. The phytate values of the subsidiary food groups were added to the nutrient databank of the NDNS and the estimated phytate intake from these groups was then calculated.

Total phytate intake from the main food groups was then calculated by aggregating the phytate intake of the related subgroups. The phytate intake from all foods was then aggregated and divided by the number of days that the food diaries were recorded. This generated the estimated average daily phytate intake of the individuals.

Statistical analysis

Normal probability plots, $Z_{Skewness}$ and $Z_{Kurtosis}$, Kolmogorov–Smirnov and Shapiro–Wilk tests were used to investigate whether variables followed a normal distribution. The mean, median and quartile ranges were used to express

Table 1 Estimates of phytate content of nuts and seeds

n	Code	Food	Phytate (mg/100 g)
56			
	56R	Nuts and seeds	850
	Includes fruit and nut mixes, salted peanuts, peanut butter, tahini, Bombay mix		
223	56R1	Peanuts (roasted)	680–2008[9,23,28,33]
224	56R2	Peanuts and raisins	440[9]
225	56R3	Peanut butter	443–1252[26,28,36]
226	56R4	Almonds	970–2111[9,24,25,28,33]
227	56R5	Cashews (roasted)	937–1229[9,24,25,28,33]
228	56R6	Macadamia nuts	290–340[9,33]
229	56R7	Walnuts	580–1977[9,24,25,33]
230	56R8	Brazil nuts	1320–1799[9,24,25]
231	56R9	Chestnuts	10–47[9,24,25]
232	56R10	Pistachio nuts	340[9]
233	56R11	Bombay mix	577[36]
234	56R12	Sunflower seeds	3000[9]
235	56R13	Sesame seeds	1380[9]

Table shows the phytate content of main and subsidiary food groups in nuts and seeds. Food groups are divided into food types (i.e. fruit and nuts), food groups (i.e. 56: nuts and seeds) and subsidiary food groups (i.e. 56R: nuts and seeds).

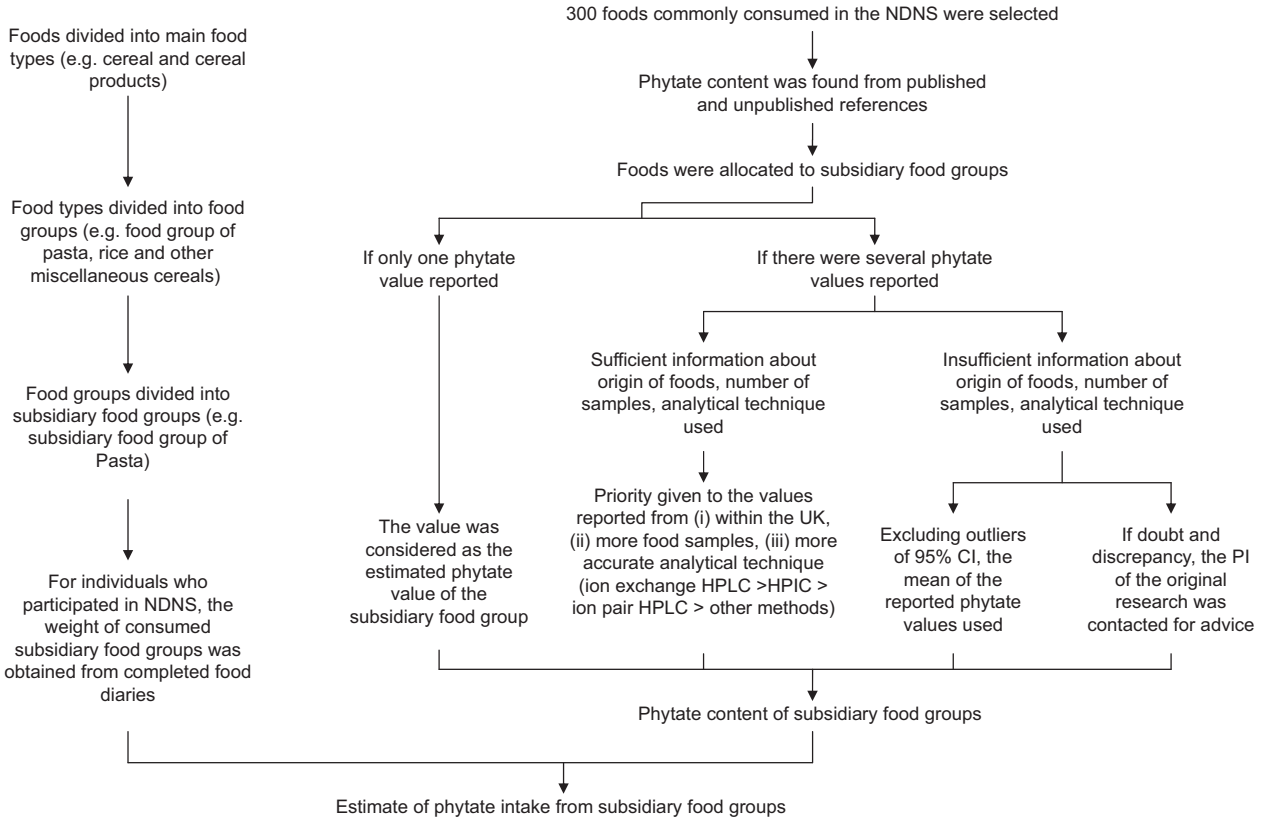

Fig. 1 The process used to estimate phytate intake from the subsidiary food groups (NDNS, National Diet and Nutrition Survey; HPIC, high-performance ion chromatography; PI, principal investigator)

the dietary intake of phytate and the molar ratio of phytate to zinc, as these variables were not normally distributed.

To eliminate any difference owing to energy intake between genders and age groups, the phytate intake was also expressed as density per 4184 kJ (1000 kcal) energy intake. The phytate-to-zinc molar ratio for the diets of the individuals was calculated as follows[2,39]:

$$\text{Phytate-to-zinc molar ratio} = \frac{\text{Phytate (mg)}/660}{\text{Zinc (mg)}/65{\cdot}4}$$

The non-parametric Mann–Whitney and Kruskal–Wallis (with *post hoc* comparison based on Benferroni correction) tests were used to compare the differences between

gender and age groups. For all non-parametric tests, the *P* value of the Monte Carlo two-tailed exact significance was reported based on the number of samples and a 95% CI. All statistical analyses were conducted with the Statistical Package for the Social Sciences statistical software package version 14·0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Phytate intake in children aged 1·5–4·5 years

The median daily intake of phytate for boys in the survey was 509 mg, and for girls it was significantly lower at 481 mg ($P < 0·05$). No variation in phytate intake between boys and girls was found after adjusting for differences in energy intake ($P > 0·05$).

The median phytate intake slightly increased with age, being lowest for children aged 1·5–2·5 years (464 mg) and highest for children aged 3·5–4·5 years (510 mg, $P < 0·05$). Phytate intake decreased with age when differences in energy intake were taken into account, falling from 453·9 mg/4184 kJ (1000 kcal) for the youngest age group to 426·7 mg/4184 kJ (1000 kcal) for the oldest age group ($P < 0·05$).

Overall, the median molar ratio of phytate to zinc was 11·84. There were no significant gender and age differences in the phytate-to-zinc molar ratios of children ($P > 0·05$). The mean, median and quartiles of phytate intake, phytate density and molar ratio of phytate to zinc are presented in Table 2.

In children aged 1·5–4·5 years, the main sources of phytate were cereal and cereal products (e.g. whole-grain and high-fibre breakfast cereals, biscuits, breads and pasta), miscellaneous foods (e.g. commercial toddler foods and drinks, beverages and soups) and vegetables, potatoes and savoury snacks (e.g. chips, crisps and savoury snacks, baked beans and potato salads and dishes).

Phytate intake in young people aged 4–18 years

The median daily intake of phytate was 674 mg for boys, whereas in girls this was significantly lower at 566 mg ($P < 0·001$). After allowing for variation in the intake of energy, the median intake of phytate per 4184 kJ (1000 kcal) energy in boys was not significantly different from girls (365·4 mg/4184 kJ (1000 kcal) *v.* 362·5 mg/4184 kJ (1000 kcal), $P > 0·05$).

The median daily phytate intake increased with age for boys from 576 mg for participants aged 4–6 years to 780 mg for 15- to 18-year-olds ($P < 0·001$). For girls, there was a similar increase with age only among girls aged less than 15 years. The median daily phytate intake increased from 494 mg among girls aged 4–6 years to 574 mg among 11- to 14-year-olds ($P < 0·001$).

After allowing for variations in intake of energy, the median intakes of phytate per 4184 kJ (1000 kcal) energy for boys and girls were not significantly different among the different age groups ($P > 0·05$).

The median molar ratio of phytate to zinc was 10·35. No variation in the phytate-to-zinc molar ratio was observed between boys and girls. The age-related difference in the median values of phytate-to-zinc molar ratio was significant only in boys, with the oldest group of boys having a significantly lower phytate-to-zinc molar ratio compared to those aged 4–6 years ($P < 0·001$), 7–10 years ($P < 0·001$) and 11–14 years ($P < 0·01$).

The mean, median and quartiles of phytate intake, phytate density and phytate-to-zinc molar ratios are presented in Table 3.

More than half of the phytate intake came from the consumption of cereal and cereal products (e.g. whole-grain and high-fibre breakfast cereals, white breads, biscuits, rice and pasta). Over a quarter of phytate intake came from vegetables, potatoes and savoury snacks. A further 9% of the phytate intake came from miscellaneous food types (mostly beverages such as chocolate, cocoa, etc.) followed by a 5% contribution from fruit and nuts (mainly from apples and pears followed by nuts and seeds).

Phytate intake in adults aged 19–64 years

The median daily phytate intake was 886 mg for men, and significantly lower for women (754 mg, $P < 0·001$). In both

Table 2 The mean, median and quartiles of the phytate intake, phytate density and molar ratio of phytate to zinc in children aged 1·5–4·5 years

		Phytate intake (mg/d)				Phytate density (mg/1000 kcal)*				Phytate-to-zinc molar ratio			
				Quartiles				Quartiles				Quartiles	
Gender and age groups	Base (*n*)	Mean	Median	P25	P75	Mean	Median	P25	P75	Mean	Median	P25	P75
Boys aged 1·5–2·5 years	298	601	465	353	733	570·4	449·2	334·0	706·2	14·13	11·50	8·08	17·37
Boys aged 2·5–3·5 years	300	636	515	408	718	536·9	443·4	337·2	591·1	14·77	12·41	9·47	16·92
Boys aged 3·5–4·5 years	250	605	526	406	725	474·4	428·8	323·4	550·3	13·36	11·84	9·03	15·83
All boys	848	615	509	379	724	530·2	440·2	333·0	595·9	14·13	11·94	8·92	16·92
Girls aged 1·5–2·5 years	278	615	463	332	695	616·5	461·7	313·5	690·3	15·39	11·90	8·10	17·18
Girls aged 2·5–3·5 years	306	577	483	337	688	510·0	429·3	332·9	614·0	13·74	11·90	8·94	15·78
Girls aged 3·5–4·5 years	243	566	497	379	680	486·8	426·7	328·7	603·4	13·25	11·58	9·10	16·27
All girls	827	587	481	347	687	539·0	435·5	329·5	626·0	14·15	11·78	8·76	16·40
All boys and girls	1675	601	496	368	707	534·6	439·1	331·5	616·5	14·14	11·84	8·85	16·56

*1 kcal = 4·184 kJ.

Table 3 The mean, median and quartiles of the phytate intake, phytate density and molar ratio of phytate to zinc in young people aged 4–18 years

		Phytate intake (mg/d)				Phytate density (mg/1000 kcal)*				Phytate-to-zinc molar ratio			
				Quartiles				Quartiles				Quartiles	
Gender and age groups	Base (*n*)	Mean	Median	P25	P75	Mean	Median	P25	P75	Mean	Median	P25	P75
Boys aged 4–6 years	184	640	576	435	770	418·7	382·3	310·1	473·3	11·57	10·90	8·99	13·08
Boys aged 7–10 years	256	733	627	519	831	414·0	365·8	303·7	455·9	11·94	10·61	9·08	13·50
Boys aged 11–14 years	237	792	714	540	929	402·4	369·7	294·0	463·0	11·08	10·39	8·15	13·10
Boys aged 15–18 years	179	855	780	616	1010	383·1	351·6	295·3	437·3	9·84	9·34	7·26	11·79
All boys	856	755	674	521	885	405·3	365·4	301·8	456·9	11·18	10·32	8·41	13·03
Girls aged 4–6 years	172	564	494	369	657	406·1	363·5	290·0	463·1	11·57	10·54	8·39	13·50
Girls aged 7–10 years	225	644	566	461	740	402·1	354·2	292·8	460·3	11·30	10·02	8·42	12·90
Girls aged 11–14 years	238	657	594	480	789	393·5	365·5	309·8	453·2	11·05	10·60	8·25	12·76
Girls aged 15–18 years	210	674	574	459	829	421·2	372·5	297·5	478·7	11·21	10·19	7·90	13·91
All girls	845	639	566	448	761	405·2	362·5	298·0	463·7	11·26	10·36	8·30	13·17
All boys and girls	1701	697	615	480	831	405·3	364·6	300·1	459·4	11·22	10·35	8·35	13·07

*1 kcal = 4·184 kJ.

men and women, the youngest age groups had significantly lower phytate intake compared with older age groups. This difference was associated with different energy intake between the age groups; however, even after adjustment for variation in energy intake, the youngest groups in both genders still had a significantly lower intake of phytate per 4184 kJ (1000 kcal) energy ($P < 0{\cdot}001$).

The median molar ratio of phytate to zinc was 8·82 for men, and significantly higher for women at 10·28 ($P < 0{\cdot}01$). For men, there were no significant differences by age in the phytate-to-zinc molar ratios.

Women in the youngest age group had a significantly lower phytate-to-zinc molar ratio than women in any other age group (35–49 years: $P < 0{\cdot}05$, all others $P < 0{\cdot}01$). The mean, median and quartiles of the phytate intake, phytate density and phytate-to-zinc molar ratios are presented in Table 4.

The main source of phytate for the respondents of the survey was from cereal and cereal products, contributing approximately half of the average phytate intake. Vegetables, potatoes and savoury snacks contributed more than quarter of the average daily phytate intake. Within this group, the main contributors were potatoes, potato salads and dishes, baked beans, vegetables (not raw) and chips. Total drinks (including coffee, tea and fruit juice), miscellaneous foods (including beverages and soups) and fruits and nuts provided a further 8 %, 7 % and 6 % of average daily phytate intake, respectively.

Phytate intake in people aged 65 years and above

The median daily intake of phytate for men was 727 mg, and for women it was significantly lower at 572 mg ($P < 0{\cdot}001$). This gender difference was largely associated with the difference in energy intake between the genders, as adjusting for this variation resulted in no significant difference in phytate intake per 4184 kJ (1000 kcal) energy intake. No variation in phytate intake and density was found between the different age groups of men and women.

The median molar ratio of phytate to zinc was 8·70. There were no significant differences in the phytate-to-zinc molar ratios between men and women or among different age groups. The mean, median and quartiles of the phytate intake, phytate density and phytate-to-zinc molar ratios are presented in Table 5.

The average intake of phytate (60 %) came from the consumption of cereal and cereal products. Breakfast cereals, breads, biscuits and buns, cakes and pastries were the main contributors within this group.

Vegetables, potatoes and savoury snacks (mainly potatoes, potato salads and dishes, chips, boiled vegetables and baked beans) contributed 23 % of the average daily phytate intake. Fruit and nuts contributed a further 5 % to the average daily intake of phytate (mainly apples and pears, followed by other fruits including plums, grapes and apricots, which were either raw, stewed, dried or in the form of fruit salads). Table 6 shows

Table 4 The mean, median and quartiles of the phytate intake, phytate density and molar ratio of phytate to zinc in adults aged 19–64 years

		Phytate intake (mg/d)				Phytate density (mg/1000 kcal)*				Phytate-to-zinc molar ratio			
				Quartiles				Quartiles				Quartiles	
Gender and age groups	Base (*n*)	Mean	Median	P25	P75	Mean	Median	P25	P75	Mean	Median	P25	P75
Males aged 19–24 years	108	817	762	565	940	404·7	365·7	303·0	421·7	9·23	8·21	6·82	10·30
Males aged 25–34 years	219	1010	904	659	1132	474·9	432·8	357·5	527·9	9·76	9·11	7·31	11·47
Males aged 35–49 years	253	993	903	670	1262	465·1	430·5	326·8	555·5	9·57	8·80	6·58	11·65
Males aged 50–64 years	253	1094	948	679	1314	522·5	449·7	357·7	607·3	10·48	9·27	7·24	12·23
All males	833	1005	886	657	1178	477·2	419·1	335·7	545·5	9·85	8·82	7·02	11·43
Females aged 19–24 years	104	650	645	438	790	420·5	398·9	320·6	502·2	9·70	9·28	7·00	12·11
Females aged 25–34 years	210	756	714	486	910	510·2	473·9	370·7	589·0	11·17	10·50	8·20	13·23
Females aged 35–49 years	318	868	792	568	1071	556·8	505·4	382·7	668·6	11·63	10·27	8·00	14·03
Females aged 50–64 years	259	928	807	599	1138	605·9	522·9	401·5	706·7	11·86	10·51	8·26	13·82
All females	891	834	754	546	1013	544·1	482·0	371·5	652·2	11·36	10·28	7·97	13·59
All males and females	1724	917	809	595	1100	511·8	452·0	353·6	601·3	10·63	9·66	7·47	12·55

*1 kcal = 4·184 kJ.

Table 5 The mean, median and quartiles of the phytate intake, phytate density and molar ratio of phytate to zinc in adults aged 65 years and above

		Phytate intake (mg/d)				Phytate density (mg/1000 kcal)*				Phytate-to-zinc molar ratio			
				Quartiles				Quartiles				Quartiles	
Gender and age groups	Base (*n*)	Mean	Median	P25	P75	Mean	Median	P25	P75	Mean	Median	P25	P75
Males aged 65–74 years	371	891	733	509	1112	455·4	386·0	267·7	549·2	9·69	8·70	6·26	11·50
Males aged 75–84 years	200	938	692	453	1145	504·4	378·5	264·5	582·3	10·96	8·78	6·32	12·58
Males aged 85 years and above	62	1059	779	496	1419	569·1	411·4	286·8	827·5	12·67	8·97	7·13	17·94
All males	633	923	727	495	1131	482·1	386·0	267·9	571·3	10·38	8·72	6·35	12·08
Females aged 65–74 years	434	693	630	426	849	476·8	434·9	310·5	570·4	9·70	8·93	6·43	11·26
Females aged 75–84 years	368	674	549	392	777	466·3	368·8	284·7	574·4	9·72	8·50	6·25	10·91
Females aged 85 years and above	251	712	538	416	772	467·2	336·8	271·4	518·5	10·62	8·40	6·90	11·62
All females	1054	690	572	416	813	470·8	387·8	285·6	556·4	9·93	8·65	6·48	11·07
All males and females	1687	778	629	434	915	475·1	386·9	277·6	557·8	10·10	8·70	6·42	11·44

*1 kcal = 4·184 kJ.

Table 6 Percentage contribution of food types to average daily phytate intake of children aged 1·5–4·5 years, young people aged 4–18 years, adults aged 19–64 years and adults aged 65 years and above

	Children aged 1·5–4·5 years	Young people aged 4–18 years	Adults aged 19–64 years	Adults aged 65 years and above
Food types	%	%	%	%
Cereal and cereal products	45	52	49	60
Vegetables, potatoes and savoury snacks	20	27	26	23
Meat and meat products	1	1	2	1
Egg and egg dishes	1	0	0	0
Fruits and nuts	4	5	6	5
Sugar, preserves and confectionary	4	4	2	1
Total drinks	0	2	8	5
Miscellaneous	25	9	7	5

the contribution of food types (by percentage) to the average daily phytate intake of the UK population.

Discussion

Tables of phytate content and their limitations

The tables on the phytate content of foods were extrapolated from published and unpublished data. Inaccuracies could have arisen in the estimation of the phytate content of foods for a number of reasons. First, there is variation in the phytate content of varieties, genotypes and species of foods[40–43]. For example, the phytate content of Korean foods[23] used in the generation of tables of phytate content of subsidiary food groups may be different from the phytate content of UK foods. Data extracted from book chapters (e.g. Harland[24]) are also used for generation of the phytate table; however, they are not necessarily derived from

peer-reviewed sources. Second, estimates of the phytate contents of foods are dependent on the assays used, sampling procedures and environmental factors. Hence, the accuracy of the estimates will depend on the accuracy of the analyses[44,45]. Finally, for many foods, phytate values have not been measured or were not found in the literature; in which case, the reported value has been estimated from the phytate values of foods of similar composition[38].

The authors acknowledge that these tables might be prone to errors, but these inaccuracies were considered as the limitations of the study and were due to the difficulties associated with the assessment of nutrient intake using food composition tables[45].

Steps were taken to minimise the impact of error. The primary references used[24,25,35,36] were those that had been validated, updated and often cited in the literature on the phytate content of foods. Considerable variability in the mean and range of the values quoted in the literature was taken into account and values deemed to be outliers were excluded.

Estimates of the phytate content were compared against the nutrient database of MBIAT software, developed by the Institute of Food Research[38]. The final version of the tables were sent to the authors of MBIAT for review[46,47].

Opportunities to set geographic criteria or to select the investigations that used the same analytical technique were very limited. Results from studies using the anion exchange HPLC, which is a well-established method for the assessment of phytate content of food, were selected above those obtained from other techniques. However, for at least five studies, the authors had to include investigations based on methods other than anion exchange HPLC[5,6,29,30,33] to extend the range of data.

Comparison with other investigations

The average phytate intake of adults in the United Kingdom is higher than that in developed countries (e.g. Finland, 370 mg/d[48] and the United States, 750 mg/d[49]) and lower than in African and Asian countries (e.g. Nigeria, 2200 mg/d[50]; India, 1955 mg/d[51]; and South Korea, 1677 mg/d[52]). The median daily phytate intake of adults in the United Kingdom (809 mg/d) is comparable to the median phytate intake in urban China (781 mg/d) and lower than in rural China (1342 mg/d)[53].

Comparing these findings to other studies in the United Kingdom is difficult. The average phytate intake of adults is close to the values suggested by Davies[13] in 1982. Davies concluded that the phytate intake of the UK population is in the range of 600–800 mg/d, although details of the investigation were unpublished.

Davies also referred to a personal communication with DH Buss (unpublished results) regarding the phytate content of some representative UK diets, which indicated an average daily phytate consumption of 806 mg/d. In this latter investigation, 70 % of the phytate intake came from cereal products, 20 % from fruit and the remainder from vegetables and nuts. Despite differing definitions for subsidiary food groups in the current investigation, findings from Buss agree with the average phytate intake and the percentage contribution of food types to average daily phytate intake found in the present study.

Findings of the current investigation did not agree with the range of phytate intake reported by Wise *et al.*[12] in 1987, in which they indicated that the mean phytate-phosphorus intake of students and staff at the Robert Gordon Institute of Technology ranged from 141 to 237 mg/d. It is important to note that these results were based on a different methodology and analytical technique (i.e. measurement of phytate-phosphorus), and the study was conducted on a limited number of participants.

The inconsistency between the results presented here and those of Wise *et al.*[12] may be related to the molecular species of phytate. The low values obtained by Wise *et al.* may represent a decreased phosphorylation state of phytate (e.g. IP2 or IP3) and thus lower zinc chelation potency. This is possible particularly since the majority of phytate intake in the study of Wise *et al.*[12] also came from breakfast cereals and breads, which agrees with findings of the current investigation. The foods may have been processed by extrusion (i.e. subjected to heat) and breads (subjected to phytase activity during fermentation). The lack of information on the phosphorylation state of phytate is another limitation of the current analysis.

Types of foods contributing to phytate intake

Cereal and cereal products were the main sources of phytate for the UK population. For all age groups, the majority of phytate intake from cereals came from breakfast cereals and breads. Phytate intake from these foods is high, as (i) they contain a high amount of phytate (e.g. 750 mg phytate in 100 g high-fibre and whole-grain breakfast cereals) and (ii) they are frequently consumed in the UK diet. The majority of children in the present survey consumed some form of bread and breakfast cereals.

Vegetables, potatoes and savoury snacks were the second largest source of phytate for the UK population. Within this group, the phytate content of the subsidiary food groups is not exclusively high, but the frequency and quantity of consumption have resulted in high phytate intake from these foods. For example, potato chips contain 147 mg phytate per 100 g chips, and the largest proportion of young people aged 4–18 years (89 % of boys and 88 % of girls) consumed potato chips during the dietary record period. The majority of the young people population also consumed savoury snacks[15].

Lower phytate intake of men and women aged 19–24 years could be explained by general differences in foods consumed by respondents of this group compared with older adults. The foods that were less likely to have been

consumed by the youngest group of men and women were the rich sources of phytate. For example, men and women aged 19–24 years were less likely to consume wholemeal breads, high-fibre and whole-grain breakfast cereals and coffee. Furthermore, for nearly half of the fruit and vegetable types (i.e. peas, leafy green vegetables, cooked tomatoes, apples, pears, citrus fruits, bananas, canned fruits in juice, and 'other fruit' such as plums, grapes and soft fruits), a significantly lower proportion of men and women aged 19–24 years had consumed these items compared with the oldest age group[16].

In the elderly population, boiled, mashed and baked potatoes, tea, white breads and biscuits were consumed by the largest proportion of the population. Almost all participants (95% of free-living and 98% of institution participants) drank tea. The average consumption of twenty-four to twenty-five cups of tea per week was greater than the four to seven cups of coffees per week consumed by the elderly participants[21]. This frequent consumption of tea and coffee contributed to a large proportion of phytate intake of adults (aged 19–64 years), as well as the elderly population.

In conclusion, the present study collected the available data on the phytate content of foods, generated a database and produced an estimate of dietary phytate intake and phytate-to-zinc molar ratio for the UK population. Further research should focus on the completion and validation of this database to assess (and if necessary improve) the accuracy and precision of these findings.

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