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Calcium, diet and fracture risk: a prospective study of 1898 incident fractures among 34 696 British women and men

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Abstract

Objective: The risk factors for fractures are incompletely understood. An outstanding question concerns the optimal amount of dietary calcium needed to minimise the risk of fracture.

Design: We examined the associations of dietary calcium and other nutrients with self-reported fracture risk in a prospective cohort study. Nutrient intakes were estimated using a semi-quantitative food-frequency questionnaire administered at recruitment.

Setting: The UK.

Participants: A total of 26 749 women and 7947 men aged 20–89 years.

Results: Over an average of 5.2 years of follow-up, 1555 women and 343 men reported one or more fractures, 72% of these resulting from a fall. Among women, fracture risk was higher at lower calcium intakes, with a relative risk of 1.75 (95% confidence interval (CI) 1.33–2.29) among women with a calcium intake of $<525\,\text{mg day}^{-1}$ compared with women with a calcium intake of at least $1200\,\text{mg day}^{-1}$ (test for linear trend, $P < 0.001$). The association of dietary calcium with fracture risk was stronger among women aged under 50 years at recruitment than among women aged 50 and above. Dietary calcium intake was not associated with fracture risk in men. Fracture risk was not related to the dietary intake of any other nutrient examined.

Conclusion: In this population, women with a low dietary calcium intake had an increased risk of bone fracture, and this association was more marked among younger women than among older women.

Keywords
Dietary calcium
Fracture risk
Recommended nutrient intake
Prospective study
EPIC–Oxford

The importance of dietary factors in preventing bone fractures is controversial. Calcium has received the most attention, but even for this nutrient it has proved difficult to reach consensus on optimal intake. In the UK the estimated average requirement for calcium in adults is $525\,\text{mg day}^{-1}$, and the associated reference nutrient intake ($700\,\text{mg day}^{-1}$) should be sufficient for 97.5% of people[1,2]. In the USA, an estimated average requirement for calcium has not been set, but an adequate intake is set at $1000\,\text{mg day}^{-1}$ for ages 19–50 years and $1200\,\text{mg day}^{-1}$ for ages 51 years and above[3], and some experts have argued that even higher intakes of $1300–1600\,\text{mg day}^{-1}$ would be ideal[4]. Other countries have produced varying recommendations, reflecting the limitations of data from balance studies and calcium accretion studies, and the inconsistent results of trials and previous observational studies of calcium intake and fracture risk[5].

We report here results from the Oxford cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC–Oxford), a prospective study of women and men in the UK. Recruitment into this cohort was designed to include people with varied dietary patterns and thus to cover wide variation in the intakes of nutrients including calcium[6]. Our principal aim was to examine the association of fracture risk with dietary calcium. We also examined the associations of fracture risk with dietary intake of seven other nutrients which have been suggested to be important for bone health: protein, vitamin D, vitamin C, retinol, carotene, potassium and magnesium.

Methods

Participants and questionnaires

The EPIC–Oxford cohort was recruited partly by postal methods targeted at vegetarians living throughout the UK, and partly through general practice surgeries in Oxfordshire, Buckinghamshire and Greater Manchester[6]. All participants completed a lifestyle questionnaire and food-frequency questionnaire (FFQ), including questions relating to current height and weight, smoking habits, alcohol drinking, physical activity at work and during leisure time (including walking, cycling, other exercise or

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sport and amount of vigorous physical activity) and marital status[6]. Women were also asked about their reproductive history and use of hormone replacement therapy. Participants' body mass index (BMI) was calculated as their self-reported weight in kilograms divided by the square of self-reported height in metres.

The FFQ required participants to estimate their average frequency of intake of each of 130 foods and drinks over the previous 12 months. Intake of tap or bottled water was not included on the questionnaire. Nutrient intakes were estimated by multiplying the nutrient content of a specific portion size of each food by the frequency of consumption, using food composition tables[6–8]. Nutrient intakes used in this analysis were energy, calcium, protein, vitamins D and C, retinol, carotene, potassium and magnesium; other than energy, these nutrients were selected for analysis because they have previously been suggested to be important in maintaining bone health. Participants were also asked to report other aspects of their usual diet, including whether or not they had regularly taken any vitamins, minerals or other dietary supplements over the previous year.

The recruitment questionnaire was completed by 57 450 participants aged 20 and above between 1993 and 2000[6]. About 5 years after completing the main questionnaire, surviving participants were sent a follow-up questionnaire. Participants were asked whether they had suffered any fractured bones over the previous 6 years, and to report the month and year of each fracture, the bone(s) affected and the cause, categorised as a fall, road traffic accident, other accident, fracture found only by X-ray or other causes. For this analysis, we defined an incident fracture as one occurring after the date of recruitment and involving bones other than the digits or ribs.

Statistical methods

Follow-up questionnaires were available for 36 956 participants. We excluded 240 participants who did not answer the question about fractures, 1360 who reported a fracture of the digits or ribs, or any type of fracture before recruitment, and 660 whose nutrient intake data were considered to be unreliable ($\geq$20% of food frequencies missing, or daily energy intakes $<$500 kcal or $>$3500 kcal for women or $<$800 kcal or $>$4000 kcal for men). This left data for 34 696 participants: 26 749 women and 7947 men.

Dietary calcium intake was categorised as $<$525, 525–699, 700–899, 900–1199 and $\geq$1200 mg day^{-1}. The cut-off points for the two lowest intake categories corresponded to the UK estimated average requirement (525 mg day^{-1}) and reference nutrient intake (700 mg day^{-1}), respectively[1], and the cut-off point for the highest intake category corresponded to the US adequate intake for ages 51 years and above (1200 mg day^{-1})[3]. Intakes of other nutrients were categorised into five groups of similar size each based on approximate quintiles of intake, except for retinol for which the highest intake category was $\geq$1000 μg day^{-1} in order to test the hypothesis that intakes above this level are associated with increased fracture risk.

Fracture incidence in relation to nutrient intakes was examined using Cox regression. Fracture-free survival time was calculated as the number of days from recruitment to the earliest incident fracture or the date of completion of the follow-up questionnaire for subjects who did not have an incident fracture. Analyses were stratified by method of recruitment (postal, general practitioners), and adjusted for the following factors: age at recruitment (20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–89 years), smoking (never, former, current cigarette smokers), log-transformed intakes of energy and each of the other nutrients under consideration, alcohol consumption ($<$1, 1–7, 8–15, $\geq$16 g day^{-1}), BMI ($<$20.0, 20.0–22.4, 22.5–24.9, 25.0–27.4, $\geq$27.5 kg m^{-2}), walking, ($<$3, 3–5, 6–9, $\geq$10 h week^{-1}), cycling (0, 0.5–1.5, 2.0–4.5, $\geq$5 h week^{-1}), other exercise or sport (0, 0.5–1.5, 2.0–4.5, $\geq$5 h week^{-1}), amount of vigorous exercise (0, 1–2, $\geq$3 h week^{-1}), physical activity at work (unemployed or sedentary, standing, manual), marital status (married or living as married, unmarried) and, for women, number of children (0, 1–2, $\geq$3) and use of hormone replacement therapy (never, past, current). Missing values existed for each of the non-dietary factors except for alcohol consumption and method of recruitment. To ensure that all relevant observations were included in each Cox regression analysis, 'unknown' categories were added for each of these factors. Data were analysed separately for women and men, and for women were also subdivided into 'younger' and 'older' women according to whether they were aged $<$50 years or $\geq$50 years at recruitment.

Relative risks and 95% confidence intervals (CIs) were calculated, with the lowest nutrient intake group as the reference category, except for calcium intake where the highest intake group was used as the reference category, and tests of trend were obtained by replacing the categorical nutrient intake variable by the logarithm of nutrient intake in the model. The significance of the difference in the association of calcium intake with fracture risk in women aged $<$50 years or $\geq$50 years at recruitment was examined using a χ^2 test for heterogeneity. Analyses were performed using STATA version 9.0[9].

Results

The median age at recruitment was 46 years. The prevalence of smoking, the mean intake of alcohol and the mean BMI among participants were all low, and many subjects reported at least 3 h of vigorous exercise each week (Table 1). Mean calcium intakes in both women and men were above the UK reference nutrient intake of 700 mg day^{-1}, 18.1% of participants had a calcium intake below 700 mg day^{-1} and 6.3% of participants had a

Table 1 Baseline characteristics

Characteristic	Women	Men
Number	26 749	7947
Age at recruitment (years)	45.8 (13.1)	49.5 (13.5)
Current smoker (%)*	8.9	11.5
Alcohol consumption (g day^{-1})	7.7 (9.6)	15.1 (17.8)
Body mass index (kg m^{-2})*	23.6 (3.9)	24.2 (3.3)
≥3 h vigorous exercise per week (%)*	27.6	34.3
Current HRT use (%)*	13.5	–
Energy intake (MJ day^{-1})	7.89 (2.09)	9.02 (2.41)
Calcium intake (mg day^{-1})	996 (329)	1046 (363)
< 525 (%)	6.4	5.9
525–699 (%)	12.0	11.5
700–899 (%)	22.3	19.1
900–1199 (%)	34.9	32.9
≥ 1200 (%)	24.5	30.5
Protein (g day^{-1})	73.1 (21.6)	77.8 (22.6)
Vitamin D (μg day^{-1})	2.70 (1.90)	2.73 (1.99)
Vitamin C (mg day^{-1})	143.1 (68.3)	125.4 (60.6)
Retinol (μg day^{-1})	487.5 (511.9)	551.7 (668.6)
Carotene (μg day^{-1})	3380 (2021)	3084 (1860)
Potassium (mg day^{-1})	3811 (984)	3968 (991)
Magnesium (mg day^{-1})	352.2 (95.4)	385.2 (106.8)
Regularly take dietary supplements (%)*	61.2	44.2

HRT – hormone replacement therapy.
Values are mean (standard deviation), except where indicated.
* Unknown for some subjects (percentages are calculated among those with a known value of the factor).

calcium intake below 525 mg day^{-1}. Mean intakes of protein, vitamin C, vitamin A (retinol equivalents), potassium and magnesium were all above the corresponding UK reference nutrient intakes. Fifty-seven per cent of participants reported regular use of dietary supplements.

A toal of 1555 (5.8%) of the women and 343 (4.3%) of the men reported having had one or more incident fractures in more than 182 000 person-years of follow-up (Table 2). The most common fracture sites were wrist/arm and ankle, accounting for 43 and 15% of the incident fractures in women and 37 and 15% of the incident fractures in men, respectively. More than half of the fractures (75% in women and 56% in men) were caused by a fall.

Table 3 shows for women and men the numbers of incident fractures and the multivariable adjusted incidence rate ratios relative to the reference category for each nutrient (except for energy which was regarded as a potential confounding variable). Based on the trend tests, only dietary calcium intake among women was associated with fracture risk. Among women, there was a significant inverse association between calcium intake and fracture risk ($P<0.001$ for trend), with fracture risk being 75% (95% CI 33–129%) higher among women with a calcium intake of <525 mg day^{-1} compared with women with a calcium intake of at least 1200 mg day^{-1}. Calcium intake was not significantly associated with fracture risk in men, although the highest risk was observed in the lowest calcium intake category. The results were similar when the analyses were restricted to fractures resulting from a fall; relative risks for calcium intakes of <525 mg day^{-1} compared with calcium intakes of at least 1200 mg day^{-1} were 1.83 (95% CI 1.34–2.51) among women and 1.22 (95% CI 0.55–2.73) among men.

The association between calcium intake and fracture risk in women was examined further among women aged <50 and ≥50 years at recruitment (Table 4). In the younger women, there was a significant inverse association between calcium intake and fracture risk ($P<0.001$ for trend); there was also a decrease in fracture risk associated with increasing calcium intake among older women, although the test of trend was not statistically significant ($P=0.20$). The difference in trends according to age was of borderline statistical significance ($\chi^2_1=3.77$, $P=0.05$).

Fifty-seven per cent of subjects reported that they regularly took dietary supplements; the proportions taking supplements were 61% in the lowest dietary calcium intake category and 58% in the highest dietary calcium intake category. The calcium content of dietary supplements was coded for a representative sample of 202 women who had reported that they were using a dietary supplement; 73% were taking supplements which did not contain calcium, 19% were taking supplements containing between 20 and 500 mg of calcium, and 8% were taking supplements containing at least 700 mg of calcium. The mean intake of calcium from supplements among these women was 95 mg day^{-1}. We repeated the main analyses excluding subjects who reported regular use of dietary supplements. In this subanalysis, 595 out of 10 726 (5.5%) women and 203 out of 4495 (4.5%) men reported having had one or more incident fractures. Results were similar to the main analysis, with only calcium intake in women, especially younger women, showing a clear association with fracture risk ($P=0.002$

Table 2 Site and cause of first incident fracture

Site of bone broken in first incident fracture	Cause of first incident fracture: Fall	Road traffic accident	Other accident	Found on X-ray	Other, multiple or unspecified	Total (%)
Women						
Wrist/arm	563	12	46	2	41	664 (42.7)*
Ankle	203	3	10	2	16	234 (15.0)
Foot	127	4	9	8	42	190 (12.2)
Leg	94	13	14	0	13	134 (8.6)
Shoulder	19	1	6	0	2	28 (1.8)
Hip	29	1	6	1	5	42 (2.7)
Other or unspecified	132	32	40	11	48	263 (16.9)
Total (%)	1167 (75.0)	66 (4.2)	131 (8.4)	24 (1.5)	167 (10.7)	1555
Men						
Wrist/arm	83	1	34	1	8	127 (37.0)
Ankle	34	3	7	0	6	50 (14.6)
Foot	16	2	1	0	7	26 (7.6)
Leg	14	2	11	1	2	30 (8.7)
Shoulder	11	3	4	0	1	19 (5.5)
Hip	7	1	2	1	0	11 (3.2)
Other or unspecified	27	9	29	2	13	80 (23.3)
Total (%)	192 (56.0)	21 (6.1)	88 (25.7)	5 (1.5)	37 (10.8)	343

* Percentages may not sum to 100 due to rounding.

for trend for all women, $P < 0.001$ for trend among women aged <50 years at recruitment; other results not shown).

Discussion

We observed a significant inverse association between estimated dietary calcium intake and fracture risk among women, but not among men. The association was stronger among women aged under 50 at recruitment than among older women.

Although fractures were self-reported, previous studies have shown that self-report is relatively accurate for several important fracture sites, including those of the hip, wrist and humerus[10,11]. The dietary questionnaire has been shown to provide valid estimates of calcium intake when compared with estimates from weighed food intakes: Spearman's rank correlation between the two estimates of calcium intake was 0.5[12]. We did not have complete data on calcium intake from dietary supplements, but there was little difference in supplement use between subjects with high and low dietary calcium intakes, and we estimated that >80% of women did not take calcium supplements. This is consistent with other recent UK data from the National Diet and Nutrition Survey in which inclusion of supplements increased the mean daily intakes of calcium by only 32 mg in women and 9 mg in men[13]. Furthermore, the results for calcium were similar when the analysis was restricted to women who did not report using any dietary supplements.

The results of previous observational studies of the association between dietary calcium and fracture risk in women have been inconsistent. In a meta-analysis of observational studies of dietary calcium published between 1966 and 1997, Cumming and Nevitt estimated that a 300 mg day^{-1} increase in calcium intake was associated with an odds ratio for hip fracture in post menopausal women of 0.96 (95% CI 0.93–0.99)[14]. However, a later meta-analysis of observational studies estimated that a 300 mg day^{-1} increase in dietary calcium did not alter the risk of hip fracture in women (risk ratio 1.01 (95% CI 0.96–1.07))[15]. Two publications from more recent large prospective studies have shown no association of calcium intake with hip fracture risk among 72 000 postmenopausal women in the US Nurses' Health Study[16] or with the risk for any osteoporotic fracture among 61 000 women in the Swedish Mammography Screening Cohort[17], whereas a recent large case–control study in California[18] found a 50% higher risk for fracture of the proximal humerus among women with a calcium intake <496 mg day^{-1} than among women with a calcium intake >969 mg day^{-1}.

The results from trials of the effect of supplemental calcium on fracture risk in women are also unclear. In a Cochrane review, the estimated fracture risks after treatment with calcium were 0.79 (95% CI 0.54–1.09) for vertebral fracture and 0.86 (95% CI 0.43–1.72) for non-vertebral fracture[19]. In two subsequent randomised controlled trials, women allocated to calcium supplementation did not have a reduced fracture rate[20,21], but in one of these trials there was some evidence that the fracture rate was reduced among women who were compliant with the treatment[21].

There are few previous data on calcium intake and fracture rates in men[22]. We observed no significant association between calcium intake and fracture risk in men, but the number of fractures among men and the proportion of men with a low calcium intake were low.

Table 3 Numbers of incident fractures and incidence rate ratios (95% CIs) by daily nutrient intake in women and men*

	Women		Men	
Nutrient and category	*n*	Incidence rate ratio (95% CI)	*n*	Incidence rate ratio (95% CI)
Calcium (mg)		$P < 0.001$†		$P = 1.00$
< 525	129	1.75 (1.33–2.29)	25	1.15 (0.63–2.09)
525–699	193	1.34 (1.07–1.66)	38	0.94 (0.59–1.49)
700–899	335	1.15 (0.96–1.37)	59	0.91 (0.62–1.32)
900–1199	517	1.05 (0.91–1.22)	111	1.02 (0.76–1.37)
≥ 1200[c]	381	1.00	101	1.00
Protein (g)		$P = 0.39$		$P = 0.46$
< 55‡§	321	1.00	77	1.00
55–64§	241	0.87 (0.72–1.05)	46	0.79 (0.52–1.18)
65–74§	264	0.86 (0.70–1.05)	67	1.25 (0.82–1.90)
75–89§	367	0.98 (0.78–1.22)	77	1.19 (0.74–1.91)
≥ 90§	362	0.97 (0.74–1.27)	76	1.29 (0.72–2.31)
Vitamin D (μg)		$P = 0.55$		$P = 0.68$
< 1.2‡	297	1.00	84	1.00
1.2–1.9	307	0.97 (0.82–1.15)	69	0.96 (0.68–1.37)
2.0–2.7	335	1.05 (0.88–1.27)	64	0.96 (0.65–1.42)
2.8–3.9	281	1.07 (0.87–1.31)	64	1.13 (0.74–1.72)
≥ 4.0	335	1.01 (0.82–1.24)	62	0.91 (0.59–1.41)
Vitamin C (mg)		$P = 0.37$		$P = 0.17$
< 80‡	212	1.00	65	1.00
80–119	354	0.79 (0.66–0.94)	103	1.05 (0.75–1.46)
120–159	425	0.95 (0.79–1.15)	96	1.23 (0.85–1.78)
160–199	243	0.87 (0.70–1.09)	41	1.03 (0.64–1.63)
≥ 200	321	1.06 (0.83–1.36)	38	1.10 (0.65–1.88)
Retinol (μg)		$P = 0.97$		$P = 0.54$
< 200‡	289	1.00	75	1.00
200–299	299	0.96 (0.80–1.14)	58	0.92 (0.62–1.36)
300–449	398	0.99 (0.82–1.19)	81	0.97 (0.65–1.45)
450–999	367	1.03 (0.84–1.27)	85	0.91 (0.58–1.42)
≥ 1000	202	0.93 (0.73–1.18)	44	0.80 (0.47–1.34)
Carotene (μg)		$P = 0.51$		$P = 0.29$
< 2000‡	329	1.00	102	1.00
2000–2999	348	1.09 (0.94–1.28)	81	0.87 (0.64–1.17)
3000–3999	374	1.06 (0.90–1.24)	72	0.85 (0.61–1.19)
4000–4999	186	1.03 (0.85–1.25)	42	1.04 (0.70–1.53)
≥ 5000	318	1.14 (0.95–1.37)	46	0.89 (0.59–1.35)
Potassium (mg)		$P = 0.09$		$P = 0.57$
< 3000‡	289	1.00	47	1.00
3000–3499	275	0.94 (0.78–1.14)	59	0.85 (0.56–1.31)
3500–3999	313	0.96 (0.77–1.20)	78	0.85 (0.53–1.35)
4000–4499	278	1.05 (0.81–1.36)	66	0.68 (0.39–1.18)
≥ 4500	400	1.17 (0.86–1.60)	93	0.54 (0.27–1.05)
Magnesium (mg)		$P = 0.48$		$P = 0.61$
< 275‡	320	1.00	41	1.00
275–324	307	0.90 (0.75–1.08)	44	0.77 (0.48–1.22)
325–374	309	0.85 (0.69–1.05)	75	1.14 (0.71–1.82)
375–449	356	0.92 (0.72–1.17)	92	0.94 (0.56–1.60)
≥ 450	263	0.95 (0.69–1.30)	91	0.82 (0.42–1.59)

CI – confidence interval.
* Incidence rate ratios are stratified by method of recruitment and adjusted for age, smoking, intakes of energy and each other nutrient, alcohol consumption, body mass index, walking, cycling, vigorous exercise, other exercise, physical activity at work, marital status and, for women, parity and use of hormone replacement therapy (see Methods for details).
† The *P*-values relate to tests of trend, with the logarithm of nutrient intake replacing the categorical nutrient intake variable in the model.
‡ Reference group.
§ Category limits are 5 g higher for men.

Compared with other prospective studies in Western countries, the current study has a similar quality of assessment of calcium intake, but the range of calcium intake may be wider due to the targeted recruitment of people with varied dietary patterns[6]. Our estimates of calcium intake can be directly compared with those from the EPIC–Norfolk cohort, which used the same dietary questionnaire as EPIC–Oxford but in a general population sample in the UK; the mean intakes of calcium are almost identical in the two cohorts, but the standard deviations

Table 4 Numbers of incident fractures and incidence rate ratios (95% CIs) in relation to daily calcium intake among women aged <50 years or ≥50 years at recruitment*

	Women aged <50 years		Women aged ≥50 years	
Calcium intake (mg)	*n*	Incidence rate ratio (95% CI)	*n*	Incidence rate ratio (95% CI)
<525	71	2.06 (1.38–3.06)	58	1.53 (1.05–2.23)
525–699	93	1.38 (1.00–1.91)	100	1.31 (0.98–1.77)
700–899	149	1.23 (0.94–1.61)	186	1.10 (0.87–1.39)
900–1199	204	1.06 (0.84–1.33)	313	1.05 (0.87–1.27)
≥1200†	150	1.00	231	1.00
		$P < 0.001$‡		$P = 0.20$

CI – confidence interval.
* Incidence rate ratios are stratified by method of recruitment and adjusted for age, smoking, intakes of energy, protein, vitamins D and C, retinol, carotene, potassium and magnesium, alcohol consumption, body mass index, walking, cycling, vigorous exercise, other exercise, physical activity at work, marital status, parity and use of hormone replacement therapy (see Methods for details).
† Reference group.
‡ The *P*-values relate to tests of trend, with the logarithm of calcium intake replacing the categorical nutrient intake variable in the model.

are about 20% larger for both women and men in EPIC–Oxford than in EPIC–Norfolk[6,23]. Other differences between this study and previous observational studies are that previous studies have concentrated on post menopausal women and particularly on hip fractures, whereas the current study included adult women and men of all ages and examined risk for all types of fractures (except for digits and ribs). In our study, the association of dietary calcium with fracture risk was stronger among women under 50 years old than among older women. A previous systematic review of dairy foods and bone health concluded that the strongest evidence for a benefit of dairy foods was among women under 30 years old, perhaps because a benefit is most likely during the period of maximum bone accretion[24]. These observations suggest that more data on calcium and fracture risk in young women would be valuable.

Our results reinforce the importance of ensuring that women consume enough calcium to reach the UK reference nutrient intake of 700 mg day^{-1}. Mean total calcium intakes in the UK fell by >200 mg day^{-1} between 1970 and 1996 due to declines in the consumption of both milk and fortified bread[1]. The recent UK National Diet and Nutrition Survey[13] estimated mean intakes from food during 2000–2001 as 777 and 1007 mg day^{-1} in women and men, respectively, with 14% of women and 4% of men consuming <500 mg day^{-1}. The food groups contributing most to calcium intake in this survey were milk and milk products (43%), cereals and cereal products (30%), and fruit and vegetables (7%). The large contribution from cereals is mainly due to the mandatory fortification of most types of flour in the UK with calcium[13].

We observed no evidence that the other nutrients examined were associated with fracture risk. For protein, it has been hypothesised both that high protein intakes might increase fracture risk by increasing calcium excretion, and that high protein intakes could help to reduce fracture risk, for example by increasing production of insulin-like growth factor-I[25]. Vitamin D is important for bone health; we did not observe any association of estimated dietary vitamin D with fracture risk, but the majority of vitamin D is produced by the action of sunlight on the skin, and we plan to investigate the role of vitamin D status in a nested case–control study of plasma 25-hydroxyvitamin D. For vitamin C, carotene, potassium and magnesium, it has been suggested that high intakes of these nutrients may benefit bone health and reduce fracture risk[26], but these hypotheses were not supported by our data. For retinol, some recent studies have observed an increase in fracture risk among people with very high consumption[27,28]. We observed no association between dietary retinol consumption and risk, but average dietary retinol intakes were low.

In conclusion, this study suggests that calcium intakes below 525 mg day^{-1} substantially increase the risk for fractures among women, and data from the National Diet and Nutrition Survey suggest that a large number of women in the UK may have calcium intakes low enough to put them at increased risk for fractures[13].

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