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Vitamin-D intake in Australian adults and the modelled effects of milk and breakfast cereal fortification

Running title: Vitamin-D intake in Australian adults

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Abstract

Objective: Vitamin-D intake from foods or supplements is a safe and attractive means to improve vitamin-D status of populations. To help identify population sub-groups that would benefit most from efforts to increase intake, we investigated which personal characteristics are associated with vitamin-D intake in an Australian population and modelled possible effects of expanded food fortification practices.

Research Methods and Procedures: We investigated vitamin-D intake in a population-based random sample of 785 adults, using a validated food frequency questionnaire, and assessed associations with personal and behavioural characteristics. We identified vitamin-D food sources and modelled the hypothetical effects of blanket fortification of milk and breakfast cereals.

Results: Average total vitamin-D intake was 4.4 (±4.0) µg/day and below Adequate Intake for most participants in all age and sex sub-groups. Higher intake was associated with being female, having a serious medical condition, energy intake below the median, and vitamin-D supplement use (all $p<0.05$). The 'meat, fish and eggs' food group contributed most to total vitamin-D intake (51%), followed by dairy products and related foods (43%). If all milk and breakfast cereals were to be fortified with vitamin-D, the average intake of vitamin-D from foods would increase from 3.6 (±2.4) µg/day to 6.3 (±3.2) µg/day, with similar increases in all age and sex sub-groups.

Conclusions: Vitamin-D intake in Australia is generally below recommended levels, and few personal characteristics help to identify sub-groups with low intake. Blanket vitamin-D fortification of milk and breakfast cereals would substantially increase average vitamin-D intake in Australian adults of all ages.

Key words: Vitamin-D intake, food fortification, food sources.

Introduction

Recognition that vitamin-D may have wider relevance than just calcium absorption and bone health has invigorated awareness of the need to safeguard vitamin-D status of populations globally. Vitamin-D may help protect against cardiovascular disease, cancer, and other diseases, although more evidence for this is needed [1]. While endogenous production of vitamin-D in the skin following exposure to sunlight is a main source of vitamin-D for many, this may be insufficient for persons living in low-sunlight regions, persons with dark skin, the elderly, or those whose skin is covered while outdoors [2]. Even in sunny climates, abundant sun exposure does not guarantee vitamin-D sufficiency [3]. Promotion of sunlight exposure is undesirable because it is the main environmental cause of skin cancer, which is responsible for major disease burden and health care costs in white populations [4]. Thus increased dietary intake of vitamin-D from food sources or supplements is an attractive method to improve vitamin-D status in individuals at risk of deficiency.

Estimated average vitamin-D intake is well below recommended levels in many countries [5, 6]. In Australia, data from a very limited number of surveys suggests that total average vitamin-D intake lies below 3µg/day (120 IU/day), despite mandatory addition of vitamin-D to all margarines and voluntary fortification of some other dairy products (but not whole milk), analogues of these, and formulated beverages [7]. This estimated average intake level is much lower than the Estimated Average Requirements publicised recently by the US Institute of Medicine (IOM) of 10µg/day (400IU/day) for all adults, and the current

Adequate Intake (AI) values for Australia of 5µg/day (200IU) for adults up 50yrs, 10µg/day (400IU) for those 50-70yrs, and 15µg/day (600IU) for persons 70+yrs old [8] .

Knowledge of the characteristics of persons with high and low vitamin-D intake is needed to inform current discussions about how to achieve sufficient vitamin-D status of populations. Presently there is a paucity of such information, including within Australia. Vitamin-D intake is difficult to estimate because food composition databases are often inadequate, and the availability of foods with added vitamin-D changes continuously, making accurate assessment of dietary intake difficult [9]. Recognising these challenges, we estimated vitamin-D intake levels of an unselected group of Australian adults who participated in our community-based cohort study of skin cancer, so to investigate how vitamin-D intake varies between sub-groups of this population. In addition, we modelled how vitamin-D intake would be altered if all milk and cereal products were fortified with vitamin-D.

Materials and Methods

Study Participants

This cross-sectional study was conducted using data from self-administered questionnaires completed by participants in the Nambour Skin Cancer Study, a 20-year cohort study in a sample of adult residents in a sub-tropical community. Full details of the study design and key findings have been published previously [10, 11]. In brief, the participants were selected at random from the electoral roll in 1986 for a study of skin cancer. Between 1992 and 1996, a randomized controlled trial of sunscreen use and beta-carotene supplementation and skin cancer prevention was carried out in 1621 persons. Subsequent to the trial, participants were invited to continue their enrolment for further study of skin cancer and other health outcomes. In 2007, participants completed a food frequency questionnaire (FFQ), provided updated information on lifestyle factors and health status, and attended study fieldwork clinics.

Assessment of Dietary Intake

Vitamin-D intake from foods was estimated using a self-administered, semi-quantitative FFQ consisting of 151 food or food group items. The FFQ was based on the validated US Nurses' Health Study FFQ [12], adapted for the Australian setting. This FFQ has been validated for nutrient intake in our study population against weighed food records [13], serum nutrient levels [14, 15] and in the Nurses' Health Study for vitamin-D intake [16]. For each food, a commonly used unit or portion size was specified, and participants were required to estimate how often, on average, they had eaten the given amount of food over the past 6 months. The 9 response options ranged from never to 4 or more times per day. Food intake in grams was estimated by multiplying the reported consumption frequencies by the standard serving size of each food specified in the FFQ. In addition, detailed information regarding cooking methods, use of sugar, fats, oils and margarines, frequency of eating breakfast cereals and fried takeaway meals, and nutritional supplement use was collected.

Vitamin-D levels in the Australian nutrient composition database AUSNUT 2007 [17] was used to estimate daily vitamin-D intakes from food, with the exception of cheddar cheese, which was taken from the United States Department of Agriculture (USDA) database (0.6µg/100g), because values provided by the Australian food databases (2.2µg/100g) seemed too high. Addition of vitamin-D to edible oil spreads and margarines has been mandated in Australia since 1987 [18]. We used detailed questions in the FFQ to collect information on specific brands of margarine consumed by the participants, and obtained information on vitamin-D content of spreadable oils and margarines, which all have added vitamin-D in Australia[18], from the food manufacturers. In Australia there is also voluntary addition of vitamin-D to modified and skim milks (but not whole milk), powdered milk, yoghurts, cheese, dairy analogues and formulated beverages [8], but consumption of these fortified foods was expected to be very low in 2007 due to limited availability, and uptake and has been assumed to be nil for the purpose of this study. Calculation of other nutrients and total energy intake was estimated using NUTTAB 2006 [19]. Nutrient contents of supplements, including vitamin-D, were estimated from the active ingredients of each supplement listed in the Australian Register of Therapeutic Goods (ARTG, maintained by the Therapeutic Goods Administration)[20], using conversion methods described previously [21].

Modelling of intake levels if additional foods were fortified with vitamin-D

Given that milk and ready-to-eat cereals with added vitamin-D are the predominant food sources of vitamin-D in the United States [9], we calculated how the vitamin-D intake of our Australian study population would change if fortification of these products was mandated. For these modelling purposes, vitamin-D fortification of all milk (including soy milk and flavoured milk) was assumed to be 1µg/100mL, which is the maximum and most commonly used level in the USA [22], and double the amount currently permitted in Australia [7]. Vitamin-D fortification of breakfast cereals, though not permitted in Australia, was assumed to be 3.5µg/100g, the upper level of usual fortification in the USA [22].

Factors associated with vitamin-D intake

Several personal and behavioural characteristic variables were selected *a priori* in order to determine associations with vitamin-D intake, including smoking status, physical activity, body mass index (BMI), history of dieting to lose weight, history of a serious medical condition, educational level, occupation and usual time spent outdoors.

Food Sources

The main food sources of vitamin-D intake were explored by calculating the proportional contribution of each food item within each group, for each participant. These contributions were then summed to give the total percentage of vitamin-D obtained from each food group, and the specific food items that contributed to this.

Data Analysis

Participants who omitted 10% or more FFQ items, or those whose daily energy intakes were considered implausible using Willett's criteria (<2940kJ and >16800kJ for women, and <3360kJ and >21000kJ for men) were excluded from the study [23].

Vitamin-D intake was adjusted for energy intake using the residual method in order to reduce variability due to the total amount of food eaten [23]. Total vitamin-D intake was calculated by adding energy-adjusted vitamin-D intake from food and intake from supplements. Vitamin-D values were log-transformed to improve normality of the data. The means and confidence intervals presented in this report were back-transformed for ease of interpretation.

The main study outcomes were vitamin-D intake from food sources alone, and total vitamin-D intake from food and supplements. Associations between personal and behavioural characteristic variables and vitamin-D intake were assessed using analysis of variance (ANOVA). We used logistic regression analysis to model the probability of having total vitamin-D intake below recommended levels, within categories of explanatory variables. Average intake levels are presented as mean ± standard deviation. Statistical Analysis Systems statistical software package (version 9.2, SAS Institute Inc., Cary, North Carolina, USA) was used in all analyses, employing a significance level of $p<0.05$.

Results

Of the 909 participants who received the FFQ, 845 (93%) responded. After exclusions due to incomplete data or extreme energy intake levels, 785 participants (342 males and 443 females) were included in the present analyses (48% of 1621 participants in the original trial). Persons who were included in this study were somewhat older (mean age 66.8yrs vs. 60.9yrs, $p<0.0001$), more likely to have an indoor occupation (49% vs. 40%, $p=0.001$) and to have obtained a qualification (49% vs. 44%, $p=0.05$), and were less likely to have a serious medical condition (43% vs. 54%, $p<0.0001$) than those excluded. Included and excluded participants did not differ by sex, BMI, smoking status, occupation, physical activity level, location of leisure activities, vitamin-D dietary intake or vitamin-D supplement use as assessed in 1992.

Average total vitamin-D intake from foods and supplements was 4.4 (± 4.0) µg/day. Whilst mean vitamin-D intake tended to increase with age in women, this was not the case for men (Table 1). More than a fifth of younger adult males and females had a total vitamin D intake from foods plus supplements that exceeded the Adequate Intake (AI) level for their age, but less than 10% of older adults achieved this. Overall, 11% of participants had a total vitamin D intake above AI level.

Mean intake of vitamin-D from food sources alone was higher in participants who used vitamin-D supplements compared to those who didn't ($p=0.03$), and persons whose energy intake was below compared to above the median of energy intake ($p<0.01$) (Table 2). Mean total vitamin-D intake was higher in females than males ($p<0.01$), those with a serious medical condition ($p=0.04$), who used vitamin-D supplements ($p<0.0001$), and who had an energy intake below the median ($p<0.05$).

The meat/fish/eggs/meat substitutes food group contributed the most to vitamin-D intake (51%), with the majority of this from canned fish (28%) (Table 3). The next highest contributing category was dairy and related foods (43%), which consisted mostly of milk (18%) and margarine (11%). The proportional contribution of meat/fish/eggs/meat substitutes to total vitamin-D intake in females was somewhat greater than that in males (53% vs. 50% respectively), whilst the contribution of dairy and related foods vitamin-D was slightly greater in males than females (44% vs. 42% respectively).

In this population, 62% of participants consumed at least one serving of milk daily, and 30% consumed at least one serving of breakfast cereals daily. If both milk and breakfast cereals were fortified to 1µg/100mL and 3.5µg/100g respectively, the average mean vitamin-D intake from foods in this population would increase from 3.6 (± 2.4) µg/day to 6.3 (± 3.2) µg/day, with comparable increases across all age and sex categories (Table 4). With such hypothetical blanket fortification, the overall proportion of persons with a vitamin-D intake from food only above current AI levels would increase from 5% to 21%. In males, the proportion with intakes above AI levels would increase from 17% to 55% in 31-50 year olds and 4% to 15% in 51-70 year olds, with those 70 years or older showing no increase (0%) (Table 4). In females, the proportion of persons with intake above AI levels would increase from 13% to 56% in 31-50 year olds, from 1% to 13% in 51-70 year olds, with no change in those 70 years and above (2%). None of the participants reached an intake above the safe upper intake level [24] of 100 µg/day (highest total intake level was 44.4 µg/day) under the modelled scenario of blanket fortification of all milk and breakfast cereals.

Use of vitamin-D supplements was reported by 10% of our study participants (3% male and 7% female), and within these persons, the median contribution of vitamin-D from supplements to total intake was 67% (range: 16-95%). The contribution of vitamin-D supplements to total vitamin-D intake was relatively similar in males and females who took vitamin-D supplements (males-median: 72%, range: 23-89%; females–median: 67%, range: 16-95%), though the proportion of females who took supplements was higher than in males (13% and 7% respectively, p=0.006). Overall, 6% (average proportion) of total vitamin-D intake was attributed to vitamin-D supplement use (4% in males, 8% in females).

Discussion

On average, vitamin D intake of the majority of persons in all age and sex categories of this Australian community did not meet current Adequate Intake (AI) levels. These findings are in line with the results of previous studies[5], however the proportion of persons meeting recommended intake levels would be even smaller if the recently published position statement by learned societies in Australia, which recommends vitamin D intake of 15µg/day for persons up to 70 years of age, and 20µg/day for those above 70 years old when sun exposure is minimal [25], were adopted as national guidelines. With as much as 18% of our study population stating that they hardly ever spend time outdoors on any day of the week, these low average intake levels may put a substantial proportion of this Australian population at risk of adverse effects on bone health. Presently there is a lack of consensus about levels of vitamin D intake needed to achieve non-skeletal benefits. Many studies suggest that such intake levels need to be much higher than those currently recommended [31]. When more evidence including that from randomised trials becomes available in the future, this may increase concern about low levels of intake.

We showed that vitamin-D intake from foods and supplements was significantly higher in participants who used vitamin-D supplements, those who had a lower energy intake, and in women (total vitamin D intake only). Supplement use is known to be associated with better dietary and health habits and other studies have reported similar findings [26]. Similarly, persons with lower energy intakes may be more conscious of their dietary intakes and health outcomes, and potentially have a higher intake of nutrient-rich foods. However, the differences between these sub-groups of energy intake whilst statistically significant, are negligible in terms of clinical significance (food only: 3.4µg vs. 3.1µg, $p<0.01$, food and supplements: 3.9µg vs. 3.5µg, $p<0.05$). Participants with a serious medical condition were more likely to have a higher total vitamin-D intake than those without, probably because use of vitamin-D supplements was more common in the former group compared to the latter (15% vs. 9% respectively, $p=0.02$; full results not shown).

In terms of food sources of vitamin-D, our results agree well with current knowledge. Fatty fish such as salmon or herring is a well-established good source of naturally occurring vitamin-D. The contribution of 28% of vitamin-D from canned fish for this study population is fairly high, considering that only 2% of the participants ate one serving of canned fish per day, and 45% of participants ate one serving of canned fish per week. There is therefore large potential to raise vitamin-D intake if consumption of fish is increased.

The high level of vitamin-D attributed to the ‘dairy and related foods’ group is partly due to the compulsory fortification of margarine (which contributed 11% to dietary vitamin-D intake), though the majority (18%) was due to milk consumption. Nowson (2006) stated that margarine provides approximately 50% of the total vitamin-D intake for Australian adults [27]. A lower estimate was reported by Pasco and colleagues (2001) who reported that margarine provided 28% of total vitamin-D intake in a sample of Australian women [28]. Thus our data agree with the view that margarine fortification plays a substantial role in the total vitamin-D intake of the Australian population.

We found that if all milk and breakfast cereals were assumed fortified with vitamin-D, average vitamin D intake would increase substantially in all age and sex sub-groups, including older adults (70+yrs). Milk and breakfast cereals were frequently consumed in this Australian population, with 26% of younger adults and 41% of adults 70+yrs of age eating a serve of breakfast cereals each day, and more than 60% of adults in all age groups consuming a serve of milk each day. However due to the higher AI level for older adults (15µg/day in current national guidelines) the proportion of older persons whose intake would exceed such levels if all milk and breakfast cereals were to be fortified with vitamin D would remain very low. Even if the more conservative Estimated Average Requirement level of 10µg/day [24] was applied to this age group, only 11% of our participants aged 70 years and over would have met such intake levels under blanket fortification assumptions. Thus for older adults, other avenues for increasing vitamin-D status, for example through increased use of supplements, which is already advocated for persons at high risk of vitamin-D deficiency in Australia [29], or fortification of other food groups, may need to be considered.

A major strength of this study was that it was nested in a longitudinal study of skin cancer, and dietary intake assessment was not a primary reason for participation, thus reducing potential participation bias. Additionally, the FFQ used in this study has shown reasonably high validity when compared with weighed food records in our study population, thus minimising bias due to misclassification. The study participants were selected at random from the electoral role and considered representative of the wider Australian population in this age group. Comparisons with the 2007 Australian National Health Survey (NHS) [30] data indicate that frequencies of fruit and vegetable consumption (as general indicators of diet) were very similar to those observed in our study, but that fewer current smokers and obese older men were enrolled in the Nambour study compared to the NHS (data not shown). Because smoking status and BMI were not associated with vitamin D intake, this is unlikely to influence our findings. Nambour Study participants who were not included in the present analyses were somewhat older, more likely to work outdoors, more often had a serious medical condition, and were less likely to have obtained a qualification than those who were included. Because these characteristics were not or minimally associated with vitamin-D intake in our data, and because the differences between those included and excluded were small, we expect that these differences had a negligible influence on our results

In terms of the vitamin-D approximation from the FFQ, the results are dependent on the assumptions that were made regarding the vitamin-D contents of some foods. For example, the relatively high measured value for whole milk provided by the AUSNUT database (0.52µg/100g) contrasts to the 0.1µg/100g provided by some food databases from other countries and may have resulted in the relatively high estimate for the contribution of milk to total vitamin-D intake in our analyses. Also, the relative contribution of cheddar cheese to total vitamin-D intake would have been higher if we had used the value published by AUSNUT 2007 (2.2µg/100g) instead of the value published by USDA (0.6µg/100g). Such assumptions affect all studies of vitamin-D intake that use food composition data, because the availability of analysed values of the vitamin-D content of foods is very limited, and values for the same foods show large variability between databases and countries. Such variability may partly be due to natural variability in the vitamin-D content of foods, but may also reflect differences in analytical techniques; the IOM has identified this as an important knowledge gap that needs addressing [24].

Conclusion

Vitamin-D intake in Australia is generally below recommended levels and few personal characteristics help to identify sub-groups with low intake. Fish, meat, milk and fortified margarine are main food sources. Blanket vitamin-D fortification of milk and breakfast cereals would substantially increase average vitamin-D intake in Australian adults of all ages.

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Table 1: Vitamin-D intake and comparisons with recommended intake levels, by age and sex

Age (yr) and sex category	n	Vitamin-D intake[a]		Adequate Intake[b]	Proportion (%) of participants above Adequate Intake[c]
		Food sources only	Food and supplements		
		Mean ± SD	Mean ± SD	μg/day	
Male					
31-50	92	3.7±1.9	4.1±3.0	5	22.8
51-70	157	4.1±3.4	4.6±4.4	10	8.0
70+	93	3.4±1.8	3.9±2.7	15	1.1
Female					
31-50	99	3.2±1.5	4.0±3.6	5	21.2
51-70	247	3.5±2.1	4.6±4.0	10	9.8
70+	97	3.9±2.7	4.9±5.5	15	4.5

[a]*Per day, prior to energy adjustment; mean and standard deviation (μg)*

[b]*Based on Australian national recommendations [8] for age and sex sub-groups*

[c]*Intake from foods plus supplements*

Table 2: Vitamin-D intake and comparisons with recommended intake levels by personal characteristics

		Food Only		Food and Supplements			
Variables	n	Mean vitamin-D intake[a] (95% CI)	P[b]	Mean vitamin-D intake[a] (95% CI)	P[b]	Proportion below Adequate Intake[c] (%)	P[d]
Demographic variables							
Sex							
Female	443	3.4(3.2-3.5)	0.09	3.9(3.7-4.1)	<0.01	89	0.64
Male	342	3.2(3.0-3.4)		3.4(3.2-3.7)		90	
Age (yr) category							
40≤years<50	171	3.3(3.1-3.5)	0.95	3.5(3.3-3.8)	0.60	78	<0.0001
50≤years<60	215	3.3(3.1-3.5)		3.8(3.5-4.2)		90	
60≤years<70	209	3.3(3.1-3.5)		3.8(3.5-4.2)		90	
70≤years<80	140	3.2(2.9-3.5)		3.6(3.2-4.0)		96	
80≤years<90	50	3.2(2.8-3.6)		3.5(2.9-4.2)		98	
Educational level							

High school only	363	3.3(3.1-3.5)	0.81	3.7(3.5-4.0)	0.63	90	0.49
Trade/other	140	3.2(2.9-3.5)		3.6(3.2-4.0)		85	
Certificate/diploma	151	3.4(3.1-3.7)		4.0(3.6-4.3)		89	
Bachelor or higher	60	3.2(2.7-3.8)		3.6(2.9-4.4)		87	
Occupation							
(Para)professional	205	3.2(3.0, 3.4)	0.44	3.6(3.3-3.9)	0.32	90	0.42
Non-professional	500	3.3(3.2, 3.5)		3.8(3.6-4.0)		88	
Lifestyle variables							
Smoking status							
Life-long non-smoker	384	3.3(3.1-3.4)	0.07	3.7(3.5-4.0)	0.10	89	0.14
Current smoker	46	3.9(3.2-4.5)		4.5(3.6-5.5)		80	
Ex-smoker	238	3.2(3.0-3.4)		3.6(3.4-3.9)		89	
Pack-years smoked							
0yrs	481	3.3(3.1-3.4)	0.40	3.7(3.5-3.9)	0.96	90	0.52
0<yrs≤7	115	3.2(2.9-3.4)		3.7(3.3-4.1)		89	
7<yrs≤20	77	3.6(3.1-4.1)		3.8(3.3-4.4)		87	
>20yrs	112	3.2(2.9-3.6)		3.7(3.2-4.3)		87	

Physical activity							
None	158	3.2(2.9-3.5)	0.10	3.6(3.2-4.0)	0.82	84	0.23
Light	246	3.3(3.1-3.5)		3.7(3.4-4.0)		91	
Moderate	192	3.2(3.0-3.5)		3.8(3.5-4.2)		86	
Vigorous	95	3.3(3.0-3.6)		3.7(3.3-4.1)		92	
BMI							
<25kg/m²	186	3.1(2.9-3.3)	0.25	3.5(3.2-3.8)	0.24	91	0.18
25≤ kg/m²< 30	304	3.4(3.2-3.5)		3.9(3.6-4.2)		88	
≥30kg/m²	177	3.4(3.1-3.6)		3.8(3.4-4.2)		86	
Dieting to lose weight in last 12 months							
No	382	3.2(3.1-3.4)	0.31	3.5(3.4-3.8)	0.07	92	0.02
Yes	387	3.4(3.2-3.5)		3.9(3.6-4.1)		87	
Health variables							
Presence of a serious medical condition							
Yes	168	3.3(3.1-3.6)	0.80	4.0(3.6-4.5)	0.04	89	0.69

No	617	3.3(3.1-3.4)		3.6(3.4-3.8)		89	
Sun exposure variable							
Time spent outdoors daily							
<1hrs	138	3.4(3.1-3.6)	0.10	3.8(3.4-4.3)	0.40	91	0.34
1≤hrs<4	604	3.2(3.1-3.4)		3.6(3.4-3.8)		89	
4≤hrs	32	3.9(2.9-5.0)		4.1(3.1-5.4)		81	
Dietary variables							
Use of vitamin-D supplements							
Yes	79	3.7(3.2-4.2)	0.03	10.7(9.6-12.1)	<0.0001	42	<0.0001
No	706	3.2(3.1-3.4)		3.2(3.1-3.4)		95	
Energy intake (kJ)							
Low (<median)	391	3.4(3.3-3.6)	<0.01	3.9(3.7-4.1)	<0.05	94	<0.0001
High (≥median)	394	3.1(2.9-3.3)		3.5(3.3-3.8)		85	

[a]*Energy-adjusted vitamin-D from food only in µg using Willett's nutrient residual method [23]; back-transformed from logged values*

[b]*Comparison between categories based on Analysis of Variance (ANOVA)*

[c]*Using original total vitamin-D intake values, thus not adjusted for energy intake; based on Australian national recommendations[8]*

[d]*Based on logistic regression analysis to compare groups*

Table 3: Contribution of foods and food products (if 1% or more) to total dietary vitamin-D intake

Food group/product	Contribution to total vitamin-D intake from food[a] (%)		
	Total n=785	Males n=342	Females n=443
Meat/fish/eggs/meat substitutes -total	51	50	53
Canned fish[b]	28	25	30
Meat[c]	15	16	14
Eggs[d]	4	4	4
Dairy and related foods-total	43	44	42
Milk[e]	18	20	17
Margarine (not used for cooking)	11	11	10
Yoghurt[f]	6	4	7
Cheese[g]	3	3	3
Butter (not used for cooking)	3	3	3
Custard	1	2	1
Vegetables-total	3	3	2
Potato[h]	2	2	2
Sweets/baked goods/snacks	2	2	2

[a]*Only showing foods that contributed more than 1%*

[b]*Includes tuna in oil, tuna or salmon in water, and sardines*

[c]*Includes beef, pork or lamb as main or mixed dish, ham, sausages and bacon*

[d]*Includes boiled, poached, fried or scrambled eggs and omelettes*

[e]*Includes whole milk, low fat milk, flavoured milk and skim milk*

[f]*Includes regular and low fat yoghurt*

[g]*Includes cheddar, cottage and other low fat cheese*

[h]*Assumed to be peeled, boiled or mashed with milk, butter or table spread*

Table 4: Modelling the effect of additional food fortification: proportion of participants with vitamin-D intake above recommended from food alone, by age and sex

Age (yr) and sex category	n	Original data		Assuming all milk fortified[a]		Assuming all breakfast cereals fortified[b]		Assuming all milk and breakfast cereals fortified[a,b]	
		% above Adequate Intake [c]	Daily vitamin-D intake[d]	% above Adequate Intake [c]	Daily vitamin-D intake[d]	% above Adequate Intake [c]	Daily vitamin-D intake[d]	% above Adequate Intake [c]	Daily vitamin-D intake[d]
Male									
31-50	92	17	3.7±1.9	49	5.8±3.0	26	4.2±2.1	55	6.3±3.2
51-70	157	4	4.1±3.4	11	6.0±3.9	5	4.7±3.5	15	6.7±4.0
70+	93	0	3.4±1.7	0	5.2±2.3	0	4.1±1.7	0	5.9±2.3
Female									
31-50	99	13	3.2±1.5	42	5.5±2.6	17	3.7±1.6	56	6.0±2.7
51-70	247	1	3.4±2.0	9	5.8±2.9	2	4.0±2.0	13	6.3±3.0
70+	97	2	3.9±2.9	2	6.0±3.6	2	4.6±3.0	2	6.6±3.7

[a] *Assuming that all milk would contain 1ug/100g of vitamin-D*

[b] *Assuming that all breakfast cereals (not oatmeal/porridge) would contain 3.5ug/100g of vitamin-D*

[c] *Based on Australian national recommendations[8]*

[d] *Mean±standard deviation in ug/day*