Original Article

Vitamin D intake and its food sources in Taiwanese

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In the early 20th Century, vitamin D was discovered and its Recommended Daily Allowance developed. However, average daily dietary intakes have not been reported until recently in the US. There are no food composition and no intake data for vitamin D available in Taiwan. We have taken advantage of several population representative Nutrition and Health Surveys in Taiwan (NAHSIT) conducted from 1993 onwards of various age groups to examine this possibility systematically. Firstly, we collected and compiled the vitamin D content of foods from various sources to supplement the Taiwanese Food Composition Tables. Though these vitamin D data may not be fully representative of local food items, they serve as a reference point. Secondly, we have used the three NAHSITs databases, which all used the 24-hr recall method to collect dietary intake data and five food frequency questionnaire type questions to collect supplement data, to estimate most gender- and age-specific (include: school children, adults and elderly) vitamin D intakes from food source and supplements. Thirdly, we have defined the sources of vitamin D intake in Taiwanese (gender- and age-specific). Vitamin D intakes of Taiwanese were adequate except for high school girls and indigenous people. Fish and its products, milk, mushrooms were the major vitamin D food sources. Supplement source vitamin D also varied greatly between age and gender groups. Elderly women consumed almost 20% of vitamin D from supplements; 16-18 years old boys consumed 2.47% vitamin D from supplements only.

Key Words: vitamin D, dietary intake, determinants, National Nutrition Survey, adults, women, elderly, school children, DRIs

INTRODUCTION

There is a paucity of representative vitamin D intake data from populations consuming Oriental diets, which may have a different profile of vitamin D sources, bioavailabilities and requirement-modifying characteristics.[1,2] Natural food sources of vitamin D are usually few and mainly vitamin D3 (cholecalciferol) from animal sources (fish, organ meats and eggs). Vitamin D2 (ergocalciferol) comes principally from fungal sources like mushrooms or from yeast, depending on type and exposure to ultraviolet (UV) irradiation.[3] Certain foods may be fortified and, in some populations, constitute a significant proportion of the total intake.[4] This notably applies to fortified cow's milk and dairy products which ordinarily contain little vitamin D, and to fatty spreads like margarines derived from plant oils. The bioavailability of vitamin D will depend on the background diet, especially the fat content since the vitamin is fat-soluble. Thus, it is not reasonable to extrapolate judgements about European diets, which are usually oriented towards non-rice grains, dairy products, lower leguminous, lower fish and decreasing organ meat consumptions insofar as vitamin D intakes or requirements are concerned.

Other sources of vitamin D, especially food supplements like cod-liver oil and isolated vitamin D supplements may have different usage histories, advocacies or age and gender utilization profiles between food cultures.

Population geography, especially latitude and sunlight exposure, and demographies also influence the intake data and relevance. This particularly relates to vulnerable groups like infants and children, women in the childbearing years and the aged (whose skin may not synthesise cholecalciferol as readily on UV exposure and whose requirements increase as renal impairment develops and renal conversion of 25-hydroxyvitamin D [25(OH)D] to 1,25(OH)D declines).[5-7]

The often exclusive focus on calciotropic functions of vitamin D (notably bone and dental health) as opposed to the increasingly recognized autocrine 1,25(OH)D producing non-calciotropic functions of vitamin D also mean that the documentation of oriental dietary sources of vitamin D is important. These include immunological, cellular differentiating, metabolic and cardio-respiratory functions of vitamin D.[8-10]

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Other dietary factors, which have to do with vitamin D functional outcomes, need also to be taken into food cultural account. A good example is that of vitamin K in regard to osteocalcin formation and bone health.[11,12]

There are now increasing efforts to define optimal vitamin D acquisition from the combination of intakes from food and supplements along with the contribution from sunlight by way of serum 25(OH)D, often in conjunction with parathyroid hormone concentrations and 1,25(OH)D status.[13,14] However, the food sources remain important to understand and optimize as exposure to sunlight is more and more limited in many communities for changing occupational and recreational reasons.

We have taken advantage of a sequence of National Nutrition Surveys in Taiwan to document a North East Asian dietary experience and describe the food sources of vitamin D. This is intended as a basis for nutritional and health policy in Taiwan and to signal the importance of such work elsewhere.

MATERIALS AND METHODS

Subjects

During 1993-2002, a series of population representative Nutrition and Health Surveys in Taiwan (NAHSIT): the NAHSIT 1993-1996,[15] the NAHSIT Elderly 1999-2000[16] and the NAHSIT Children 2001-2002[17] were carried out. Data for the present paper were obtained from these three NAHSITs for participants who were aged six and above. We used data provided by 5662 adolescents and adults (2855 men and 2807 women, aged 13-64), 1805 elderly (920 men and 885 women, aged 65 and above) and 2385 school children (1275 boys and 1110 girls, aged 6-12) to estimate the population vitamin D intakes.

Estimation of vitamin D intake

A. Compilation of food vitamin D information

1. Food item identification, combination, categorization and encoding

There were 3646, 3865 and 7646 food items, respectively, in the three NAHSITs 24-hour dietary records as listed above. We selected all food items which could contain vitamin D from these three surveys. For vitamin D supplements, there were up to five food frequency questionnaire (FFQ) type questions about supplement usage in the previous month. Due to the limited availability of food vitamin D composition, we combined, categorized and encoded similar food items as well as supplements. Food combination and categorization were based on: (1) the same or similar names; (2) similar nutrient profile; (3) comparable food physical properties; and (4) similar ingredients and preparation. Each food category was assigned a food code.

2. Estimation of vitamin D food composition

Food vitamin D data are not available in the Taiwanese Food Composition Table. We consulted several sources to compile an in-house vitamin D food composition database for the food categories generated from the three surveys. Those included: the Fourth Version of Standard Tables of Food Composition in Japan,[18] the Fifth Version of Standard Tables of Food Composition in Japan,[19] Food Values of Portions Commonly Used,[20] USDA NUTRIENT DATA LABORATORY,[21] Finnish Food Composition Database.[22] Vitamin D values of supplements and processed foods were obtained from food labels. We formulated recipes for mixed dishes and bakery goods to calculate their vitamin D content.

3. Panel discussion

We formed a Panel (two senior dietitians with food service expertise along with four nutrition investigators) to evaluate the appropriateness of vitamin D food categorization and value assignment. We revised the vitamin D food composition in accordance with the Panel recommendations. There were a total of 12 food groups (319 categories) and five supplement groups (91 categories). We assigned a vitamin D value (per 100 g for food or per serving for supplement) to each food code by using the most relevant source of information.

B. Estimation of daily vitamin D intake

We calculated daily vitamin D intake for both food sources (24-hour dietary recall) and supplements (5 FFQ type questions) for each subject. Total vitamin D intake was the sum of the two.

Statistical analysis

The sampling weight of each surveyed individual was calculated by dividing the sample size by the population size of his or her own sex/age group in the stratum. All data were weighted to represent the three populations in Taiwan. The SAS version 8.01 and[23] SUDAAN version 8.0[24] were used to account for the effect of this multi-staged complex sampling design. For comparison purpose, we used various ways to classify subjects by age. Gender-age-specific vitamin D intakes were calculated accordingly. By using 24-hour dietary recall, an over-estimated standard deviation of nutrient intake is created due to large within-person or day-to-day variation. We used the repeated 24-hr recall measurements of a sub-set of the study population to obtain the within person/between person ratio, which is used to reduce the variance of dietary vitamin D intake.[25] A stepwise regression approach was used to identify the food predictors of vitamin D intakes in Taiwan by gender and age groups. Statistical significance was defined as $p<0.05$.

RESULTS

Table 1 shows the gender-age-specific mean vitamin D intakes in Taiwan which ranged between 3.24 μg/day in adolescent women aged 16-18 to 6.00 μg/day in older women aged ≥80 from food. With food and supplements combined, the range is from 3.67 μg/day in adolescent women aged 16-18 to 8.67 μg/day in older women aged ≥80. Except for the elderly, in each age group, males have higher intake than females of both food and supplementary vitamin D. In male subjects aged 6-50, vitamin D from food alone accounts for more than 90% of DRIs (5 μg/day for subjects younger than 51). By contrast, men aged over 50 do not exceed 60% of their DRIs despite higher absolute intakes with age, because of the age-related increase in DRIs (10 μg/day for subjects older than 50). However, females aged 6-50 consumed substantially less vitamin D from food than men. The worst case was girls aged 16-18; they consumed only 64.8% of DRIs. Nevertheless, the intake of vitamin D in women older

Table 1. Gender-age-specific mean vitamin D intake, Taiwan, 1993-2002.

Gender	Age (yr)	Vitamin D from food (μg/day)	DRIs %†	Vitamin D from supplements (μg/day)	Total vitamin D intake (μg/day)	DRIs %†	Source‡
Male	6-12	4.52	90.3	0.698	5.21	104.0	3
	6-9	4.53	90.5	0.764	5.30	106.0	3
	10-12	4.51	90.1	0.633	5.16	103.0	3
	13-15	4.80	95.9	0.697	5.49	110.0	1
	16-18	4.89	97.9	0.124	5.02	100.0	1
	19-44	4.70	94.0	0.420	5.12	102.0	1
	45-64	5.26	52.6 §	0.202	5.47	54.7 §	1
	13-50	4.83	96.6 §	0.373	5.20	104.0	1
	51-64	5.70	57.0 §	0.267	5.97	59.7 §	1
	≥65	5.36	53.6 §	0.986	6.34	63.4 §	2
	65-69	5.46	54.6 §	0.716	6.17	61.7 §	2
	70-74	5.34	53.4 §	1.230	6.58	65.8 §	2
	75-79	5.95	59.5 §	0.635	6.59	65.9 §	2
	≥80	4.52	45.2 §	1.480	6.00	60.0 §	2
Female	6-12	3.91	78.1	0.825	4.73	94.6	3
	6-9	3.50	69.9	1.088	4.58	91.7	3
	10-12	4.32	86.3	0.564	4.88	97.6	3
	13-15	3.56	71.3	0.339	3.90	78.0	1
	16-18	3.24	64.8 §	0.432	3.67	73.4	1
	19-44	3.85	76.9	0.544	4.39	87.8	1
	45-64	4.24	42.4 §	0.371	4.61	46.1 §	1
	13-50	3.71	74.2	0.395	4.11	82.1	1
	51-64	4.59	45.9 §	0.683	5.27	52.7 §	1
	≥65	5.69	56.9 §	1.365	7.06	70.6	2
	65-69	5.79	57.9 §	0.760	6.55	65.5 §	2
	70-74	5.52	55.2 §	1.120	6.65	66.5 §	2
	75-79	5.53	55.3 §	1.984	7.51	75.1	2
	≥80	6.00	60.0 §	2.662	8.67	86.7	2

† Vitamin D DRIs (AI): 5 μg/day (≤ 50 years old), 10 μg/day (>50 years old)
‡ Source:
1. The Nutrition and Health Surveys in Taiwan, 1993-1996
2. The Elderly Nutrition and Health Surveys in Taiwan, 1999-2000
3. The School Children Nutrition and Health Surveys in Taiwan, 2001-2002
§ The grey shading indicates the number of the food and supplement vitamin D < 2/3 DRIs,

than 65 from each of food and supplements is greater than in men.

Due to large within-person or day-to-day variation, the distribution of vitamin D intakes derived from a single 24-hour dietary recall would be wider than the "true intake". After variance reduction, the 50th percentiles (i.e., the median) of food vitamin D intakes in all gender-age groups are not far from the intake means as can be seen from a comparison of these values in Tables 1 and 2. In Figure 1 A, which shows probability density or distribution, it is evident that the distribution has shrunk and symmetric when applied to the example of vitamin D intake in boys aged 6-12. Figure 1 B is the cumulative probability, by which the food vitamin D intake percentiles can be found.

Table 2 demonstrates the gender-age specific distributions of the variance reduced vitamin D intakes in the three surveys. The grey shading indicates the food vitamin D intake below which a Dietary Reference Intakes (DRIs) of 66.7% (3.33 and 6.67 μg/day for subjects younger and older than 50 years, respectively) is not met. For boys aged 6-12, this intake is 3.53 μg/day, which corresponds to a percentile intake of 25%. Thus 75% of 6-12 years boys have food vitamin D intakes which reached two thirds of DRIs, which is the conventional approach to the evaluation of micro-nutrient adequacy. However, only 10% and 25% of the adolescent girls aged 13-15 and 16-18 fulfilled this DRIs criterion, respectively. Only a quarter of elderly subjects met the criterion, though their absolute intakes were higher than the younger subjects.

Table 3 lists the contribution of six food groups and one supplement group to daily vitamin D intake as percentages. Shaded numbers are the lowest and the highest proportions of vitamin D obtained from a source group by age in males and females. In general, fish is the most important source of vitamin D, which contributes 36.8% in 6-12 years old girls to 64.5 % in 45-64 years adult men. However, the relative importance of each food source varied among gender-age groups. For example, fish contributes 64.5% vitamin D for males aged 45-64, but contributes much less (38.5%) for 6-12 year old boys. Dairy accounts for a quarter of vitamin D in the elderly for both genders, but only 1.84% for boys aged 13-15. Eggs contributed about 10% of vitamin D (0.347 to 0.597 μg/day) for all age groups, except the elderly. Elderly men and women only obtained 4.51% (0.286 μg/day) and 3.61% (0.255 μg/day) vitamin D from eggs, respectively. Supplement source vitamin D also varied greatly between age and gender groups. Elderly women consumed almost 20% of vitamin D from supplements. Quite differently, 16-18 years old boys consumed 2.47% vitamin D from

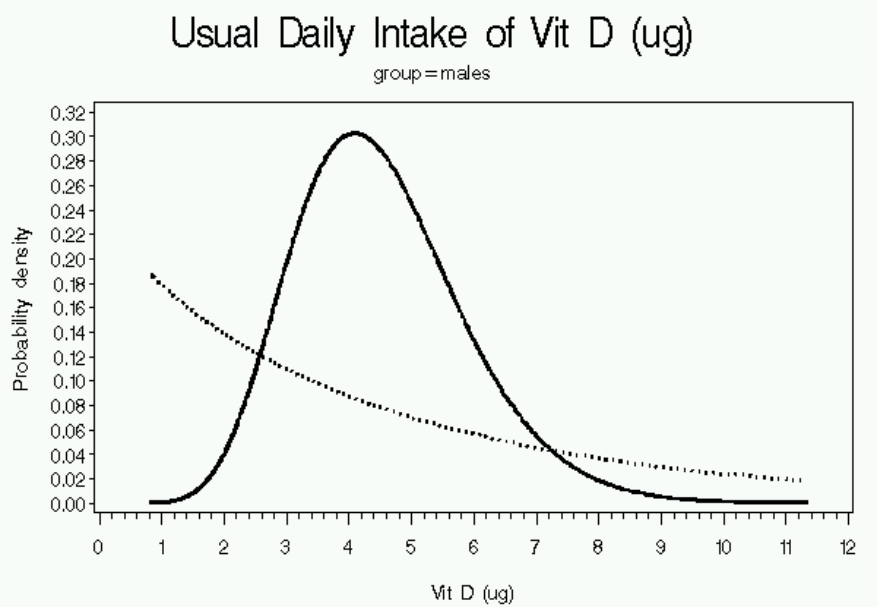

Figure 1A. Probability density (Distribution) of original and variance reduced dietary vitamin D intake, boys aged 6-12

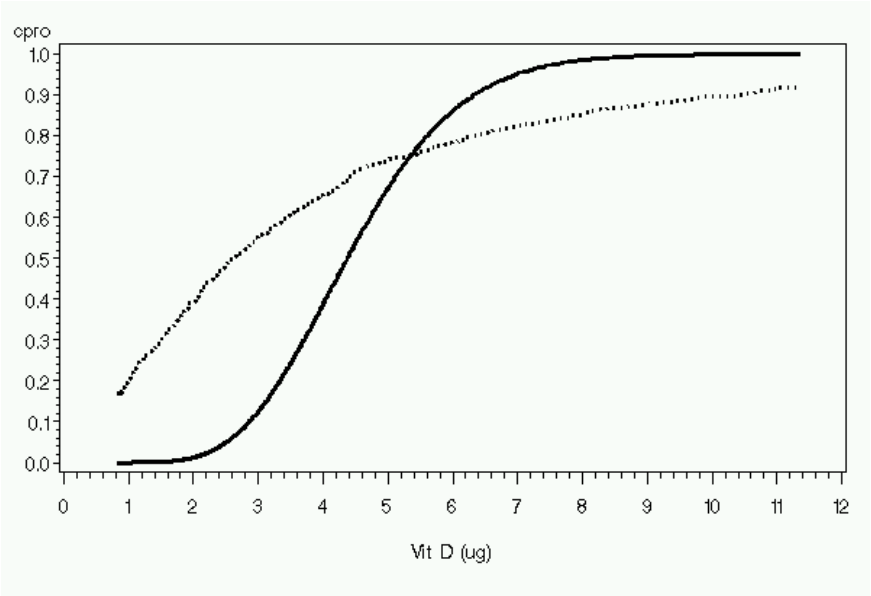

Figure 1B. Cumulative distribution of original and variance reduced dietary vitamin D intake, boys aged 6-12 (cpro is cumulative probability)

supplements only. Though mushrooms were used only in limited quantity, they provided fair amounts of vitamin D across age and gender groups.

Tables 4-6 are the comparisons of total vitamin D intake between various characteristics in the three NAHSITs. In children, as for the elderly, those who are indigenous have the lowest intake of vitamin D among the four major ethnic groups in Taiwan. Their intake was significantly lower than for Fukienese (3.49 vs. 4.95 μg/day). Both paternal and maternal education levels predicted children's vitamin D intakes. The children of those parents with a college or above education have a significantly higher vitamin D intake than do other categories. (Table 4)

In the population aged 13-64, males have a higher intake than do women. The older and the married consumed more vitamin D. Unlike the other two NAHSITs, indigenous adults have the highest vitamin D intake among the four major ethnic groups. (Table 5)

Among the elderly, females consumed more vitamin D than men, mainly from supplements. Vitamin D intake was positively correlated with education level in a dose-response manner. For those who have a college education, the consumption was 9.06 μg/day, while it was only 6.23 μg/day for those who were illiterate. (Table 6)

DISCUSSION

International comparison of intake and food sources

There are few estimates of dietary intakes of vitamin D intake available. Those published for the US, Australia, Norway and Japan is summarized in Table 7.[1,2,4,26,27] The common characteristics of these estimates are that, with divergent food cultures intakes for adults are generally around 4-7 μg per day and are highly dependent on ani-

Table 2. Gender-age-specific distribution of variance reduced vitamin D intake (μg/day), Taiwan, 1993-2002

Source	Age (yr)	Gender	Percentiles							
			1th%	25th%	50th%	75th%	80th%	90th%	95th%	99th%
3	6-12	M	1.95	3.53†	4.38	5.36	5.62	6.40	6.99	8.34
		F	1.95	3.19	3.84	4.57	4.73	5.26	5.69	6.63
	6-9	M	1.95	3.49	4.32	5.26	5.51	6.21	6.84	8.11
		F	1.91	3.05	3.64	4.28	4.44	4.92	5.37	6.25
	10-12	M	1.96	3.63	4.52	5.59	5.90	6.83	7.29	8.77
		F	2.06	3.50	4.27	5.08	5.34	6.01	6.74	7.55
	13-15	M	1.58	2.73	3.33	3.98	4.17	4.66	5.10	5.99
		F	1.30	2.15	2.61	3.10	3.24	3.59	3.94	4.68
	16-18	M	1.92	3.65	4.70	5.69	6.04	6.85	7.61	9.33
		F	1.54	2.55	3.05	3.61	3.86	4.16	4.49	5.21
	19-44	M	0.30	2.21	3.99	6.56	7.37	9.70	11.9	17.3
		F	0.64	2.33	3.53	5.10	5.60	6.85	8.20	10.9
1	45-64	M	0.28	2.53	4.73	8.01	9.04	12.0	14.9	21.6
		F	0.48	2.27	3.70	5.62	6.20	7.86	9.41	12.9
	13-50	M	0.31	2.22	3.99	6.53	7.29	9.56	11.7	16.6
		F	0.58	2.18	3.32	4.82	5.24	6.49	7.63	10.1
	51-64	M	0.26	2.36	4.52	7.90	8.83	11.9	14.7	21.2
		F	0.48	2.41	3.98	6.13	6.93	8.61	10.5	14.2
2	≥65	M	0.30	2.39	4.41	7.31	8.17	10.8	13.3	19.1
		F	0.89	3.34	5.14	7.44	8.09	10.0	11.8	15.7
	65-69	M	0.31	2.43	4.57	7.41	8.61	11.1	13.8	19.3
		F	0.79	3.35	5.14	7.70	8.39	10.5	12.7	17.2
	70-74	M	0.41	2.58	4.52	7.22	8.05	10.7	12.9	17.7
		F	0.98	3.35	4.98	7.46	7.81	9.61	11.3	15.0
	75-79	M	0.25	2.46	4.96	8.55	9.39	12.5	15.7	25.8
		F	0.99	3.33	5.02	7.33	7.87	9.58	11.3	15.5
	≥80	M	0.25	2.01	3.67	6.70	6.94	9.60	12.0	20.2
		F	1.30	3.98	5.94	7.89	10.0	10.5	12.4	16.0

† The grey shading indicates the food vitamin D intake below which a Dietary Reference Intakes of 66.7%
‡ Source:
1. The Nutrition and Health Surveys in Taiwan, 1993-1996
2. The Elderly Nutrition and Health Surveys in Taiwan, 1999-2000
3. The School Children Nutrition and Health Surveys in Taiwan, 2001-2002

mal-derived sources (fish, eggs, meats and milk) with little from plant sources.

From the present study in Taiwan, we see the lowest intakes in relation to need among children, young women and the elderly whose total intake is influenced appreciably by food (cod liver oil) or nutrient (vitamin) supplements. If much higher vitamin D acquisition is required to achieve higher serum (tissue) concentrations, then sunlight exposure is critical.[10,14] Ultraviolet-dependent cutaneous synthesis of cholecalciferol depends on geography, climate, season, clothing, culture, occupation, recreation, atmospheric conditions (e.g., ozone layer) and screening with lotions to reduce sun-burn or skin cancer risk.

We have been particularly interested in those dietary patterns which are comparable to Taiwanese diets, like the Japanese, and have relatively high proportions of energy from plant foods. Of interest, oriental diets, even though relatively lower in red meats, except pork, than occidental diets, have vitamin D intake potential, which is relatively high because of fish, organ meat, and egg consumption. Moreover, oriental (Chinese and Okinawan) food patterns are often high in poultry and pork skin consumptions, which, potentially, because of cutaneous vitamin D synthesis in these animals, could provide a sig nificant source of vitamin D.[18] This is rarely considered in estimates of vitamin D intake.

Table 3. Percentage of contribution of various food groups to mean daily vitamin D intakes in Taiwan

Gender	Age group	Total vitamin D intake (mcg/day)	Percentage of contribution of various food groups (%)						
			Fish	Dairy	Meat	Eggs	Mushroom	Other	Supplement
Male	6-12	5.21	38.5[†]	9.93	8.78	11.0	5.33	13.0	13.4
	13-15	5.49	54.4	1.84	14.1	10.5	2.69	3.72	12.7
	16-18	5.02	60.3	5.67	10.9	11.9	3.28	5.50	2.47
	19-44	5.12	57.9	6.26	9.57	10.1	3.05	4.85	8.20
	45-64	5.47	64.5	5.39	9.69	9.10	2.66	4.96	3.70
	≥ 65	6.34	43.6	24.9	4.95	4.51	2.13	4.34	15.5
Female	6-12	4.73	36.8	9.62	6.81	10.3	5.75	13.3	17.4
	13-15	3.90	60.0	7.43	8.44	8.91	2.96	3.62	8.69
	16-18	3.67	49.7	8.86	7.07	11.2	4.55	6.90	11.8
	19-44	4.39	39.2	14.3	8.07	9.60	3.39	13.0	12.4
	45-64	4.61	53.2	12.4	7.40	8.36	4.92	5.74	8.05
	≥65	7.06	39.1	23.9	5.82	3.61	4.15	4.08	19.3

[†] Shaded numbers are the lowest and the highest proportion of vitamin D obtain from a food group for each gender by age.

Table 4. Comparisons of daily total vitamin D intakes by demographic characteristics, Nutrition and Health Survey in Taiwan Elementary School Children (NAHSIT 2001-2002)[†]

Characteristics	%	Mean ± SE
Gender		
Boy	52.1	5.16 ± 0.29
Girl	47.9	4.81 ± 0.32
Grade		
5^{th}-6^{th}	34.0	5.09 ± 0.34
3^{rd}-4^{th}	32.9	4.87 ± 0.32
1^{st}-2^{nd}	33.1	5.02 ± 0.33
Ethnic group		
Fukienese	73.3	4.95 ± 0.21[a]
Hakka	13.3	4.96 ± 0.66
Mainlanders	9.0	5.80 ± 0.57
Indigenous	1.8	3.49 ± 0.56[a]
Paternal education level		
Elementary school	5.2	4.03 ± 0.41[a]
Junior high school	20.4	4.48 ± 0.39[b]
Senior high school	34.7	5.06 ± 0.38
College and above	23.9	5.54 ± 0.32[ab]
Maternal education level		
Elementary school	6.1	4.83 ± 1.17
Junior high school	18.1	4.07 ± 0.30[ab]
Senior high school	38.7	5.05 ± 0.34[a]
College and above	16.0	6.32 ± 0.52[b]
Family income (1000NTD/month)		
< 40	19.9	4.42 ± 0.28
40-80	44.0	5.26 ± 0.38
> 80	24.6	5.19 ± 0.32
Anthropometry		
Underweight	20.6	5.23 ± 0.38
Normal	56.9	4.99 ± 0.26
Overweight	12.6	4.79 ± 0.44
Obesity	9.8	4.79 ± 0.44

[†] All values are weighted to reflect their representation in the population.
Means in a demographic category share a common superscript are significantly different at $p<0.05$.

Table 5. Comparisons of total vitamin D intake by various characteristics, Nutrition and Health Survey in Taiwan (NAHSIT 1993-1996)[†]

Characteristics	%	Mean ± SE
Gender		
Male	52.1	5.30 ± 0.44[a]
Female	47.9	4.26 ± 0.17[a]
Age (yr)		
13-15	8.00	3.41 ± 0.33[ab]
16-18	7.99	4.17 ± 0.38[c]
19-44	61.8	4.80 ± 0.24[a]
45-64	22.2	5.51 ± 0.60[bc]
Marriage		
Unmarried	34.8	4.44 ± 0.38[a]
Married	65.2	5.01 ± 0.19[a]
Ethnic group		
Fukienese	81.2	4.86 ± 0.36
Hakka	10.6	4.32 ± 0.49
Mainlanders	6.30	4.78 ± 0.31
Indigenous	0.57	6.53 ± 2.64
Work status		
Has a job	60.7	5.05 ± 0.29[a]
Retired	1.64	5.68 ± 0.78
Students	17.1	4.04 ± 0.22[ab]
Housewife	11.6	4.84 ± 0.24[b]
No job	9.00	4.51 ± 0.46

[†] All values are weighted to reflect their representation in the population.
Means in a demographic category share a common superscript are significantly different at $p<0.05$.

A characteristic of North-East Asian diets is the relatively high and regular consumption of mushrooms or fungi. These are important sources of ergosterol ('ergo' refers to 'fungal') which may be converted to ergocalciferol (vitamin D2) under the influence of UV (ultraviolet) light. The extent to which this occurs depends on the growth conditions of the organism and any post-harvest UV exposure. Thus, there is a range of vitamin D2 concentrations in mushrooms, which we have taken into account as far as possible in our estimates of Taiwanese vitamin D intakes.[28] At the same time, there remains controversy about the bio-equivalence of vitamins D2 and D3 with most literature favouring comparable potency.

Yet another consideration in regard to diet and vitamin D status in Taiwanese and other oriental diets is the intake of soy and its products. Although these might provide plant sterols as substrate for ultraviolet-stimulated-synthesis of vitamin D, there are no data to this effect. However, there is growing evidence that soy isoflavones up-regulate the vitamin D receptor and so reduce the dependency on higher vitamin D intakes.[29]

Plant-based diets and vitamin D intake

There is increasing evidence that plant-based diets have advantage in terms of food system sustainability[30] and reduction of chronic diseases.[31] A theoretical difficulty with such dietary patterns is that they restrict the food sources of vitamin D depending on how vegan (complete vegetarian) they are, with the pisco-ovo-vegetarian alternative being the least and no-animal-derived food (vegan) the most risky. In the present study, the vegetarian elderly has lower vitamin D intakes than the non-vegetarian elderly (6.67 vs. 7.00 μg/day, data not shown). The inclusion of milk is often regarded as a vitamin D risk reduction strategy, but there is actually little vitamin D in cow's milk unless it or its products are fortified; and it has little relevance to populations whose food culture is non-dairy or have low lactase status and milk tolerance. That milk and dairy products are a good source of calcium is often regarded as sufficient evidence for a favorable role in regard to bone health. In reality that depends on the associated vitamin D status which can markedly alter calcium bio-availability, intrinsically low in any case.[8] Moreover, oriental non-dairy diets like the Taiwanese studied provide about 400-600 mg calcium daily which is the range of intake for non-dairy consumers compatible with good bone health.[32]

Table 6. Comparisons of total vitamin D intake by various characteristics, the Elderly Nutrition and Health Survey in Taiwan (NAHSIT 1999-2000)

Characteristics	%	Mean ± SE
Gender		
Male	50.9	6.81 ± 0.41
Female	49.1	7.03 ± 0.43
Age (yr)		
65-69	36.0	6.43 ± 0.45
70-74	30.4	7.04 ± 0.48
75-79	18.8	7.46 ± 0.69
≥ 80	14.9	7.19 ± 0.76
Ethnic group		
Fukienese	62.2	6.83 ± 0.55
Hakka	13.5	6.85 ± 0.59
Mainlanders	22.2	7.28 ± 0.52
Indigenous	2.0	6.58 ± 1.74
Education		
Illiterate	36.6	6.23 ± 0.74[ab]
Elementary school	38.0	6.65 ± 0.31[c]
High school	15.0	7.80 ± 0.70[a]
College and above	9.8	9.06 ± 0.73[bc]
Marriage		
Unmarried	2.9	3.98 ± 0.73[a]
Married	97.1	7.01 ± 0.38[a]
Economic status		
Adequate	74.4	7.29 ± 0.43
Difficult	22.4	5.92 ± 0.56
Vegetarian		
Yes	26.9	6.67 ± 0.62
No	72.9	7.00 ± 0.34
Alcohol		
Drinker	59.2	7.31 ± 0.58
Non-drinker	40.5	6.79 ± 0.39
Appetite		
Fair	55.1	6.60 ± 0.54
Good	35.8	7.36 ± 0.51
Poor	7.6	7.78 ± 0.82
Chewing ability		
Without difficulty	64.1	7.48 ± 0.35[a]
With difficulty	34.0	5.99 ± 0.35[a]

† All values are weighted to reflect their representation in the population.
Means in a demographic category share a common superscript are significantly different at $p<0.05$.

However, in the Taiwanese population studied, a significant proportion of dairy consumption is based on imported dried milk powder, which has been fortified with vitamin D. We have consulted the food labels of each available brand of milk powder and applied this to dairy vitamin D intake calculations.

Appropriateness of vitamin D DRIs

Recent evidence makes it unlikely that the present Taiwanese DRIs of 5 μg daily will be sustained. Some authors are proposing 25 μg (1000 IU) vitamin D daily intake for those who without enough sunlight exposure to maintain a serum 25(OH)D level of 32 ng/mL (80 nmol/L). Below this blood level it seems difficult to achieve the calciotropic and non- calciotropic functions of vitamin D.[10,14] In Taiwan, people are increasingly dependent on food sources rather than sun exposure to ensure adequacy of vitamin D. In women this is partly because of a preference for fair skin by sun avoidance; for men and women, it is partly more indoor occupational and recreational activities.

Populations at risk of vitamin D deficiency

Children.

In previous generations, the most concerning outcome of vitamin D deficiency was rickets among children as a consequence of dietary inadequacy and, often, of limited sunlight exposure. Historically it is difficult to know from public records, how prevalent a problem this was. Internationally, including in Asia, there were vigorous campaigns to protect children from rickets with fish liver oil. This knowledge still exists among older Taiwanese.

The apparent adequacy of vitamin D intakes among Taiwanese children in the present study, as for older people, depends on the validity of DRIs derived principally from the observations on prevalence of clinical rickets. As the knowledge of vitamin D pathophysiology advances, this view is bound to be revised.

Adolescent women.

Young women have added risks for vitamin D deficiency. Our data show that they restrict food intake and use few supplements. This means that before peak bone mass is reached, bone accretion will be compromised.[33] The phenomenon of low vitamin D intake is also seen in US adolescent women.[26]

Adult women aged 40 to 70 in Northern Taiwan achieved a mean serum 25(OH)D concentration of 33 ng/mL in summer and 29 ng/mL in winter which was compatible with acceptable BMDs and bone turnover in 1997.[13] However, the cohort of young women that they represented (in 1940-1970) were probably very different in life style in terms of diet and sun exposure than the cohort we examined in 1993-1996. It is unlikely that we can have the same confidence that measures of bone health in our cohort once they are peri- and post-menopausal will be as reassuring in the light of our data.

Another consideration in regard to the earlier Taiwanese study on adequacy of vitamin D intake in women, as judged by measures of bone health,[13] is that more recent information points to a number of non-calciotropic functions of vitamin D. End points would be, for instance, immunomodulation, cell turnover (and risk of neoplasia), metabolic including insulin and glucose, cardiovascular, respiratory and ocular, both lens and retinal and are required for contemporary vitamin D DRIs.[10]

The Elderly.

The elderly are at risk of vitamin D deficiency because of the likelihood of reduced sunlight exposure (less mobility and outdoor life) and because of reduced cutaneous responsiveness in vitamin D synthesis to UV light.[14] In other words, they are likely to be more dependent on vitamin D intake for adequate status. At the same time, there is a tendency to avoid vitamin D containing foods

Table 7. Average vitamin D intake and major sources of selected countries

Country	Specification	Vitamin D from food (μg/day)	Vitamin D from food and supplements (μg/day)	Major sources (Top three)
Current study	Men	4.70	5.12	Fish (58%), meat (10%), supplement (8.2%)
	Women	3.85	4.39	Fish (39%), dairy (14%), supplement (12%)
Australia[4]	Men	2.6-3.0		
	Women	2.0-2.2		
Japan[1]	Women	7.1	7.1	Fish (91%), eggs (3%), meat (2%)
Norway[1]	Man		6.8	Supplement (42%), fish (27%), margarine (27%)
	Women		5.9	Supplement (49%), fish (26%), margarine (23%)
United Kingdom[1]	Man		4.2	Meat (21%), fish (18%), margarine & cereal (17%)
	Women		3.7	Supplement (24%), fish (19%), cereal (16%)
United States[1]	Man		8.12	Milk (58%), supplement (30%), cereal (5%)
	Women		7.33	Supplement (40%), milk (39%), , cereal (3%)

for fear of their atherogenicity: this applies to high cholesterol containing foods like animal skin, organ meats, eggs and certain seafood like shrimps and crabs and was evident in our study.

The consequences of vitamin D deficiency in the aged are manifold and include not only bone health and fracture, but reduced muscle strength, immunodeficiency, neoplasia, diabetes and macrovascular diseases. Reassuringly, in Taiwan, the elderly frequently supplement their vitamin D intake from food with supplements (Table 3). An US longitudinal study[34] demonstrated that fracture rates are reduced with vitamin D supplementation: this may have as much to do with reduced risk of falls with improved muscle strength as with direct effects on bone health.

Indigenous and remote people.

In the present study, indigenous children and elderly had average vitamin D intakes of 3.49 and 6.58 μg per day which were the lowest among the four major ethnic groups in Taiwan. There was a time when vitamin D status of indigenous Taiwanese was unlikely to have been a problem. Many lived by the coast who are now mountain dwellers and had more access through fishing and subsistence farming to fish and eggs and to sunlight. Although the island of Taiwan is not a large land mass, most of its 23 million population live in 4 major cities are concentrated along the west coast, leaving indigenous people to be relatively more populous in remote mountainous areas and on the east coast, separated from the major population and resource epicenters by a central mountain range. Access to education and preventive health care are not as good as elsewhere in Taiwan. Socio demographic characteristics are probably contributors to some of the variation in vitamin D status in Taiwan.

Supplements

On present indications, supplementation of food intake with vitamin D-rich fish liver oil and/or vitamin supplements may increasingly be required, especially as sunlight exposure is more and more restricted and unless public health nutrition campaigns successfully address the dilemmas of enough outdoor pursuits on the one hand and skin protection on the other. Fortunately, there is promise that nutrient-rich diets may also be favorable to skin health.[35,36]

We need to be sure that the vitamin D supplements are conferring not only bone health but also the non-calciotropic benefits of vitamin D and optimal life spans.[8-10] There is some concern that isolated vitamin D may not be as safe as food sources or supplements of this vitamin. The usual considerations are is arterial calcification, hypercalcemia and hypercalciuria.[37] More recently, there has been interest in the possibility of secondary vitamin K deficiency.[11] An approach to risk analysis of vitamin D supplementation is provided by Hathcock et al,[38] where there is an absence of toxicity in healthy adults who used vitamin D supplements up to 250 μg/d (10,000 IU vitamin D3).

A lack of vitamin D food composition data

One of the greatest barriers to appraisal of the vitamin D status of populations and its dietary contributors is the lack of vitamin D food composition data. Very few national food composition tables have such data.

Although the data we have compiled for the present study come from various sources,[18-22, 31] they allow an update of the current National Taiwan Food composition Database for evaluation of individual and population vitamin D status. The caveats must be that the inclusion of such data is with informational gaps where approximations or surrogate values must be applied, particularly with imported foods like dairy products and with sources of vitamin D2 from non-animal sources. There is also the potential of UV irradiated yeast to be a vitamin D source and this needs further appraisal.

Future monitoring and surveillance

Despite the limitations of the present Taiwanese food composition and intake data for vitamin D, they provide direction as where the problems might be. Added to this are the rapid advances in knowledge of vitamin D pathophysiology which underscore the need to revise the DRIs. Changes in the relative contributions of food, sunlight and supplements to vitamin D status are dynamic and further emphasis the need for regular surveillance of intakes and outcomes.

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AUTHOR DISCLOSURES

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Original Article

Vitamin D intake and its food sources in Taiwanese

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台灣地區民眾維生素 D 攝取量及主要食物來源

維生素 D 在二十世紀初被發現，並訂定每日建議攝取量。然而直到最近美國才有其民眾攝取狀況報告。臺灣地區沒有維生素 D 食物成分資料，也從未有人民維生素 D 的營養狀況報告。本研究先彙編不同來源之食物維生素 D 含量，以之估算三個涵蓋不同年齡層且具全國代表性之營養調查(1993-1996，老人，學童)之 24 小時飲食回憶資料及最多五項的補充劑使用頻率。結果包括性別、年齡(學童、成人、婦女與老人)及地區層別的維生素 D 攝取(含補充劑)狀況。台灣地區民眾維生素 D 攝取量一般而言已經足夠，但是高中女學生及原住民，有攝取較少的危險。魚類(鹹水及淡水)、魚肉製品、奶類及蕈類為台灣地區民眾維生素 D 最重要的食物來源。學童之「鹹水魚」、「魚肉加工製品」及「乳類及其製品」三項佔總攝取量的 55%。奶類佔老人總攝取量的四分之一；蛋類在較年輕族群約佔 10%，但是在老人就僅剩 5%。魚肝油仍是學童及青少年使用最多的維生素 D 補充劑來源，老年人則使用綜合維生素礦物質；部份鈣片也添加維生素 D。維生素 D 補充劑在學童約佔總攝取的 13%(男)及 17%(女)，13-15 歲青少年分別為 13%（男）及 9%(女)，到 16-18 歲男性只剩下 2%。之後緩步上升，到老年期，男女性其補充劑可達 16%及 19%。

關鍵字：維生素 D，膳食攝取量，補充劑，國民營養調查，DRIs