Estimated vitamin D synthesis and dietary vitamin D intake among Asians in two distinct geographical locations (Kuala Lumpur, 3°N versus Aberdeen, 57°N) and climates

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Conflict of Interest

None

Authorship

The authors' contributions were as follows: Jamil NA, Gray SR and Macdonald HM contributed to designing of the study, the data analysis and interpretation and wrote the manuscript. Yew MH, Noor Hafizah Y and Poh BK did data collection in Kuala Lumpur. All authors critically reviewed the manuscript.

Ethical Disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures were approved by the Research Ethics Committees of University of Aberdeen (CERB/2013/3/895) and Universiti Kebangsaan Malaysia (UKM 1.5.3.5/244/NN-123-2013). All participants gave their written informed consent prior to participate in the study.

Abstract

Objective: To compare the contributions of UVB exposure and diet to total vitamin D among Asians living in Kuala Lumpur (KL) and Aberdeen (AB).

Design: Longitudinal study

Setting: UVB exposure (using polysulphone film badges) and skin colour and dietary vitamin D intake (by web-based questionnaire) were measured at each season in AB and during Southwest (SWM) and Northeast monsoons (NEM) in KL.

Subjects: 115 Asians in KL and 85 Asians in AB aged 20-50 years.

Results: Median summer UVB exposure of Asians in AB (0.25 SED/d) was higher than UVB exposure for the KL participants (SWM=0.20 SED/d, p=0.02; NEM=0.14 SED/d, p<0.01). UVB exposure was the major source of vitamin D in KL year-round (60%) but only during summer in AB (59%). Median dietary vitamin D intake was higher in AB (140 IU/d), year-round, than intakes in KL (SWM=82 IU/d; NEM=73 IU/d, p<0.01). Median total vitamin D (UVB plus diet) was only higher in AB during summer (338 IU/d) than KL (SWM=241 IU/d, p=0.04; NEM=214 IU/d, p<0.01), with a comparable intake across the full year (AB=230 IU/day; KL=246 IU/d, p=0.78).

Conclusions: UVB exposure among Asians in their home country is low. For Asians residing at the northerly latitude of Scotland, acquiring vitamin D needs from UVB exposure alone (except in summer) may be challenging due to low ambient UVB in AB (only available from April-October).

Keywords: sunlight exposure behaviour, UVB exposure, polysulphone badges, ethnic

Introduction

It is known that UVB radiation (wavelength 290-315 nm) stimulates cutaneous synthesis of vitamin D and that geographical location, time of day and year (season), skin pigmentation, sunscreen use and clothing may influence the amount of UVB reaching the skin for synthesis of vitamin D[1]. Excess exposure to UV light can, however, increase the risks of photoaging and skin cancer[2], causing a challenge for public health advice to minimise these risks, but at the same time maintain vitamin D requirements. Diet makes little contribution to vitamin D requirements as foods that are naturally rich in vitamin D are few and not widely consumed[3]. A small number of foods are fortified with vitamin D. However, the number and types of foods fortified with vitamin D differs significantly between countries due to varied country-specific policies on food fortification[3].

The climate in Kuala Lumpur (3°N), Malaysia, is fairly consistent throughout the year with relatively uniform temperature (averages from 20°C to 30°C) and high humidity and rainfall. Yet, low vitamin D status (defined as serum 25-hydroxyvitamin D (25OHD) <50 nmol/L) has been reported in those living in urban areas in Malaysia[4–6]. Lifestyle behaviours which reduce sunlight exposure (e.g. sun avoidance and excessive clothing) have been suggested as the contributing factors, although the method (questionnaire) used to assess UVB exposure in this study was subjective[5]. Further examination of population UVB exposure in Malaysia with objective measurements is therefore needed.

Studies in the UK consistently show that people with darker skin have lower vitamin D status, compared to Caucasians[7,8]. The amount of melanin in the skin is thought to interfere with vitamin D synthesis by blocking out UVB light and may explain the increased risk of vitamin D deficiency among Asians in the UK[9]. Recent small studies, however, reported that skin pigmentation has no role in the cutaneous synthesis of vitamin D[10,11]. Limited UVB exposure and cultural practices (i.e. wearing clothing that covers exposed skin) have also been associated with poor vitamin D status among Asians residing in the UK[12]. However, no longitudinal data has so far studied the effect of migration from low to high latitude on personal sunlight behaviour. It is uncertain whether UVB exposure among Asians living at high latitude is the same as that in Asians living at the lower latitude of their home country.

The aims of the current longitudinal study were to compare sunlight behaviour among Asians in Kuala Lumpur (KL, 3°N), Malaysia and Aberdeen (AB, 57°N), UK and to assess the relative contributions of UVB exposure and diet to total vitamin D intakes in these two cities.

Methods

Participants

This study was conducted at universities in Aberdeen and Kuala Lumpur. In the UK, people from Asian countries who were currently visiting or residing in AB and intending to stay for a minimum of 1 year were invited to participate. In KL, only citizens of Malaysia were included. Posters were placed around the university and public common areas (i.e., hospitals, mosques and church halls) as well as on Facebook. Potential participants were excluded if they were bed-bound or hospitalized.

Number of participants recruited

Based on cross-sectional data among Asians in Surrey (standard deviation of standard erythermal dose (SED) in summer = 3.1)[(7)], recruiting 68 participants at each site would be sufficient to detect a mean difference of 1.5 SED between season, with 5% significance and 80% power. This sample size was estimated using PS Power and Sample Size Calculation version 3.0.43. After allowing for a 20% drop-out, a total of 82 participants at each site were required.

Study Protocol

In AB, participants were recruited in autumn (September-November) and assessed every 3 months for one year (winter: December-February; spring: March-May; summer: June-August). In KL, recruitment was performed during the Southwest monsoon (SWM; June-August, relatively dry period) and repeated during the Northeast monsoon (NEM; November-February, rainy season).

A web-based questionnaire was designed with two options of language (English and Malay) for the KL site and English for the AB site. Basic demographic information [e.g. date of birth, place of birth, sex, ethnicity and country of living before departure to AB (for participants in AB only)] were asked at baseline only. Participants did not have to complete the questionnaire in one sitting; they could pause and come back to it at a later time. Reminder emails with a link to access their personal questionnaires were sent 7, 14 and 28 days after participants' first login to start the questionnaire. During the next season, participants were contacted via email with a unique link to access their personal questionnaire. Similarly, reminder emails to complete the questionnaire were sent at the same intervals (7, 14 and 28 days) after the initial email of that season.

After completing the online questionnaire, subjects in KL were asked to attend an appointment for anthropometric measurements (baseline only). Body weight was measured with a TANITA digital weighing scale Model HD-309 (TANITA Corp., Tokyo, Japan) to the nearest 0.1 kg whilst height was measured with a portable SECA bodymeter Model 206 (SECA, Hamburg, Germany) to the nearest 0.1 cm. In AB, no visits were carried out and participants self-reported their body weight and height on the online questionnaire.

Sunlight behavior and UVB exposure

Body surface area (BSA) exposure, previous sun exposure and holidays abroad were assessed by a questionnaire adapted from a previous study[7]. Each participant self-assigned a Fitzpatrick skin type (ranging from I, always burns never tans; to VI, never burns, tans easily)[13] based on evaluation of their skin colour. They were asked to estimate the fairest colour the skin on the back of their hand could be (without sun exposure), using a photograph of different skin colours for reference.

Two polysulphone film badges which measure UVB exposure were given to the participants (during the study visit in KL and sent by post in AB). Participants were instructed to wear the badges on their outdoor clothing for a total of seven consecutive days (one badge for 4 days and the second badge for 3 days). Once used, the badges were kept in a sealed envelope. The absorbance of the badges was read on a spectrophotometer (Perkin Elmer UV/VIS Lambda 2 Spectrophotometer) at the University of Aberdeen, before and after use, at a wavelength of 330 nm. Standard erythema dose (SED) was calculated using the following equation:

$$SED = 10.7[\Delta A330] + 14.3[\Delta A330]^2 - 26.4[\Delta A330]^3 + 89.1\ [\Delta A330]^4,$$

where ΔA330 was the change in absorbance of the film badge pre- to post-UVB exposure[14,15].

The equivalent vitamin D intake was estimated from the SED measurements, based on observations that 100 percent of pale skin exposed to the minimal erythemal dose of sunlight (MED) is sufficient to produce 15,500 IU vitamin D[16]. One MED is defined as the minimum amount of UVB to cause erythema or slight pink colouration of the skin after sunlight exposure. As one MED is equivalent to 320 J/m^2 for Fitzpatrick skin type II, and 1 SED is equivalent to 100 J/m^2 UVB exposure, this means that whole body exposure of type II skin to 1 SED sunlight would produce 4900 IU vitamin D. For other Fitzpatrick skin types, 1 MED is equivalent to 200 J/m^2 (2 SED) for skin type I, 250-350 J/m^2 (average = 300 J/m^2 or 3 SED for skin type II, 300-500 J/m^2 (4 SED) for skin type III, 450-600 J/m^2 (5.3 SED) for skin type IV, 600-900 J/m^2 (7.5 SED) for skin type V and 600-2000 J/m^2 (13 SED) for skin type VI. Consequently, specific skin type factors (STF) as suggested by Godar et al. were used when calculating the amount of vitamin D that can be made for a given UVB exposure, for each skin type[17]. The usual BSA exposed to sunlight was also incorporated into the calculation. Thus, the equation for estimating cuntaneous synthesis of vitamin D is as follows:

$$\text{Cutaneous vitamin D (IU)} = 4900 \times STF \times \text{daily sunlight exposure (SED)} \times BSA\ (\%)$$

Dietary vitamin D intake

Dietary vitamin D was assessed by a questionnaire which listed common vitamin-D rich foods and also supplement intake. Subjects were asked to determine the frequency and amount of intake as well as the brand name for commercial products (breakfast cereals, margarine/butter and dietary supplement) in a week during each season. Since the Malaysian Food Composition database does not have data for vitamin D[18], the vitamin D content of raw foods was obtained from McCance and Widdowsons' Composition of Foods[19] whilst the commercial products information was taken from the packaging labels.

Statistical analysis

All analyses were carried out using SPSS version 22. Data were checked for normality and when the distribution was skewed, the natural log was used to transform the data (dietary vitamin D intake, UVB exposure, cutaneous vitamin D and total vitamin D intake). Variables were described using mean and standard deviation or median and inter-quartile range as appropriate. Categorical variables were described with number and percentage. Comparisons between characteristics at each study site were undertaken using an independent t-test or chi square as appropriate. Non-parametric tests (i.e., Wilcoxon signed-rank test and Mann Whitney) were used when the data remained skewed after the natural log-transformation was performed. $P<0.05$ was considered as a statistically significant difference.

Results

Baseline participants' characteristics

A total of 115 Asians (74% female) in KL were recruited during SWM with 102 participants continuing to take part in NEM. In AB, 85 Asians (61% female) were recruited in autumn with retention rates of 92% at 12 months (Figure 1). The physical characteristics of the study population are presented in Table 1. Participants in AB were slightly older, heavier and had a higher body mass index compared to those in KL ($p<0.01$). The majority (~70%) of the participants at both sites reported to have skin type II and III, a quarter of participants (21%) in KL reported to have skin type I ($p=0.024$).

Personal sunlight behavior

In AB, at each season, approximately half (~40-50%) of the Asians reported spending between 30 minutes and 2 hours outside during weekdays and weekend (Table 2). There was a higher proportion of participants spending more than 2 hours outside during the weekend compared to weekdays. No seasonal difference was found for the time spent outside on weekdays, but more participants (31%) were outside between 15 minutes and 30 minutes in winter at weekend, compared to other seasons (autumn: 14%, spring: 18%, summer: 14%, p=0.01). A similar trend was seen in KL when nearly half the participants reported spending between 30 minutes and 2 hours outside during weekdays and weekend. However, there was a lower proportion of participants who spent time outside for between 30 minutes and 2 hours in NEM (41%) compared to SWM (53%, p=0.028) during weekdays. No seasonal difference was observed for the time spent outside at the weekend in KL.

The majority of participants in AB exposed face and hands only (10% BSA) when outside (84% in autumn, 83% in winter, 80% in spring, 71% in summer). Compared to winter, more participants in summer exposed 25% BSA (2% vs 27%) and fewer participants exposed only 5% BSA (14% vs 3%; p<0.01). A high proportion of participants in KL (65% in SWM and 62% in NEM) exposed 10% BSA whilst outside, with no evidence of seasonal variation in BSA exposed. Only a quarter of the participants in both locations reported using sunscreen when outdoors with no seasonal difference.

Seasonal estimates of daily vitamin D intake from diet and cutaneous (UVB) sources

Dietary vitamin D intake and UVB exposure were compared between Asians in AB and KL during times of ambient UVB radiation in AB (summer and spring) (Table 3). There were no seasonal differences in estimated dietary vitamin D intake among Asians in AB and KL. Median dietary vitamin D intake was higher in AB (140 IU/d), year-round, than intakes in KL (83 IU/d). Dietary intakes were below the recommendations in both locations (UK RNI=400 IU/d; Malaysian RNI=600 IU/d)[(20,21)]. The major contributor to dietary vitamin D intake is fresh oily fish, providing an average of 66% of intake in AB and 59% in KL, followed by eggs (17% in AB, 22% in KL) and canned oily fish (e.g. sardines and tuna) (10% in AB, 14% in KL).

The polysulphone film badges revealed substantially lower median daily UVB exposure in autumn (0.04 SED/d) and winter (0.02 SED/d) compared to spring (0.22 SED/d) and summer (0.25 SED/d; p<0.001) in AB. In KL, median daily UVB exposure was higher in SWM (0.20 SED/d) compared to NEM (0.14 SED/d; p=0.001). UVB exposure of Asians in AB during summer was higher than that for KL participants in both SWM (p=0.017) and NEM (p<0.001). The SED doses received in spring (AB) was also higher than NEM (KL) (p=0.003). UVB exposure in AB was lower in autumn and winter compared to SWM and NEM in KL (p<0.001).

After considering skin type factors and BSA exposed, median total vitamin D (diet plus cutaneous sources) was only higher in AB during summer only (338 IU/d) when compared to in KL (SWM=241 IU/d; NEM=214 IU/d), but intakes across the year were comparable (AB=230 IU/d; KL=246 IU/d). Sunlight was the major source of vitamin D in KL year-round (60%; 133 IU/d), but not in AB (38%; 80 IU/d).

Discussion

This is the first longitudinal study comparing sunlight behaviors, UVB exposure and dietary vitamin D intake between Asians living near the equator in KL and at a higher latitude in AB. Sunlight behaviors were similar between the two populations. The results demonstrate a higher UVB exposure (SED) during SWM compared to NEM in KL and this could possibly be due to participants spending less time outdoors in NEM as the latter is the rainy season. Indeed, the proportion of time participants spent outside for between 30 minutes and 2 hours was lower in NEM (41%) compared to SWM (53%). These observations highlight that in spite of relatively high ambient UVB levels during the NEM (~30 SED/day), other climate factors such as rain present a potential barrier for sunlight exposure. The average monthly rainfall recorded during the study period was 853 mm/month in NEM with an average of 22 rainy days/month compared to 133 mm/month with 14 rainy days/month in SWM[22]. In AB, although a high proportion of Asians reported spending time outside for between 30 minutes and 2 hours in each season, the seasonal difference in SED between spring/summer and autumn/winter reflects the negligible amount of ambient UVB radiation in autumn/winter in Scotland. This finding was not surprising as it is known that the intensity of UVB radiation (290-310 nm) from October to March in the UK is too low for cutaneous synthesis of vitamin D.

The finding of a higher daily SED received among Asians in AB during summer and spring compared to those in KL was unexpected. A possible explanation for this observation could be due to participants in KL spending their time outside in the shade, resulting in minimal UVB exposure. It has been demonstrated that the UVB intensity can be reduced by up to 50% in some shady environments (e.g., umbrella shade and tree shade) and no UVB light can penetrate a car with the windows closed[(23)]. Malaysia is a developing country and KL, the capital city, is surrounded by many tall buildings which block a significant amount of UVB and thus abate UV radiation. Given that Malaysia is a tropical country, sun-seeking behavior is uncommon in this population due to hot weather (average daily temperature of 27.7°C). In addition, Asians prefer to have fair skin than tanned skin as it is viewed as beautiful[(24,25)].

The low sunlight exposure among participants in KL might also be due partly to environmental factors such as air pollution and cloud cover, which can influence the extent of UVB reaching ground level[(26)]. Engelsen et al. suggested that these two factors can impose a period of insufficient outdoors UV radiation, even at the equator[(27)]. Of note, there was a particular period of pollution (haze) reported in KL (during SWM) as a result of biomass burning. Although this study was conducted one month after the incident (when the air pollutant index was reported to be good), it is unknown if the event had long-term repercussions that might influence sunlight behaviours among the study population (i.e. subjects still limit their outdoor activities in line with the recommendations given during the haze). Previous studies have shown a significant association between ambient air pollution and low vitamin D status in children in India[(28)] and pregnant women in France[(29)]. In addition, the cloud cover in Malaysia is generally high throughout the year with an average of 7.0 oktas/day reported in KL (indicating only a tiny portion of blue sky showing) with less seasonal variation[(30)].

It is also possible that the low sunlight exposure among participants in KL due to non-compliance in wearing the polysulphone badges. Although participants were instructed to wear the badge on the lapel (just under the collarbone), it is possible that the badge might have become covered up with scarfs (often worn by Asian females). Although this may also happen among Asian females in AB, this is less likely as badges were more likely to be pinned on a jacket rather than on scarfs (scarfs worn inside jackets). It is, unfortunately, not possible to distinguish between a participant not going outside or forgetting to wear the badge. For other sunlight-related behaviors, there were no marked differences between these two study populations.

The higher dietary vitamin D intakes among Asians in AB compared to those in KL may be explained by the frequent intake of oily fish among Asians in AB (AB: 66% versus KL: 59%). However, since a vitamin D database of Malaysian food is absent, there may be some under-estimation if their fish were more vitamin D rich. Fortified foods (i.e., margarines and breakfast cereals) contribute a small amount to the total vitamin D intakes in both populations.

Our study has demonstrated that cutaneous synthesis of vitamin D provides ~60% of the total annual vitamin D intake among a population near the equator. At latitude of 57°N, a lower contribution from sunlight exposure (40-60%) was observed during spring and summer. Although Asians living in AB in this study had lighter skin colour (type II-IV) than South Asians in Surrey (51°N) (type V), a higher contribution from cutaneous synthesis of vitamin D (50-70%) was observed among those in Surrey likely due to the higher SED doses they received at lower latitudes in Southern England[(7)] and warmer climate compared to Scotland. In contrast, both lighter skin type and higher SED doses were likely to contribute to the higher contribution (60-80%) of cutaneous synthesis of vitamin D among the Caucasians in Aberdeen during spring and summer[(7)].

To the best of our knowledge, the current study was the first study in Malaysia to investigate sunlight exposure using an objective measure. A strength of the study is that the same questionnaires were used in two study sites and made available in two languages in KL. However, a limitation is that sunlight behaviours were self-reported which are subject to recall bias and assumes that the individual's pattern of behavior was the same throughout each season. The use of polysulphone badges to capture actual sunlight exposure is limited by participants forgetting to wear the badges, or if the badges were covered up by clothing at any point. Skin colour was also self-reported and physical activity levels were not measured. Finally, there is no vitamin D database of Malaysian food. However, every effort was made to match the food appropriately and as the key foods providing vitamin D in these population (oily fish and eggs) are not fortified it is unlikely that the content would differ greatly between countries.

Conclusion

The extent of low UVB exposure as measured by the polysulphone badges among Asians in their home country is of concern. For Asians in AB, acquiring vitamin D needs from UVB exposure alone (except in summer) is challenging due to low ambient UVB in AB. Promoting outdoor lifestyle with sensible sun protection and food-based strategies may be useful approaches to make up the shortfall in vitamin D needs among Asians in both locations and climates.

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Figure 1: Recruitment and participants' retention

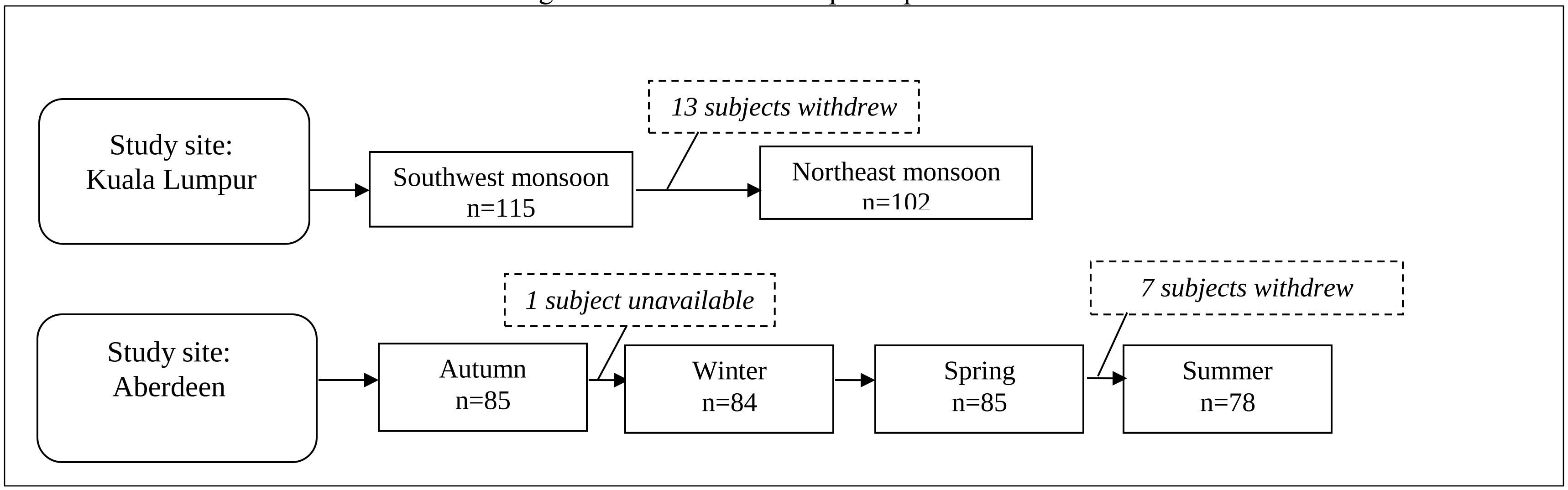

Table 1: Baseline participants’ physical characteristics and comparison between the study sites

	Kuala Lumpur (n=115)			Aberdeen (n=85)			p
Physical characteristics (Median, 25^{th}, 75^{th} percentile)							
[a]Age (years)	24.6	21.7	27.6	27.8	23.1	33.6	<0.001
[a]Weight (kg)	56.0	50.5	65.0	63.4	53.3	74.0	0.002
[b]Height (cm)*	161.3	8.9		163.5	8.1		0.078
[a]BMI(kg/m^2)	21.5	19.9	24.7	24.1	20.6	25.9	0.006
Gender (n,%)[c]							
Male	30	26.1		33	38.8		0.055
Female	85	73.9		52	61.2		
Skin type (n, %) [c]							
Type I	24	20.9		5	5.9		0.024
Type II	38	33.0		27	31.8		
Type III	39	33.9		34	40.0		
Type IV	13	11.3		18	21.2		
Type V and IV	1	0.9		1	1.2		

BMI: body mass index

[a]Mann-Whitney test, [b]Independent t-test, [c]Pearson Chi-Square

*Mean, SD

Table 2: Personal sunlight behaviour, n (%)

	Aberdeen								Kuala Lumpur			
	Autumn		Winter		Spring		Summer		Southwest monsoon		Northeast monsoon	
Typical time spent outdoors (weekdays)												
Never	1	1.2	0	0	0	0	0	0	1	0.9	0	0
< 15 min	3	3.5	6	7.1	4	4.7	3	3.8	0	0	0	0
15-30 min	26	30.6	33	39.3	30	35.3	25	32.1	26	22.6	41	41.0
30 min–2 hr	46	54.1	37	44.0	40	47.1	33	42.3	61	53.0	41	41.0
> 2 hr	9	10.6	8	9.5	11	12.9	17	21.8	27	23.5	18	18.0
Chi-square (p-value)	0.421								0.028			
Typical time spent outdoors (weekend)												
Never	0	0	0	0	0	0	0	0	0	0	0	0
< 15 min	3	3.5	5	6.0	7	8.2	1	1.3	2	1.7	3	3.0
15-30 min	12	14.1	26	31.0	15	17.6	11	14.1	33	28.7	32	32.0
30 min–2 hr	38	44.7	28	33.3	44	51.8	33	42.3	49	42.6	45	45.0
> 2 hr	32	37.6	25	29.8	19	22.4	33	42.3	31	27.0	20	20.0
Chi-square (p-value)	0.008								0.632			
% BSA exposed												
5%	6	7.1	12	14.3	10	11.8	2	2.6	0	0	0	0
10%	71	83.5	70	83.3	68	80.0	55	70.5	65	65.0	62	62.0
25%	8	9.4	2	2.4	7	8.2	21	26.9	31	31	33	33.0
60%	0	0	0	0	0	0	0	0	4	4.0	5	5.0
Chi-square (p-value)	<0.001								0.885[a]			
Sunscreen user	15	17.6	13	15.5	17	20.0	24	30.8	28	24.3	22	22.0
Chi-square (p-value)	0.082								0.684			

BSA: body surface area; 5% (face only); 10% (face and hands); 25% (face and hands plus arms/legs); 60% (face and hands plus arm/legs and some/all of the trunks)

[a]Fisher-exact test

Table 3: Seasonal estimates of daily vitamin D intake from diet and cutaneous (UVB) sources

Location and season	*n* food questionnaire / *n* sunlight estimate	Dietary source (IU/day)		UVB exposure (SED/day)		Cutaneous source* (IU/day)		Total vitamin D (IU/day)		Cutaneous / total (%)
		Median	25^{th}-75^{th} percentile	Median	25^{th}-75^{th} percentile	Median	25^{th}-75^{th} percentile	Median	25^{th}-75^{th} percentile	Mean
Aberdeen										
Autumn	85/83	113	63 – 191	0.04	0.01 – 0.09	15	4 – 41	148	89 – 234	12
Winter	83/82	126	70 – 223	0.02	0.00 – 0.04	6	2 – 16	143	77 – 236	4
Spring	85/82	142	63 – 219	0.22	0.10 – 0.34	83	39 – 165	253	253 – 409	38
Summer	78/71	106	106 – 194	0.25	0.14 – 0.45	152	68 – 269	338	338 – 430	59
Aberdeen year-round		140	93 – 215			80	48-121	230	174 – 309	38
Kuala Lumpur										
SWM	100/100	82	33 – 152	0.20	0.11 – 0.30	120	60 – 261	241	160 – 414	61
NEM	100/100	73	28 – 133	0.14	0.07 – 0.23	96	52 – 222	214	121 – 358	59
Kuala Lumpur year-round		83	43 – 142			133	65 – 248	246	152 – 372	60
Comparisons within group (seasonal changes), p-value										
Aberdeen		0.154[a]		<0.001[a]		<0.001[a]		<0.001[a]		<0.001[a]
Kuala Lumpur		0.073[b]		0.001[c]		0.086[b]		0.100[b]		0.259[b]
Comparisons between group (Aberdeen vs Kuala Lumpur), p-value										
Summer vs SWM		0.039[d]		0.017[d]		0.546[d]		0.044[d]		0.153[d]
Summer vs NEM		0.002[d]		<0.001[d]		0.083[d]		0.001[d]		0.441[d]
Spring vs SWM		0.001[d]		0.574[e]		0.008[e]		0.745[e]		<0.001[d]
Spring vs NEM		<0.001[d]		0.003[e]		0.182[e]		0.093[e]		<0.001[d]
Aberdeen-Kuala Lumpur year-round		<0.001[d]				<0.001[d]		0.782[d]		<0.001[d]

SED: standard erythema dose; SWM: Southwest monsoon; NEM: Northeast monsoon

[a]Repeated measures ANOVA using natural log-transformed data; [b]Paired t-test using natural log-transformed data; [c]Wilcoxon-signed rank test; [d]Mann-Whitney test; [e]Independent t-test using natural log-transformed data

*Estimated from SED, body surface area exposed and skin type