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Short Communication

Prevalence and predictors of vitamin D inadequacy amongst Lebanese osteoporotic women

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In Middle-Eastern countries, more particularly in Lebanon, the incidence of vitamin D deficiency has been found to be surprisingly high in schoolchildren and young individuals. However, the prevalence and risk factors for vitamin D inadequacy amongst Lebanese osteoporotic women seeking medical health care has never been studied. We analysed vitamin D-inadequacy risk factors among the 251 Lebanese postmenopausal osteoporotic women (from both Muslim and Christian communities) who participated in a vitamin D international epidemiological study. Vitamin D inadequacy prevalence (25-hydroxyvitamin D (25(OH)D) < 30 ng/ml) was 84·9 %. 25(OH)D was negatively correlated with BMI (r −0·41; $P<0·001$) and positively correlated with educational level (r 0·37; $P<0·001$) and self-reported general health (r 0·17; $P<0·01$). No significant correlation was found with age and no seasonal variation was observed. There was no significant correlation between 25(OH)D and sun exposure index or vitamin D-rich food consumption. However, 25(OH)D strongly correlated with vitamin D supplement intake (r 0·48; $P<0·0001$). Muslim community participants had lower 25(OH)D levels compared with their Christian counterparts ($P<0·001$). They also had higher BMI, lower educational level and vitamin D supplement consumption and followed more frequently a dress code covering the arms ($P<0·0001$ for all variables). In a multivariate model, in Muslims, inadequate vitamin D supplements and a dress code covering the arms are the independent predictors of 25(OH)D inadequacy ($P<0·001$ for both variables). However, in Christians, the predictors are inadequate vitamin D supplements, high BMI and low educational level ($P<0·001$; $P=0·002$ and $P=0·02$ respectively). There is an urgent need to increase vitamin D supplement use in Middle-Eastern osteoporotic women, more particularly in those from the Muslim community.

Vitamin D: Osteoporotic women: Middle-East: Lebanese

Among factors contributing to bone health, satisfactory vitamin D status is of major importance[1,2]. Both inadequate vitamin D intake and low sun exposure lead to vitamin D deficiency[1–4]. Fish being the only natural important dietary sources of vitamin D, all other dietary sources are in need of supplementation. Milk, some milk products and cereals are supplemented to different degrees depending on the country, with a much higher degree of fortification in the USA. On the other hand, season, latitude and time of the day, clothing and sunscreen, pigmentation of the skin and ageing are the main factors contributing to the cutaneous production of vitamin D[1].

Vitamin D inadequacy is a highly prevalent condition worldwide, more particularly in Europe and elsewhere[1,5,6]. In Middle-Eastern countries, more particularly in Lebanon, several recent studies have shown a surprisingly high incidence of vitamin D deficiency in young individuals[7] and schoolchildren[8]. Similar results were observed in Saudi Arabia[9], Kuwait[10] and Jordan[11]. Dress codes, culinary habits and a very hot sun enabling sun exposure account for these differences[1,7].

Despite the fact that adequate vitamin D intake is considered an essential component of osteoporosis management[12], the prevalence of vitamin D inadequacy in osteoporotic women is very high; more than half of North American women have vitamin D inadequacy[13]. Moreover, in a recently published international study, vitamin D inadequacy affects 64 % of osteoporotic women worldwide[14]. In this latter study, Lebanon had

Abbreviations: Ln25(OH)D, natural logarithm of 25-hydroxyvitamin D; 25(OH)D, 25-hydroxyvitamin D.

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the lowest regional 25-hydroxyvitamin D (25(OH)D) values; the major risk factors for vitamin D inadequacy were high BMI, inadequate vitamin D supplementation and poor self-reported health[15].

The purpose of the present subanalysis is to study risk factors for vitamin D inadequacy in the Lebanese subgroup of the international population and to compare those risk factors in both Muslim and Christian communities.

Materials and methods

Participants

The present study is part of a cross-sectional survey performed at fifty-five sites in eighteen countries and including 2606 postmenopausal osteoporotic women. Participating countries represented a variety of latitudes and were grouped in five regions: Europe, Middle-East (Lebanon, Turkey), Asia, Latin America and Australia. In Lebanon (latitude 34°N), 251 participants were selected from three sites typical of medical outpatient practices treating postmenopausal women. Women were recruited either because they sought medical advice for osteoporosis or via the osteodensitometry centre of the sites. Two of the three sites were in two university hospitals of the Eastern part of Beirut (sixty-six and eighty-five participants respectively), and the third site was in a hospital centre of Saida, a south Lebanese town (100 participants). In the first two sites, all women were from the Christian community while in the third site, all women were Muslims. Recruitment was done during two periods, from July to August 2004 and from February to March 2005 covering respectively the winter and summer seasons of Lebanon. Inclusion criteria were female gender, age over 50 years, postmenopausal status for at least 2 years, and prevalent osteoporosis diagnosed according to the WHO criteria (bone mineral density T-score $\leq 2{\cdot}5$ at any site or a history of low-trauma non-pathological fragility fracture at any site after age of 45 years).

After providing informed consent, data collection was performed in each of the centres in a single visit. In every woman weight and height were measured. BMI was calculated as weight (kg)/height (m^2). A survey including information regarding past medical history, prior and current medications for osteoporosis, use of vitamin D supplements and Ca was filled in. A dietary recall using a twenty-item questionnaire was done to evaluate the amount of intake of vitamin D-rich food (milk, fish and chicken liver). Information on sun exposure (time spent outside with or without sunscreen, body parts exposed to sun) was also collected. Sun exposure was calculated as number of hours spent outside without sun protection multiplied by percentage of the body exposed to sunlight (9 % for face, 1 % for each hand, 9 % for each arm, and 18 % for each leg). Body part exposure to sunlight (arms, face, hands, legs) corresponds to the answer yes/no to the question: 'During the past month, when you spent time outside, which of the following body parts were usually exposed?'. Finally, the questionnaire included information on self-reported general health (poor, fair, good, very good, excellent) and level of education obtained (less than primary school, primary school, secondary school, university degree). A score was used for self-reported general health and educational level (score from 0 to 4 and from 0 to 3 respectively).

Laboratory studies

A single non-fasting blood sample was collected for the assessment of blood chemistry, serum 25(OH)D and intact parathyroid hormone. All tests of biological samples were performed in a single central laboratory (Quest Diagnostics Clinical Trials Laboratory, Van Nuys, CA, USA). 25(OH)D and parathyroid hormone were measured using two Nichols Advantage® two-site chemiluminescence assays (Nichols Institute Diagnostics, San Clemente, CA, USA). For 25(OH)D, the normal range is 10–68 ng/ml, with intra-assay CV 4 % and lower limit of sensitivity 7 ng/ml. For parathyroid hormone, the normal range is 10–65 pg/ml, with intra-assay CV $<7{\cdot}5$ % and lower limit of detection 2 pg/ml.

Statistical analysis

SPSS release 13 (SPSS, Inc., Chicago, IL, USA) was used to perform the statistical analysis. Because 25(OH)D is not normally distributed, a logarithmic transformation was used for its analysis (Ln25(OH)D). The Pearson coefficient was used for linear correlations between Ln25(OH)D and other variables. A multilinear regression analysis was performed separately in the two communities in order to look at the explanatory variables for 25(OH)D. This analysis was performed without logarithmic transformation in order to facilitate the interpretation of the β coefficients and because it gives similar P values compared with the regression with logarithmic transformation. Clinical and biological characteristics between communities were compared using Student's t test and where indicated the χ^2 test. For all analysis, a P value $<0{\cdot}05$ was considered statistically significant.

Results

Participants' age varied between 50 and 87 years with a mean of 67·5 (SD 6·69) years (Table 1). Of the participants, 33·9 % had a history of fragility fractures and 71·9 % were treated by an anti-resorptive osteoporotic treatment (biphosphonates, hormone replacement therapy, raloxifene and/or calcitonine), of which 68·5 % by biphosphonates. A total of 48·6 % of the subjects reported a daily use of at least 10 μg (400 IU) of vitamin D supplements; in 18·7 % this dose was less than 400 IU and 32·7 % did not take vitamin D supplements. A Ca supplement was taken by 62·9 % of our participants.

Baseline 25-hydroxyvitamin D levels and their relationships to other parameters

The mean 25(OH)D levels in the whole population was 19·5 (SD 9·8) ng/ml (Table 1). Ln25(OH)D levels were negatively correlated with BMI (r −0·41; $P<0{\cdot}001$) and positively correlated with educational level score (r 0·37; $P<0{\cdot}001$) and self-reported general health score (r 0·17; $P=0{\cdot}007$). No seasonal variation was observed (19·5 (SD 9·4) v. 19·6 (SD 10·3) ng/ml respectively for summer and winter; $P=0{\cdot}90$) and no significant correlation was found with sun exposure index ($P=0{\cdot}26$). Despite this fact, Ln25(OH)D was lower in women who followed a dress code covering the arms compared with the others (16·8 (SD 10) v. 22·2 (SD 9·7) ng/ml respectively; $P<0{\cdot}0001$) while the significance was border-

Table 1. Comparison between Christian and Muslim communities
(Mean values and standard deviations)

	All (*n* 251)		Christians (*n* 151)		Muslims (*n* 100)	
	Mean	SD	Mean	SD	Mean	SD
Clinical markers						
Age (years)	67·5	6·69	68·1	6·65	66·8	6·87
BMI (kg/m^2)***	28·8	5·34	26·9	4·49	31·5	5·35
Education level (%)						
Primary school or less***	65·7		54·3		83·0	
Secondary school or university degree***	34·3		45·7		17·0	
Self-reported health score	2·23	0·90	2·17	0·95	2·34	0·82
Sun exposure index >0·63 (%)	49·2		51·3		46·0	
Body part exposed to sunlight (%)						
Arms***	37·2		50·7		17·0	
Face	94·0		92·0		97·0	
Hands	98·0		97·3		99·0	
Legs*	37·2		42·7		29·0	
Vitamin D-rich food consumption†						
Milk	0·55	0·63	0·53	0·62	0·57	0·62
Fish and chicken liver*	2·47	2·22	2·74	2·25	2·05	2·11
Vitamin D supplements (μg/d)***	7·68	7·77	9·91	8·27	4·30	5·40
Vitamin D supplements (IU/d)***	307·1	310·9	396·6	331·0	171·9	216·0
Biochemical markers						
25-Hydroxyvitamin D (ng/ml)***	19·5	9·8	22·5	10·6	15·1	6·6
Parathyroid hormone (pg/ml)*	42·1	30·0	37·8	17·4	48·6	41·7
Ca (mmol/l)	2·37	0·12	2·37	0·11	2·37	0·12
P (mmol/l)*	1·19	0·18	1·21	0·16	1·15	0·20
Alkaline phosphatase (IU/l)	69·0	23·5	67·2	21·1	71·6	25·2
Creatinine (μmol/l)	66·2	18	68·0	21·1	63·6	11·5
Mg (mmol/l)	0·86	0·09	0·86	0·08	0·85	0·10

* $P<0·05$, *** $P<0·001$.
† For milk, number of cups drunk daily. For fish and chicken liver, number of servings consumed during the past month.

line for the exposure of legs ($P=0·06$). Finally, no significant correlation was found between Ln25(OH)D levels and the consumption of milk and of vitamin D-rich food (fish and chicken liver). However, Ln25(OH)D values strongly correlated with vitamin D supplement use (r 0·48; $P<0·0001$).

Comparison between Muslim and Christian communities

No statistical difference in 25(OH)D levels was observed between the two Christian sites, so we compared both Christian sites with the Muslim site. 25(OH)D levels were significantly lower in Muslim women compared with Christians ($P<0·0001$). Of the Muslim participants, 20 % had 25(OH)D levels below the detection limit of the kit compared with only 1·3 % of the Christians. Muslims had significantly higher BMI and lower educational level compared with their Christians counterparts. They also followed more commonly a dress code covering the arms ($P<0·0001$ for all variables). No significant difference between the groups was found regarding self-reported general health. No seasonal variation in 25(OH)D levels was observed when the analysis was performed separately in Muslims and Christians. There was a significantly higher consumption of fish and chicken livers in Christian women compared with Muslim ones ($P=0·015$). In a multivariate model, in Muslims, inadequate vitamin D supplementation and a dress code covering the arms were independent predictors of 25(OH)D inadequacy ($P<0·001$ for both variables), while, in Christians, the predictors were inadequate vitamin D supplementation, high BMI and low educational level ($P<0·001$, $P=0·002$ and $P=0·02$ respectively) (Table 2). We finally performed interaction tests comparing the results for Christian and Muslim women. The P value of the interaction factor was significant for BMI ($P=0·045$) and for the exposure of arms to sunlight ($P=0·012$) while there were no significant differences for educational level, self-reported general health and vitamin D supplements, suggesting that there was a statistically different effect of BMI and exposure of the arms to sunlight between the communities.

Discussion

The results of the present study show that in Lebanon, despite the sunny weather, there is a high degree of vitamin D inadequacy. Of the postmenopausal osteoporotic women studied, 85 % had serum 25(OH)D <30 ng/ml *v.* 64 % worldwide[14] and 54 % in the US population[13], confirming results of previous studies in our young population[7]. These results were observed despite the fact that the study target individuals were seeking health care for osteoporosis, 71·9 % were taking antiresorptive drugs and 67·3 % some vitamin D supplements.

Consistent with findings from the larger international study, inadequate vitamin D supplementation, high BMI and low educational levels were found to be the main risk factors for vitamin D inadequacy while season, sun exposure index and vitamin D-rich food consumption were not. Newly identified

Table 2. Separate multilinear regression analyses with 25-hydroxyvitamin D as a dependent variable in Muslims and Christians

	Muslims			Christians		
	β	SE	*P*	β	SE	*P*
Constant	20·05	4·09	<0·0001	32·02	5·86	<0·0001
Vitamin D supplements (2·5μg/d; 100 IU/d)	1·1	0·003	<0·0001	1·0	0·002	<0·0001
Self-reported health*	−1·48	0·75	0·052	−0·63	0·811	0·44
BMI (kg/m^2)	−0·215	0·112	0·058	−0·561	0·18	0·002
Education level†	1·229	0·804	0·13	2·042	0·86	0·02
Exposure of arms to sunlight‡	5·802	1·64	<0·001	0·517	1·56	0·74

* Self-reported general health was evaluated by a score from 0 to 4 for the following: poor; fair; good; very good; excellent.
† Educational level was evaluated by a score from 0 to 3 for the following: did not complete primary school; primary school; secondary school and university degree.
‡ For no exposure of arms to sunlight, 0; for exposure of arms to sunlight, 1.

factors were a dress code covering the arms and belonging to a Muslim community.

Comparing the present results with those of the international study, we found in our population a lower educational level (66 % had a level of primary school or less *v.* 38·2 % in the international population) and higher BMI (mean 28·8 *v.* 25·1 kg/m^2 in the international study). These two findings were observed in both our communities and can partly explain the higher prevalence of vitamin D inadequacy in Lebanon compared with other countries worldwide.

Interestingly, we found a huge prevalence of vitamin D deficiency in our Muslim community compared with the Christian one while 25(OH)D values in Christians were closer but still significantly lower than those of the international study (respectively 22 *v.* 26 ng/ml; $P<0·0001$). The community difference we observed is probably multifactorial; in Muslims a much lesser vitamin D supplement use, a dress code covering the arms, higher BMI and lower educational level.

We then looked separately in each community at the main contributors to 25(OH)D deficiency. We found, in both communities, similarly to the international study, that the most significant contributor is inadequate vitamin D supplementation, while season and vitamin D provided by food have no impact. However, in Muslims, opposite to Christians, BMI had a minor impact, while exposure of the arms to sunlight is of major importance, suggesting that dress code in Muslims is crucial. The reason for the limited effect of BMI in Muslims is unclear and could be related to our overweight Muslim sample.

The lack of seasonal variation in 25(OH)D values is not surprising in Muslims where the area of skin exposed to the sun is limited, but is surprising in Christians who followed a Western style of dress code. A seasonal variation was observed in some countries of the international study such as the UK and Switzerland. It was also previously reported in Lebanese schoolchildren[8], suggesting that, in our population, age may limit the effect of sun exposure on the cutaneous production of vitamin D.

In contrast to our previous study[7] performed in young adults, vitamin D intake provided from food was not a risk factor in both communities. This could be explained by the fact that vitamin D supplements may mask the vitamin D contribution by food to vitamin D status. In Lebanon, the only vitamin D-rich foods are fish and supplemented milk, and, in the present study, the mean milk intake is of only half a cup daily, mainly due to the high prevalence of lactose intolerance in the Lebanese population[16].

The present results emphasise the importance of educational level in our overall population, more particularly in our Christian community, in contrast to the international population. This risk factor was also previously reported in Lebanese schoolchildren[8]. Other studies from the USA[17] and Italy[18] found a high prevalence of 25(OH)D inadequacy in low-income elderly populations[17] and in osteoporotic women with lower educational level[18]. All these results suggest that educational level is not a common factor worldwide.

In conclusion, the high prevalence of vitamin D inadequacy found in the Lebanese subgroup of the international study was mainly observed in Muslim women. In this community, very low vitamin D supplementation and a dress code covering the arms are the main risk factors while BMI has a lesser impact, suggesting an urgent need to largely increase vitamin D supplement use in these women. It is not clear if similar differences between communities will be found in the younger generations of our population where educational level, and probably BMI, are quite equivalent. Further research is needed to elucidate this finding.

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M.-H. G.-Y. was one of the primary investigators of the Lebanese subpopulation and wrote the manuscript. G. M. and Y. Y. were the two other primary investigators in Lebanon. S. K. contributed to the statistical analysis. S. C. performed the data collection. N. Z. was the co-investigator in one of the three sites. A. C. was the Lebanese Merck Sharp and Dohme representative for the study. J. C. and J. N. conducted the international study and contributed to the writing of the article. The paper was reviewed by all the co-authors. The authors declare no conflicts of interest.

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