ISSN: 2659-2029
Proceedings of the 3rd Research Symposium of the Faculty of Allied Health Sciences
University of Ruhuna, Galle, Sri Lanka
October 02, 2020

R 01

Vitamin D deficiency and its associated factors: A descriptive study among a selected group of premenopausal women in Sri Lanka

Subasinghe HWAS[1#], Lekamwasam S[2], Ball P[3], Morrissey H[3], Waidyaratne EI[2]
[1] Department of Pharmacy, Faculty of Allied Health Sciences, University of Ruhuna, Sri Lanka
[2] Faculty of Medicine, University of Ruhuna, Sri Lanka
[3] School of Pharmacy, University of Wolverhampton, United Kingdom

*[#]**Corresponding author**: sewwandisubasinghe@gmail.com*

Abstract

Background: Vitamin D (vit-D) plays a significant role in bone health, largely by regulation of calcium homeostasis in the body. Hypovitaminosis D is linked with a multitude of co-morbidities. Many nutritional and behavioural factors are associated with low vit-D levels.

Objectives: To assess the prevalence of vit-D deficiency and its associated factors in a sample of premenopausal women in Sri Lanka

Methods: Community dwelling healthy women (free of diseases and drugs including vitamins) between 20-40 years (n = 132) were selected from Matara and Kandy districts. Consumption of vit-D rich dairy and non-dairy foods and the duration of sun exposure were estimated. Serum vit-D level was measured. Vit-D reference values introduced by Lips *et al* were used to categorize subjects.

Results: Eight subjects (6.1%) were vit-D deficient while 68 (51.5%) had vit-D insufficiency. There was no difference in median vit-D levels according to age (20-30 vs 31-40 years). Vit-D was higher in women who had sun exposure >2 hours/day compared to women who had <2 hours/day. Vit-D positively associated with dairy (r = 0.189, p = 0.04) and non-dairy vit-D rich food intake (r = 0.263, p = 0.01).

Conclusions: Hypovitaminosis D is prevalent among community dwelling healthy middle-aged women in Sri Lanka. Interventions should be planned based on sun exposure and diet to overcome this prevalent problem.

Key Words: *Vitamin D, Hypovitaminosis, Sri Lankan premenopausal women, Sun light exposure, Dairy intake*

Background

Vitamin D is essential for the maintenance of calcium homeostasis and optimum skeletal health. In the body, vitamin D is available in two bioequivalent forms: D_2 (ergocalciferol) and D_3 (cholecalciferol). Vitamin D_2 is obtained from vegetables, mushrooms and oral supplements while vitamin D_3 is obtained mainly from skin exposure to ultraviolet B (UVB) radiation in sunlight and from oily fish, fortified foods and oral supplements in limited amounts. Vitamin D_3 is the circulating mode while vitamin D_2 is the active metabolite responsible for major biological actions. Recent studies have discovered the pleiotropic effects of vitamin D therapy especially on renal, cardiovascular, reproductive and immune systems in the body (Pittas and Dawson-Hughes, 2011; Talaei et al., 2013; Pérez-Hernández et al., 2016).

Vitamin D deficiency (VDD) has become a major public health concern as it is prevalent in all age groups and ethnicities (Palacios and Gonzalez, 2015). Further, VDD is not uncommon in countries with sufficient UV-B light and among populations who consume vitamin D fortified food (Holick and Chen, 2008). According to Forrest and Stuhldreher (2011), VDD is found in 41.6% Caucasians and among them the highest rate is noted in those of Afro-Caribbean decent (82.1%), followed by Hispanics (69.2%).

Higher prevalence of VDD is found among both South and Southeast Asian populations despite sunlight throughout the year in some regions (Nimitphong and Holick, 2013; Akhtar, 2016; Lowe and Bhojani, 2017). Nearly 70% of Indian population is VDD or Vitamin D insufficient (VDI) despite high consumption of dairy products (Harinarayan et al., 2013). Certain religious beliefs and cultural practices, wearing fully covered cloths, vegetarian food pattern and dwelling in multi-storied apartments are associated with low vitamin D levels in India (Sachan et al., 2005; Harinarayan et al., 2011). Recent studies show that a significant proportion of Indian females living in North as well as South including Muslims have hypovitaminosis D. Nearly 76% of South Indian females inclusive-of pregnant women, child bearing mothers and postmenopausal women have VDD (Harinarayan et al., 2011; Akhtar, 2016). Furthermore, 96% of neonates, 91% of healthy school girls and 84% of pregnant women in North India suffer from VDD (Sachan et al., 2005; Marwaha and Sripathy, 2008; Akhtar, 2016;). Prevalence of VDD is above 70% among healthy adult Pakistani population and another 21% has insufficient vitamin D levels (Akhtar, 2016). More importantly 55% of infants and 45% of nursing mothers in Pakistan have serum vitamin D below 10 ng/mL (Baig et al., 2007; Iqbal and Khan, 2010). Similar situation is observed in Bangladesh where many women wear a veil that restricts exposure to sun (Islam et al., 2006; Akhtar, 2016). Many studies, especially from South Asia support the link between limited sun exposure and low vitamin D level (Baig et al., 2007; Iqbal and Khan, 2010). According to the Thai 4th National Health Examination Survey, 57% of females and 33% males have a vitamin D level <30 ng/mL (Nimitphong and Holick, 2013).

Vitamin D is mainly synthesized in the skin (Nair and Maseeh, 2012; Wacker and Holick, 2013) but the process is influenced by environmental and lifestyle factors. People with dark skin are more susceptible to VDD probably because melanin pigment absorbs Ultra-Violet B (Nair and Maseeh, 2012). Sun screen applications and minimum outdoor activities are human behaviours that, reduce vitamin D production endogenously. Further, skin vitamin D production varies according to the time of the day, season of the year and the Zenith angle of the sun (Wacker and Holick, 2013).

Studies on vitamin D in Sri Lankan population are scarce. Limited data, however, show a high prevalence of VDD among community-dwelling women. Rodrigo et al (2013) showed that 56.2% women aged 20-40 years have either VDD or VDI (<35 nmol/L). (Rodrigo et al., 2013) A study conducted in the central part of Sri Lanka showed that, 58.6% of women aged 30-60 have vitamin D <50 nmol/L (Meyer et al., 2008).

The high prevalence of hypovitaminosis D in some Asian countries despite the abundance of sunlight throughout the year has raised many questions. Whether this is related to the restricted exposure to sunlight or the inability of the pigmented skin to produce sufficient vitamin D is not known. Further, the high prevalence observed is a result of the inappropriate cut-off values used to define VDD and VDI is also being raised.

It is important for a country to know the determinants of vitamin D level of the population. The information can be used in designing health promotion programs to optimize vitamin D level at

population level. This will prevent indiscriminative use of vitamin D supplementation and thereby reduce the additional cost that patients have to bear.
The objectives of this study were to assess the prevalence of vitamin D deficiency and its associations with the diet and sunlight exposure among young women in two selected areas in Sri Lanka.

Materials and Methods

Study design and place
This cross-sectional study was conducted in Matara and Kandy districts in Sri Lanka.

Study sample
Two Pradeshiya Sabha Divisions (intermediate administrative unit) were selected from each district and two Grama Sewa Divisions (the smallest administrative unit) of each Pradeshiya Sabha Divisions were randomly selected for data collection. Community-dwelling women between 20-40 years of age were invited to participate in the study by posters displayed in public places. Women who filled the 'expression of interest form' were invited to take part in the study. Postmenopausal women, pregnant or breast-feeding mothers, women who had diseases (chronic diseases of liver, kidney, heart or lungs and endocrine diseases) or were on medications that can affect vitamin D metabolism (corticosteroids, hormonal contraceptives, diuretics, vitamin D supplementations) were excluded from the study sample.

Ethical considerations
Ethical approval was obtained from the Ethics Review committee of Faculty of Medicine, University of Ruhuna (Ref No. 09.03.2016:3.3). All the participants (n = 132) were educated about the research and their written consent was obtained before enrolling into the study.

Data collection
Data were collected by interviewing study participants individually using a content validated data sheet. Their weight and height were measured adhering to the standard protocols. Five milliliters of venous blood were drawn for biochemical analyses. Vitamin D analysis was performed by Chemiluminescence Binding Assay method using CobasElecsys 411 analyser (Roche Diagnostics International Ltd, Switzerland). Total calcium analysis was performed by colorimetric method using a laboratory test kit. Exposure to sunlight was measured as the number of hours stayed out-door between 6.30 a.m. - 6.30 p.m. while not taking measures to avoid sun exposure (use of an umbrella or sun protection cream). The times of sunrise and sunset were monitored with the meteorological department website during the study period. Participants were divided into two categories as; those who had sun exposure time <2 hours/ day and 2-6 hours/ day.

Amount of dairy and non-dairy vitamin D rich food intake was estimated by a food frequency questionnaire. Dairy food consumption was measured as the number of glasses of milk (either fresh milk or milk powder), wedges of cheese, tea spoons of butter and cups of yogurt and curd. These numbers were added and total diary intake was calculated in units per week. The weekly intake of non-dairy vitamin D rich food was calculated in the same manner considering weekly consumption of fish and meat products (pieces).
Based on the consumption, subjects were categorized as 'low', 'medium' and 'high' consumption considering 33rd and 66th percentiles to decide the cut-off level of those categories. (The cut-off values of dairy food consumption; 0 - 9 'low', 10 - 15 'medium' and 16 ≤ 'high'. In non-dairy vitamin D rich food consumption; 18 - 51 'low', 52 - 70 'medium' and 71 ≤ 'high'.)

Statistical analysis

All anthropometric measurements and calcium levels are presented as mean ±SD. Vitamin D is presented as median (IQR). Pearson and spearman correlations were calculated to assess the associations between continuous variables. Independent t-test, ANOVA followed Bonferroni post-hoc test, Mann Whitney U-test and Kruskal-Wallis test were used to detect significant differences between groups. $p < 0.05$ was considered as statistically significant.

Results

Mean (±SD) body weight, height, BMI and age of the study sample were 55.2 (±11.0) kg, 155 (±5.9) cm, 23 (±4.5) kg/m^2 and 31.3 (±5.9) years, respectively. Mean total serum calcium was 9.28 (±0.64) mg/dL. Median (IQR) of serum vitamin D was 19.54 (15.38 - 24.55) ng/mL. Median serum vitamin D level was not different in the two districts or in two age groups (Table 1).

Table 1- Serum vitamin D levels and calcium at different age categories and two districts

Variable		N	Vitamin D (ng/mL) Median (IQR)	Calcium (mg/dL) Mean (±SD)
District	Matara	71	19.56 (14.1-24.4)	9.39 (±0.36)
	Kandy	61	19.11 (16.37-24.86)	9.16 (±0.85)
Age (years)	20-30	60	19.02 (15.3-24.86)	9.42 (±0.67)
	31-40	72	20.1 (15.41-24.39)	9.17 (±0.60)

This table shows median (IQR) serum vitamin D (ng/mL) and mean (±SD) calcium (mg/dL) levels of women in two districts and two age categories.

Vitamin D cut-off values published by Lips *et al*. were used to assess vitamin D status in this study group (Lips et al., 2001; Lips, 2007). According to that, vitamin D <10 ng/mL- "deficient" (VDD), 10 - 20 ng/mL "insufficient" (VDI), vitamin D >20 ng/mL- "adequate". VDD was observed in 6.1% (n = 8) subjects while 51.5% (n = 68) were VDI (10 - 20 ng/mL). Only 42.4% women in the study sample (n = 56) had normal (>20 ng/mL) vitamin D levels.
No significant correlations were observed between serum vitamin D and age (r = -0.01, p = 0.90) body weight (r = -0.11, p = 0.21) or BMI (r = -0.11, p = 0.21).

Among the study participants, 81 people reported sun exposure <2 hours while the rest (n = 51) reported sun exposure 2 - 6 hours per day during their routine work. Majority of women with VDD (75%) and VDI (69%) had been exposed to sun light less than two hours per day.
Vitamin D level of women who had been exposed to sun light <2 hours per day (19.11 ng/mL) was significantly lower (p = 0.009) compared to women who had 2 - 6 hours of sun exposure (22.93 ng/mL). Among women who had <2 hours sun exposure, 60.5% were vitamin D deficient. In contrast, only 43.1% of women with 2 - 6 hours of sun exposure was vitamin D deficient.

Table 2 shows the vitamin D and calcium levels in different categories based on dairy or non-dairy food intake.

Table 2- Vitamin D status of dairy and non-dairy food categories of premenopausal women

Food type	Variable	Food quantity		
		Low	Medium	High
Non-dairy food	Number (n)	46	42	44
	Vitamin D median (IQR) ng/mL	17.51 (13.24-20.23)	18.8 (12.51-24.82)	22.10 (18.05-27.56)
	Calcium mean (±SD) mg/dL	9.27 (±0.69)	9.18 (±0.55)	9.40 (±0.66)
Dairy food	Number (n)	48	42	42
	Vitamin D median (IQR) ng/mL	18.43 (14.36-25.82)	18.19 (14.48-23.25)	23.22 (17.6-27.06)
	Calcium mean (±SD) mg/dL	9.25 (±0.64)	9.26 (±0.53)	9.34 (±0.75)

Note: SD = standard deviation, IQR = interquartile range

Vitamin D showed a positive association with the amount of dairy food intake per week (r = 0.189, p = 0.04). Vitamin D levels of 'medium' and 'low' diary groups were significantly lower compared to 'high' diary group (table 2, p = 0.03 and 0.01 respectively). However, vitamin D level between 'low' and 'medium' dairy groups was not significantly different (p > 0.05).

Further, serum vitamin D showed a positive correlation, with the intake of non-dairy vitamin D rich food (r = 0.263, p = 0.01). The mean serum vitamin D level of 'high' non-dairy group was significantly higher compared to 'low' and 'medium' groups (p = 0.01 and p = 0.03 respectively). However, there was no significant difference of vitamin D level between the 'low' and 'medium' non-dairy groups.

Discussion

This study shows a high prevalence of VDD/VDI among community dwelling healthy females of 20 - 40 years in two selected districts in Sri Lanka. Further, the study demonstrates a positive association between vitamin D and exposure to sunlight. In addition, high dietary intake of vitamin D, both dairy or non-dairy, is associated with higher serum vitamin D level.

The high prevalence of VDD/VDI seen among study subjects is concordant with previous studies undertaken in Sri Lanka (Meyer et al., 2008; Rodrigo et al., 2013). Unlike previous studies which included one area (Meyer et al., 2008; Rodrigo et al., 2013) we recruited subjects from two geographically distinct regions in the country. While Matara is in the Southern coastal area, Kandy is in the mid country and has a mountainous geography. We found no regional difference in vitamin D level in this study.

Previous studies have shown a high prevalence of hypovitaminosis D among females despite the abundance of sunlight throughout the year (Sachan et al., 2005; Marwaha and Sripathy, 2008; Harinarayan et al., 2013; Nimitphong and Holick, 2013;). There are uncertainties regarding the adequate duration and the ideal time of the day for sun exposure required for adequate vitamin D synthesis (Lips et al., 2006; Wacker and Holick, 2013). According to

Nimitphong and Holick, exposing face and arms to sunlight for 25 minutes, 3 times a week at 9 a.m. helps maintaining adequate vitamin D level (Nimitphong and Holick, 2013). We too observed a significant association between the duration of sun exposure and vitamin D level. The majority of women (61%) in our study were office workers with very limited sun exposure. Most of them reported only 5-10 minutes sun exposure, mostly in early morning or late evening where UV-B exposure is minimum. A study conducted in India shows that, the maximum endogenous vitamin D production is between 11.00 a.m. and 2.00 p.m. when the zenith angle is narrow (Harinarayan et al., 2013).

Apart from restricted sun exposure, dark skin and clothing pattern may have contributed to hypovitaminosis D seen among our subjects. Melanin pigment absorbs UV-B light making skin vitamin D production ineffective. Hence, people with dark skin need more sun exposure to achieve optimum vitamin D level (Nair and Maseeh, 2012; Wacker and Holick, 2013). Sri Lankans usually possess a dark skin colour and thus need to stay longer under the direct sunlight. The majority of our subjects wore "Saree" for work which covered the entire body except the face and part of upper arms.

Fatty fish is the richest natural food source of vitamin D while egg yolk and cod liver oil are also rich in vitamin D (Calvo et al., 2005). Vitamin D content in other dietary sources is minimal unless they are fortified. Strict vegetarians are at high risk of hypovitaminosis D. Fortified food items are expensive and they are not very popular in Sri Lanka and other developing South-Asian countries (Ritu and Gupta, 2014a).
We presume that our findings could be of interest to many sections related to community health in Sri Lanka. This study will add to the emerging body of evidence that VDD and VDI are prevalent in Sri Lanka. The positive association of vitamin D with sun exposure and some food products can be used in health promotion campaigns. Life style modifications would be the best option to address hypovitaminosis D which has a high prevalence. Fortification of commonly used food items with vitamin D can also be considered. Many countries have adopted the policy of fortifying commonly consumed food items to combat hypovitaminosis D (Calvo et al., 2004; Ritu and Gupta, 2014b).

As a health promotion behaviour, people can be encouraged to have more sun exposure. In Sri Lanka, day time temperature varies from 26°C to 32°C, except in the hill country (Department of Meteorology Sri Lanka, 2016). People avoid sun exposure due to high temperature and high humidity especially in hours where vitamin D production is maximum (Harinarayan et al., 2013).

Future research is needed to investigate the best time and the optimum period of sun exposure that enhance vitamin D production in the local setting. Attention should be paid to the detrimental effects of sun exposure particularly the possibility of skin malignancies. Further, it is essential to identify food items that can be fortified with vitamin D in Sri Lankan context. These food items should be freely available, affordable and acceptable to all communities.

Indiscriminate vitamin D supplementation should not be considered until inexpensive life-style modifications are implemented and the cost effectiveness of such supplementation is proven. Recent reports highlight the emergence of hypercalcaemia due to indiscriminate use of vitamin D by clinicians in some countries (Pirotte et al., 2015; Guerra et al., 2016).

This study has few limitations. Subjects were selected by open invitations and those who responded could be health-conscious people. This may make the sample not representative of the population. Also, we have studied only middle-aged women and this data cannot be applied to men and women outside this age range. Measurement of sun exposure was crude and we suggest prospective studies where subjects maintain a record of daily sun exposure and food intake as well.

Conclusions

In conclusion, our results show a high prevalence of vitamin D deficiency/insufficiency among community dwelling healthy middle-aged women in Sri Lanka. Data also indicate a positive association of vitamin D with the duration of sun exposure and daily consumption of food rich in vitamin D. Interventions should be planned based on sun exposure and diet to overcome this prevalent problem.

Acknowledgement
Authors acknowledge the participants of the study, Phlebotomists and Laboratory technicians who participated in blood analysis.

Conflict of Interest
The authors declare that there is no conflict of interest.

Financial assistance
This work was financially supported by the University Grants Commission of Sri Lanka (grant number UGC/VC/DRIC/PG2016(I)/RUH/01) and the University of Wolverhampton, United Kingdom.

References

Akhtar, S., 2016. Vitamin D Status in South Asian Populations – Risks and Opportunities. Crit. Rev. Food Sci. Nutr. 56, 1925–1940.

Baig, A., Anjum, P., Khani, M.K., Islam, N., Rahman, A., 2007. Pattern of serum Vitamin D in OPD patients. Pak J Surg 23, 145–149.

Calvo, M.S., Whiting, S.J., Barton, C.N., 2004. Vitamin D fortification in the United States and Canada: current status and data needs. Am J Clin Nutr 80, 1710S–1716.

Calvo, M.S., Whiting, S.J., Barton, C.N., 2005. Vitamin D Intake: A Global Perspective of Current Status. J. Nutr. 135, 310–316.

Department of Meteorology Sri Lanka (2016) [online] Available from: http://www.meteo.gov.lk/index.php?lang=en (accessed 15 May 2018).

Forrest, K.Y.Z., Stuhldreher, W.L., 2011. Prevalence and correlates of vitamin D deficiency in US adults. Nutr. Res. 31, 48–54.

Guerra, V., Neto, O.M.V., Laurindo, A.F., Paula, F.J.A. de, Moysés Neto, M., Guerra, V., Neto, O.M.V., Laurindo, A.F., Paula, F.J.A. de, Neto, M.M., 2016. Hypercalcemia and renal function impairment associated with vitamin D toxicity: case report. J. Bras. Nefrol. 38, 466–469.

Harinarayan, C. V, Holick, M.F., Prasad, U. V, Vanil, P.S., Himabindu, G., 2013. Vitamin D status and sun exposure in India. Dermatoendocrinol. 5, 130–141.

Harinarayan, C. V, Sachan, A., Reddy, P.A., Satish, K.M., Prasad, U. V, Srivani, P., 2011. Vitamin D status and bone mineral density in women of reproductive and postmenopausal age groups: a cross-sectional study from south India. J. Assoc. Physicians India 59, 698–704.

Holick, M.F., Chen, T.C., 2008. Vitamin D defciency: a worldwide problem with health consequences. Am. J. Clin. Nutr. 87, 1080S–6S.

Iqbal, R., Khan, A.H., 2010. Possible causes of vitamin D deficiency (VDD) in Pakistani population residing in Pakistan. J. Pak. Med. Assoc. 60, 1–2.

Islam, M.Z., Akhtaruzzaman, M., Lamberg-Allardt, C., 2006. Hypovitaminosis D is common in both veiled and nonveiled Bangladeshi women. Asia Pac. J. Clin. Nutr. 15, 81–7.

Lips, P., 2007. Relative value of 25(OH)D and 1,25(OH)2D measurements. J. Bone Miner. Res. 22, 1668–1671.

Lips, P., Duong, T., Oleksik, A., Black, D., Cummings, S., Cox, D., Nickelsen, T., Group, for the M.O. of R.E.S., 2001. A Global Study of Vitamin D Status and Parathyroid Function in Postmenopausal Women with Osteoporosis: Baseline Data from the Multiple Outcomes of Raloxifene Evaluation Clinical Trial. J. Clin. Endocrinol. Metab. 86, 1212–1221.

Lips, P., Hosking, D., Lippuner, K., Norquist, J.M., Wehren, L., Maalouf, G., Ragi-Eis, S., Chandler, J., 2006. The prevalence of vitamin D inadequacy amongst women with osteoporosis: An international epidemiological investigation. J. Intern. Med. 260, 245–254.

Lowe, N.M., Bhojani, I., 2017. Special considerations for vitamin D in the south Asian population in the UK. Ther Adv Musculoskel Dis 9, 137 –144.

Marwaha, R.K., Sripathy, G., 2008. Vitamin D & bone mineral density of healthy school children in northern India. Indian J. Med. Res. 127, 239–244.

Meyer, H.E., Holvik, K., Lofthus, C.M., Tennakoon, S.U.B., 2008. Vitamin D status in Sri Lankans living in Sri Lanka and Norway. Br. J. Nutr. 99, 941–944.

Nair, R., Maseeh, A., 2012. Vitamin D: The "sunshine" vitamin. J. Pharmacol. Pharmacother. 3, 118–26.

Nimitphong, H., Holick, M.F., 2013. Vitamin D status and sun exposure in Southeast Asia. Dermatoendocrinol. 5, 34–37.

Palacios, C., Gonzalez, L., 2015. Is vitamin D deficiency a major global public health problem? J Steroid Biochem Mol Biol. October, 138–145.

Pérez-Hernández, N., Aptilon-Duque, G., Nostroza-Hernández, C.M., Vargas-Alarcón, Gilberto Rodríguez-Pérez, J.M., Blachman-Braun, R., 2016. Vitamin D and its effects on cardiovascular diseases: a comprehensive review. Korean J Intern Med 31, 1018–1029.

Pirotte, B., Stifkens, F., Kaye, O., Radermacher, L., Putzeys, V., Deflandre, J., Vijverman, A., 2015. Hypercalcemia and acute renal failure: a case report of vitamin D intoxication. Rev Med Liege 70, 12–16.

Pittas, A.G., Dawson-Hughes, B., 2011. The role of vitamin D in type 2 diabetes and hypertension. In: Vitamin D. pp. 1907–1930.

Ritu, G., Gupta, A., 2014a. Vitamin D Deficiency in India: Prevalence, Causalities and Interventions. Nutrients 6, 729–775.

Ritu, G., Gupta, A., 2014b. Fortification of Foods with Vitamin D in India. Nutrients 6, 3601–3623.

Rodrigo, M., Hettiarachchi, M., Liyanage, C., Lekamwasam, S., 2013. Low serum vitamin D among community-dwelling healthy women in Sri Lanka. Health (Irvine. Calif). 05, 1997–2003.

Sachan, A., Gupta, R., Das, V., Agarwal, A., Awasthi, P.K., Bhatia, V., 2005. High prevalence of vitamin D deficiency among pregnant women and their newborns in northern India. Am. J. Clin. Nutr. 81, 1060–4.

Talaei, A., Mohamadi, M., Adgi, Z., 2013. The effect of vitamin D on insulin resistance in patients with type 2 diabetes. Diabetol. Metab. Syndr. 5.

Wacker, M., Holick, M.F., 2013. Sunlight and Vitamin D: A global perspective for health. Derm. Endocrinol. 5, 51–108.