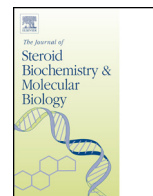




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Review

Is vitamin D deficiency a major global public health problem?☆

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ABSTRACT

Vitamin D deficiency is a major public health problem worldwide in all age groups, even in those residing in countries with low latitude, where it was generally assumed that UV radiation was adequate enough to prevent this deficiency, and in industrialized countries, where vitamin D fortification has been implemented now for years. However, most countries are still lacking data, particularly population representative data, with very limited information in infants, children, adolescents and pregnant women. Since the number of recent publications is escalating, with a broadening of the geographic diversity, the objective of the present report was to conduct a more recent systematic review of global vitamin D status, with particular emphasis in at risk groups. A systematic review was conducted in PubMed/Medline in April–June 2013 to identify articles on vitamin D status worldwide published in the last 10 years in apparently healthy individuals. Only studies with vitamin D status prevalence were included. If available, the first source selected was population-based or representative samples studies. Clinical trials, case-control studies, case reports or series, reviews, validation studies, letters, editorials, or qualitative studies were excluded. A total of 103 articles were eligible and included in the present report. Maps were created for each age group, providing an updated overview of global vitamin D status. In areas with available data, the prevalence of low vitamin D status is a global problem in all age groups, in particular in girls and women from the Middle East. These maps also evidenced the regions with missing data for each specific population groups. There is striking lack of data in infants, children and adolescents worldwide, and in most countries of South America and Africa. In conclusion, vitamin D deficiency is a global public health problem in all age groups, particularly in those from the Middle East.

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1. Introduction

Vitamin D is an essential fat-soluble vitamin for calcium maintenance homeostasis, for bone health and for preventing falls and fractures, and it has also been related to hypertension, diabetes, metabolic syndrome, cancer, autoimmune and infectious diseases, among others [1]. These conditions are major public health problems worldwide.

Several reviews have found high prevalence of vitamin D deficiency worldwide [2–4], even in countries with low latitude, where

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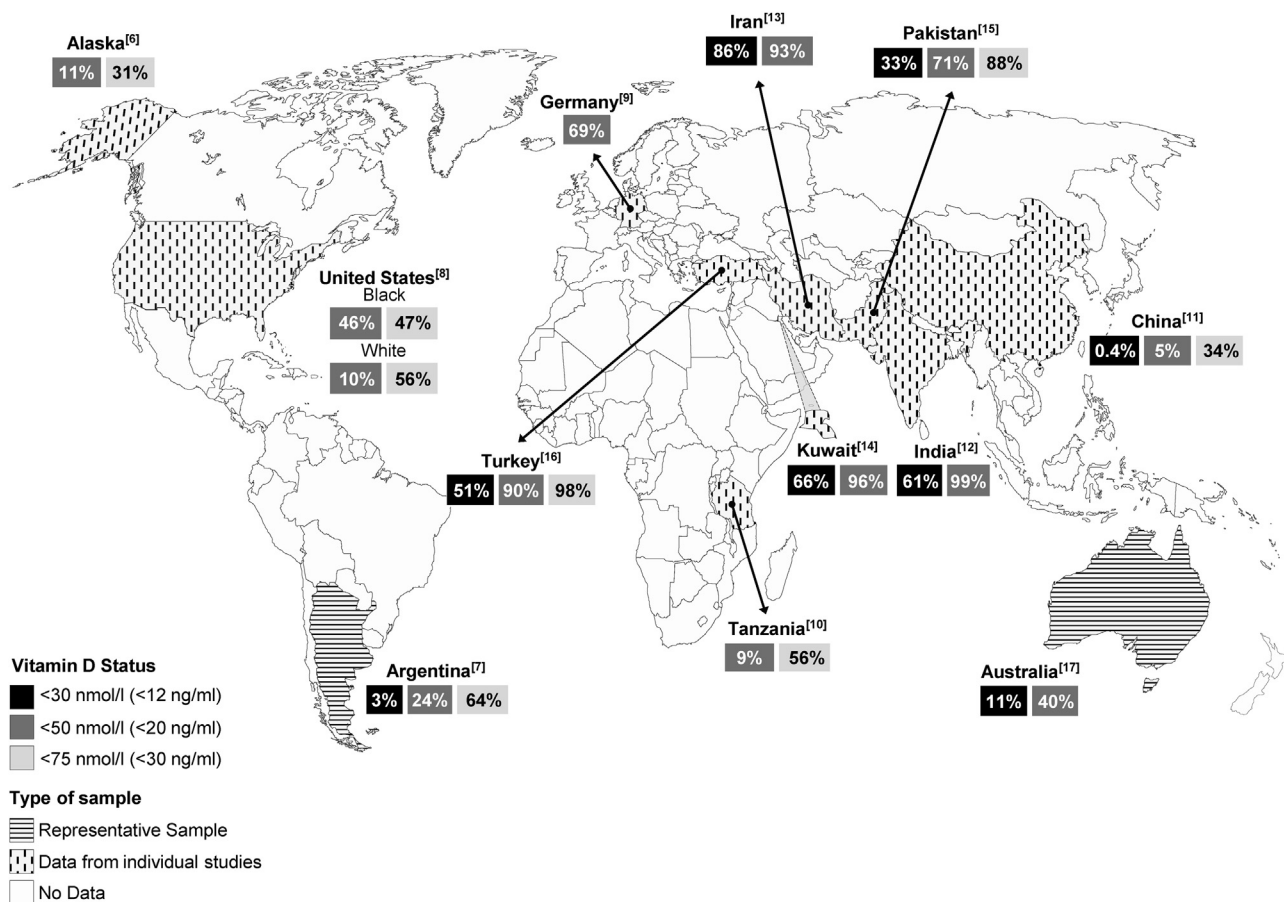


Fig. 1. Prevalence of low vitamin D status in infants worldwide.

it was generally assumed that UVB radiation was adequate enough to prevent vitamin D deficiency, and in industrialized countries, where vitamin D fortification has been implemented now for years; although substantial fortification has only occurred in a few countries. However, prevalence of vitamin D deficiency worldwide is still uncertain, as there is data lacking from many countries. About 1 billion people have low vitamin D levels and this is found in all ethnicities and age groups [1].

The available reviews illustrate the lack of data in most countries, particularly population representative data, with very limited information in infants, children, adolescents and pregnant women. However, the number of recent publications in this area is escalating, with a broadening of the geographic diversity. Therefore, the objective of the present report was to conduct a systematic review of recent literature on global vitamin D status, with a particular emphasis on at risk groups.

2. Methods

2.1. Identification and selection of studies

A systematic review was conducted in PubMed/Medline in April–June 2013 to identify articles on vitamin D status worldwide published in the last 10 years. Two independent reviewers performed the search using the keywords “vitamin D status or deficiency or insufficiency” or any form for “25(OH)D”.

2.2. Eligibility criteria

Only studies in English with data on low vitamin D status prevalence, as determined from serum 25(OH)D levels measured by any

method, in apparently healthy individuals were included. If available, the first source selected was population-based studies. If not available, cross-sectional studies were used. Clinical trials, case-control studies, case reports or series, reviews, validation studies, letters, editorials, or qualitative studies were excluded. When available, the data were specified by gender, age, skin pigmentation and season of the year. A total of 3226 articles were identified; after the initial review, 2860 did not meet the inclusion criteria. An additional 263 were excluded after title and abstract reviewing due to very small sample size; a larger sample from the same country was found; use of non-healthy population; no data on prevalence of vitamin D status or duplicated. A total of 103 articles were eligible and included in the present report.

2.3. Levels used for vitamin D status

There has been a long debate on the cutoff points for vitamin D status. The Institute of Medicine considers inadequate if 25(OH)D levels are <50 nmol/L (<20 ng/mL) [5]. However, many consider inadequate/insufficient if levels are <75 nmol/L (30 ng/mL). For the present analysis, the cutoff points used were: <30 nmol/L (12 ng/mL); <50 nmol/L (<20 ng/mL) and <75 nmol/L (30 ng/mL). When studies used different cut-off points, it was specified.

Maps of vitamin D status worldwide were created for each age group. Corresponding detailed tables can be found in the online version.

3. Results

Fig. 1 shows the prevalence of low vitamin D status in infants worldwide. A total of 12 studies were found; 3 in America, 1 in

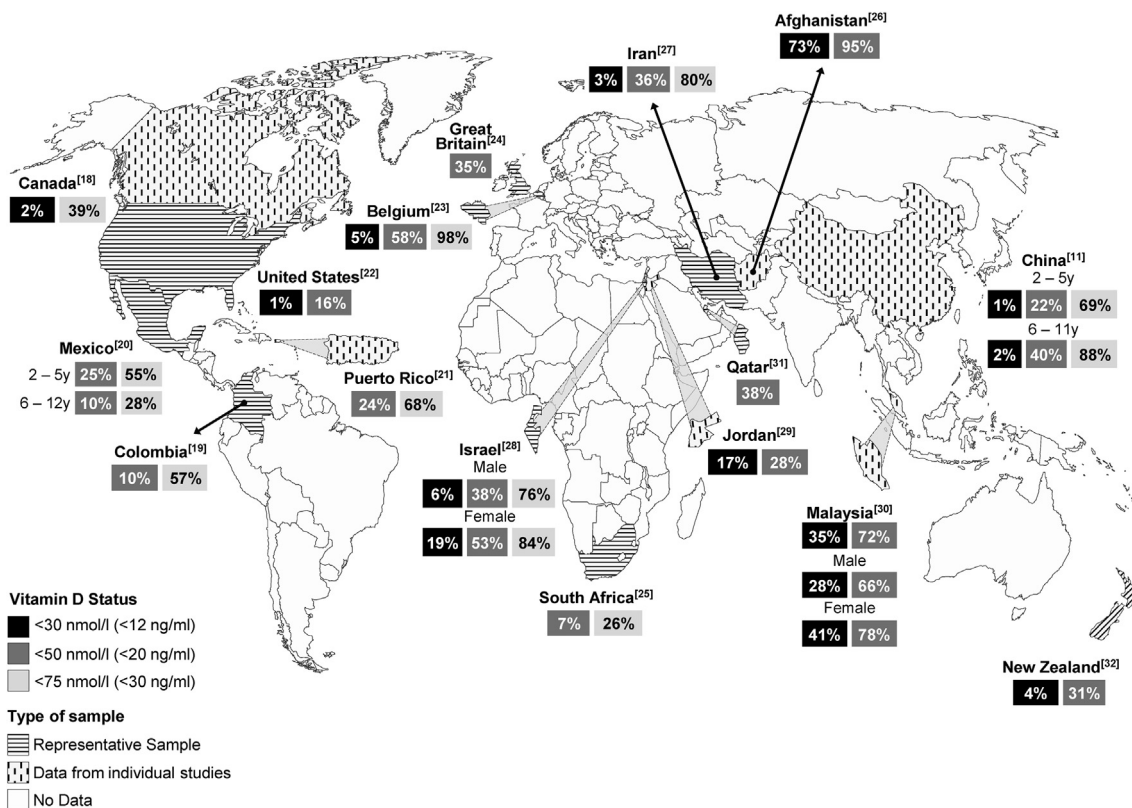


Fig. 2. Prevalence of low vitamin D status in children worldwide.

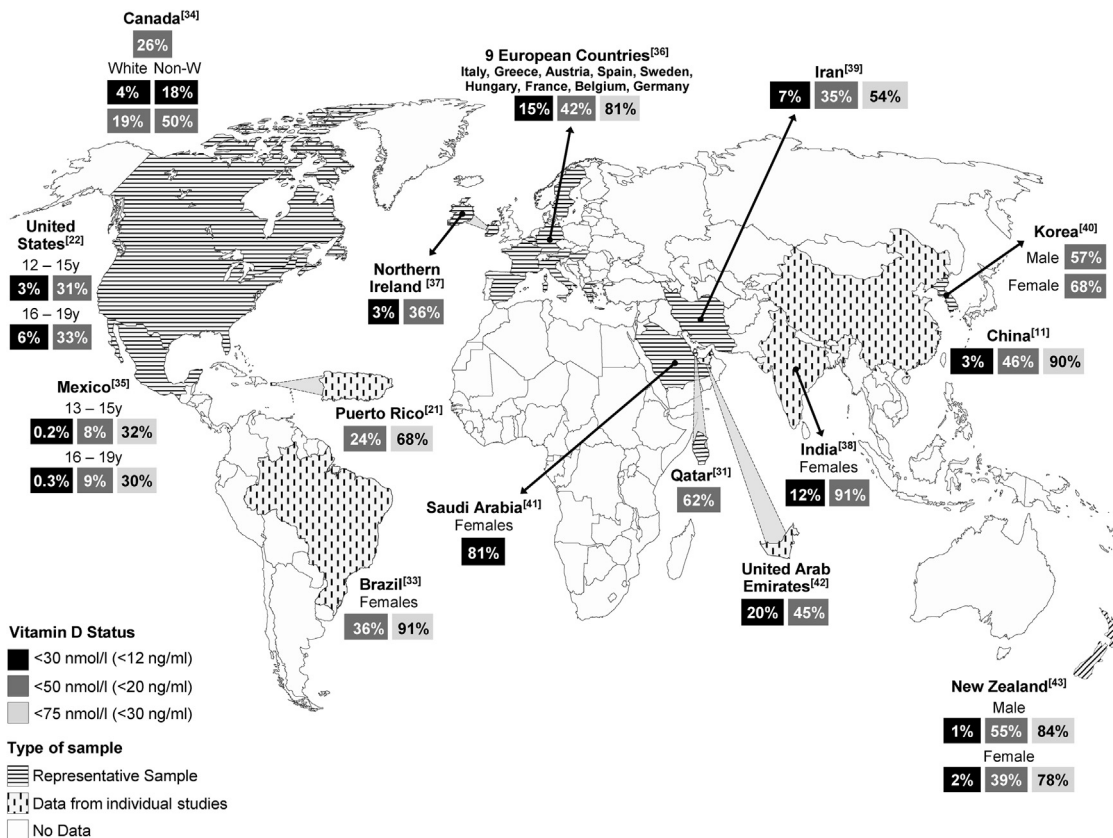


Fig. 3. Prevalence of low vitamin D status in adolescents worldwide.

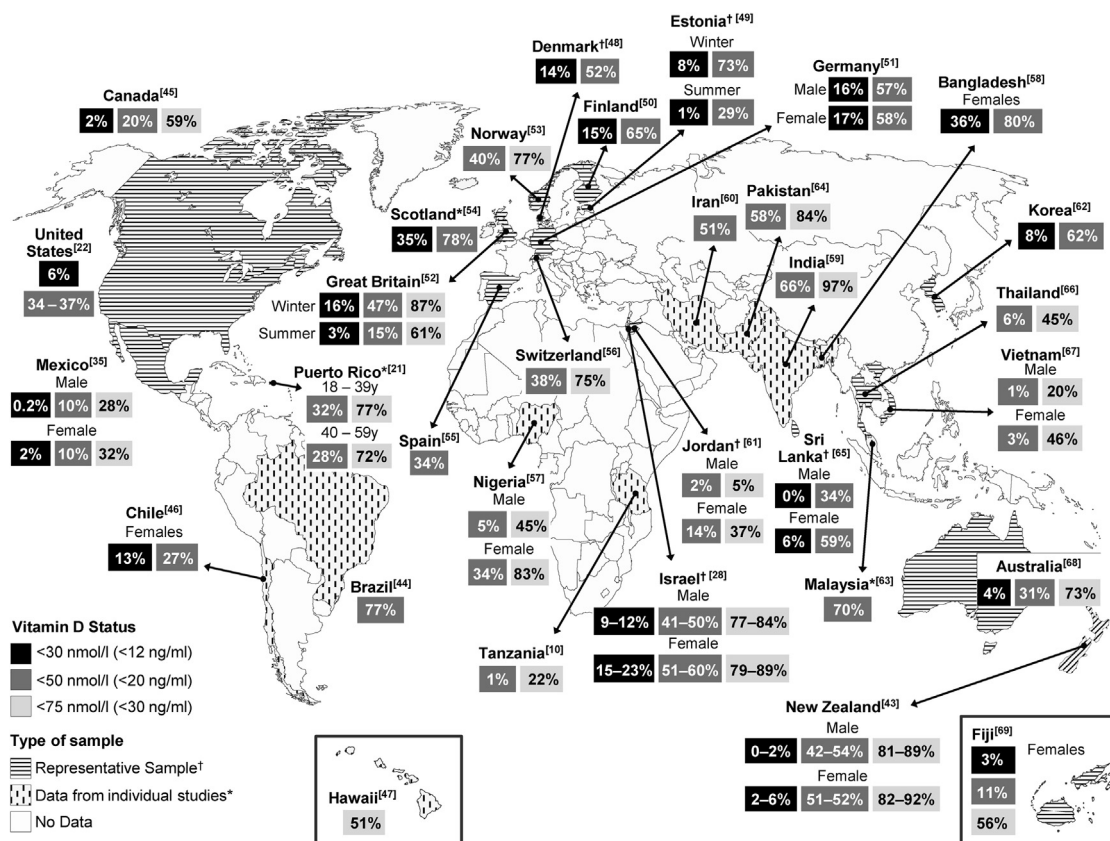


Fig. 4. Prevalence of low vitamin D status in adults worldwide.

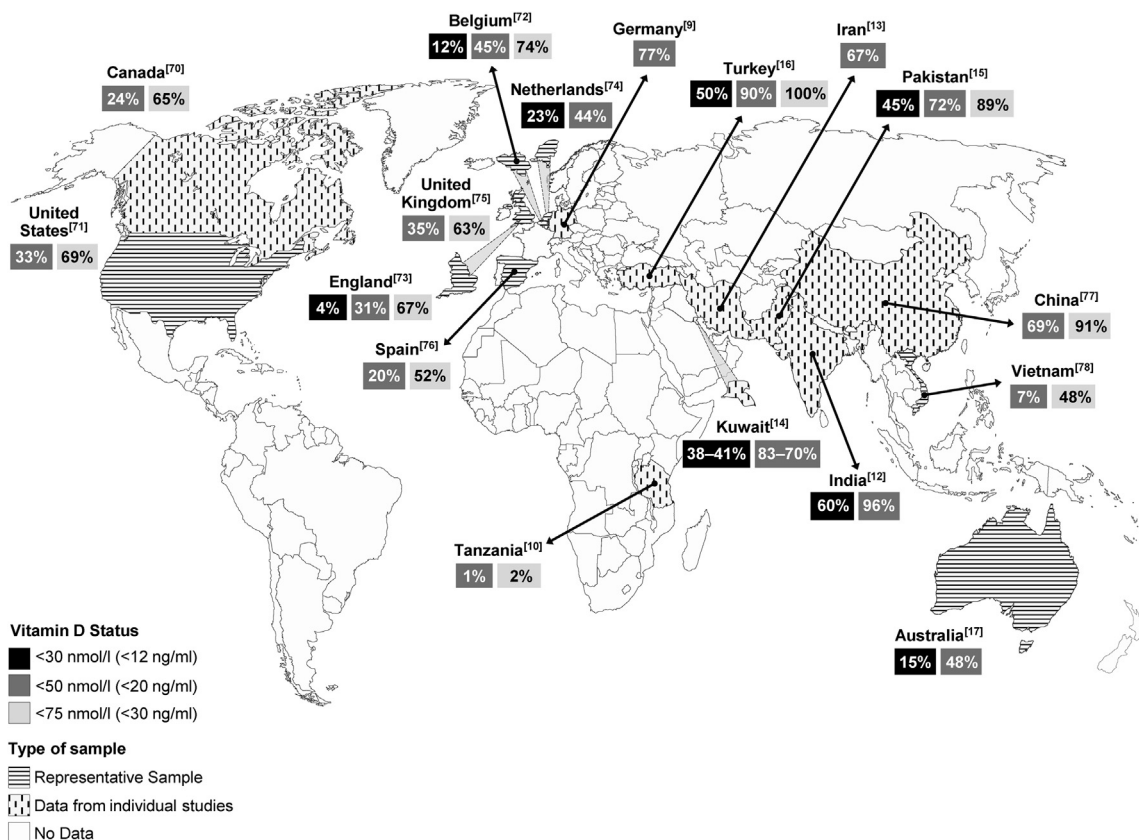


Fig. 5. Prevalence of low vitamin D status in pregnant or lactating women worldwide.

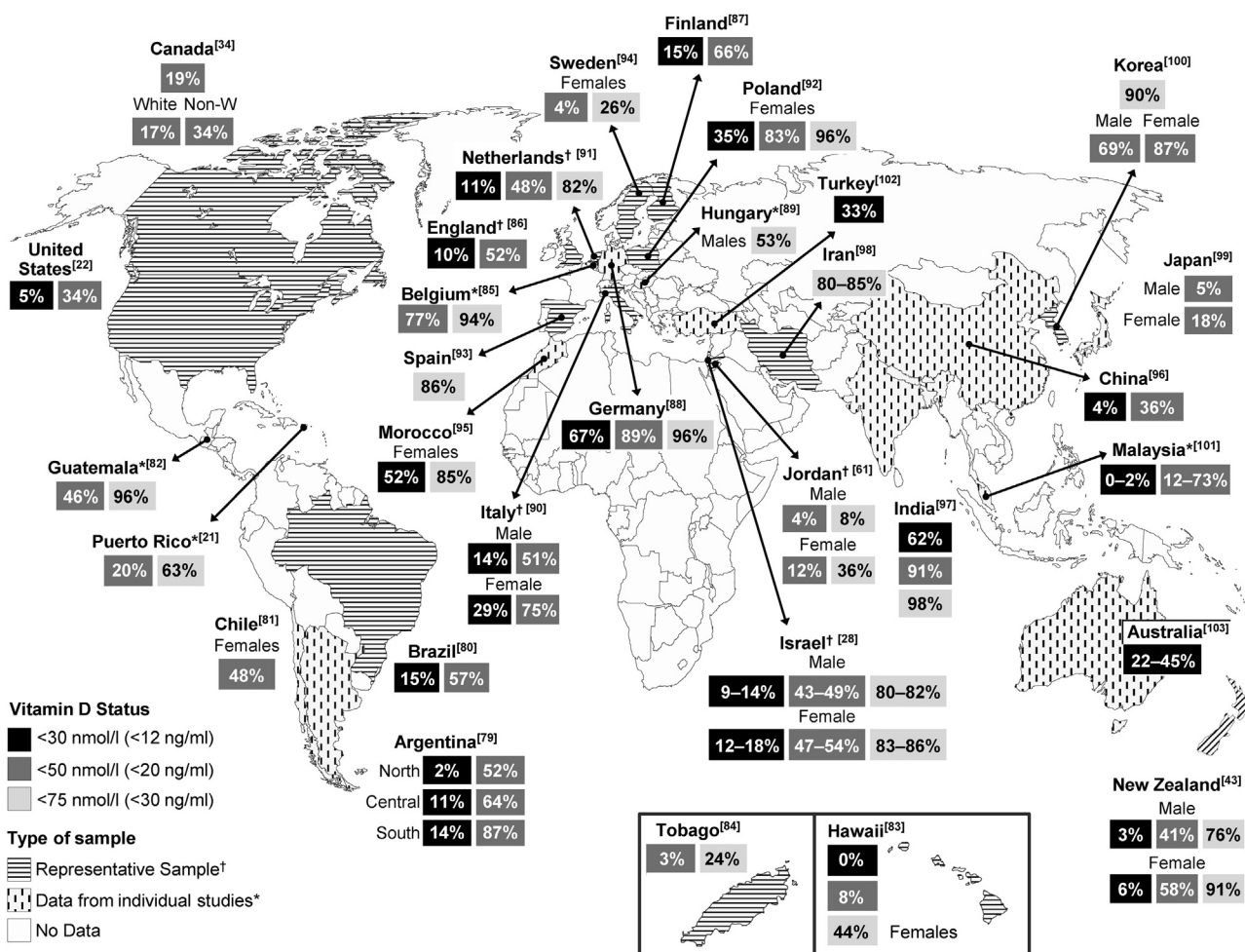


Fig. 6. Prevalence of low vitamin D status in elders worldwide.

Europe, 1 in Africa, 6 in Asia, and 1 in Oceania. The highest prevalence of vitamin D deficiency was found in neonates from the Middle East.

Fig. 2 illustrates the prevalence of low vitamin D status in children worldwide. A total of 17 studies were found; 5 in America, 2 in Europe, 1 in Africa, 8 in Asia and 1 in Oceania. Again, the highest prevalence of vitamin D deficiency was found in children from the Middle East.

A total of 15 studies were found reporting the prevalence of low vitamin D status in adolescents (Fig. 3); 5 in America, 2 in Europe (1 representing 9 countries), 7 in Asia, 1 in Oceania and none in Africa. The highest prevalence of vitamin D deficiency was found in girls from the Middle East. In adults, a total of 32 studies were found; 7 in America, 9 in Europe, 2 in Africa, 11 in Asia, 3 in Oceania (Fig. 4). As with the other age groups, adults from the Middle East had higher deficiency rates, particularly in women. In pregnant and lactating women, a total of 17 studies were found; 2 in America, 6 in Europe, 1 in Africa, 7 in Asia, 1 in Oceania (Fig. 5). Very high deficiency rates were found in those from the Middle East. In elders, a total of 31 studies were found; 9 in America, 10 in Europe, 1 in Africa, 9 in Asia, 2 in Oceania (Fig. 6). Most countries reported high vitamin D deficiency prevalence.

4. Discussion

This review provides an updated overview of global vitamin D status. In areas with available data, the prevalence of low vitamin D status is a global problem in all age groups, even in countries with

sun exposure all year round. It is important to note that the problem is greater in the Middle East, particularly in girls and women. The data also pinpoint the regions with missing data for each specific population groups. There is a striking lack of data in infants, children and adolescents, and in most countries of South America and Africa.

In general, this high prevalence of low vitamin D status may be related to several issues, such as less vitamin D photosynthesis in response to UVB in individuals with high skin melanin content or due to aging, use of extensive skin coverage and scarce exposure to sunlight, which has often been described in individuals from Africa, the Middle East and Central and South America. Moreover, a low vitamin D intake and high rates of obesity worldwide can also contribute to the problem. Season appears to be a small component to the problem worldwide, as countries with long winters have less deficiency rates overall compared to sunny countries, which is probably related to the fortification of staples, consumption of fatty fish and regular use of vitamin D supplements.

There are several limitations of the present report. The data from vitamin D status were derived from a variety of methods used in the different reports. This measurement is difficult, with large variations between methods and between laboratories using the same methods. In addition, there is lacking representative data from many countries, which precludes the ability to accurately assess vitamin D status from such countries; this is particularly important in countries with different latitudes within its territory.

In conclusion, the available data indicate that vitamin D deficiency is a global public health problem, in all age groups, particularly in those from the Middle East.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.jsbmb.2013.11.003>.

References

- [1] M.F. Holick, T.C. Chen, Vitamin D deficiency: a worldwide problem with health consequences, *Am. J. Clin. Nutr.* 87 (4) (2008) 1080S–1086S.
- [2] A. Mithal, D.A. Wahl, J.P. Bonjour, P. Burckhardt, B. Dawson-Hughes, J.A. Eisman, G. El-Hajj Fuleihan, R.G. Josse, P. Lips, J. Morales-Torres, IOF Committee of Scientific Advisors (CSA) Nutrition Working Group, Global vitamin D status and determinants of hypovitaminosis D, *Osteoporos. Int.* 20 (11) (2009) 1807–1820.
- [3] N.M. van Schoor, P. Lips, Worldwide vitamin D status, *Best Pract. Res. Clin. Endocrinol. Metab.* 25 (4) (2011) 671–680.
- [4] D.A. Wahl, C. Cooper, P.R. Ebeling, M. Eggersdorfer, J. Hilger, K. Hoffmann, R. Josse, J.A. Kanis, A. Mithal, D.D. Pierroz, J. Stenmark, E. Stocklin, B. Dawson-Hughes, A global representation of vitamin D status in healthy populations, *Arch. Osteoporosis* 7 (1–2) (2012) 155–172.
- [5] Institute of Medicine, IOM, Dietary Reference Intakes for Calcium and Vitamin D, The National Academy Press, Washington, DC, 2011.
- [6] B.D. Gessner, J. Plotnik, P.T. Muth, 25-hydroxyvitamin D levels among healthy children in Alaska, *J. Pediatr.* 143 (4) (2003) 434–437.
- [7] P. Duran, G. Mangialavori, A. Biglieri, L. Kogan, E. Abeya Gilardon, Nutrition status in Argentinean children 6 to 72 months old: results from the National Nutrition and Health Survey (ENNyS), *Arch. Argent. Pediatr.* 107 (5) (2009) 397–404.
- [8] L.M. Bodnar, H.N. Simhan, R.W. Powers, M.P. Frank, E. Cooperstein, J.M. Roberts, High prevalence of vitamin D insufficiency in black and white pregnant women residing in the northern United States and their neonates, *J. Nutr.* 137 (2) (2007) 447–452.
- [9] C. Wuertz, P. Gilbert, W. Baier, C. Kunz, Cross-sectional study of factors that influence the 25-hydroxyvitamin D status in pregnant women and in cord blood in Germany, *Br. J. Nutr.* (2013) 1–8.
- [10] M.F. Luxwolda, R.S. Kuipers, I.P. Kema, E. van der Veer, D.A. Dijck-Brouwer, F.A. Muskiet, Vitamin D status indicators in indigenous populations in East Africa, *Eur. J. Nutr.* 52 (3) (2013) 1115–1125.
- [11] Z. Zhu, J. Zhan, J. Shao, W. Chen, L. Chen, W. Li, C. Ji, Z. Zhao, High prevalence of vitamin D deficiency among children aged 1 month to 16 years in Hangzhou, China, *BMC Public Health* 12 (2012) 126–2458.
- [12] R.K. Marwaha, N. Tandon, S. Chopra, N. Agarwal, M.K. Garg, B. Sharma, R.S. Kanwar, K. Bhadra, S. Singh, K. Mani, S. Puri, Vitamin D status in pregnant Indian women across trimesters and different seasons and its correlation with neonatal serum 25-hydroxyvitamin D levels, *Br. J. Nutr.* 106 (9) (2011) 1383–1389.
- [13] Z. Maghbooli, A. Hossein-Nezhad, A.R. Shafaei, F. Karimi, F.S. Madani, B. Larjani, Vitamin D status in mothers and their newborns in Iran, *BMC Pregnancy Childbirth* 7 (2007) 1.
- [14] A.M. Molla, M. Al Badawi, M.S. Hammoud, A.M. Molla, M. Shukkur, L. Thalib, M.S. Eliwa, Vitamin D status of mothers and their neonates in Kuwait, *Pediatr. Int.* 47 (6) (2005) 649–652.
- [15] N. Hossain, R. Khanani, F. Hussain-Kanani, T. Shah, S. Arif, L. Pal, High prevalence of vitamin D deficiency in Pakistani mothers and their newborns, *Int. J. Gynaecol. Obstet.* 112 (3) (2011) 229–233.
- [16] O. Halicioglu, S. Aksit, F. Koc, S.A. Akman, E. Albudak, I. Yaprak, I. Coker, A. Colak, C. Ozturk, E.S. Gulec, Vitamin D deficiency in pregnant women and their neonates in spring time in western Turkey, *Paediatr. Perinat. Epidemiol.* 26 (1) (2012) 53–60.
- [17] L. Bowyer, C. Catling-Paull, T. Diamond, C. Homer, G. Davis, M.E. Craig, Vitamin D, PTH and calcium levels in pregnant women and their neonates, *Clin. Endocrinol. (Oxf)* 70 (3) (2009) 372–377.
- [18] C.A. Stoian, M. Lyon, R.G. Cox, D.K. Stephure, J.K. Mah, Vitamin D concentrations among healthy children in Calgary, Alberta, *Paediatr. Child Health* 16 (2) (2011) 82–86.
- [19] D. Gilbert-Diamond, A. Baylin, M. Mora-Plazas, C. Marin, J.E. Arsenaault, M.D. Hughes, W.C. Willett, E. Villamor, Vitamin D deficiency and anthropometric indicators of adiposity in school-age children: a prospective study, *Am. J. Clin. Nutr.* 92 (6) (2010) 1446–1451.
- [20] M. Flores, N. Macias, A. Lozada, L.M. Sanchez, E. Diaz, S. Barquera, Serum 25-hydroxyvitamin D levels among Mexican children ages 2 y to 12 y: a national survey, *Nutrition* 29 (5) (2013) 802–804.
- [21] E.B. Suárez-Martínez, C.M. Pérez, S.K. Cruz, S. Khorsandi, C. Chardón, L. Ferder, Importance of vitamin D and vitamin D levels status in Puerto Ricans, *J. Health Care Poor Underserved* 24 (4) (2013) 38–47, <http://dx.doi.org/10.1353/hpu.2014.0000>.
- [22] V. Ganji, X. Zhang, V. Tangpricha, Serum 25-hydroxyvitamin D concentrations and prevalence estimates of hypovitaminosis D in the U.S. population based on assay-adjusted data, *J. Nutr.* 142 (3) (2012) 498–507.
- [23] I. Sioen, T. Mouratidou, J.M. Kaufman, K. Bammann, N. Michels, I. Pigeot, B. Vanaelst, K. Vyncke, S. De Henauw, IDEFICS consortium Determinants of vitamin D status in young children: results from the Belgian arm of the IDEFICS (identification and prevention of dietary- and lifestyle-induced health effects in children and infants) study, *Public Health Nutr.* 15 (6) (2012) 1093–1099.
- [24] M. Absoud, C. Cummins, M.J. Lim, E. Wassmer, N. Shaw, Prevalence and predictors of vitamin D insufficiency in children: a Great Britain population based study, *PLoS ONE* 6 (7) (2011) 22179.
- [25] M.A. Poopedi, S.A. Norris, J.M. Pettifor, Factors influencing the vitamin D status of 10-year-old urban South African children, *Public Health Nutr.* 14 (2) (2011) 334–339.
- [26] S. Manaseki-Holland, M. Zulf Mughal, Z. Bhutta, M. Qasem Shams, Vitamin D status of socio-economically deprived children in Kabul, Afghanistan, *Int. J. Vitam. Nutr. Res.* 78 (1) (2008) 16–20.
- [27] B. Olang, M. Naghavi, D. Bastani, B. Strandvik, A. Yngve, Optimal vitamin A and suboptimal vitamin D status are common in Iranian infants, *Acta Paediatr.* 100 (3) (2011) 439–444.
- [28] W. Saliba, H.S. Rennert, A. Kershenbaum, G. Rennert, Serum 25(OH)D concentrations in sunny Israel, *Osteoporos. Int.* 23 (2) (2012) 687–694.
- [29] K.K. Abdul-Razzak, M.J. Ajlony, A.M. Khoursheed, B.A. Obeidat, Vitamin D deficiency among healthy infants and toddlers: a prospective study from Irbid, Jordan, *Pediatr. Int.* 53 (6) (2011) 839–845.
- [30] G.L. Khor, W.S. Chee, Z.M. Shariff, B.K. Poh, M. Arumugam, J.A. Rahman, H.E. Theobald, High prevalence of vitamin D insufficiency and its association with BMI-for-age among primary school children in Kuala Lumpur, Malaysia, *BMC Public Health* 11 (2011) 95.
- [31] A. Bener, M. Al-Ali, G.F. Hoffmann, Vitamin D deficiency in healthy children in a sunny country: associated factors, *Int. J. Food Sci. Nutr.* 60 (Suppl. 5) (2009) 60–70.
- [32] J.E. Rockell, T.J. Green, C.M. Skeaff, S.J. Whiting, R.W. Taylor, S.M. Williams, W.R. Parnell, R. Scragg, N. Wilson, D. Schaaf, E.D. Fitzgerald, M.W. Wolhers, Season ethnicity are determinants of serum 25-hydroxyvitamin D concentrations in New Zealand children aged 5–14 y, *J. Nutr.* 135 (11) (2005) 2602–2608.
- [33] B.R. Santos, L.P. Mascarenhas, F. Satler, M.C. Boguszewski, P.M. Spritzer, Vitamin D deficiency in girls from South Brazil: a cross-sectional study on prevalence and association with vitamin D receptor gene variants, *BMC Pediatr.* 12 (2012) 62–2431.
- [34] S.J. Whiting, K.A. Langlois, H. Vatanparast, L.S. Greene-Finestone, The vitamin D status of Canadians relative to the 2011 Dietary Reference Intakes: an examination in children and adults with and without supplement use, *Am. J. Clin. Nutr.* 94 (1) (2011) 128–135.
- [35] M. Flores, L.M. Sánchez-Romero, N. Macías, A. Lozada, E. Díaz, S. Barquera, Concentraciones séricas de vitamina D en niños, adolescentes, adultos mexicanos, in: *Resultados de la ENSANUT 2006*, Instituto Nacional de Salud Pública, Cuernavaca, México, 2011, Available at: <http://www.insp.mx/images/stories/Centros/cinys/Docs/111202.ReporteVitaminaD.pdf>
- [36] M. Gonzalez-Gross, J. Valtuena, C. Breidenassel, L.A. Moreno, M. Ferrari, M. Kersting, S. De Henauw, F. Gottrand, E. Azzini, K. Widhalm, A. Kafatos, Y. Manios, P. Stehle, HELENA Studygroup Vitamin D status among adolescents in Europe: the Healthy Lifestyle in Europe by Nutrition in Adolescence study, *Br. J. Nutr.* 107 (5) (2012) 755–764.
- [37] T.R. Hill, A.A. Cotter, S. Mitchell, C.A. Boreham, W. Dubitzky, L. Murray, J.J. Strain, A. Flynn, P.J. Robson, J.M. Wallace, M. Kiely, K.D. Cashman, Vitamin D status and its determinants in adolescents from the Northern Ireland Young Hearts 2000 cohort, *Br. J. Nutr.* 99 (5) (2008) 1061–1067.
- [38] S. Puri, R.K. Marwaha, N. Agarwal, N. Tandon, R. Agarwal, K. Grewal, D.H. Reddy, S. Singh, Vitamin D status of apparently healthy schoolgirls from two different socioeconomic strata in Delhi: relation to nutrition and lifestyle, *Br. J. Nutr.* 99 (4) (2008) 876–882.
- [39] A. Rabbani, S.M. Alavian, M.E. Motlagh, M.T. Ashtiani, G. Ardalan, A. Salavati, B. Rabbani, A. Rabbani, S. Shams, N. Parvaneh, Vitamin D insufficiency among children and adolescents living in Tehran, Iran, *J. Trop. Pediatr.* 55 (3) (2009) 189–191.
- [40] H.S. Choi, H.J. Oh, H. Choi, W.H. Choi, J.G. Kim, K.M. Kim, K.J. Kim, Y. Rhee, S.K. Lim, Vitamin D insufficiency in Korea – a greater threat to younger generation: the Korea National Health and Nutrition Examination Survey (KNHANES) 2008, *J. Clin. Endocrinol. Metab.* 96 (3) (2011) 643–651.
- [41] A.M. Siddiqui, H.Z. Kamfar, Prevalence of vitamin D deficiency rickets in adolescent school girls in Western region, Saudi Arabia, *Saudi Med. J.* 28 (3) (2007) 441–444.
- [42] S.J. Muhairi, A.E. Mehairi, A.A. Khouri, M.M. Naqbi, F.A. Maskari, J. Al Kaabi, A.S. Al Dhaheri, N. Nagelkerke, S.M. Shah, Vitamin D deficiency among healthy adolescents in Al Ain, United Arab Emirates, *BMC Public Health* 13 (2013) 33–2458.
- [43] J.E. Rockell, C.M. Skeaff, S.M. Williams, T.J. Green, Serum 25-hydroxyvitamin D concentrations of New Zealanders aged 15 years and older, *Osteoporos. Int.* 17 (9) (2006) 1382–1389.
- [44] M.D. Unger, L. Cuppari, S.M. Titan, M.C. Magalhaes, A.L. Sasaki, L.M. dos Reis, V. Jorgetti, R.M. Moyses, Vitamin D status in a sunny country: where has the sun gone? *Clin. Nutr.* 29 (6) (2010) 784–788.
- [45] L.S. Greene-Finestone, C. Berger, M. de Groh, D.A. Hanley, N. Hidiroglou, K. Sarafin, S. Poliquin, J. Krieger, J.B. Richards, D. Goltzman, CaMos Research Group, 25-Hydroxyvitamin D in Canadian adults: biological, environmental, and behavioral correlates, *Osteoporos. Int.* 22 (5) (2011) 1389–1399.
- [46] G. Gonzalez, J.N. Alvarado, A. Rojas, C. Navarrete, C.G. Velasquez, E. Arteaga, High prevalence of vitamin D deficiency in Chilean healthy postmenopausal women with normal sun exposure: additional evidence for a worldwide concern, *Menopause* 14 (3 Pt 1) (2007) 455–461.

- [47] N. Binkley, R. Novotny, D. Krueger, T. Kawahara, Y.G. Daida, G. Lensmeyer, B.W. Hollis, M.K. Drezner, Low vitamin D status despite abundant sun exposure, *J. Clin. Endocrinol. Metab.* 92 (6) (2007) 2130–2135.
- [48] B. Thuesen, L. Husemoen, M. Fenger, J. Jakobsen, P. Schwarz, U. Toft, L. Ovesen, T. Jorgensen, A. Linneberg, Determinants of vitamin D status in a general population of Danish adults, *Bone* 50 (3) (2012) 605–610.
- [49] M. Kull Jr., R. Kallikorm, A. Tamm, M. Lember, Seasonal variance of 25-(OH) vitamin D in the general population of Estonia, a Northern European country, *BMC Public Health* 9 (2009) 22–2458.
- [50] J.K. Virtanen, T. Nurmi, S. Voutilainen, J. Mursu, T.P. Tuomainen, Association of serum 25-hydroxyvitamin D with the risk of death in a general older population in Finland, *Eur. J. Nutr.* 50 (5) (2011) 305–312.
- [51] B. Hintzpetter, G.B. Mensink, W. Thierfelder, M.J. Muller, C. Scheidt-Nave, Vitamin D status and health correlates among German adults, *Eur. J. Clin. Nutr.* 62 (9) (2008) 1079–1089.
- [52] E. Hypponen, C. Power, Hypovitaminosis D in British adults at age 45 y: nationwide cohort study of dietary and lifestyle predictors, *Am. J. Clin. Nutr.* 85 (3) (2007) 860–868.
- [53] X.M. Mai, Y. Chen, C.A. Camargo Jr., A. Langhammer, Cross-sectional and prospective cohort study of serum 25-hydroxyvitamin D level and obesity in adults: the HUNT study, *Am. J. Epidemiol.* 175 (10) (2012) 1029–1036.
- [54] L. Zgaga, E. Theodoratou, S.M. Farrington, F. Agakov, A. Tenesa, M. Walker, S. Knox, A.M. Wallace, R. Cetnarskyj, G. McNeill, J. Kyle, M.E. Porteous, M.G. Dunlop, H. Campbell, Diet, environmental factors, and lifestyle underlie the high prevalence of vitamin D deficiency in healthy adults in Scotland, and supplementation reduces the proportion that are severely deficient, *J. Nutr.* 141 (8) (2011) 1535–1542.
- [55] I. Gonzalez-Molero, S. Morcillo, S. Valdes, V. Perez-Valero, P. Botas, E. Delgado, D. Hernandez, G. Oliveira, G. Rojo, C. Gutierrez-Repiso, E. Rubio-Martin, E. Menendez, F. Sorriquer, Vitamin D deficiency in Spain: a population-based cohort study, *Eur. J. Clin. Nutr.* 65 (3) (2011) 321–328.
- [56] I. Guessous, V. Dudler, N. Glatz, J.M. Theler, O. Zoller, F. Paccaud, M. Burnier, M. Bochud, Swiss Survey on Salt Group, Vitamin D levels and associated factors: a population-based study in Switzerland, *Swiss Med. Wkly.* 142 (2012).
- [57] R.H. Glew, M.J. Crossey, J. Polanams, H.I. Okolie, D.J. VanderJagt, Vitamin D status of seminomadic Fulani men and women, *J. Natl. Med. Assoc.* 102 (6) (2010) 485–490.
- [58] M.Z. Islam, M. Akhtaruzzaman, C. Lamberg-Allardt, Hypovitaminosis D is common in both veiled and nonveiled Bangladeshi women, *Asia Pac. J. Clin. Nutr.* 15 (1) (2006) 81–87.
- [59] V. Majumdar, D. Nagaraja, R. Christopher, Vitamin D status and metabolic syndrome in Asian Indians, *Int. J. Obes. (Lond)* 35 (8) (2011) 1131–1134.
- [60] S. Hovsepian, M. Amini, A. Aminorrozay, P. Amini, B. Iraj, Prevalence of vitamin D deficiency among adult population of Isfahan City, Iran, *J. Health Popul. Nutr.* 29 (2) (2011) 149–155.
- [61] A. Batieha, Y. Khader, H. Jaddou, D. Hyassat, Z. Batieha, M. Khateeb, A. Belbisi, K. Ajlouni, Vitamin D status in Jordan: dress style and gender discrepancies, *Ann. Nutr. Metab.* 58 (1) (2011) 10–18.
- [62] S.Y. Rhee, Y.C. Hwang, H.Y. Chung, J.T. Woo, Vitamin D and diabetes in Koreans: analyses based on the Fourth Korea National Health and Nutrition Examination Survey (KNHANES), 2008–2009, *Diabet. Med.* 29 (8) (2012) 1003–1010.
- [63] F.M. Moy, A. Bulgiba, High prevalence of vitamin D insufficiency and its association with obesity and metabolic syndrome among Malay adults in Kuala Lumpur, Malaysia, *BMC Public Health* 11 (2011) 735–2458.
- [64] A. Sheikh, Z. Saeed, S.A. Jafri, I. Yazdani, S.A. Hussain, Vitamin D levels in asymptomatic adults – a population survey in Karachi, Pakistan, *PLoS ONE* 7 (3) (2012) e33452.
- [65] H.E. Meyer, K. Holvik, C.M. Lofthus, S.U. Tennakoon, Vitamin D status in Sri Lankans living in Sri Lanka and Norway, *Br. J. Nutr.* 99 (5) (2008) 941–944.
- [66] L.O. Chailurkit, W. Aekplakorn, B. Ongphiphadhanakul, Regional variation and determinants of vitamin D status in sunshine-abundant Thailand, *BMC Public Health* 11 (2011) 853–2458.
- [67] L.T. Ho-Pham, N.D. Nguyen, T.Q. Lai, J.A. Eisman, T.V. Nguyen, Vitamin D status and parathyroid hormone in a urban population in Vietnam, *Osteoporos. Int.* 22 (1) (2011) 241–248.
- [68] R.M. Daly, C. Gagnon, Z.X. Lu, D.J. Magliano, D.W. Dunstan, K.A. Sikaris, P.Z. Zimmet, P.R. Ebeling, J.E. Shaw, Prevalence of vitamin D deficiency and its determinants in Australian adults aged 25 years and older: a national, population-based study, *Clin. Endocrinol. (Oxf)* 77 (1) (2012) 26–35.
- [69] C. Heere, C.M. Skeaff, L. Waqatakiwira, P. Vatucaawaqa, A.N. Khan, T.J. Green, Serum 25-hydroxyvitamin D concentration of Indigenous–Fijian and Fijian–Indian women, *Asia Pac. J. Clin. Nutr.* 19 (1) (2010) 43–48.
- [70] W. Li, T.J. Green, S.M. Innis, S.I. Barr, S.J. Whiting, A. Shand, P. von Dadelnszen, Suboptimal vitamin D levels in pregnant women despite supplement use, *Can. J. Public Health* 102 (4) (2011) 308–312.
- [71] A.A. Ginde, A.F. Sullivan, J.M. Mansbach, C.A. Camargo Jr., Vitamin D insufficiency in pregnant and nonpregnant women of childbearing age in the United States, *Am. J. Obstet. Gynecol.* 202 (5) (2010) 436.e1–436.e8.
- [72] S. Vandevijvere, S. Amsalkhir, H. Van Oyen, R. Moreno-Reyes, High prevalence of vitamin D deficiency in pregnant women: a national cross-sectional survey, *PLoS ONE* 7 (8) (2012) e43868.
- [73] S. Sullivan, A. Wills, D. Lawlor, J. McGrath, S. Zammit, Prenatal vitamin D status and risk of psychotic experiences at age 18 years—a longitudinal birth cohort, *Schizophr. Res.* 148 (2013) 87–92.
- [74] J. Brandenbarg, T.G. Vrijkkotte, G. Goedhart, M. van Eijdsen, Maternal early-pregnancy vitamin D status is associated with maternal depressive symptoms in the Amsterdam born children and their development cohort, *Psychosom. Med.* 74 (7) (2012) 751–757.
- [75] S.R. Crozier, N.C. Harvey, H.M. Inskip, K.M. Godfrey, C. Cooper, S.M. Robinson, SWS Study Group, Maternal vitamin D status in pregnancy is associated with adiposity in the offspring: findings from the Southampton Women's Survey, *Am. J. Clin. Nutr.* 96 (1) (2012) 57–63.
- [76] E. Morales, M. Guxens, S. Llop, C.L. Rodriguez-Bernal, A. Tardon, I. Riano, J. Ibarluzea, N. Lertxundi, M. Espada, A. Rodriguez, J. Sunyer, I.N.M.A. Project, Circulating 25-hydroxyvitamin D3 in pregnancy and infant neuropsychological development, *Pediatrics* 130 (4) (2012) e913–e920.
- [77] M. Tao, H. Shao, J. Gu, Z. Zhen, Vitamin D status of pregnant women in Shanghai China, *J. Matern. Fetal Neonatal Med.* 25 (3) (2012) 237–239.
- [78] V.T. Hien, N.T. Lam, C.M. Skeaff, J. Todd, J.M. McLean, T.J. Green, Vitamin D status of pregnant and non-pregnant women of reproductive age living in Hanoi City and the Hai Duong province of Vietnam, *Matern. Child Nutr.* 8 (4) (2012) 533–539.
- [79] B. Oliveri, L. Plantalech, A. Bagur, A.C. Wittich, G. Rovai, E. Pusiol, J. Lopez Giovanelli, G. Ponce, A. Nieva, A. Chaperon, M. Ladizesky, J. Somoza, C. Casco, S. Zeni, M.S. Parisi, C.A. Mautalen, High prevalence of vitamin D insufficiency in healthy elderly people living at home in Argentina, *Eur. J. Clin. Nutr.* 58 (2) (2004) 337–342.
- [80] G.L. Saraiva, M.S. Cendoroglo, L.R. Ramos, L.M. Araujo, J.G. Vieira, I. Kunii, L.F. Hayashi, M.P. Correa, M. Lazaretti-Castro, Influence of ultraviolet radiation on the production of 25 hydroxyvitamin D in the elderly population in the city of Sao Paulo (23 degrees 34' S), Brazil, *Osteoporos. Int.* 16 (12) (2005) 1649–1654.
- [81] P.J.A. Rodriguez, C.G. Valdivia, M.P. Trincado, Vertebral fractures, osteoporosis and vitamin D levels in Chilean postmenopausal women, *Rev. Med. Chile* 135 (1) (2007) 31–36.
- [82] S.R. Sud, G. Montenegro-Bethancourt, O.I. Bermudez, R.P. Heaney, L. Armas, N.W. Solomons, Older Mayan residents of the western highlands of Guatemala lack sufficient levels of vitamin D, *Nutr. Res.* 30 (11) (2010) 739–746.
- [83] P. Pramyothin, S. Techasurungkul, J. Lin, H. Wang, A. Shah, P.D. Ross, R. Puapong, R.D. Wasnich, Vitamin D status and falls, frailty, and fractures among postmenopausal Japanese women living in Hawaii, *Osteoporos. Int.* 20 (11) (2009) 1955–1962.
- [84] I. Miljkovic, L.M. Bodnar, J.A. Cauley, C.H. Bunker, A.L. Patrick, V.W. Wheeler, L.H. Kuller, J.M. Zmuda, Low prevalence of vitamin D deficiency in elderly Afro-Caribbean men, *Ethn. Dis.* 21 (1) (2011) 79–84.
- [85] V. Verhoeven, K. Vanpuynbroeck, M. Lopez-Hartmann, J. Wens, R. Remmen, Walk on the sunny side of life – epidemiology of hypovitaminosis D and mental health in elderly nursing home residents, *J. Nutr. Health Aging* 16 (4) (2012) 417–420.
- [86] V. Hirani, Associations between vitamin D and self-reported respiratory disease in older people from a nationally representative population survey, *J. Am. Geriatr. Soc.* 61 (6) (2013) 969–973.
- [87] A. Hurskainen, J.K. Virtanen, T. Tuomainen, T. Nurmi, S. Voutilainen, Association of serum 25-hydroxyvitamin D with type 2 diabetes and markers of insulin resistance in a general older population in Finland, *Diabetes Metab. Res.* 28 (5) (2012) 418–423.
- [88] S. Schilling, Epidemic vitamin D deficiency among patients in an elderly care rehabilitation facility, *Dtsch. Arztebl. Int.* 109 (3) (2012) 33–38.
- [89] H.P. Bhattoa, E. Nagy, C. More, J. Kappelmayer, A. Balogh, E. Kalina, P. Antal-Szalmas, Prevalence and seasonal variation of hypovitaminosis D and its relationship to bone metabolism in healthy Hungarian men over 50 years of age: the HunMen Study, *Osteoporos. Int.* 24 (1) (2013) 179–186.
- [90] D.K. Houston, M. Cesari, L. Ferrucci, A. Cherubini, D. Maggio, B. Bartali, M.A. Johnson, G.G. Schwartz, S.B. Kritchevsky, Association between vitamin D status and physical performance: the INCHIANTI study, *J. Gerontol. A: Biol. Sci. Med. Sci.* 62 (4) (2007) 440–446.
- [91] M.M. Oosterwerff, E.M. Eekhoff, M.W. Heymans, P. Lips, N.M. van Schoor, Serum 25-hydroxyvitamin D levels and the metabolic syndrome in older persons: a population-based study, *Clin. Endocrinol. (Oxf)* 75 (5) (2011) 608–613.
- [92] L. Napiorkowska, T. Budlewski, W. Jakubas-Kwiatkowska, V. Hamzy, D. Gozdowski, E. Franek, Prevalence of low serum vitamin D concentration in an urban population of elderly women in Poland, *Pol. Arch. Med. Wewn.* 119 (11) (2009) 699–703.
- [93] J. Almirall, M. Vaqueiro, M.L. Bare, E. Anton, Association of low serum 25-hydroxyvitamin D levels and high arterial blood pressure in the elderly, *Nephrol. Dial. Transplant.* 25 (2) (2010) 503–509.
- [94] P. Gerdhem, K.A. Ringsberg, K.J. Obrant, K. Akesson, Association between 25-hydroxy vitamin D levels, physical activity, muscle strength and fractures in the prospective population-based OPRA Study of Elderly Women, *Osteoporos. Int.* 16 (11) (2005) 1425–1431.
- [95] A. El Maghraoui, Z. Ouzzif, A. Mounach, A. Rezqi, L. Achemlal, A. Bezza, S. Tellal, M. Dehhaoui, I. Ghozli, Hypovitaminosis D prevalent asymptomatic vertebral fractures in Moroccan postmenopausal women, *BMC Womens Health* 12 (1) (2012) 11.
- [96] H.K. Lu, Z. Zhang, Y.H. Ke, J.W. He, W.Z. Fu, C.Q. Zhang, Z.L. Zhang, High prevalence of vitamin D insufficiency in China: relationship with the levels of parathyroid hormone and markers of bone turnover, *PLoS ONE* 7 (11) (2012) e47264.
- [97] R.K. Marwaha, N. Tandon, M.K. Garg, R. Kanwar, A. Narang, A. Sastry, A. Sabarwal, K. Bandra, Vitamin D status in healthy Indians aged 50 years and above, *J. Assoc. Physicians India* 59 (2011) 706–709.

- [98] M. Maddah, S.H. Sharami, T.R. Neyestani, Vitamin D insufficiency among postmenopausal women in urban and rural areas in Guilan Northern Iran, *J. Nutr. Elder.* 28 (4) (2009) 386–393.
- [99] T. Suzuki, J. Kwon, H. Kim, H. Shimada, Y. Yoshida, H. Iwasa, H. Yoshida, Low serum 25-hydroxyvitamin D levels associated with falls among Japanese community-dwelling elderly, *J. Bone Miner. Res.* 23 (8) (2008) 1309–1317.
- [100] J.A. Seo, H. Cho, C.R. Eun, H.J. Yoo, S.G. Kim, K.M. Choi, S.H. Baik, D.S. Choi, M.H. Park, C. Han, N.H. Kim, Association between visceral obesity and sarcopenia and vitamin D deficiency in older Koreans: the Ansan Geriatric Study, *J. Am. Geriatr. Soc.* 60 (4) (2012) 700–706.
- [101] S.A. Rahman, W.S. Chee, Z. Yassin, S.P. Chan, Vitamin D status among postmenopausal Malaysian women, *Asia Pac. J. Clin. Nutr.* 13 (3) (2004) 255–260.
- [102] T. Atli, S. Gullu, A.R. Uysal, G. Erdogan, The prevalence of vitamin D deficiency and effects of ultraviolet light on vitamin D levels in elderly Turkish population, *Arch. Gerontol. Geriatr.* 40 (1) (2005) 53–60.
- [103] L. Flicker, K. Mead, R.J. MacInnis, C. Nowson, S. Scherer, M.S. Stein, J. Thomas, J.L. Hopper, J.D. Wark, Serum vitamin D and falls in older women in residential care in Australia, *J. Am. Geriatr. Soc.* 51 (11) (2003) 1533–1538.