Vitamin D status and dietary intake in young university students in the UK

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Abstract

Purpose

Vitamin D deficiency is prevalent worldwide. This cross-sectional study aimed to investigate the vitamin D status and dietary intake in young university students.

Design/methodology/approach

Forty-one healthy students aged 18-29 years from Coventry University UK were recruited during January-February 2019, including white Caucasians (n=18), African-Caribbeans (n=14) and Asians (n=9). Plasma 25(OH)D concentrations were measured, and dietary vitamin D intake was determined. Chi-square and simple linear regression were used to analyse the data.

Findings

The plasma 25(OH)D concentrations were (36.0 ± 22.2) nmol/L in all subjects, (46.5 ± 25.3) nmol/L in white Caucasians, (22.6 ± 7.4) nmol/L in African-Caribbeans and (37.4 ± 21.7 nmol/L) in Asians. The majority (85.7 %) of African-Caribbeans were vitamin D deficient compared with 22.2 % of white Caucasians and 33.3 % of Asians (P=0.001). Overweight/obese subjects showed a significant higher proportion of vitamin D deficiency (65 %) than normal weight subjects (28.6 %) (P=0.04). The average dietary vitamin D intake in all subjects was (4.6 ± 3.9) μg/day. Only 12.1 % of the subjects met the recommended dietary vitamin D intake of 10μg/day. Dietary vitamin D intake (P=0.04) and ethnicity (P=0.01) were significant predictors of 25(OH)D levels and accounted for 13 % and 18.5 % of 25(OH)D variance respectively.

Research limitations/implications

This small-scale study showed an alarmingly high prevalence of vitamin D deficiency amongst subjects from African-Caribbean origin during wintertime. Education programs and campaigns are urgently needed to fight the vitamin D deficiency in this population.

Originality

The targetted population were in a critical period of transition from adolescence toward adulthood involving changes in behaviours and nutrition.

Keywords

ethnicity, vitamin D status, vitamin D deficiency, dietary vitamin D intake, young adults

Introduction

Vitamin D, a fat-soluble pre-hormone, is a unique essential nutrient with limited natural food sources mostly of animal origin such as oily fish, red meat and egg yolk. Most vitamin D (80-90%) is produced in the skin in response to ultraviolet B (UVB) radiation from the sun (Wacker and Holick, 2013). Apart from its classical role of promoting calcium absorption in the gut, vitamin D also plays important roles in the modulation of cell growth, neuromuscular and immune function, and anti-inflammation (Nair and Maseeh, 2012). Vitamin D deficiency is prevalent worldwide reported as 9.9 % in the US (Ganji *et al*., 2012), 7.4 % in Canada (Sarafin *et al*., 2015), 4.6 % to 30.7% in Western Europe (Lips *et al*., 2019) (vitamin D deficiency was defined as serum 25(OH)D < 30 nmol/L), and 18.8 % in the UK (vitamin D deficiency was defined as serum 25(OH)D concentration < 25 nmol/L) (Sutherland *et al*., 2021). Reasons for vitamin D deficiency include personal, social and cultural factors influencing sun exposure and dietary intake, skin pigmentation, and the genetics of vitamin D metabolism (Patel *et al*., 2013; Gallagher *et al*., 2014). Evidence shows vitamin D deficiency is significantly associated with increased risks to musculoskeletal disease such as osteomalacia (Minisola *et al*., 2021), and non-musculoskeletal health outcomes such as cardiovascular disease (CVD) and diabetes (Ganji *et al*., 2020a), breast cancer (Estébanez *et al*., 2018), mortality from respiratory diseases (Brenner *et al*., 2020) and reduced lung functions (Ganji *et al*., 2020b). Serum 25(OH)D levels increase in summer and decrease in winter due to dependency of vitamin D on sunlight (Klingberg *et al*., 2015). People with dark skin colour have reduced cutaneous vitamin D biosynthesis, primarily due to increased skin pigmentation that absorbs sun's UVB (Webb *et al.*, 2018). It has also been demonstrated that serum 25(OH)D levels depend on latitude where less cutaneous vitamin D is synthesised at higher latitudes (Nikooyeh *et al.*, 2017). In the UK serum 25(OH)D concentration falls by around 50 % through winter due to the seasonal variation and high latitude (55.3781° N, 3.4360° W) (Hypponen and Power, 2007). Although the worldwide prevalence of vitamin D deficiency is well known, few studies have focused on young university students. An American study (Tangpricha *et al.,* 2002) found that vitamin D deficiency was significantly more prevalent in young adults (aged 18-25 years old, most were university students) than other older adult groups in winter. A recent Australian study showed similar results that more young adults (aged 18–24 years) were vitamin D deficient than adults aged ≥ 25 years due to low dietary vitamin D intake, being overweight and low physical activity (Horton-French *et al.,* 2021). The transition from adolescence toward adulthood is a critical period regarding changes in health behaviours (Desbouys *et al.*, 2019). Early adulthood is associated with poor diet due to an age of transition, including environmental, social and lifestyle changes (Winpenny *et al.*, 2018). Moreover, the peak bone mass is achieved in the early 20s and vitamin D is an important nutrient for bone health (Gordon *et al.*, 2016).

The aim of the study was to examine the vitamin D status and dietary vitamin D intake during the winter in a sample of university students of white Caucasian, African-Caribbean and Asian origin.

Methods

This was a cross-sectional study carried out during January and February 2019 in Coventry, UK (latitude 52.4068° N, 1.5197° W). The study was approved by the Coventry University Ethics Committee (Ref P79982). All subjects gave their written consent before participating the study.

Subjects

The study recruited Coventry University students, 18-29 years old, white Caucasians (CA), Black/African/African-Caribbean origin (collectively presented as AC), and Asians in self-reported good health. Exclusion criteria were taking vitamin D supplementation at a dose of more than 10 μg/day, liver or kidney disease, digestive system disease, diabetes, cancer, autoimmune disease, regular smokers (one or more cigarettes per day), alcohol consumption more than 14 units per day, travelling to a sunny region for holidays in the past 3 months. The exclusion criteria were set up to avoid potential influences of certain diseases and unhealthy lifestyles on vitamin D status (Tsiaras and Weinstock, 2011). A health and lifestyle questionnaire was used to screen the eligibility of the subjects. Eligible subjects were scheduled a visit to the Health and Life Sciences building of Coventry University. The body weight was measured without coats, shoes, and personal possessions (keys, mobile, watch, belt etc.) using weighing scales. The height was measured using a stadiometer. Body mass index (BMI) was calculated by body weight (kilogram) divided by square of height (meter). A blood sample and a food diary were collected for measures of the plasma 25(OH)D concentration and dietary vitamin D intake.

Plasma 25(OH)D measurement

A 2 ml blood sample was collected via phlebotomy into EDTA-treated tubes (Bunzl PLC, London). Plasma was separated by centrifuging for 15 minutes at 1500 x g, at 2-8°C and then stored in -20°C until analysis. Vitamin D status was evaluated by the measurement of plasma 25(OH)D concentrations using Tosoh AIA-900 immunoassay analyser (Tosoh Bioscience, USA) following the manufacturers instruction. The Tosoh ST AIA-PACK 25(OH)D assay correlates well with gold standard methods (Liquid chromatography–mass spectrometry, LC-MS), measures 25(OH)D2 and 25(OH)D3 in equimolar proportions and aligns to the reference measurement procedure used in the Vitamin D standardization program (VDSP) (TOSOH Bioscience, 2020). The quality control was in place to verify that the result obtained was within the range of expected values. Assay range of 25(OH)D was between 10 to 300 nmol/L.

Dietary vitamin D intake analysis

Subjects were asked to record a 3-day (consecutive days, including a weekend day) estimated food diary. Food recording with a minimum of three days is regarded as a gold standard method to assess nutrient intake (Ortega *et al.*, 2015). A template food diary with an example and guidance was provided to subjects. Completed food diaries were collected via email or hard copy and dietary vitamin D intake was analysed using the nutrition analytical software Nutritics (Nutritics *LTD*, Dublin). Food diaries that were incomplete or with an energy intake ≤1000 kcal/day or ≥ 4000 kcal/day were excluded. This was to address the issue of implausible energy intake that might indicate inaccuracy in the food record (Banna *et al.,* 2017). In this study none of the food diaries collected were excluded.

Statistical analysis

Continuous variables were presented as mean ± SD including plasma 25(OH)D concentration, dietary vitamin D intake, age and BMI. Categorical variables were presented as percentage (%) e.g. % of vitamin D deficiency. Vitamin D status was categorised based on the plasma 25(OH)D concentration as deficient (< 30 nmol/L), insufficient (30 - 50 nmol/L), sufficient (> 50 nmol/L), according to guidelines by the Institute of Medicine (IOM) (IOM, 2011) and optimal or desirable (≥ 75 nmol/L) (Zittermann *et al*., 2012). Body weight was classified based on BMI as underweight (BMI< 18.5 kg/m^2), normal weight (BMI 18.5 - 24.9 kg/m^2) and overweight/obese (BMI≥ 25 kg/m^2) (NICE, 2014). Statistical analysis was performed using SPSS software (version 26). Difference in frequency (percentage) between groups were tested by Pearson Chi-Square. A simple linear regression was conducted to investigate the contribution of each of the independent variables including dietary vitamin D intake, BMI, age, gender, and ethnicity to the variance of plasma 25(OH)D concentration (dependent variable). Categorical variables (gender and ethnicity) were recoded to create dummy variables with male and CA as the reference category respectively against which all other groups were compared. The statistically significant level was set up at $P \leq 0.05$ with two-tail. All continuous variables were normally distributed tested by Kolmogorov-Smirnov method.

Results

Subject characteristics

Forty-four subjects were screened for the study, among which three were excluded due to travel to sunny places during the Christmas holiday (n=2) or taking vitamin D supplement at a dose of more than 10 μg/day (n=1). Therefore, a total of 41 subjects participated in the study. Apart from one participant in the CA group who took Omega-3 capsules, none of the other eligible participants took any dietary supplements.

Table I shows the descriptive characteristics of the subjects. The mean age was 22 y, and mean BMI was 25 kg/m^2 for all subjects. There was a similar number in gender with 21 females and 20 males. Regarding ethnic groups, 44 % (n=18) were CAs, 34 % (n=14) were ACs and 22 % (n=9) were Asians (2 Indians, 3 Pakistani, 3 Arabians and one Chinese). The range of BMI was 19.1-41.4 kg/m^2. Fifty-one percent (n=21) of the subjects were normal weight, while 49% (n=20) were either overweight (n=16) or obese (n=4) (Table I).

[insert Table I here]

Plasma 25(OH)D levels and vitamin D status

Table II shows the plasma 25(OH)D levels and vitamin D status in different groups. The average plasma 25(OH)D in all subjects (n=41) was (36.0 ± 22.2) nmol/L, ranging between 11.0 -128.6 nmol/L. The average plasma 25(OH)D concentrations were (22.6 ± 7.4) nmol/L in ACs (n=14), (46.5 ± 25.3) nmol/L in CAs (n=18) and (37.4 ± 21.7) nmol/L in Asians (n=9). Forty-six percent of all subjects were vitamin D deficient, while 31.7 % were insufficient, and only 22 %

were sufficient. Only two subjects (4.9 %, one from the CA and one from the Asian group) achieved the optimal level of plasma 25(OH)D at 75 nmol/L (128.6 nmol/L and 88.7 nmol/L respectively). There was a significant difference in vitamin D status in ethnic groups (*P*=0.001). Eighty-six percent of AC subjects were vitamin D deficient compared with 22.2 % in CAs, and 33.3 % in Asians. None of ACs was vitamin D sufficient compared with 44.4 % in CAs and 11.1 % in Asians. There was no significant difference in vitamin D status between genders (*P*=0.47), but there was a significant difference in vitamin D status between body weight categories (*P*=0.04). Sixty-five percent of the overweight/obese subjects were vitamin D deficient compared with 28.6 % in normal weight, while 15 % of the overweight/obese subjects were insufficient compared with 47.6 % in normal weight. The sufficiency proportion was similar between normal weight and overweight/obese subjects (23.8 % vs 20 %).

[insert Table II here]

Dietary vitamin D intake adequacy compared with the government recommendation

The results of the dietary vitamin D intake were based on 33 subjects who returned their food diaries, 16 CAs, 9 ACs and 8 Asians. The average dietary vitamin D intake was 4.6 µg/day in all subjects, 6.3 µg/day in CAs and 3.1 µg/day in both ACs and Asians (Table III).

The current UK government recommendation of dietary vitamin D intake is 10 µg/day for adults and children over the age of one (SACN, 2016). Data in Table III shows that only 12.1 % of all subjects met the recommendation, and all of them were CA (3 males and one female), while none in the AC or Asian groups met the recommendation. However, there was no significant difference in dietary vitamin D intake adequacy between ethnicities, genders and body weight categories (Table III).

[insert Table III here]

Linear regression analysis

Table IV shows the simple linear regression models of the different independent variables and the dependent viable, plasma 25(OH)D. It was found that dietary vitamin D intake (*P*=0.04) and ethnicity (*P*=0.01) were significant predictors of 25(OH)D, which accounted for 13 % and 18.5 % of 25(OH)D variance respectively. An increase of 1 μg dietary vitamin D intake was associated with an increase in plasma 25(OH)D of approximately 2.2 nmol/L. ACs had a significant reduction of 23.9 nmol/L in the mean of 25(OH)D concentration compared with CAs (*P*=0.002). No significant reduction of 25(OH)D was seen for Asians compared with CAs in this model (*P*=0.28). Age, gender and BMI were not significant predictors of 25(OH)D variance in the analysis.

[insert Table IV here]

Discussion

This study had a target population of university students in the UK from three ethnic origins: CA, AC and Asian. Their vitamin D status was measured, and their dietary vitamin D intake was evaluated during the wintertime. Vitamin D deficiency was prevalent in this population (46.3 %), with only 4.9 % of the subjects having the optimal level of plasma 25(OH)D (≥75 nmol/L). An alarmingly high proportion (85.7 %) of vitamin D deficiency and extremely low average plasma 25(OH)D at 22.6 nmol/L was observed in AC subjects. In addition, overweight/obese subjects had a significant higher prevalence of vitamin D deficiency (65 %) than normal weight subjects (28.6 %). Of the independent variables considered: age, gender, BMI, dietary vitamin D intake and ethnicity, the simple linear repression analysis indicated that only dietary vitamin D intake and ethnicity were significant predictors of plasma 25(OH)D levels.

An American study found that African Americans had a significantly lower serum 25(OH)D concentration at 29 nmol/L than CAs at 36.4 nmol/L (Gallagher *et al.*, 2014), while similar results were found in the UK showing that the geometric mean of serum 25(OH)D concentration was much lower in black (30.3 nmol/L) and Asian (mainly South Asian) (24.3 nmol/L) than in white adults (44.9 nmol/L) (Sutherland *et al.*, 2021). Vitamin D deficiency (defined as serum 25(OH)D concentration < 30 nmol/L) was 76.2 % in South Asian vs. 54.7 % in black African-Caribbeans in the UK (Patel *et al.*, 2012). Another recent study showed 50 % of South Asians and 33 % of black African-Caribbeans demonstrated vitamin D deficiency (defined as serum 25(OH)D concentration < 25 nmol/L) compared with around 17.5% in white Caucasians (Sutherland *et al.*, 2021). The current study found that the scale of vitamin D deficiency in university students is much worse than reported in the previous studies, demonstrated by 86 % of AC being vitamin D deficient (defined as 25(OH)D < 30 nmol/L, or 64.3 % if vitamin D deficiency is defined as 25(OH)D < 25 nmol/L) compared with 22 % in CAs and 33 % in Asians. This may be due to the fact that the current study was conducted in winter when vitamin D deficiency is greatest, and in university students who have previously been shown to have a greater prevalence of vitamin D deficiency than other adult groups (Tangpricha *et al.,* 2002). Previous studies consistently showed that South Asians had higher incidence of vitamin D deficiency than black people in the UK, although they have a paler skin tone (Lin *et al.,* 2021, Patel *et al*., 2012, Sutherland *et al.,* 2021). This might be due to poor dietary intake of vitamin D (many South Asians in the UK follow a vegetarian diet), cultural needs to cover the body amongst many South Asian women, and sun avoidance common to both male and female South Asian adults (Lowe & Bhojani, 2017), indicating the importance of sociocultural factors in determining vitamin D status. The Asian group in the current study included five subjects (55.6%) of South Asian origin and showed a lower vitamin D deficiency rate (33.3%) than AC subjects (85.7 %). It is thus inappropriate to compare our results with other studies on South Asians alone. In addition, among all subjects that were approached, only one from AC origin took vitamin D supplement (this subject was excluded from the study) and only 12.1 % (n=4 out of 33) of the subjects met the dietary intake of 10 µg/day vitamin D recommended by the government, all of whom were from CA group. During recruitment, subjects were asked about their vitamin D awareness (not documented), the majority of the subjects had never heard of vitamin D and did not know the UK government recommendation of dietary vitamin D intake (10 µg/day). The poor awareness or practice of the government recommendation of vitamin D intake in the young university students is of particular concern especially considering the limited sunlight availability in the UK winter. Education programs or public awareness campaigns aiming to improve the vitamin D awareness and intake particularly in populations of AC and Asian origin, are urgently needed in the UK.

There is evidence to support daily sunlight exposure between April and September of 10-15 minutes for people with lighter skin types, but 25-40 minutes for dark skin (brown) is required to provide sufficient year-round vitamin D (Webb *et al.*, 2018). The recommended dietary intake recommendation is 10 µg/day of vitamin D from the diet or supplement in the UK for people above one year old regardless of age and ethnicity (SACN, 2016). The current study showed dietary vitamin D intake was a significant predictor to the 25(OH)D variance, and an increase of 1 µg dietary vitamin D intake led to a rise of 2.2 nmol/L of plasma 25(OH)D, indicating the importance of dietary vitamin D intake in the wintertime. Due to the reduced sunlight exposure and limited dietary sources of vitamin D, vitamin D supplementation would be key to prevent vitamin D deficiency during the wintertime in the UK. However, it is questionable whether AC or Asian people could achieve comparable levels of plasma 25(OH)D to CAs from the same recommended dietary vitamin D intake or same dose of vitamin D supplementation. For example, 10 µg/day of vitamin D from the diet or supplementation would raise 25(OH)D concentration by only 22 nmol/L based on our model, or by only 10 nmol/L based on the Holick formula of 2.5 µg dietary vitamin D raising 25(OH)D concentration by 2.5 nmol/L (Holick, 2008), which is insufficient for ACs or Asians to achieve the comparable level as CAs, let alone to achieve 75 nmol/L which is regarded as optimal for nonskeletal health outcomes (Ganji *et al*. 2020a; Zittermann *et al*., 2012). Therefore, further research is needed to investigate whether higher dietary vitamin D recommendation is required for the AC and South Asian ethnic groups in the UK.

The recent UK National Diet and Nutrition Survey (NDNS) report showed an average dietary vitamin D intake of 2.7 µg/day in the UK adults (19-64 y) (PHE, 2018), similar to that in AC and Asians at 3.1 µg/day in the current study. However, CA subjects showed a much higher dietary intake at 6.3 µg/day, among which 4 out of 16 had a dietary vitamin D intake more than 10 µg/day. The food diaries showed that the high dietary vitamin D intake was mainly from salmon, fortified breakfast cereal, canned tuna, and eggs.

Though the simple linear regression did not indicate a significant contribution of BMI to 25(OH)D variance, our results show that overweight/obese subjects had a significantly higher prevalence of vitamin D deficiency (65 %) than normal weight subjects (29 %), which supports the observation that obesity has been associated with lower 25(OH)D concentrations (Rafiq and Jeppesen, 2018). Volumetric dilution is the most accepted explanation (Duan *et al.*, 2020), while vitamin D, being fat soluble, can also be stored in cutaneous and visceral adipose tissues, resulting in lower plasma vitamin D levels in overweight and obese individuals (Duan *et al.*, 2020). It is still unclear whether vitamin D deficiency is a cause or an outcome of obesity, and it may be a complex of mutual influence because vitamin D receptors are expressed on adipose cells and have a role in the function of those cells (Vranić *et al.*, 2019).

Although observational studies have shown no association of poor vitamin D status with elevated incidence of osteoporosis in South Asian adults in the UK (Lowe *et al.,* 2010) and in Black Americans (Aloia *et al.,* 2000), levels of 25(OH)D less than 30 nmol/L render a greater risk for osteomalacia or rickets (Brown *et al.*, 2018). Apart from bone health, lower serum 25(OH)D levels are associated with a 1.77-fold higher risk of Type 2 Diabetes Mellitus (Tabatabaeizadeh & Tafazoli, 2021) and increased the risk of CVD by 44 % and CVD mortality by 54 % (Gholami, *et al.* 2019). Recent data indicated that people of AC and South Asian origin had a 2-fold and 2.4-fold higher mortality rate respectively from COVID-19 compared with white CAs (CDC, 2021), and vitamin D deficiency was significantly associated with COVID-19 severity and mortality (Campi *et al*., 2021) and longer recovery time from COVID-19 (Al-Salman *et al*., 2021). Currently, the role of vitamin D supplementation, and the optimal vitamin D dose and status, are subjects of debate, because large interventional studies have been unable to consistently show a clear benefit of vitamin D supplementation (Amrein *et al.*, 2020), however very few such studies have been conducted in minority populations in the UK.

The key limitation of the current study is the small sample size; however, the results provided a glimpse of the vitamin D status in a specific population of university students in the UK (Coventry University). Education programs or campaigns are urgently needed to promote the awareness of vitamin D deficiency and encourage the use of vitamin D supplements in young university adults during the wintertime. It is worth investigating a revision of dietary recommendation of vitamin D intake to ACs in the UK to reduce the vitamin D deficiency prevalence observed. Future large-scale studies to investigate the vitamin D status and its health implications in the university students are warranted.

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Authors' contributions

HD, VA, NM and MM designed the study. VA, NM and MM conducted the study. HD took blood samples from subjects. HD and VA prepared the manuscript.

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Data Availability

The data of the study are available upon request to the corresponding author.

Consent for publication

All authors approved the submission of the manuscript and consented to the publication of this manuscript.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Aloia, J. F., Vaswani, A., Feuerman, M., Mikhail, M. and Ma, R. (2000), “Differences in skeletal and muscle mass with aging in black and white women”, *The American Journal of Physiology-Endocrinology and Metabolism*, Vol. 278 No. 6, pp. E1153- E1157.

Al-Salman, J., Alghareeb, S., Alarab, E., Jahrami, H. and Grant, W. B. (2021), "In COVID-19 patients, low 25-hydroxyvitamin D level in serum is associated with longer viral clearance time and higher risk of intensive care unit admission", *Nutrition & Food Science*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/NFS-05-2021-0143.

Amrein, K., Scherkl, M., Hoffmann, M., Neuwersch-Sommeregger, S., Köstenberger, M., Berisha, A. T., Martucci, G., Pilz, S. and Malle, O. (2020), "Vitamin D deficiency 2.0: an update on the current status worldwide", *European Journal of Clinical Nutrition*, Vol. 74, pp. 1498-1513.

Banna, J. C., McCrory, M. A., Fialkowski, M. K. and Boushey, C. (2017), “Examining Plausibility of Self-Reported Energy Intake Data: Considerations for Method Selection”. *Frontiers in nutrition*, Vol. 4, pp. 45-55.

Brenner, H., Holleczek, B. and Schöttker, B. (2020), “Vitamin D Insufficiency and Deficiency and Mortality from Respiratory Diseases in a Cohort of Older Adults: Potential for Limiting the Death Toll during and beyond the COVID-19 Pandemic?”. *Nutrients*, Vol. 12 No. 8, pp. 2488-2498.

Brown, L. L., Cohen, B., Tabor, D., Zappalà, G., Maruvada, P. and Coates, P. M. (2018), “The vitamin D paradox in Black Americans: a systems-based approach to investigating clinical practice, research, and public health - expert panel meeting report”, *BMC Proceedings,* Vol. 12, pp. 6-10.

CDC (Centers for Desease Control and Prevetion) (2021), “Risk for COVID-19 Infection, Hospitalization, and Death By Race/Ethnicity”, available at: https://www.cdc.gov/coronavirus/2019-ncov/covid-data/investigations-discovery/hospitalization-death-by-race-ethnicity.html (accessed 27 September 2021).

Campi, I., Gennari, L., Merlotti, D., Mingiano, C., Frosali, A., Giovanelli, L., Torlasco, C., Pengo, M. F., Heilbron, F., Soranna, D., Zambon, A., Stefano, M. D., Aresta, C., Bonomi, M., Cangiano, B., Favero, V., Fatti, L., Perego, G. B., Chiodini, I., Parati, G. and Persani, L. (2021), “Vitamin D and COVID-19 severity and related mortality: a prospective study in Italy”, *BMC Infectious Diseases*, Vol. 21, pp. 566-578.

Desbouys, L., De Ridder, K., Rouche, M. and Castetbon, K. (2019), "Food Consumption in Adolescents and Young Adults: Age-Specific Socio-Economic and Cultural Disparities (Belgian Food Consumption Survey 2014)", *Nutrients*, Vol. 11 No. 7, pp. 1520-1535.

Duan, L., Han, L., Liu, Q., Zhao, Y., Wang, L. and Wang, Y. (2020), “Effects of Vitamin D Supplementation on General and Central Obesity: Results from 20 Randomized Controlled Trials Involving Apparently Healthy Populations”, *Annals of Nutrition and Metabolism*, Vol. 76, pp.153-164.

Estébanez, N., Gómez-Acebo, I., Palazuelos, C. Llorca, J. and Dierssen-Sotos, T. (2018), “Vitamin D exposure and Risk of Breast Cancer: a meta-analysis”, *Scientific Reports,* Vol. 8, pp. 9039-9041.

Gallagher, J. C., Jindal, P. S. and Smith, L. M. (2014), "Vitamin D Supplementation in Young White and African American Women", *Journal of Bone and Mineral Research*, Vol. 29 No. 1, pp. 173-181.

Ganji, V., Al-Obahi, A., Yusuf, S., Dookhy, Z. and Shi, Z. (2020b), “Serum vitamin D is associated with improved lung function markers but not with prevalence of asthma, emphysema, and chronic bronchitis”, *Scientific Reports*, Vol. 10 No. 1, pp. 11542-11551.

Ganji, V., Tangpricha, V. and Zhang, X. (2020a), “Serum Vitamin D Concentration ≥75 nmol/L Is Related to Decreased Cardiometabolic and Inflammatory Biomarkers, Metabolic Syndrome, and Diabetes; and Increased Cardiorespiratory Fitness in US Adults”, *Nutrients*, Vol. 12 No. 3, pp. 730-747.

Ganji, V., Zhang, X. and Tangpricha, V. (2012), “Serum 25-hydroxyvitamin D concentrations and prevalence estimates of hypovitaminosis D in the U.S. population based on assay-adjusted data”, *Journal of Nutrition*, Vol. 142 No. 3, pp. 498-507.

Gholami, F., Moradi, G., Zareei, B., Rasouli, M. A., Nikkhoo, B., Roshani, D. and Ghaderi, E. (2019), “The association between circulating 25-hydroxyvitamin D and cardiovascular diseases: a meta-analysis of prospective cohort studies”, *BMC Cardiovascular Disorders,* Vol. 19, pp. 248-258.

Gordon, C. M., Zemel, B. S., Wren, T. A. L., Leonard, M. B., Bachrach, L. K., Rauch, F., Gilsanz, V., Rosen, C. J. and Winer, K. K. (2016), “The Determinants of Peak Bone Mass”. *The Journal of Pediatrics*, Vol. 180, pp. 261-269.

Holick, M. F. (2008), "Vitamin D and Sunlight: Strategies for Cancer Prevention and Other Health Benefits. Clinical journal of the American Society of Nephrology", *Clinical Journal of the American Society of Nephrology*, Vol. 3 No. 5, pp. 1548-1554.

Horton-French, K., Dunlop, E., Lucas, R .M. Pereira, G. and Black, L. J. (2021), “Prevalence and predictors of vitamin D deficiency in a nationally representative sample of Australian adolescents and young adults”, *European Journal of Clinical Nutrition,* available at: https://www.nature.com/articles/s41430-021-00880-y.pdf (accessed 27 September 2021)

Hypponen, E. and Power, C. (2007), “Hypovitaminosis D in British adults at age 45y: nationwide cohort study of dietary and lifestyle predictors”, *The American Journal of Clinical Nutrition*, Vol. 85, pp. 860-868.

IOM (Institute of Medicine) (2011), *Dietary Reference Intakes for Calcium and Vitamin D*, The National Academies Press, Washington DC.

Klingberg, E., Oleröd, G., Konar, J., Petzold, M. and Hammarsten, O. (2015), “Seasonal variations in serum 25-hydroxy vitamin D levels in a Swedish cohort”, *Endocrine*, Vol. 49 No. 3, pp. 800-808.

Lin, L., Smeeth, L., Langan, S. and Warren-Gash, C. (2021), *“*Distribution of vitamin D status in the UK: a cross-sectional analysis of UK Biobank”, *BMJ Open,* Vol. 11, pp. e038503.

Lips, P., Cashman, K.D., Lamberg-Allardt, C., Bischoff-Ferrari, H.A., Obermayer-Pietsch, B., Bianchi, M.L., Stepan, J., El-Hajj Fuleihan, G. and Bouillon, R. (2019), “Current vitamin D status in European and Middle East countries and strategies to prevent vitamin D deficiency: a position statement of the European Calcified Tissue Society”. *European journal of endocrinology*, Vol. 180 No. 4, pp. 23-54.

Lowe, N. M. and Bhojani, I. (2017), “Special considerations for vitamin D in the south Asian population in the UK”, *Therapeutic Advances in Musculoskeletal Disease*, Vol. 9 No. 6, pp. 137-144.

Lowe, N. M., Mitra, S. R., Foster, P. C., Bhojani, I. and McCann, J. F. (2010), "Vitamin D status and markers of bone turnover in Caucasian and South Asian postmenopausal women living in the UK", *British Journal of Nutrition*, Vol. 103 No. 12, pp. 1706-1710.

Minisola, S., Colangelo, L., Pepe, J., Diacinti, D., Cipriani, C. and Rao, S. (2021), "Osteomalacia and Vitamin D Status: A Clinical Update 2020", *Journal of the American Society for Bone and Mineral Research plus,* Vol. *5* No. 1, pp. E10447-N/a.

Nair, R. and Maseeh, A. (2012), "Vitamin D: The "sunshine" vitamin", *Journal of pharmacology & pharmacotherapeutics*, Vol. 3 No. 2, pp.118-126.

NICE (2014), "Obesity: identification, assessment and management", available at: https://www.nice.org.uk/guidance/cg189 (accessed 30 June 2021).

Nikooyeh, B., Abdollahi, Z., Hajifaraji, M., Alavi-Majd, H., Salehi, F., Yarparvar, A. H. and Neyestani, T. R. (2017), "Vitamin D Status, Latitude and their Associations with Some Health Parameters in Children: National Food and Nutrition Surveillance", *Journal of Tropical Pediatrics*, Vol. 63 No. 1, pp. 57-64.

Ortega, R. M., Pérez-Rodrigo, C. and López-Sobaler, A. M. (2015), "Dietary assessment methods: dietary records", *Nutrición hospitalaria: organo oficial de la Sociedad Española de Nutrición Parenteraly Enteral*, Vol. 31 Suppl 3, pp. 38-45.

Patel, J. V., Chackathayil, J., Hughes, E. A., Webster, C., Lip, G. Y. and Gill, P. S. (2013), "Vitamin D deficiency amongst minority ethnic groups in the UK: a cross sectional study", *International Journal of Cardiology*, Vol. 167 No. 5, pp. 2172-2176.

PHE (2018), "NDNS: results from years 7 and 8 (combined)", available at: https://www.gov.uk/government/statistics/ndns-results-from-years-7-and-8-combined (accessed 25 May 2021).

Rafiq, S. and Jeppesen, P. B. (2018), "Body Mass Index, Vitamin D, and Type 2 Diabetes: A Systematic Review and Meta-Analysis", *Nutrients*, Vol. 10 No. 9, pp. 1182-1191.

SACN (2016), "Vitamin D and Health", available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/537616/SACN_Vitamin_D_and_Health_report.pdf (accessed 30 June 2021).

Sarafin, K., Durazo-Arvizu, R., Tian, L., Phinney, K. W., Tai, S., Camara, J. E., Merkel, J., Green, E., Sempos, C. T. and Brooks, S. P. (2015), "Standardizing 25-hydroxyvitamin D values from the Canadian Health Measures Survey", *The American Journal of Clinical Nutrition,* Vol. 102, pp. 1044-1050.

Sutherland, J. P., Zhou, A. Leach, M. J. and Hyppönen, E. (2021), "Differences and determinants of vitamin D deficiency among UK biobank participants: A cross-ethnic and socioeconomic study", *Clinical Nutrition*, Vol. 40 No. 5, pp. 3436-3447.

Tabatabaeizadeh, S. A. and Tafazoli, N. (2021), "The role of vitamin D in prevention of type 2 diabetes. A meta-analysis", *Clinical Nutrition ESPEN*, Vol. 41, pp. 88-93.

Tangpricha, V., Pearce, E. N., Chen, T. C. and Holick, M. F. (2002). "Vitamin D insufficiency among free-living healthy young adults", *The American Journal of Medicine*, Vol. 112 No. 8, pp. 659-662.

TOSOH Bioscience (2020), "Vitamin D technical", available at: https://www.diagnostics.us.tosohbioscience.com/assays/vitamin-d (accessed 27 August 2021).

Tsiaras, W. G. and Weinstock, M. A. (2011), “Factors Influencing Vitamin D Status”, *Acta Dermato-Venereologica*, Vol. 91, pp. 115-124.

Vranić, L., Mikolašević, I. and Milić, S. (2019), "Vitamin D Deficiency: Consequence or Cause of Obesity?”, *Medicina (Kaunas),* Vol. 55 No. 9, pp. 541-550.

Wacker, M. and Holick, M. F. (2013), "Sunlight and Vitamin D: A global perspective for health", *Dermatoendocrinol*, Vol. 5 No. 1, pp. 51-108.

Webb, A. R., Kazantzidis, A., Kift, R. C., Farrar, M. D., Wilkinson, J. and Rhodes, L. E. (2018), "Colour Counts: Sunlight and Skin Type as Drivers of Vitamin D Deficiency at UK Latitudes", *Nutrients,* Vol. 10 No. 4, pp. 457-469.

Winpenny, E. M., van Sluijs, E. M. F., White, M. Klepp, K., Wold, B. and Lien, N. (2018), “Changes in diet through adolescence and early adulthood: longitudinal trajectories and association with key life transitions”, *International Journal of Behavioral Nutrition and Physical Activity,* Vol. 15, pp. 86-95.

Zittermann, A., Iodice, S., Pilz, S., Grant, W. B., Bagnardi, V. and Gandini, S. (2012), “Vitamin D deficiency and mortality risk in the general population: a meta-analysis of prospective cohort studies”, *The American Journal of Clinical Nutrition*, Vol. 95 No. 1, pp. 91-100.

Tables

Table I. Descriptive characteristics of study subjects

		Number (%)	Age (year)	BMI (kg/m^2)
Total subjects		41 (100 %)	22.0 ± 2.6	25.1 ± 4.4
Gender	Female	21 (51.2 %)	21.2 ± 2.3	24.9 ± 3.3
	Male	20 (48.8 %)	22.8 ± 2.7	25.4 ± 5.3
Ethnicity	CA	18 (43.9 %)	22.0 ± 2.6	24.2 ± 3.4
	AC	14 (34.1 %)	22.2 ± 2.5	25.7 ± 3.7
	Asian	9 (22.0 %)	21.6 ± 3.0	26.1 ± 6.8
Body weight	Normal weight	21 (51.2 %)	21.2 ± 2.0	21.8 ± 1.6
	Overweight/obese	20 (48.8 %)	22.8 ± 3.0	28.6 ± 3.5

Data are presented as mean ± SD; AC, African-Caribbean; BMI, body mass index; CA, Caucasian. Normal weight: body mass index (BMI) 18.5-24.9 kg/m^2; Overweight/Obese: BMI ⩾ 25 kg/m^2.

Table II. Plasma 25(OH)D concentrations and vitamin D status

Groups		Plasma 25(OH)D (nmol/L)	Vitamin D status (%)			*P* value*
			Deficient	Insufficient	Sufficient	
Total subjects		36.0 ± 22.2	46.3	31.7	22.0	
Ethnicity	CA	46.5 ± 25.3	22.2	33.3	44.4	0.001
	AC	22.6 ± 7.4	85.7	14.3	0.0	
	Asian	37.4 ± 21.7	33.3	55.6	11.1	
Gender	Female	31.6 ± 17.3	40.0	30.0	30.0	0.47
	Male	41.4 ± 26.2	52.4	33.3	14.3	
Body weight	Normal weight	38.4 ± 18.4	28.6	47.6	23.8	0.04
	Overweight/obese	34.1 ± 26.1	65.0	15.0	20.0	

Plasma 25(OH)D concentration was presented as mean ± SD. AC, African-Caribbean; CA, Caucasian. *Pearson Chi-Square for vitamin D status. Vitamin D deficiency: < 30 nmol/L; insufficiency: 30-50 nmol/L; sufficiency: > 50 nmol/L based on the plasma 25(OH)D concentration. Normal weight: body mass index (BMI) 18.5-24.9 kg/m^2; Overweight/Obese: BMI $\geqslant$25 kg/m^2.

Table III. Dietary vitamin D intake and the percentage of subjects who met dietary vitamin D intake recommendation

	Groups	Dietary vitamin D intake (μg/day)	Adequate % (n)	Inadequate % (n)	*P* values*
All subjects		4.6 ± 3.9	12.1 % (4)	87.9 % (29)	
Ethnicity	CA	6.3 ± 4.6	25.0 % (4)	75.0 % (12)	0.09
	AC	3.1 ± 2.9	0	100 % (9)	
	Asian	3.1 ± 2.0	0	100 % (8)	
Gender	Female	3.2 ± 3.1	5.9 % (1)	94.1 % (16)	0.26
	Male	6.2 ± 4.2	18.8 % (3)	81.2 % (13)	
Body weight	Normal weight	5.2 ± 3.9	11.1 % (2)	88.9 % (16)	0.85
	Overweight/Obese	4.0 ± 4.0	13.3 % (2)	86.7 % (13)	

Dietary vitamin D intake was presented as mean ± SD. AC, African-Caribbean; CA, Caucasian; *Pearson Chi-Square for dietary vitamin D intake adequacy. Adequacy: dietary vitamin D intake ≥ 10 μg/day; Inadequacy: dietary vitamin D intake < 10 μg/day. Normal weight: body mass index (BMI) 18.5-24.9 kg/m^2; Overweight/Obese: BMI ≥25 kg/m^2.

Table IV. Simple linear regression analysis summary for plasma 25(OH)D concentration (dependent variable)

Independent variables (predictors)	Adjusted R^2	*P* value (ANOVA)	Constant	Unstandardized beta (B)	Standardized beta (β)	95 % CI for B
Dietary vitamin D intake	0.13	0.04	28.234	2.164	0.36	(0.109, 4.218)
BMI	0.003	0.72	43.852	-0.298	-0.059	(-1.944, 1.348)
Age	0	0.93	33.487	0.131	0.015	(-2.649, 2.911)
Gender	0.025	0.16	41.374	-9.794	-0.222	(-23.738, 4.150)
Ethnicity	0.185	0.01	46.497	AC -23.869, Asian -9.063	AC -0.513, Asian -0.170	AC (-38.423, -9.314)[1], Asian (-25.737, 7.612)[2]

[1] Coefficient *P*= 0.002; [2] Coefficient *P*= 0.28; AC, African-Caribbean; BMI, body mass index; CI, Confidence interval.