RELATIONSHIP BETWEEN BODY FAT DISTRIBUTION AND VITAMIN D STATUS AMONG UNIVERSITY EMPLOYEES AT A PRIVATE UNIVERSITY IN LEBANON: A CROSS-SECTIONAL STUDY

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Contents

Abstract

Background: High prevalence of suboptimal vitamin D status has paralleled the obesity epidemic; thus there has been a growing scientific interest in understanding the relationship between serum vitamin D levels and adiposity. Given the 1) high prevalence of vitamin D deficiency in Lebanon 2) lack of evidence on the association between body fat distribution (BFD), particularly direct measures of BFD, and serum vitamin D levels 3) lack of simultaneous control for important confounding variables, including indices of body composition, our study is the first to explore the association between a direct measure of body fat distribution (upper-to-lower body fat ratio-ULBFR) and vitamin D status, independent of %BF. The aim of our study is to examine the independent associations between different body fat location measurements and suboptimal vitamin D levels. We hypothesize that there is an independent association between different measures of BFD, particularly, ULBFR, and suboptimal vitamin D status.

Methods: A cross sectional study was conducted among employees at a private university in Lebanon (Notre Dame University-Louaize). Anthropometric data (waist circumference (WC), height and hip circumference) were collected using standardized techniques. Waist-to hip ratio (WHR) and waist-to-height ratio (WHtR) were calculated as the waist measurement divided by the hip measurement or height, respectively. Cutoff points of ≥ 102 cm for men and ≥ 88 for women, ≥ 0.9 for men and ≥ 0.85 for women, > 0.5 for men and women, were used to identify individuals with unhealthy WC, waist-to-hip ratio, and waist-to-height ratio respectively. Body weight and body composition variables (fat mass, trunk fat mass, fat mass in the right and left legs/right and left arms, body fat percentage (BFP), fat free mass, skeletal muscle mass and visceral

fat area (VFA)) were measured using the bioelectrical impedance anlaysis machine (BIA)- (InBody 720, Biospace, Seoul, Korea). ULBFR was calculated as: (trunk fat mass (kg)) / (fat mass in right/lefty legs (kg)). Stratified analyses by gender, with women also stratified by menopausal status, was performed. Men, premenopausal and postmenopausal women were divided into three groups according to the tertiles of 1) ULBFR level and 2) VFA level. Serum 25-hydroxyvitamin D levels were measured using ELIZA and vitamin D status was determined according to the US Endocrine Society guidelines (Vitamin D deficiency: 25(OH) D ≤20 ng/mL; vitamin D insufficiency: 25(OH)D > 21 - 29 ng/ml and vitamin D sufficiency as 25(OH)D ≥30ng/ml). Statistical analysis was done using SPSS version 22.

Results: A total of 344 employees participated in the study. About 71% of the study participants were found to have suboptimal vitamin D status (69% M vs. 75% W, P>0.05). Among men (n=176), no significant associations were found between suboptimal vitamin D status and WC, WHR, WHtR, VFA and ULBFR. Among premenopausal women (n=146), significant associations were found between suboptimal vitamin D status and WC, WHR, VFA and ULBFR. Premenopausal women with unhealthy WC and WHR were found to have about 4.6 times higher odds of developing suboptimal vitamin D status than those with healthy WC and WHR, after controlling for confounders. In addition, premenopausal women whose visceral fat areas fell in the second, third tertiles/ upper-to-lower body fat ratios levels fell in the third tertile were found to have about 5, 9 times/4 times higher odds of developing suboptimal vitamin D status as compared to those whose visceral fat areas/ upper-to-lower body fat ratios fell in the first tertile, respectively, after controlling for confounders. It is worth mentioning that 1) the association pertaining to ULBFR was independent of BFP and 2) BFP was found to be not associated with suboptimal

vitamin D status independent of upper-to-lower body fat ratio and the other confounding variables in the final model.

Conclusion: Our study results revealed that an increased ULBFR in premenopausal women increases the odds of suboptimal vitamin D status, independent of BFP, indicating a possible complementary role of body fat distribution than body composition in determining vitamin D status. Dieticians should consider examining body fat distribution in addition to body composition to identify and refer those with increased odds of suboptimal vitamin D levels for measurement of their serum vitamin D levels.

Keywords: Vitamin D deficiency, visceral fat area, upper- to- lower body fat ratio, 25-hydroxyvitamin D_3

Introduction/Literature review

Vitamin D is a fat soluble vitamin that can be obtained from different sources: sun exposure, food (natural, fortified) and supplements. Sources of vitamin D include: egg yolk (35 IU per egg), fatty fish (144 IU in 75g), tuna, salmon, vegetables (mushroom), fortified cereals, fortified cheeses, and sunlight and oral supplements. Vitamin D has two distinct types; Vitamin D_2 and Vitamin D_3. Vitamin D_2 (also known as Ergocalciferol) is obtained from vegetable sources (mainly mushrooms) and oral supplements. Vitamin D_3 (also known as Cholecalciferol) is obtained mainly from egg yolk, fatty fish, fortified cereals, sunlight and oral supplements. Both types are metabolized in the liver, where they undergo hydroxylation to form 25- hydroxyvitamin D (25(OH) D). In the kidneys, 25(OH) D will be hydrolyzed by 1α-hydroxylase to form the active form of vitamin D, 1, 25-dihydroxyvitamin D (1, 25(OH) $_{2D}$), named calcitriol.

The classic function of vitamin D is the endocrine function that involves stimulation of optimal intestinal calcium absorption (Pligt et al, 2018), therefore promoting the mineralization of the bone (Maleab et al., 2016) and decreasing the risk of osteoporosis. Because vitamin D receptor is found in multiple tissues, there has been interest in evaluating other potential functions of vitamin D, particularly in cardiovascular disease (CVD) and diabetes mellitus (DM). Epidemiological evidence for vitamin D deficiency as a risk factor for CVDs and diabetes exist (Pannu et al., 216). In an observational cohort study done among 247,574 Danish adults, CVD mortality was 2 times higher in those who were severely vitamin D deficient (serum 25(OH)D< 12.5 nmol/L) compared to those who were non-deficient in vitamin D (serum 25(OH)D ≥70 nmol/l) (95% CI 1.8 –2.1) ; subgroup analyses revealed men to have a higher risk (OR = 2.5 ; 95% CI 2.2–2.9) compared to

women (OR= 1.7 ; 95% CI 1.5–1.9) (Durup et al., 2015). A cohort study done by Health and her colleagues in Melbourne Australia on 41,514 healthy participants (age range = 40-69) in 2018, showed that for each 25 nmol/L increase in 25(OH) D a 24% decrease in risk of developing type 2 DM was observed during 11 years of follow up (OR= 0.71 , 95% CI: 0.56, 0.89; p=0.003).

Although 1, $25(OH)_2$ D is the biologically active form of vitamin D, and, thus, would be thought of as the ideal measure for vitamin D status, it is not. This is because 1) The circulating half-life of $1,25(OH)_2D$ is only 8 hours compared to 3 weeks for 25(OH) D, 2) Circulating levels of $1,25(OH)_2D$ are one thousand times lower than those of 25(OH) D, 3) 1,25(OH)D is produced under the effect of parathyroid hormone which firmly regulates calcium levels; as serum 25(OH) D levels become below normal, the parathyroid glands respond by secreting parathyroid hormone (PTH) which increases the renal production of $1,25(OH)_2$ D to maintain normal serum calcium levels. Therefore, elevated levels of $1,25\ (OH)_2$ D are observed in patients with severe vitamin D insufficiency/ deficiency , leading to false negative results while testing for vitamin D deficiency (Judd et al , 2009).

Till now, no universal cutoff values were set to categorize vitamin D status. Different cutoffs exist of which are those of the Institute of Medicine and those of the National Osteoporosis Foundation and Endocrine society. According to the Institute of Medicine, individuals with serum 25(OH) D level of ≥ 20 ng/ml (≥ 50 nmol/L)have normal vitamin D levels, individuals with serum 25(OH) D_3 level between 12 to less than 20 ng/ml (30 to < 50 nmol/L) have vitamin D insufficiency; individuals with serum 25(OH) D_3 level less than 12 ng/ml(< 30 nmol/L) have vitamin D deficiency (Ross et al., 2011). According to the National Osteoporosis foundation, vitamin D deficiency is diagnosed when serum 25(OH)D concentration is below 30 ng/ml (<50 nmol/L), and

vitamin D sufficiency is defined as serum 25(OH)D concentration ≥30 ng/ml (≥75 nmol/L) (Cosman et al., 2014). The US Endocrine Society guidelines define vitamin D deficiency as 25(OH)D ≤20 ng/mL (≤ 50 nmol/L), vitamin D insufficiency as 25(OH)D > 21 - 29 ng/ml (50–75 nmol/L) and vitamin D sufficiency as 25(OH)D ≥30ng/ml (Holick et al., 2011).

Prevalence of low vitamin D level is high worldwide. Serum 25(OH) D levels of < 10 ng/mL (severe deficiency) were observed in adults in Europe (2–30%). A cross sectional study, done in Russia on 435 participants , found 40.2 % of the studied population to be vitamin D deficient (<50 nmol/l) (Karonova et al., 2016). As for Asian countries, In China for example, a cross-sectional study involving 1,105 adults (age range=20–70 years) found that 26.60 % had vitamin D insufficiency (25(OH) D < 50 nmol/l) and 24.89 % had vitamin D deficiency (25(OH) D< 20 nmol/l) (Zhang et al., 2015). In North India, studies have shown that 96% of neonates, 91% of healthy school girls and 78% of healthy hospital employees had hypovitaminosis D (serum 25(OH) D < 50 nmol/L) (Mithal et al., 2009).

Despite abundant sunshine in the Middle East, vitamin D deficiency and insufficiency are quite prevalent. In a systematic review including 103 studies done in USA, Europe, Africa, Asia and Oceania, the highest prevalence of vitamin D deficiency was found in children, adolescents, adults and elderly from the ME. Specifically, in adults, the highest percentages of hypovitaminosis was found in adults from Pakistan (58%- 84%) and females from Israel (51% - 89%) (Palacios et al., 2013) (Figure 1). In a retrospective study conducted among 60,979 participants from the UAE, 83% of women and 81.9% of men had low serum 25(OH) D (<75 nmol/L) according to endocrine cutoffs (Haq et al., 2016). In a retrospective study done on 425 subjects living in the UAE, the prevalence of hypovitaminosis D was found to be 96.9%; 48.9 % were found to be vitamin D

deficient (25(OH) D between10–20 ng/mL), 33.2% had severe vitamin D deficiency (25(OH) D) <10 ng/mL) and 14.8% showed to have vitamin D insufficiency (25(OH) D between 21–30 ng/mL) (Sridhar et al., 2016). A retrospective study done by Hussain et al in 2014, on 10,709 Saudi patients showed that 40.2% of men reported having vitamin D deficiency (<25 nmol/l) and 53.5% reported having vitamin D insufficiency (25 (OH)D between 25–75 nmol/L). A cross-sectional study done in Saudi Arabia among 1,722 healthy Saudi Arabian men showed that 87.8% had vitamin D deficiency (25(OH)D<50 nmol/L) and 9.7% had vitamin D insufficiency (25(OH) D ≥50–75 nmol/L) (Ardawi et al., 2011). In Lebanon, a cross sectional study done among 392 subjects found that 26.78 % of the population had severe vitamin D deficiency (25(OH) D < 10 ng/ml) with only 5.1 % having normal Vitamin D levels (≥30 ng/ml) (Gannage´-Yared et al., 2014). Another cross sectional study done among boys and girls (age range between 10-16) in three private schools in Beirut showed that more than 50% of children had vitamin D insufficiency (serum 25(OH) D< 50 nmol/ml) (Fuleihan et al.,2001). In a retrospective study, done in American University of Beirut-Medical Center in Lebanon, records collected from 2000 till 2004 among 2386 adult patients (49.2 ± 11.4 years; 86% females) showed that 60% had vitamin D deficiency/insufficiency (25(OH) D_3 < 20 ng/ml) whereas records collected from 2007 -2008 showed that 44% of 3024 adult patients (49.5 ± 11.6 years; 84% females) had vitamin D deficiency(25(OH) D_3 < 20 ng/ml cutoffs) (Hoteit et al., 2014). In another cross sectional study done in Lebanon among 105 ambulatory patients (18 men and 87 women, mean age of 49.21 ± 14.59 years, mean BMI of 26.31 ± 5.25 kg/m^2) researchers found that 51.43% had vitamin D deficiency (<50 nmol/l) (Rashkidi et al., 2016).Recently, a cross sectional study conducted among 344 healthy employees at a private university in Lebanon showed that, according to IOM guidelines, 68.3% had vitamin

D sufficiency (25(OH)D ≥30 ng/mL), 22% had 25(OH)D insufficiency (25(OH)D ≥ 12-20 ng/mL) and 9.7% of the participants had vitamin D deficiency (25(OH)D ≤ 12 ng/mL)(Hayek et al., 2018).

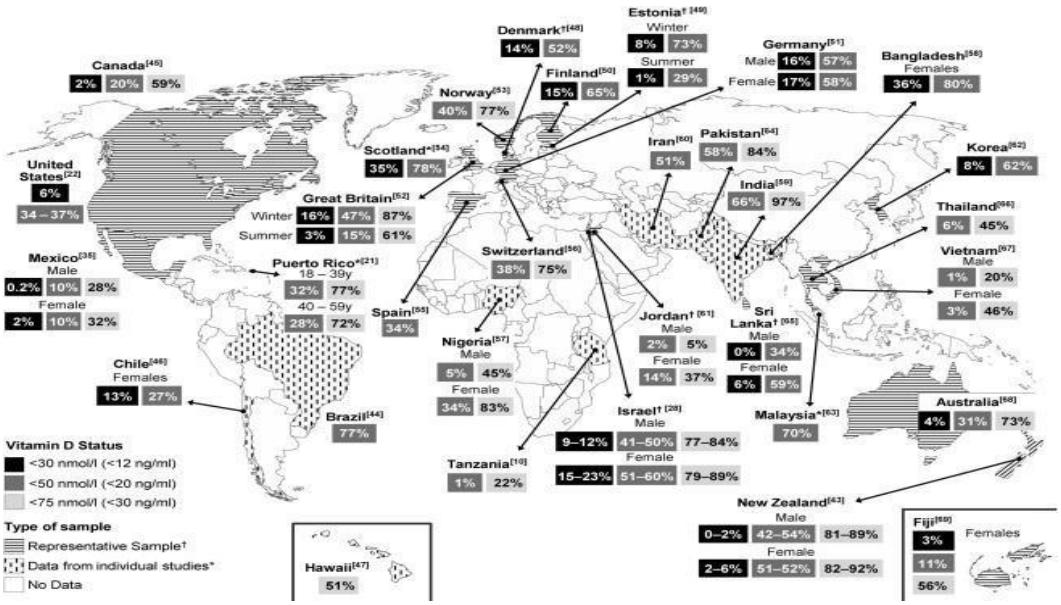

Figure 1: Prevalence of low vitamin D status in adult's worldwide (Pacilios et al., 2013)

Obesity is now classified as a worldwide epidemic (Pozza et al., 2017) and is recognized to be a significant risk factor for diseases such as CVD, type 2 diabetes, hypertension, respiratory disorders, infertility, etc... High prevalence of vitamin D deficiency/insufficiency has paralleled the obesity epidemic (Vanlint, 2013) and because both conditions are involved in the development of several similar diseases, there has been a growing scientific interest in understanding the relationship between these two conditions. Vitamin D inadequacy has indeed been linked to obesity, whether obesity is assessed by body mass index (BMI), waist circumference (WC), body fat percentage (BFP) or visceral fat. A cross-sectional study done on 250 overweight and obese adults from new Zealand revealed modest yet significant inverse correlations between 25(OH) D_3 and body weight (r = -0.212 , p = 0.0009), BMI (r =-0.182 , p = 0.005) and WC (r =-0.141, p =

0.03) (McGill et al., 2008). In another cross sectional study done in Southeast Norway on 110 adults, it was found that morbidly obese women and men had significantly lower serum (25 OH D) compared to their healthy counterparts (W: 48 ± 18 nmol/l vs. 74 ±14, p<0.001; M: 34± 15 nmol/l vs. 48 ± 14 nmol/l vs 63 ± 15, p<0.001) (Aasheim et al., 2008). Moreover, another cross sectional and prospective study done in Norway among 25,616 adults (age range: 19–55 years) showed that at baseline serum 25(OH) D level of <50.0 nmol/L was significantly associated with 2.6 times increase in prevalence of obesity and 1.6 times increase in incidence of obesity. In addition, it was found that a decrease of 25 nmol/l in 25(OH) D level was associated with an increase of 0.4 kg in body weight and 0.14 units increase in BMI (p = 0.037 and 0.042, respectively); among subjects with healthy BMI; This study established the cross-sectional relationship between obesity and vitamin D and highlighted that lower 25(OH) D levels in adults can lead to new-onset incident obesity (Mai et al., 2011). A retrospective chart review of medical records of 1,191 obese adult patients in a Hospital in Boston showed that serum vitamin D levels were inversely correlated with weight (r= -0.325. p<0.001), BMI (r= -0.325, p<0.01) and WC (r= −0.285, p= 0.001) (Boonchaya-anant1 et al., 2014). A cross sectional study, done in china on 567 men with normal glucose tolerance, showed negative correlation between 25 hydorxycholicalceferol and BMI (r = -0.101, p = 0.016). A cross sectional study done in Russia, on 435 participants (132 males, 303 females) found that body mass index and waist circumference were negatively correlated with serum 25(OH)D levels (r = -0.15, p = 0.02 and r = - 0.20, p = 0.001 respectively) in women (Karonova et al, 2016).

In a randomized clinical controlled trial done in the USA, 2161 obese participants (51.0 ± 10.8 years) were divided into two groups, the intensive lifestyle group) and the placebo group (standard

lifestyle). Researchers reported an inverse association between plasma 25OHD concentration and weight (β= 0.0048, p <0.0001), total fat (β=−0.0006, p< 0.0001), subcutaneous adipose tissue (SAT) (β= −0.0007 <0.0001) and no association between 25(OH)D concentration and Visceral adipose tissue (VAT) (β= −0.0002, p = 0.5198) in unadjusted analyses. After adjusting for age, race, gender, alcohol, glomerular filtration rate, calcium intake, physical activity, clinical site, season of blood draw, smoking status and total fat in case of weight, weight in case of total fat and weight and the opposite type of fat in case of SAT and VAT, plasma 25(OH)D became significantly associated with VAT (β=−0.0009, p = 0.0076), and the association with total fat (β= −0.0004, p =0.0495), SAT (β=−0.0002, p <=0.2618) and weight (β=−0.0009, p =0.6314) became non-significant. Vitamin D was inversely correlated with BMI and waist circumference (β = −0.0174, β = −0.0064, p < 0.001 respectively) (Ceglia et al., 2015). A cross sectional study involving 4771 Korean subjects (1,989 males and 2,782 females aged >19 years) showed that serum 25(OH) D concentration was inversely correlated with percent body fat in men and women (r = -0.114, r=-0.084, p < 0.0001, respectively). Serum 25(OH)D concentration was inversely associated with total body fat content in both men and women (β= -17.577, P = 0.0047 ; β=-20.9554. p= 0.0244 respectively) after adjusting for age, BMI, region, smoking status, educational level, energy consumption, alcohol intake and physical activity in men and adjusting for age in women. As for Waist circumference, no significant association was found in both men and women (β= 0.0073, p=0.4043 ; β= 0.0138 , p= 0.0902 respectively) after adjusting for age, BMI, income, region, smoking status, educational level, energy consumption, alcohol intake.(Kim et al., 2016). A cross-sectional conducted in the UAE among 309 obese and diabetic adults (aged between 30 and 60years) showed negative correlation between serum 25(OH) D level and BMI (r = -0.15,

p<0.05), fat mass (r = -0.16, p<0.05) and WC (r = -0.17, p< 0.05) (Sadiya et al., 2014). On the other hand, other studies reported contradictory results. In a cross-sectional study done in North India, no correlation was found between 25(OH) D levels and percent body fat (r =0.017, p= 0.83) among 137 overweight and obese participants (74 men and 63 women; age range between18–60 years).In addition, researchers in a 1-year randomized double-blind placebo controlled trial done in Pakistan on154 participants (88 women and 77 men) found no association between vitamin D status and body fat percentage(p < 0.783)(Gronborg et al, 2014).

Few studies were conducted on the relationship between body fat distribution (BFD) and vitamin D. A cross-sectional study done in North India, among 137 overweight and obese participants (74 men and 63 women; age range between18–60 years) showed no correlation between 25(OH) D levels and WC (r = 0.001, p= 0.92), waist- to-hip ratio (r = - 0.059, p =0.5) and total abdominal adipose tissue (r =0.070, p = 0.47). However, this study had some limitations including small sample size, lack of control for confounding factors such as sun exposure and nutritional status (Bhatt et al., 2014). In China, a cross-sectional study involving 1105 adults (age range between 20–70 years) showed that men who had highest visceral fat area (≥140.46 cm^2) had 4.9-fold risk of vitamin D insufficiency or deficiency (CI{1.792– 13.365}, p=0.002) compared to control group (individuals with the lowest VFA (<89.95 cm^2) after adjusting for age, drinking status, exercise status, smoking status,lipid profiles and sun exposure ; As for pre-menauposal women , those who had highest visceral fat area (≥84.47 cm2) had 1.8-fold risk of vitamin D insufficiency and deficiency (95 % CI: 1.051–3.210 , p=0.033) compared to individuals with the lowest VFA(<53.15 cm^2)after adjusting for age, smoking, lipid profile, drinking, exercise and sun exposure. This association, however, was not observed in postmenopausal women (p=0.625) (Zhang et al, 2015).

But this study had a major limitation which is lack of control for an important confounder, the parathyroid hormone. A randomized controlled trial done among 103 French Canadian men ,aged between 30 and 65 years, with abdominal obesity (WC > 90 cm) showed that after providing these patients with a weight loss regimen, a 26% decrease in visceral adipose tissue was related to a 26% increase in 25(OH) D circulating levels ($p<0.0001$). However, this study was done on men only, which resulted in limited generalizability (Gangloff et al., 2015). A cross sectional study, done in china on 567 men with normal glucose tolerance showed that after adjusting for age and BMI, there were associations between $25(OH)D_3$ and percent body fat ($r = - 0.137$, $p = 0.001$) and visceral fat area ($r = - 0.154$, $p <0.01$) but not between $25(OH)D_3$ and WC ($r = -0.055$, $p = 0.192$). The limitations of this study included: small sample size and inclusion of only middle-aged and elderly; which limited the generalizability of these findings (Hoa et al., 2014).

Several factors have been suggested to explain the relationship between vitamin D insufficient/deficient levels and decreased bioavailability of 25-hydroxyvitamin D in obese adults. These factors include dietary intake (limited intake of egg yolk, fortified foods, fatty fish, fish oil), inadequate sun exposure (very little outdoor movement) which will affect the synthesis of vitamin D3 from skin (Entrenas et al., 2016) and its deposition in the excess adipose tissues due to its lipophilic nature thus cleared from plasma, signaling low status (Gangloff et al., 2015)

Given the 1) high prevalence of vitamin D deficiency in Lebanon 2) lack of evidence on the association between body fat distribution (BFD), particularly direct measures of BFD, and serum vitamin D levels 3) lack of simultaneous control for important confounding variables, including indices of body composition, our study is the first to explore the association between a direct measure of body fat distribution (upper-to-lower body fat ratio-ULBFR) and vitamin D status,

independent of %BF. This study aims at exploring the relationship between body fat distribution, with a particular emphasis on ULBFR, and vitamin D levels among a sample of employees at a private university in Lebanon. The study objectives are to (in men, premenopausal and postmenopausal women): 1) to assess the prevalence of inadequate vitamin D levels 2) to identify predictors of high level of visceral fat area (VFA) and ULBFR 3) to identify the correlates of serum vitamin D levels adjusted for age and 4disc) to examine the independent associations between different body fat location measurements and suboptimal vitamin D status. We hypothesize that there is an independent association between different measures of body fat distribution, particularly, ULBFR, and suboptimal vitamin D status.

Methods

Study design and recruitment methods:

The study design was cross-sectional. Subjects were employees at a private university in Lebanon (Notre Dame University (NDU)) and recruited from the different university campuses (at the main campus (Zouk Mosbeh) and the regional campuses (North, and Shouf). After obtaining the NDU IRB approval, researchers sent an e-invite to participate in the study to all NDU staff and faculty members. Those who expressed interest in participation were screened for eligibility using the following inclusion/exclusion criteria. Inclusion criteria included being healthy and the exclusion criteria included having a pacemaker or metal piece in their body, being pregnant or lactating or unwilling to undergo all study procedures. Those who were found to be eligible were asked to read and sign the IRB-approved consent.

Independent Variables Assessment

After obtaining the consent of the eligible NDU faculty members/staff, trained nutritionists visited them in their offices, as per pre-scheduled 30- min face to face interviews, to collect data by filling out three questionnaires (background questionnaire, short-form of the International Physical Activity Questionnaire (IPAQ-short form) and food frequency questionnaire [FFQ]) based on the participants' responses. The background questionnaire included questions on socio-demographic characteristics (age, gender, marital status, etc…), lifestyle habits (sun exposure practices, sunscreen use, smoking, alcohol intake, etc….) and current health status (chronic medical conditions, intake of medications, etc…) of the study participants. The IPAQ-short form is a 7-item self-administered questionnaire that asks about three specific types of activity: walking, moderate and vigorous physical activities and time spent by an individual doing the activity. Four continuous scores were calculated: Walking MET-minutes/week = 3.3 * walking minutes * walking days; Moderate MET-minutes/week = 4.0 * moderate-intensity activity minutes * moderate-intensity days; Vigorous MET-minutes/week = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days; Total physical activity (PA) MET-minutes/week = sum of Walking + Moderate + Vigorous MET-minutes/ week scores. Low-level, moderate-level and high-level PA were defined by scores of less than 600 MET-minutes per week, between 600 to less than 3000 MET-minutes per week, and of 3000 or more MET-minutes per week respectively (Booth et al., 2000) .

The FFQ was an existing FFQ prototype for assessment of vitamin D intake that was developed (El Hayek et al, 2014) .It included 9 food items: full-fat/low-fat dairy products, eggs and egg-based dishes, fish, margarine, cheeses, and ice cream. For each food item, participants were requested to

mark their frequency of intake of a selected serving/portion size per day/week/month or rarely/never during the past year. The Nutritionist Pro diet analysis software, version 31.0, the Middle-East Food Composition Tables and the Canadian Nutrient File (Axxya Systems, Woodinville, WA, USA) were used to generate estimates of dietary intake of vitamin D (Block et al, 1994; Pellet et al, 1970; Verdier at all, 1984). Anonymous data were recorded so that the information cannot be linked to the subject who provided it and confidential data (questionnaires and test results) were coded, by assigning each participant a unique identifier at the beginning of the interview. All questionnaires were pre-tested using a random sample of thirty NDU employees. Revisions and corrections were done before initiating the study. At the end of the interview, participants were asked to come in person to the nutrition research lab, at each of the three campuses, on specific days and during specific hours for anthropometric, body composition (BC) and biochemical assessments. They were instructed to fast for 12 hours prior to their lab visit.

Anthropometric assessments included height, waist circumference (WC), hip circumference (HC) and body weight. Height was measured to the nearest 0.1 cm using a portable stadiometer with no shoes, heels together, and head touching the stadiometer's ruler with line aligned horizontally. WC was measured with a non-stretchable tailor measuring tape; the tape was placed around the bare abdomen just above the hip bone and parallel to the floor. Participants were asked to exhale, and measurement were taken to the nearest centimeter at the midpoint between the lower margin of the last palpable rib cage and the top of the iliac crest at the end of a normal expiration. WC values were classified as high/low cardio-metabolic disease risk, using the World Health Organization (WHO) cutoffs for men $\geq$ 102 cm and women $\geq$ 88 cm. HC was measured around the widest portion of the buttocks. For measurement of WC and HC, subjects were asked to stand with arms

at the sides, feet positioned close together and weight evenly distributed across the feet (WHO, 2008b). Waist-to hip ratio (WHR) and waist-to-height ratio (WHtR) were calculated as the waist measurement divided by the hip measurement or height, respectively. Cutoff points of ≥ 0.9 for men ≥ 0.85 for women, > 0.5 for men and women, were used to identify individuals with unhealthy WHR, and WHtR respectively.(WHO, 2008)(Yoo et al., 2016). Body weight and BC variables (fat free mass (FFM), skeletal muscle mass (SMM), fat mass (FM), body fat percentage (BFP), trunk fat mass (TFM), right leg fat mass (RLFM), left leg fat mass (LLFM) and visceral fat area (VFA) were measured using the bioelectrical impedance analysis (BIA) machine 'InBody 720 (Biospace, Seoul, Korea)'; BIA is a widely used BC assessment method in research; it is accurate, quick, safe, and inexpensive (Prapimporn et al, 2015). By measurement of the impedance (resistance to the electrical current when it hits fat tissue); and inputting it into scientifically validated equations, BIA estimates fat mass and fat-free mass. The BIA machine was only available at the main campus so, it was transported to the regional campuses. The machine was calibrated before using it for data collection. The participants were asked to stand on the machine barefooted, without wearing any metal/jewelry, after wiping hands and feet with electrolyte wipes.

Body mass index (BMI) was calculated as: weight (kg)/ height (m^2). BMI categories were classified as (1) underweight: BMI < 18.5 kg/m^2, (2) normal weight: 18.5 kg/m^2 < BMI < 24.9 kg/m^2, (3) overweight: 25.0 kg/m^2 < BMI < 29.9 kg/m^2, and (4) obese: BMI ≥ 30.0 kg/m^2 (WHO Expert Consultation, 2004). ULBFR was calculated as truncal fat (kg)/ lower extremity fat (kg) (trunk fat mass (kg) / right fat mass in legs (kg). Cutoff points of > 23 % for men / >15 % for women and ≥ 100 cm^2 for men and women were used to identify individuals with unhealthy BFP and VFA respectively (InBody 720, Biospace, Seoul, Korea)The study participants were also

divided into three groups according to the tertiles of 1) upper-to-lower body fat Ratio (ULBFR) level and 2) visceral fat area (VFA) level in men, premenopausal and postmenopausal women. For the purpose of creating bar graphs that show associations between serum 25 (OH)D levels and ULBFR , after controlling for BFP or BMI, the median ULBFR of men/ premenopausal women /postmenopausal women was determined and used as the cutoff for unhealthy ULBFR (2.11,1.73 and 2.02, respectively).

During the visit to the nutrition research lab, a nurse collected a fasting blood sample from participants. Blood was fractionated by centrifugation for 15 minutes at a speed of 1,800 rpm at site of blood withdrawal within 2 hours of collecting blood samples. After fractionation, serum was pipetted into separate tubes while the other components of blood were discarded. Samples collected at the regional campuses were transported to the main campus on ice where they were stored at -20 °C in the freezer for a maximum period of 6 weeks before analysis. The fasting blood sample was used to measure serum triglycerides (TG) level, HDL-cholesterol, fasting blood glucose (FBG) and C-reactive protein (CRP)which were measured using a dry chemistry analyzer Vitros 250 (Ortho Clinical Diagnostic, Raritan, New Jersey, USA) available at the Biology laboratory in NDU main campus. The definition of the Third Report of the National Cholesterol Education Program (NCEP-ATP III) was used to identify individuals with any of metabolic syndrome (MeTs) components and MeTs. Participants who met any of the following definitions or at least three of the following criteria were considered as having the MeTs component or MetS, respectively: WC ≥102 cm in men or ≥ 88 cm in women, serum TG level ≥ 150 mg/dL, HDL-cholesterol levels< 40 mg/dL in men or < 50 mg/ dL in women, impaired fasting blood glucose (FBG ≥100 mg/dL) or on antidiabetic treatment and blood pressure (BP) ≥130/ 85 mmHg or on

treatment for hypertension (21). Participants with CRP levels below 1 mg/L were considered to be at low risk of developing CVD disease, those with CRP levels between 1 -3 mg/L were considered to be at average risk, and those with more than 3 mg/L were considered to be at high risk (WHO, 2014).

Dependent variable Assessment

The fasting blood sample collected during the visit to nutrition research lab were used to measure serum 25(OH) D level. Serum 25(OH)D levels were measured in the Biology laboratory at NDU Zouk Mosbeh campus using enzyme linked immunosorbent assay kit (ELISA) (Calbiotech, spring Valley, California, USA), with an intra-assay coefficient variation of 4.95% and an inter-assay coefficient variation of 5.63%, and a sensitivity of 0.67 ng/mL. Vitamin D status was determined according to the the US Endocrine Society guidelines (Vitamin D deficiency: 25(OH)D ≤20 ng/mL (≤ 50 nmol/L); vitamin D insufficiency : 25(OH)D > 21 - 29 ng/ml (>50–75 nmol/L) and vitamin D sufficiency as 25(OH)D ≥30ng/ml (Haq et al., 2016).

Statistical analyses

Assuming a prevalence rate of vitamin D deficiency of 73% among healthy adults in Lebanon (Hoteit, 2014), the sample size was calculated and found to be 303 participants.

For all analyses, underweight subjects were excluded (n=3). For all analyses pertaining to vitamin D, individuals taking vitamin D supplements (n=72) were excluded and in case of analyses including women, women taking oral contraceptive pills (n=3) were also excluded from analyses. Normality of the continuous variables for each of the groups being compared was assessed by examining the skewness and Kurtosis values, p-values of the Shapiro-wilk and Kolmogorov-Smirnov tests, shape of the distribution, using a histogram, normal QQ plots, detrended Normal

QQ plots and boxplots. Continuous and categorical variables were summarized as mean ±standard deviation for normally distributed/Median (interquartile range-IQR) for non-normally distributed variables and n (%), respectively. Significant differences in sociodemographic characteristics, lifestyle habits, and biochemical and adiposity measurements by sex and menopausal status were observed; as a result, we performed data analyses stratified by sex, with women also stratified by menopausal status. For continuous variables, independent samples t-test/ one way analysis of variance (ANOVA) or mann-whitney U test/ kruskal Wallis test were used for between-group comparisons of normally distributed/ non-normally distributed variables, respectively. For comparisons of categorical variables, the chi-square /Fisher's exact tests were used. Partial correlation analyses were performed to examine the correlation between serum vitamin D levels, adiposity and biochemical measures, adjusted for age.

Logistic regression analyses were performed to examine the independent association between vitamin D status and adiposity indices. Covariates that were found to be associated with serum vitamin D levels and adiposity indices at $p < 0.05$ level in the bivariate analyses were forced into the models whereas, covariates that were found to be associated with serum vitamin D levels at $p < 0.1$ level in the bivariate analyses were introduced into the models in a stepwise fashion. Violation of the assumption of multicollinearity was assessed by examining the correlations between the variables and the tolerance and VIF values. Model 1 was unadjusted, showing the main effect of an adiposity index (main independent variable) on serum vitamin D levels (dependent variable); Model 2 was adjusted for BFP in case of ULBFR; Model 3 was our fully adjusted model in which we differently adjusted, according to adiposity indices, for the confounding factors for adiposity and serum vitamin D levels. In our analyses, missing values

were excluded case by case/ pairwise. Data were analyzed using SPSS, (Chicago, IL) version 23. A p-value of < 0.05 was considered to be indicative of statistical significance.

Results

The Sociodemographic, biochemical and adiposity characteristics of the study participants are shown in **Table 1**. A total of 344 individuals participated in this study. After excluding the underweight individuals (n=3), a total of 342 were included in the analyses , (176 men & 166 women: 146 premenopausal, 19 postmenopausal) with a mean age of 42.55 (±11.52) years. The participants had a mean serum vitamin D level of 25.62 (±12.46) ng/ml, fat-free mass of 52.98 (±12.31) kg, skeletal muscle mass of 29.49 ± 7.29 kg, body fat percentage of 31.11 (±7.89) %, and visceral fat area of 118.63(±44.06)cm^2 and a median fat mass of 22.1 (12.6) kg and upper-to lower body fat ratio of 1.94 (0.41). The majority of the study participants reported to live in urban areas (~ 61%), be married (~66%), have a monthly income of at least $1,250 (~91%) and a university degree (~78%), be non-smokers (~61%), non-alcohol drinkers (~74%) and free from chronic diseases (~59%) and were found to have normal blood pressure (~79%), fasting blood glucose (~ 80%), triglyceride (~67%), cholesterol (~64%) and HDL (76%) levels. On the other hand, most of the study participants reported to be sedentary (~64%) and were found to have suboptimal vitamin D (~71%) and an unhealthy body mass index (~64%) with fat deposited around the abdominal area (unhealthy waist circumference (~51%), waist-to-hip ratio (~75%) and waist-to-height ratio (~90%), elevated LDL (64%) and C-reactive protein (~61%) levels.

In our study population, men were older than women (M: 45.57 (±11.92) years vs. W: 39.34 (±10.18) years, p=0.000) with a higher percentage of them being non-university degree holders (M ~27% vs. W: ~16%, p=0.037) smokers (M: ~47% vs. W: ~30%, p=0.003), alcohol drinkers (M: ~34% vs. W: ~17%, p=0.000) and overweight/ obese (M: ~84% vs. W: 45%, p=0.020) with

unhealthy waist to height ratio (M: ~ 94% vs. W: ~ 86%, p=0.020). In addition, men had higher mean fat free mass (FFM) (M: 62.36 (±9.36) kg vs. W: 43.21(±5.54) kg p=0.000), skeletal muscle mass (SMM) (M: 35.16 ±5.31) kg vs. W: 23.58 (±3.28 kg, p=0.000), and visceral fat area (VFA) (M: 135.86 (±37.85) cm^2 vs. W: 100.66(±42.99) cm2, p=0.000), with a significantly higher percentage of them having visceral fat obesity (VFO) (M: ~ 85% vs. W: ~42%, %, p=0.000) and higher median fat mass (FM) (M: 23.60 (12.30) kg vs. W: 20.90 (±11.90) kg p=0.043) and upper-to-lower body fat ratio (ULBFR) (M: 2.11 (0.29) vs. W: 1.74(0.26), p=0.000). As, expected, a significantly higher percentage of men reported to have chronic diseases (M: ~47% vs. W: ~34%, p=0.014) and were found to have hypertension (M: 33% vs. W: ~9%, p=0.000), impaired fasting glucose (M: ~30% vs. W: ~10%, p=0.000), hypertriglyceridemia (M: ~48% vs. W: ~17%, p=0.000) and elevated CRP levels (M: ~69% vs. W: ~51%, p=0.001). Unexpectedly, however, no differences were observed in serum 25 (OH) D levels (Table1).

Associations of sociodemographic, lifestyle, biochemical and adiposity characteristics with visceral fat area levels among study participants are shown in **Table 2-a**. The study participants were divided into three groups according to their visceral fat area (VFA) level (men: (tertile 1 (T1): VFA ≤ 121.cm^2, tertile 2 (T2):121.2 ≤VFA ≤151.6 cm^2, tertile 3 (T3): VFA ≥ 151.7cm^2); premenopausal women: (tertile 1 (T1): VFA ≤ 72.4 cm^2, tertile 2 (T2): 72.5≤VFA ≤102.0 cm^2, tertile 3 (T3): VFA ≥102.1cm^2); post menopausal women: tertile 1 (T1): VFA ≤ 111.5 cm^2, tertile 2 (T2): 111.6≤VFA ≤159.0 cm^2, tertile 3 (T3): VFA ≥ 159.1cm^2).

Among men , those with older age, chronic morbidity, lower serum vitamin D levels, hypertension, impaired fasting glucose, hypertriglyceridemia, high CRP levels, unhealthy BMI, abdominal obesity, increased SMM, FM, body fat percentage (BFP), and ULBFR were found to be associated

with increased VFA level. Specifically, the mean age/ SMM /FM/ BFP /ULBFR of men in tertile 3 of VFA was found to be significantly higher than that of men in tertile1, with similar differences also observed between men in tertiles 2 and 1 for age, FM, BFP and ULBFR and in tertiles 3 and 2 for FM and BFP (Age: T1: 37.84±9.51years vs. T2: 48.58±10.74 years vs.T3: 50.89±11.43 years, $p_{(T3 \text{ vs. } T1;\ T2 \text{vs.} T1)}$= 0.000/ SMM (T1: 33.64±5.08 kg vs. T2: 35.67±5.21 kg vs. T3: 36.16±5.38 kg, $p_{(T3 \text{ vs. } T1)}$=0.029)/ FM: (T1: 16.69±4.83 kg vs. T2: 23.82±4.81 kg vs. T3: 33.90±6.94 kg, $p_{(T3 \text{ vs. } T1;\ T3 \text{vs.} T2;\ T2 \text{vs.} T1)}$=0.000)/ BFP: (T1: 22.29±5.22 % vs. T2: 27.47±4.70 % vs. T3: 34.54±4.52 %, $p_{(T3 \text{ vs. } T1;\ T3 \text{vs.} T2;\ T2 \text{vs.} T1)}$=0.000)/ ULBFR (T1: 1.93±0.27 vs. T2: 2.17±0.18vs. T3: 2.20±0.22, $p_{(T3 \text{ vs. } T1;\ T2 \text{vs.} T1)}$ =0.000). In contrast, the mean serum vitamin D levels of men in tertile 3 of VFA was found to be significantly lower than that of men in tertile 1(T3: 21.48±10.31 ng/ml vs. T1: 30.64±17.10ng/ml, $p_{T3 \text{ vs. } T1}$=0.003). As for the associations between categorical variables and VFA level in men, a significantly higher percentage of men with chronic morbidity (T3: yes: 47.5% vs. no: 20.0%, p=0.000), hypertension (T3: yes: 51.8% vs. no: 24.3%, p=0.000), impaired Fasting glucose (T3: Yes: 50.9% vs. No: 25.4%, p=0.001), hypertriglyceridemia (T3: Yes: 44.6 % vs. No: 22.7 %, p=0.000), high CRP levels (T3: high: 41.5% vs. moderate: 15.1%, p=0.002),obesity (T3: obese: 71.7% vs. overweight: 16.9% vs. normal; 0.0% p=0.000),abdominal obesity (waist circumference (T3: unhealthy: 60.7 % vs. healthy: 3.7 % p=0.000); waist-to-hip-ratio (T3: unhealthy: 44.9% vs. healthy: 0.0%, p=0.000); waist-to-height-ratio (T3: unhealthy: 35.6% vs. healthy: 0.0% , p=0.000), were found to be in the highest tertile of VFA as compared to those without the characteristic under study.

Among premenopausal women, older age, lower education level, chronic morbidity, hypertension, impaired fasting glucose, hypertriglyceridemia, hypercholesterolemia, high LDL-c levels, high

CRP levels, obesity, abdominal obesity; increased FFM, SMM, FM, BFP, and ULBFR were found to be associated with increased visceral fat area level. Specifically, the mean age and BFP and the median FM and ULBFR of premenopausal women in tertile 3 of VFA was found to be significantly higher than that of premenopausal women in tertiles 1 and 2, with similar differences observed between men in tertiles 2 and 1 (Age: T1: 31.63±6.30years vs. T2: 38.18±6.85years vs. T3: 42.09±9.67years, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000, $p_{T2vs.T1}$ =0.039/ BFP: T1: 27.33±4.18% vs. T2: 31.55±4.40% vs. T3: 41.74±5.12%, $p_{T3\ vs.\ T1}$ = 0.000; $p_{T2vs.T1}$=0.000, $p_{T2\ vs.\ T3}$ = 0.000/ FM: T1: 15.50 (4.03) kg vs. T2: 19.60 (5.55) kg vs. T3: 31.80 (10.30) Kg, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000, $p_{T2vs.T1}$ =0.000; ULBFR: T1: 1.60 (0.19) Kg, T2: 1.73 (0.14) Kg, T3: 1.87 (0.25) Kg, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000, $p_{T2vs.T1}$ =0.000).. Similarly, the mean FFM/ SSM of premenopausal women in tertile 3 of VFA was found to be significantly higher than that of premenopausal women in tertiles 1 and 2 (FFM: T1: 41.38±5.900kg vs. T2: 42.56±4.43 kg vs. T3: 46.10±6.50 kg, $p_{T3\ vs.\ T1}$ = 0.000; $p_{T3vs.T2}$=0.004; SSM: T1: 22.49±2.90kg vs. T2: 23.20±2.63kg vs. T3: 25.31±3.88kg, $p_{T3\ vs.\ T1}$ = 0.000; $p_{T3vs.T2}$=0.004). As for the associations between categorical variables and VFA level in premenopausal women, a significantly higher percentage of premenopausal women without a university degree (T3: high school: 63.6 % vs. bachelor's: 38.6 % vs. graduate: 20.5 %, p=0.003), with chronic morbidity (T3: yes: 51.2% vs. no: 25.2%, p=0.010), hypertension (T3: yes: 90.0% vs. no: 28.4%, p=0.000), impaired fasting glucose (T3: Yes: 90.0% vs. No: 28.4 %, p=0.000), hypertriglyceridemia (T3: Yes: 80.0% vs. No: 25.0%, p=0.000), hypercholesterolemia (T3: Yes: 51.1% vs. No: 23.7%, p=0.001), high LDL-c levels (T3: high: 42.4% vs. normal 15.4%, p=0.002), high CRP levels (T3: high: 52.9% vs. moderate: 13.5%, p=0.000),obesity (T3: obese: 100.0% vs. overweight: 60.0% vs. normal; 3.5% p=0.000),abdominal obesity (waist circumference

(T3: unhealthy: 62.1 % vs. healthy: 7.7 % p=0.000); waist-to-hip-ratio (T3: unhealthy: 43.3% vs. healthy: 5.0%, p=0.000); waist-to-height-ratio (T3: unhealthy: 39.2% vs. healthy: 0.0% , p=0.000), were found to be in the highest tertile of VFA as compared to those without the characteristic under study.

Among postmenopausal women, obesity, increased FFM, SSM, FM and BFP were found to be associated with increased VFA level. Specifically, a significantly higher percentage of postmenopausal women with obesity (T3: obese: 83.3% vs. overweight: 25.0 % vs. normal 0.0%, p=0.005) were found to be in the highest tertile of VFA compared to those without the characteristic under study. In addition, the median FFM/ SSM /FM/ BFP of premenopausal women in tertile 3 of VFA was found to be significantly higher than that of premenopausal women in tertiles 1 and 2, with similar differences additionally observed between postmenopausal in tertiles 2 and 1 for BFP (FFM: T1: 37.6 (6.45)kg vs. T2: 40.9 (4.4)kg vs. T3: 45.9 (4.7)kg, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000; SSM : T1: 20.2 (3.67)kg vs. T2: 22.3 (3.1) kg vs. T3: 25.1 (1.8)kg, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000; FM : T1: 20.4 (2.6)kg vs. T2: 25 (8.1)kg vs. T3: 38.7 (7.4)kg, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000; BFP : T1: 33.9 (4.05)kg vs. T2: 39.7 (6.2)kg vs. T3: 44.3 (6.0)kg, $p_{T3\ vs.\ T1}$=0.000, $p_{T3vs.T2}$=0.000, $p_{T2vs.T1}$ =0.000).

Associations of sociodemographic, lifestyle, biochemical and adiposity characteristics with upper to lower body fat ratio among study participants are shown in **Table 2-b**. The study participants were divided into three groups according to their upper to lower body fat ratio(men: tertile 1(T1): ULBFR ≤ 2.01, tertile 2(T2): 2.02 ≤ULBFR ≤ 2.20, tertile 3 (T3): ULBFR ≥2.21); premenopausal women: tertile 1(T1): ULBFR ≤ 1.65, tertile 2(T2): 1.66 ≤ULBFR ≤ 1.79, tertile 3 (T3): ULBFR

≥1.80); post menopausal women: tertile 1(T1): ULBFR ≤ 1.81, tertile 2(T2): 1.82 ≤ULBFR ≤ 2.05, tertile 3 (T3): ULBFR ≥2.06).

Among men, low HDL-c levels, obesity, abdominal obesity; increased FFM, SMM, FM, and VFA were found to be associated with increased ULBFR. Specifically, the mean FFM, SMM, FM, and VFA of men in tertile 3 of ULBFR was found to be significantly higher than that of men in tertile 1, with similar differences also observed in the mean FFM, SSM and VFA between men in tertiles 3 and 2 and in the mean SMM and VFA between men in tertiles 2 and 1 of ULBFR (FFM :T1: 58.34±9.97kg vs. T2: 61.82±7.38kg vs. T3: 66.77±8.71kg, $p_{(T3\ vs.\ T1\ ;)}$=0.000; $_{T3vs.T2;)}$=0.008)/ SSM (T1: 32.44±4.80 kg vs. T2: 34.98±4.41kg vs. T3: 37.97±4.23kg, $p_{(T3\ vs.\ T1\ )}$=0.000; $_{(T2\ vs.\ T1)=}$0.016 $_{T3vs.T2)}$=0.003)/ FM: T1: 21.35±9.91kg vs. T2: 24.77±7.61kg vs. T3: 28.18±8.21kg, $p_{(T3\ vs.\ T1)}$=0.000)/ VFA (T1: 116.38±40.37cm^2 vs. T2: 136.57±33.93cm^2 vs. T3: 153.97±29.35cm^2, $p_{(T3vs.\ T1=}$0.000 $_{T2vs.T1)}$=0.007, $_{T2vs.T3=}$0.022). As for the associations between categorical variables and ULBFR in men, a significantly higher percentage of men low HDL-c levels (T3: low : 51.1% vs. normal: 27.8 %, p=0.018),obesity (T3: obese: 53.3% vs. overweight: 31.3% vs. normal; 0.0 % p=0.000), abdominal obesity (waist circumference (T3: unhealthy: 48.3 % vs. healthy: 18.3% p=0.000); waist-to-height-ratio (T3: unhealthy: 36.2% vs. healthy: 0.0%, p=0.000)were found to be in the highest tertile of VFA as compared to those without the characteristic under study.

Among premenopausal women, marriage, lower education level, smoking, lower physical activity (PA) level, lower serum vitamin D levels, suboptimal vitamin D status, hypertriglyceridemia, high LDL-c levels, high CRP levels, obesity, abdominal obesity; increased FFM, SMM, FM, BFP, and VFA were found to be associated with increased ULBFR. Specifically, the mean FFM, SMM,BFP and median FM and VFA of premenopausal women in tertile 3 of ULBFR was found to be

significantly higher than that of premenopausal women in tertiles 2 and 1 of ULBFR, with similar differences also observed in mean BFP and median FM and VFA between premenopausal women in tertiles 2 and 1 of ULBFR (FFM: T1: 41.89±6.32kg vs. T2: 42.58±4.44kg vs. T3: 45.49±5.60kg, $p_{T3\ vs.\ T2} = 0.029$; $p_{T3vs.T1)}=0.005$/ SMM: T1: 22.75±3.67kg vs. T2: 23.23±2.58kg vs. T3: 24.98±3.41kg, $p_{T3\ vs.\ T2} = 0.025$; $p_{T3vs.T1)}=0.003$)/FM: T1: 15.20 (5.33) kg vs. T2: 20.55 (8.03) kg vs. T3: 27.35 (13.53) kg, $p_{T3\ vs.\ T1} = 0.000$; $p_{T2vs.T}=0.000$; $p_{T3vs.T2}=0.000$, / BFP: T1: 28.53±6.45% vs. T2: 33.77±6.12% vs. T3: 38.11±6.91%, $p_{T3\ vs.\ T1} = 0.000$; $p_{T2vs.T}=0.000$; $p_{T3vs.T2}=0.004$/VFA:T1: 64.95 (22.88) cm^2 vs. T2: 84.90 (26.95) cm^2 vs. T3: 114.70 (54.28) cm^2, $p_{T3\ vs.\ T1} = 0.000$; $p_{T2vs.T}=0.000$; $p_{T3vs.T2}=0.000$).In contrast, an inverse association between serum vitamin D levels and ULBFR was found (T1: 28.395±12.46kg vs.T2: 23.69±9.34kg vs. T3: 22.09±9.77 kg, $p_{T3vs.T1}=0.030$). As for the associations between categorical variables and ULBFR in premenopausal women, a significantly higher percentage of married women (married T3: 39.8%, T2: 34.1 %, T1: 26.1 %vs. Single separated/ Divorced T3: 23.2 %, T2: 32.1%, T1: 44.6 %, p=0.026), women without a graduate degree (high school T3: 50.0 % ,T2: 27.3 % ,T1: 22.7 % vs. bachelor's T3: 43.2% T2: 34.1 %, T1: 22.7%, vs. graduate T3: 23.1% T2: 34.6 %, T1: 42.3%, p=0.041) and who smoke (Smokers: T3: 51.2%, T2: 34.9 %, T1: 14.0 % vs. non-smokers: T3: 25.7%, T2:32.7 %, T1: 41.6%, p=0.002), women with lower physical activity level (high T3:0.0%, T2: 0.0%, T1:100.0% vs. moderate T3: 32.6%, T2:20.9%, T1:46.5 % vs. low T3:34.3%, T2: 39.4%, T1:26.3%, p=0.023), suboptimal vitamin D status (deficiency T3: 45.7% ,T2: 26.1% ,T1: 28.3% vs. insufficiency: T3: 35.7% ,T2: 42.9% ,T1: 21.4 % vs. optimal T3:16.7 % ,T2: 23.3% ,T1: 60.0 vs. p=0.004), hypertriglyceridemia (Yes T3: 60.0% ,T2: 20.0 % ,T1: 20.0%vs. No: T3: 29.0% T2: 35.5%, T1: 35.5%, p=0.024), high LDL-c levels (high T3: 41.3 %, T2: 32.6%, T1: 26.1 %vs.

Normal: T3: 19.2% T2: 34.6%, T1: 46.2%, p=0.012) , high CRP levels (high T3: 48.6%,T2: 31.4% ,T1: 20.0% vs. moderate T3: 18.9% T2: 35.1%, T1: 45.9%, p=0.000),obesity (obese T3: 78.3% ,T2: 13.0% ,T1: 8.7% vs. overweight: T3: 51.4% ,T2: 42.9% ,T1: 5.7%vs. vs. normal T3:14.0 % ,T2: 34.9% ,T1: 51.2 vs. p=0.000), abdominal obesity (waist circumference (unhealthy T3: 54.5% T2: 34.8%, T1: 10.6%vs. healthy: T3: 15.4% T2: 32.1%, T1: 52.6% p=0.000); waist-to-hip-ratio (unhealthy T3: 44.2% T2: 39.4%, T1: 16.3%vs. healthy: T3: 5.0% T2: 17.5%, T1: 77.5%, p=0.000); waist-to-height-ratio (unhealthy T3: 40.0% T2: 37.5%, T1: 22.5%vs. healthy: T3: 0.0% T2: 12.5%, T1: 87.5%, p=0.000), were found to be in the second and third tertiles of ULBFR as compared to those without the characteristic under study.

Among postmenopausal women, a significantly higher percentage of women with suboptimal vitamin D status (deficiency T3: 0.0, T2: 66.7%, T1: 33.3% vs. insufficiency: T3: 100.0%, T2: 0.0%, T1: 0.0 % vs. optimal T3:0.0 %, T2: 0.0%, T1: 100.0 vs. p=0.021) was found to be in the second and third tertiles of ULBFR as compared to those with optimal vitamin D status.

Tables 3-a, 3-b and 3-c show correlation coefficients among serum 25(OH) D3 level, adiposity and biochemical measures, adjusted for age in in men, premenopausal women and postmenopausal women , respectively.

Among men, no correlation was found between serum 25(OH)D_3 level and adiposity measures (Body Mass Index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to height ratio (WHtR), fat free mass (FFM), skeletal muscle mass (SMM), fat mass (FM), body fat percent (BFP), upper to lower body fat ratio (ULBFR) and visceral fat area (VFA). As for the correlation between serum 25(OH)D_3 level and biochemical measures, a significant yet weak negative

correlation was found between serum 25(OH) D_3 levels and total cholesterol (TC) (r = -0.220, p=0.004) as well as with Low Density Lipoprotein cholesterol (LDL-c) (r = -0.243, p=0.001) As for the correlations between measures of adiposity and biochemical measures, BMI was found to be moderately positively correlated with systolic blood pressure (SBP) (r=0.339, p=0.000), diastolic blood pressure (DBP) (r = 0.374, p=0.000), triglyceride (TG) (r = 0.344, p=0.000) and c-reactive protein (CRP) (r = 0.315, p=0.000) , moderately negatively correlated with high Density Lipoprotein cholesterol HDL-c (r=-0.301, p=0.000), and weakly positively correlated with fasting glucose (FG) (r =0.236, p=0.001). WC was found to be moderately positively correlated with SBP (r=0.336, p=0.000), DBP (r = 0.357, p=0.000), CRP (r= 0.324, p=0.000),weakly positively correlated with FG (r =0.247, p=0.001) and TG (r = 0.291, p=0.000) LDL (r =0.168. p=0.032) and weakly negatively correlated with HDL (r=-0.208, p=0.000).WHR was found to be moderately positively correlated with TG (r= 0.333, p=0.000) and CRP (r = 0.313, p=0.000), weakly positively correlated with SBP (r=0.249, p=0.001), DBP (r = 0.270 p=0.000), FG (r=0.175, p=0.023) and weakly negatively correlated with HDL (r = -0.182, p=0.018). WHtR was found to be moderately positively correlated with DBP (r = 0.299, p=0.000), TG (r = 0.298, p=0.000) CRP (r = 0.344, p=0.000), weakly positively correlated with SBP (r =0.267, p=0.000), FG (r =0.226, p=0.003), and weakly negatively correlated with HDL(r = -0.230, p=0.002). FFM was found to be weakly positively correlated with SBP (r =0.248, p=0.001), DBP (r = 0.293, p=0.000) and FG (r =0.153, p=0.047) and weakly negatively correlated with HDL (r = -0.264, p=0.001). SMM was found to be weakly positively correlated with SBP (r =0.230, p=0.003), DBP (r = 0.277, p=0.000) and FG (r = 0.157, p= 0.041) and weakly negatively correlated with HDL (r = -0.261, p=0.001). FM was found to be strongly positively with CRP (r =0.853, p=0.000), moderately positively correlated

with SBP (r = 0.333, p=0.001), DBP (r = 0.354, p=0.000), TG (r= 0.363, p=0.000), weakly positively correlated with FG (r =0.197, p=0.010), and weakly negatively correlated with HDL (r = -0.245, p=0.001). BFP was found to be moderately positively correlated with CRP (r =0.339, p=0.000), weakly positively correlated with SBP (r=0.241, p=0.002), DBP (r = 0.261, p=0.001), FG (r = 0.162, p=0.035), TG (r= 0.291, p=0.000), and weakly negatively correlated with HDL(r =-0.159, p=0.038), ULBFR was found to be moderately negatively correlated with HDL (r = -0.330, p=0.000) and weakly positively correlated with SBP (r =0.231, p=0.002), DBP (r = 0.232, p=0.002), FG (r=0.183, p=0.017), TG (r= 0.272, p=0.000), CRP (r = 0.227, p=0.003). VFA was found to be moderately positively correlated with SBP (r=0.332, p=0.002), DBP (r = 0.320, p=0.002), TG (r= 0.353, p=0.000) and CRP (r = 0.342, p=0.000), weakly positively correlated with FG (r=0.217, p=0.005) and negatively weakly correlated with HDL ((r =-0.216, p=0.005).As expected, adiposity measures were found to be strongly positively correlated with each other **(Table 3-a).**

Among premenopausal women, significant inverse correlations were found between serum 25(OH) D_3 level and all measures of adiposity; specifically, serum 25(OH) $D_{3\ level}$ was found to be moderately negatively correlated with VFA (r = -0.318, p= 0.000) and weakly negatively correlation with BMI (r=-0.275, p=0.001), WC (r=-0.292, p=0.000), WHR (r=-0.275, p=0.001), WHtR (r=-0.292, p=0.000), FM (r=-0.281, p=0.001), BFP (r=-0.287,p=0.001), UTLBFR (r = -0.265, p=0.001).. As for the correlation between serum 25(OH)D_3 level and biochemical measures, serum 25(OH) D_3 level was found to be weakly negatively correlated with SBP (r = -0.231, p=0.005), DBP (r -0.185, p= 0.026) and TG (r = -0.195, p=0.019). As for the correlations between measures of adiposity and biochemical measures, BMI was found to be moderately

positively correlated with SBP (r=0.329, p=0.000), DBP (r = 0.377, p=0.000), FG (r =0.321, p=0.000), TG (r= 0.391, p=0.000)and CRP (r= 0.4566, p=0.000),weakly positively correlated with TC (r=0.173, p=0.037) a and LDL-c, (r =0.206, p=0.013) and weakly negatively correlated with HDL (r=-0.307, p=0.000). WC was found to be moderately positively correlated with SBP (r=0.301, p=0.000), DBP (r = 0.325, p=0.000), FG (r=0.328, p=0.000), TG (r= 0.389, p=0.000) and CRP (r= 0.365, p=0.000), moderately negatively correlated with HDL (r =-0.307, p=0.000) and weakly positively correlated with LDL (r=0.199, p=0.016). WHR was found to be moderately positively correlated with TG (r= 0.437, p=0.000) and CRP (r= 0.482, p=0.000), weakly positively correlated with SBP (r=0.245, p=0.000), DBP (r = 0.297, p=0.000) and FG (r = 0.202, p=0.016) and weakly negatively correlated with HDL (r =-0.281, p=0.000). WHtR was found to be moderately positively correlated with SBP (r=0.304, p=0.000), DBP (r = 0.351, p=0.000), TG (r= 0.431, p=0.000), CRP (r= 0.408, p=0.000), moderately negatively correlated with HDL (r=-0.315, p=0.000) and weakly positively correlated with FG (r=0.274, p=0.000), TC (r = 0.183, p= 0.028) and LDL (r=0.219, p=0.008) FFM was found to be weakly positively correlated with SBP (r=0.198, p=0.018), DBP (r = 0.189, p=0.024), FG (r=0.190, p=0.023) and weakly negatively correlated with HDL (r=-0.189, p=0.024). SMM was found to be weakly positively correlated with SBP (r=0.190, p=0.023), DBP (r = 0.186, p=0.026), FG (r=0.191, p=0.023) and weakly negatively correlated with HDL (r=-0.195, p=0.020). FM was found to be moderately positively correlated with SBP (r=0.309, p=0.000), DBP (r = 0.349, p=0.000), FG (r=0.336, p=0.000), TG (r= 0.433, p=0.000) and CRP (r =0.488, p=0.000), weakly positively correlated with TC (r= 0.214, p=0.010) and LDL (r=0.229, p=0.006) and weakly negatively correlated with HDL (r=-0.270, p=0.001). BFP was found to be strongly positively correlated with CRP (r =0.513, p=0.000),

moderately positively correlated with DBP (r = 0.332, p=0.000), FG (r=0.327, p=0.000), TG (r= 0.446, p=0.000), weakly positively correlated with TC (r= 0.262, p=0.002), LDL (r=0.257, p=0.002) and SBP (r=0.290, p=0.000) and weakly negatively correlated with HDL (r=-0.241, p=0.004) . ULBFR was found to be moderately positively correlated with TG (r= 0.366, p=0.000), CRP (r = 0.353, p=0.000), weakly positively correlated with SBP (r=0.126, p=0.032) and moderately negatively correlated with HDL (r=-0.304, p=0.004. VFA was found to be moderately positively correlated with DBP (r = 0.355, p=0.000), FG (r=0.308, p=0.000), TG (r= 0.441, p=0.000) and CRP (r = 0.485, p=0.000) weakly positively correlated with SBP (r = 0.279, p=0.001), TC (r= 0.219, p=0.009) and LDL (r=0.221, p=0.008) and weakly negatively correlated with HDL (r=-0.250, p=0.003) **(Table 3-b)**.

Among postmenopausal women, no correlation was found between serum 25(OH) D3 level and adiposity and biochemical measures. As for the correlations between measures of adiposity and biochemical measures, BMI was found to be strongly positively correlated with both SBP (r=0.649, p=0.004), DBP (r = 0.560, p=0.016), FG (r =0.778, p=0.000) and TG (r= 0.577, p=0.012) and borderline significantly moderately negatively associated with HDL-c (r=-0.466, p=0.051).WC was found to be strongly positively correlated with SBP (r=0.548, p=0.019), DBP (r = 0.540, p=0.021), FG (r=0.707, p=0.001) and TG (r= 0.593, p=0.009) and moderately negatively associated with HDL-c (r=-0.485, p=0.041). WHR was found to be strongly positively correlated with SBP (r=0.698, p=0.001) and FG (r=0.784, p=0.000). WHtR was found to be strongly positively correlated with SBP (r=0.543, p=0.020), DBP (r = 0.516, p=0.028), FG (r=0.678, p=0.002) and TG (r= 0.630, p=0.005) and strongly negatively correlated with HDL-c (r=-0.506, p=0.032). FFM was found to be strongly positively correlated with SBP (r=0.573,

p=0.013), DBP (r = 0.587 p=0.010), FG (r=0.654, p=0.003) andTG (r= 0.550, p=0.018) and strongly negatively correlated with HDL-c (r=-0.507, p=0.032)... SMM was found to be strongly positively correlated with SBP (r=0.596, p=0.009), DBP (r = 0.595, p=0.009), FG (r=0.671, p=0.002) and TG (r= 0.590, p=0.010) and strongly negatively correlated with HDL-c (r=-0.508, p=0.032). FM was found to be strongly positively correlated with SBP (r=0.585, p=0.011), FG (r =0.781, p=0.000), moderately positively correlated with DBP (r = 0.480, p=0.044) and borderline significantly moderately positively correlated with TG (r=0.466, 0=0.051). BFP was found to be strongly positively correlated with FG (r =0.671, p=0.002). VFA was found to be strongly positively correlated with SBP (r =0.617, p=0.006), DBP (r = 0.540, p=0.021), FG (r =0.791, p=0.000) and TG (r = 0.483, p=0.042). No correlation was found between ULBFR and the biochemical measures **(Table 3-c)**.

Tables 4 and 5 show results of logistic regression done to examine independent associations between suboptimal vitamin D status and adiposity measures in men and premenopausal women, respectively.

Among men, no significant associations were found between suboptimal vitamin D status and WC , after controlling for age, systolic blood pressure, physical activity level, triglycerides, metabolic syndrome, marital status, vitamin D supplement and sun exposure, and WHR/VFA after controlling for the same variables as those in the final model for WC, except for marital status, in addition to cholesterol and vitamin D intake , and WHtR after controlling for the same variables as those in the final model for WC in addition to creatinine and vitamin D intake, and ULBFR after controlling for the same variables as those in the final model for WC in addition to cholesterol.

Among premenopausal women, significant associations were found between suboptimal vitamin D status and WC, WHR, VFA and ULBFR. Specifically, premenopausal women with unhealthy WC and WHR were found to have about 4.6 times higher odds of developing suboptimal vitamin D status than those with healthy WC and WHR, after controlling for age, SBP, clinical diagnosis of a family member with depression or any other mental illness, physical activity level, HDL-c and vitamin D intake and vitamin D supplement in the final model for WC and after controlling in the final model for WHR for the same variables as those in the final model for WC, except for clinical diagnosis of a family member with depression or any other mental illness and physical activity level, in addition to triglycerides. As for the association between suboptimal vitamin D status and VFA, premenopausal women whose visceral fat areas fell in the second/ third tertile were found to have about 5/9 times higher odds of developing suboptimal vitamin D status as compared to those whose visceral fat areas fell in the first tertile, respectively, after controlling for age, SBP, clinical diagnosis of a family member with depression or any other mental illness, HDL-c, vitamin D intake, vitamin D supplement and breakfast. With regard to findings pertaining to the association between suboptimal vitamin D status and ULBFR, premenopausal women whose upper-to-lower body fat ratios levels fell in the third tertile were found to have about 4 times higher odds of developing suboptimal vitamin D status as compared to those whose upper-to-lower body fat ratios levels fell in the first tertile, after controlling for age, body fat percentage, SBP, HDL-c, vitamin D intake and vitamin D supplement. It is worth mentioning that body fat percentage was found to be not associated with suboptimal vitamin D status independent of upper-to-lower body fat ratio and the other confounding variables in the final model.

In an attempt to understand the relationship between VFA/ULBFR and serum 25(OH)D levels, after adjusting for BMI or BFP, something that we weren't able to do using regression analyses because of the violation of the assumption of multicollinearity, we created bar graphs that show associations between serum 25 (OH)D_3 levels and VFA/ULBFR , after controlling for BMI or BFP. When men with overweight/obesity were stratified according to the cutoff for unhealthy VFA ($\geq$100 $cm^{2)}$, serum 25 (OH) D levels were found to be significantly lower for overweight/obese men with unhealthy VFA ($\geq$100 cm^2), as compared to overweight/obese men with healthy VFA (<100 cm^2). On the other hand, among men with healthy body weight, serum 25 (OH) D levels of men with unhealthy VFA ($\geq$100 cm^2) did not differ significantly from those with healthy VFA (<100 cm^2) **(Figure 1-a).** When men with overweight/obesity and healthy body weight were stratified according to the cutoff for unhealthy ULBFR (> 2.11), serum 25 (OH) D levels of men with unhealthy ULBFR (> 2.11) did not differ significantly from those with healthy ULBFR among men with overweight/obesity and healthy body weight, separately (<2.11) **(Figure 1-b).**

When men with unhealthy BFP (>15%) and healthy BFP ($\leq$ 15%) were stratified according to the cutoffs for unhealthy VFA ($\geq$100 cm^2) and unhealthy ULBFR (> 2.11) (Figure 1-d), serum 25 (OH) D levels of men with unhealthy VFA ($\geq$100 cm^2) and unhealthy ULBFR (> 2.11) did not differ significantly from those with healthy VFA (<100 cm^2) and those with healthy ULBFR ($\leq$2.11), respectively, respectively **(Figures 1-c & 1-d)**.

Findings in men indicate that there is no association between ULBFR and serum vitamin D levels a, after controlling for BMI or after controlling for BFP. Similarly, no association was found between VFA and serum vitamin D levels a, after controlling for BFP however, an association

between VFA and serum vitamin D levels was found among overweight/obese men but not among men with healthy body weight, indicating that BMI is an effect modifier.

When premenopausal women with overweight/obesity and healthy body weight were stratified according to the cutoffs for unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 1.73), serum 25 (OH) D levels of premenopausal with unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 1.73) did not differ significantly from those with healthy VFA (<100 cm^2) and those with healthy ULBFR (≤1.73) among premenopausal women with overweight/obesity and healthy body weight**,** respectively **(Figures 2-a & 2-b)**.

When premenopausal with unhealthy BFP (> 23%) and healthy BFP (≤ 23%) were stratified according to the cutoffs for unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 1.73), serum 25 (OH) D levels of premenopausal women with unhealthy VFA (≥100 cm^2) did not differ significantly from those of premenopausal women with healthy VFA (<100 cm^2) in each of the strata . However, for premenopausal with healthy BFP (≤ 23%), serum 25 (OH) D levels of premenopausal women with unhealthy ULBFR (> 1.73) were found to be significantly lower than those for premenopausal with healthy ULBFR (≤1.73)**,** respectively **(Figures 2-c & 2-d)**.

Findings in premenopausal women indicate that there is no association between VFA and serum vitamin D levels a, after controlling for BMI or after controlling for BFP. Similarly, no association was found between ULBFR and serum vitamin D levels a, after controlling for BMI however, an association between ULBFR and serum vitamin D levels was found among premenopausal women with healthy BFP but not among premenopausal women with unhealthy BFP, indicating that BFP is an effect modifier.

When postmenopausal women with overweight/obesity and healthy body weight were stratified according to the cutoffs for unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 2.02), serum 25 (OH) D levels of postmenopausal with unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 2.02) did not differ significantly from those with healthy VFA (<100 cm^2) and those with healthy ULBFR (≤2.02) in each of the strata**,** respectively (**Figures 3-a & 3-b)**.

When postmenopausal with unhealthy BFP (> 23%) and healthy BFP (≤ 23%) were stratified according to the cutoffs for unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 2.02), serum 25 (OH) D levels of postmenopausal women with unhealthy VFA (≥100 cm^2) and unhealthy ULBFR (> 2.02) did not differ significantly from those with healthy VFA (<100 cm^2) and those with healthy ULBFR (≤2.02) in each of the strata**,** respectively **(Figures 3-c & 3-d)**.

Findings in postmenopausal women indicate that there is no association between VFA/ULBFR and serum vitamin D levels, after controlling for BMI or after controlling for BFP.

Discussion

In our study population, men were older than women, had higher mean BMI (data not shown), waist circumference (data not shown), visceral fat area, median fat mass and upper-to-lower body fat ratio (ULBFR) than women, with no significant gender differences in serum vitamin D levels and vitamin D status. Our results were supported by those reported in a cross sectional study done in North India in which researchers found no significant difference in serum vitamin D levels between men and women (M: 18.50±5.70 ng/ml vs. W: 19.40±6.30p=0.4) (4). However, these findings contradict with those of three cross sectional studies conducted in Korea, Russia and China. The two studies done on Korean and Russian individuals showed that serum vitamin D levels were higher in men than women ($p<0.0001$, $p<0.001$, respectively (Kim et al., 2016, Karonova, 2018) whereas the one conducted on Chinese individuals showed that men had lower serum vitamin D levels than women ($p=0.018$, Zhang et al., 2015). Our study population had dissimilar composition to those of Kim's and Karonova's, in kim's study, women were older and had higher mean fat mass than men; in Karonova's study, women were of similar age and waist circumference to men and had higher mean BMI than men, and therefore comparison of findings cannot be made. On the other hand, though participants in our study and Zhang's study have similar composition in terms of age, body composition, daily exposure to sun and vitamin D supplement use, a valid comparison of findings of our study and Zhang's study is also not possible. This is because Zhang, did not collect data on two important variables, associated with serum vitamin D concentration, that we collected data on, namely dietary vitamin D intake and sunscreen use. Discrepancy in results could , therefore, be explained, among other factors, by 1) the possibly

lower dietary vitamin D intake vs. no difference in dietary vitamin D intake in men as compared to women in Zhang's study and our study , respectively or/and 2) the greater prevalence of sunscreen use among men as compared to women vs. women as compared to men in Zhang's study and our study , respectively (W: ~54% vs. ~ M:5%, p=0.002)or/ and 3) genetic variations among different populations; for e.g., several genetic variants of vitamin D receptor were shown to have a significant association with decreased serum vitamin D levels (35) and several genes (CYP2R1 and GC genes) were found to contribute to the variation of serum 25(OH)D levels in different populations (Danish, Americans, Turkish,…) and populations with different characteristics (healthy, diseased, children, adults, elderly) (6, 27,28,36) or/and 4) the lack of inclusion of pregnancy/ lactation as one exclusion criterion in Zhang's study as opposed to our study.

The results of our bivariate analyses showed that lower serum vitamin D levels were associated with increased visceral fat area level in men, where the mean serum vitamin D levels of men in tertile 3 of VFA was found to be significantly lower than that of men in tertile 1 (p=0.003). This association, however, was not observed in pre- and postmenopausal women (p>0.05). Our findings for men and postmenopausal women are supported by those reported in a study conducted by Zhang and his colleagues in 2015, which showed a significant decrease in serum 25 (OH) D levels with an increase in visceral fat area level in men (Q1: 42.30±19.59 vs. Q2: 34.90±20.93 vs. Q3: 30.80±20.15 vs. Q4: 25.01±14.05, p=0.000) and no significant association between serum 25 (OH) D levels and visceral fat area level in postmenopausal women. However, contrary to our findings on premenopausal women, Zhang and his colleagues reported a significant decrease in serum 25 (OH) D levels with an increase in visceral fat area level in premenopausal women (Q1:

43.25±28.90 vs. Q2: 43.30±28.02 vs. Q3 : 38.39±24.11 vs. Q4: 35.80±27.38, p=0.002). Given that premenopausal women in our study and Zhang's study have similar composition, in terms of age, body composition, daily exposure to sun and vitamin D supplement use, the inconsistency in results could , therefore, be explained, among other factors, by 1) genetic variations among different population or/and 2) the lack of inclusion of pregnancy/ lactation as one exclusion criterion in Zhang's study as opposed to our study 3) the larger number of premenopausal women included in Zhang's study as compared to our study ($n_{(\text{premenopausal women})\text{Zhang}} = 613$ vs $n_{(\text{premenopausal women})\text{our study}} = 146$ in our study)

As for vitamin D status, our study showed no significant association between Vitamin D status and VFA level in men, pre- and post- menopausal women. The findings for postmenopausal women are supported by those reported in Zhang's. However, the findings pertaining to men and premenopausal women are different from those of the study done by Zhang and his colleagues, which showed that the prevalence of vitamin D deficiency in the 4th quartile of VFA was higher than that in the first, second and third quartiles in both men and premenopausal women and the prevalence of vitamin D insufficiency in the 4th quartile of VFA was higher than that in the first and second quartiles in men only ($P<0.05$). the inconsistency in results could, therefore, be explained, among other factors, by 1) genetic variations among different population or/and 2) the lack of inclusion of pregnancy/ lactation as one exclusion criterion in Zhang's study as opposed to our study 3) the larger number of premenopausal women included in Zhang's study as compared to our study ($n_{(\text{premenopausal women})\text{Zhang}} = 613$ vs $n_{(\text{premenopausal women})\text{our study}} = 146$ in our study)

In our study we found no correlation between serum 25(OH) D3 levels and adiposity measures, adjusted for age in men. Two cross sectional studies (Karanova et al., 2018, Kim et al., 2016) supported our results by showing no correlation between serum 25(OH) D3 and WC in men, the latter of which also adjusted for age. However, our findings contradict with those found by Zhang and his colleagues in 2015, showing that 25(OH) D3 was negatively correlated, after adjustment for age, with WC (r=-0.310, $p<0.05$); WHR (r =-0.325, $p<0.05$) and VFA (r =-0.318, $p<0.05$) in men; as well as with those found in a cross sectional study conducted by Hao and his colleagues among men in 2014 showing that 25(OH) D3 was negatively correlated with WC (r =-0.115, $p=0.006$) and VFA (r =-0.182, $p<0.001$). The differences in the results could be attributed to lack of adjustment for age (Hao's study) and differences in composition of the study population, in terms of factors associated with serum vitamin D levels (dietary vitamin D intake, sun exposure, vitamin D supplement intake, ,…, of the studies being compared. On the other hand, our findings of significant inverse correlations, after adjustment for age, between serum 25(OH)D_3 levels and WC, WHR and VFA in premenopausal women, and no correlation between serum 25(OH) D3 levels and adiposity measures in postmenopausal women were supported by the findings of a study done by Zhang et al., 2015 which, after adjustment for age, showed negative correlations between serum 25(OH) D3 and WC (r = -1.160, $p<0.05$), WHR (r =-0.151, $p<0.05$), VFA (r = -0.161, $p < 0.05$) in pre- menopausal women and no correlation between serum 25 (OH)D_3 and WC, WHR, VFAin postmenopausal women ($p>0.05$).

Among men and after controlling for confounding factors; no significant associations were found between suboptimal vitamin D status and the examined adiposity measures. These results contradict with those found in a cross sectional study conducted in China in which suboptimal

vitamin D was found to be positively associated with WC,WHR and VFA (WC: OR: 2.199, p:0.020; WHR: OR:2.052, p=0.047, VFA: OR $_{Q4 \text{ vs. } Q1:}$ 4.894,p:0.002) (Zhang et al., 2015).The difference in the results could be due to differences in the confounding factors controlled for and genetic variations between the Chinese and Lebanese populations that could potentially modify the relationship between adiposity and vitamin D status.

Our study found independent associations between suboptimal vitamin D status and unhealthy WC and WHR as well as increased VFA level in premenopausal women. Our findings pertaining to WC and VFA are similar to those reported by Zhang and his colleagues in 2015, showing that in premenopausal women suboptimal Vitamin D status was positively associated with unhealthy WC (OR:1.647, p:0.011) and increased VFA level (OR $_{Q4 \text{ vs. } Q1}$: 1.837,p=0.033). Our finding regarding WHR though contradict with reported in Zhang's study which showed no independent association of unhealthy WHR and VFA level (OR: 1.28, p: 0.199).

Strengths and limitations:

Our study is the first to explore the association between a direct measure of body fat distribution (upper-to-lower body fat ratio-ULBFR) and vitamin D status independent of %BF. Compared to the studies done on the relation between body fat distribution and vitamin D, we took into account adjustment for important confounders in the relationship between adiposity measures and serum vitamin D levels such as dietary vitamin D intake and metabolic syndrome.

However, our study had several limitations. **First,** the temporal relationship between adiposity measures and vitamin D status cannot be established because of the cross-sectional study design; **Second,** the study participants were employees at a private university in Lebanon; thus generalizability of the findings to employees at other private/ public universities or the general population cannot be made; **Third,** in our study, we used BIA for assessment of body composition and ELISA for measurement of serum vitamin D levels rather than the gold standards: dual energy x-ray absorptiometry (DEXA) and High Performance Liquid Chromatography, respectively. DEXA is impractical for use because it is expensive, not portable, trained technician required (38). HPLC is impractical for use because it is complex, it requires trained staff, large volumes of blood and longer turnaround time (44). Thus, though the techniques that we used to measure BC and serum 25(OH)D_3 are deemed appropriate, it is possible that different BC and 25(OH)D values would have been obtained had we used the gold standard methods; **Fourth,** the data was collected between mid-October to mid-December, thus results cannot be generalized to other seasons or compared to those reported in other studies in which data were collected in other seasons; **Fifth,** the vitamin D content of many foods in the FFQ was not listed in the Lebanese food composition

tables. So, the vitamin D content of these food was estimated using the Canadian Nutrient File; **Sixth,** data on menopausal status, diagnosis of chronic diseases and many other variables were self-reported; hence it is likely that some data may not be accurate. **Seventh,** though we adjusted for important potential confounders, we cannot exclude the role of others such as intake of certain medications or presence of chronic disease known to affect serum vitamin D levels.

In conclusion, there remains a need for studies to further explore this association in a representative large sample of Lebanese adults. More studies that address the limitations of this study are needed and cohort studies are particularly needed to elucidate the temporal relationship between serum vitamin D levels and adiposity measures.

Tables and Figures

Table 1. Sociodemographic, biochemical and adiposity characteristics of study participants[1]

Characteristic	Total (n=342)	Men (n= 176)	Women (n=166)	P-value[2]
	Mean ± SD	Mean ± SD/Median (IQR)	Mean ± SD	
	Or n (%)	Or n (%)	Or n (%)	
Age (years)	42.55 ±11.52	45.57 ±11.92	39.34 ±10.18	0.000
Gender				-
Male	176 (51.5)	-	-	
Female	166 (48.5)	-	-	
Residence				0.498
Urban	209 (61.1)	104 (59.1)	105 (63.3)	
Rural	133 (38.9)	72 (40.9)	61 (36.7)	
Marital status				0.397
Single/separated/divorced	117 (34.2)	56 (31.8)	61 (36.7)	
Married	225 (65.8)	120 (68.2)	105 (63.3)	
Monthly income ($)				0.083
< 1,250	30 (8.8)	13 (7.4)	17 (10.2)	

1,250- 2,250	81(23.7)	48 (27.3)	33 (19.9)	
2,250- 4,000	86(25.1)	35 (19.9)	51 (30.7)	
4,000- 5,333	68 (19.9)	40 (22.7)	28 (16.9)	
> 5,333	77 (22.5)	40 (22.7)	37 (22.3)	
Education level				0.037
High school	75 (21.9)	48 (27.3)	27 (16.3)	
Bachelor	85 (24.9)	38 (21.6)	47 (28.3)	
Graduate	182(53.2)	90 (51.1)	92 (55.4)	
Smoking				0.003
No	210 (61.4)	94 (53.4)	116 (69.9)	
Yes	132 (38.6)	82 (46.6)	50 (30.1)	
Alcohol drinking				0.000
No	254 (74.3)	116 (65.9)	138 (83.1)	
Yes	88 (25.7)	60 (34.1)	28 (16.9)	
Physical activity level				0.107
Low	220 (64.3)	105 (59.7)	115 (69.3)	
Moderate	111 (32.5)	63 (35.8)	48 (28.9)	
High	11 (3.2)	8 (4.5)	3 (1.8)	
Daily Sun exposure, past 3 months				0.002
≤ 15 min	135 (39.5)	67 (38.1)	68 (41.0)	
16-60 min	111 (32.5)	46 (26.1)	65 (39.2)	
>60 min	96 (28.1)	63 (35.8)	33 (19.9)	

Sunscreen use				0.000
No	244 (71.3)	167 (94.9)	77 (46.4)	
Yes	98 (28.7)	9 (5.1)	89 (53.6)	
Menopausal Status				-
Premenopausal	-	-	146 (88.5)	
Post-menopausal	-	-	19 (11.5)	
Oral Contraceptive use				-
No	-	-	163 (98.2)	
Yes	-	-	3 (1.8)	
Chronic morbidity				0.014
No	202 (59.2)	92 (52.6)	110 (66.3)	
Yes	139 (40.8)	83 (47.4)	56 (33.7)	
Dietary Vitamin D intake (µg)	2.25 ± 3.19	2.46±3.96	2.03±2.06	0.206
25(OH)D_3 levels (ng/mL)[3]	25.62 ±12.46	26.17±13.61	24.97± 10.98	0.437
25(OH)D_3 Status[4]				0.369
Optimal	76 (28.7)	45 (31.5)	31 (25.4)	
Insufficiency	85 (32.1)	41 (28.7)	44 (36.1)	

Deficiency	104(39.2)	57(39.9)	47(38.5)	
Vitamin D supplement, past 3 months				0.346
No	270 (78.9)	143 (81.3)	127 (76.5)	
Yes	72 (21.1)	33 (18.8)	39 (23.5)	
Hypertension (mmHg)[&]				0.000
No	269 (78.7)	118 (67.0)	151 (91.0)	
Yes	73 (21.3)	58 (33.0)	15 (9.0)	
Impaired Fasting glucose(mg/dL)[&]				0.000
No	272(79.5)	123 (69.9)	149 (89.8)	
Yes	70 (20.5)	53 (30.1)	17 (10.2)	
Hypertriglyceridemia (mg/dL)[&]				0.000
No	230 (67.3)	92 (52.3)	138 (83.1)	
Yes	112 (32.7)	84 (47.7)	28 (16.9)	
Hypercholesterolemia (mg/dL)[&]				0.456
No	218 (63.7)	116 (65.9)	102 (61.4)	
Yes	124 (36.3)	60 (34.1)	64 (38.6)	
LDL-c (mg/dL)[&]				0.670
Normal	122 (36.0)	65 (37.4)	57 (34.5)	
High	217 (64.0)	109 (62.6)	108 (65.5)	
HDL-c (mg/dL)[&]				0.276
Normal	260 (76.0)	129 (73.3)	131 (78.9)	

Low	82 (24.0)	47 (26.7)	35 (21.1)	
CRP (mg/L)[&]				0.001
Moderate	135 (39.5)	54 (30.7)	81 (48.8)	
High	207 (60.5)	122 (69.3)	85 (51.2)	
Body mass index (kg/m^2)[&]				0.000
Normal	122 (35.7)	29 (16.5)	93 (56.0)	
Overweight	130 (38.0)	86 (48.9)	44 (26.5)	
Obese	90 (26.3)	61 (34.7)	29 (17.5)	
Waist circumference (cm)[&]				0.836
Healthy	168 (49.1)	85 (48.3)	83 (50.0)	
Unhealthy	174 (50.9)	91 (51.7)	83 (50.0)	
Waist-to-hip-ratio [&]				0.875
Healthy	84 (25.1)	44 (25.7)	40 (24.4)	
Unhealthy	251 (74.9)	127 (74.3)	124 (75.6)	
Waist-to-height-ratio [&]				0.020
Healthy	35 (10.2)	11 (6.2)	24 (14.5)	
Unhealthy	307 (89.8)	165 (93.8)	142 (85.5)	
Fat free mass (kg)	52.98 ±12.31	62.36 ±9.36	43.21±5.54	0.000
Skeletal muscle mass(kg)	29.49 ± 7.29	35.16±5.31	23.58±3.28	0.000
Fat mass (kg)	22.1(12.6)	23.60(12.30)	20.90(11.9)	0.043
Body fat percentage	31.11±7.89	28.10±6.95	34.24±7.59	0.000
Body fat percentage [&]				0.148

Healthy	14(4.2)	4(2.3)	10(6.1)	
Unhealthy	321(95.8)	167 (97.7)	154(93.9)	
Upper-to-lower body fat ratio[&]	1.94(0.41)	2.11(0.29)	1.74(0.26)	0.000
Visceral Fat Area (cm^2)	118.63±44.06	135.86±37.85	100.66±42.99	0.000
Visceral Fat Area[&]				
Healthy	122(36.4)	26(15.2)	96(58.5)	0.000
Unhealthy	213(63.6)	145(84.8)	68(41.5)	

Values are means ±SDs /medians (interquartile ranges) for normally/non-normally distributed continuous variables, respectively and counts (percentages for categorical variables)

[5] Excluding underweight participant (n=3)

[2] P-value pertains to comparisons between the 2 gender groups

[3] Excluding individuals taking vitamin D supplement users (n=72) and OC users (n=3).

[4] $25(OH)D_3$ status was defined as follows: A serum level of $25(OH)D_3$ <=20 ng/ml is considered to be vitamin D deficiency ; insufficiency is considered at a level between 21-29 ng/ml; optimal levels are <=30 ng/ml / participants taking vitamin D supplements (n=72) and OC users (n=3) were excluded.

[&]: hypertension: BP ≥130/ 85 mmHg, impaired fasting blood glucose: FBG ≥100 mg/dL; hypertriglyceridemia: ≥ 150 mg/dL; hypercholesterolemia: ≥ 200 mg/dl ;high LDL-c levels: ≥ 100mg/dl; low HDL-c levels: < 40 mg/dL in men or < 50 mg/ dL in women; CRP levels: moderate : 1 -3 mg/L high : >3 mg/L; BMI : normal: 18.5 kg/m2 < BMI < 24.9 kg/m2, overweight: BMI > 25.0 kg/m2 < BMI < 29.9 kg/m2, obese: BMI ≥ 30.0 kg/m2; WC: unhealthy : WC ≥102 cm in men or ≥ 88 cm in women; WHR: unhealthy : ≥ 0.9 for men ≥ 0.85 for women; WHtR: unhealthy : > 0.5 for men and women; BFP: Unhealthy >15% in men , >23%in women ; VFA: Unhealthy ≥100cm^2

Table 2-a: Associations of sociodemographic, lifestyle, biochemical and adiposity characteristics with visceral fat area levels among study participants[1]

Characteristic	Visceral Fat Area (cm^2)											
	Men (n=176)			P-value[2]	Premenopausal Women (n=146)[3]			P-value	Postmenopausal Women (n=19)			P-value
	Mean± SD or n (%)				Mean± SD or Median (interquartile range) or n (%)				Median (interquartile range) or n (%)			
	Tertile 1 (VFA ≤ 121.1cm^2)	Tertile 2 (121.2≤VFA ≤151.6 cm^2)	Tertile 3 (VFA ≥151.7 cm^2)		Tertile 1 (VFA ≤ 72.4cm^2)	Tertile 2 (72.5≤VFA ≤102.0cm^2)	Tertile 3 VFA ≥102.1cm^2)		Tertile 1 (VFA ≤ 111.5 cm^2)	Tertile 2 (111.6≤VFA ≤159.0 cm^2)	Tertile 3 (VFA ≥ 159.1cm^2)	
Age (years)	37.84±9.51	48.58±10.74	50.89±11.43	0.000[*$]	31.63±6.30	38.18±6.85	42.09±9.67	0.000[*$], 0.039[#]	57 (10.0)	57 (5.0)	52 (16.0)	0.454
Marital status				0.214				0.153				0.621
Single/ Separated/ Divorced	23 (42.6)	15 (27.8)	16 (29.6)		24 (42.9)	16 (28.6)	16 (28.6)		2 (50.0)	1 (25.0)	1 (25.0)	
Married	34 (29.1)	42 (35.9)	41 (35)		24 (27.3)	33 (37.5)	31 (35.2)		3 (20.0)	6 (40.0)	6 (0.0)	
Monthly income ($)				0.331				0.397				0.378
< 2,250	14 (24.1)	20 (34.5)	24 (41.4)		13 (30.2)	12 (27.9)	18 (41.9)		1 (16.7)	4 (66.7)	1 (16.7)	

2,250- 4,000	12 (34.3)	11 (31.4)	12 (34.3)		15 (30.6)	17 (34.7)	17 (34.7)		0 (0.0)	0 (0.0)	1 (100.0)	
≥ 4,000	31 (39.7)	26 (33.3)	21 (26.9)		20 (38.5)	20 (38.5)	12 (23.1)		4 (33.3)	3 (25.0)	5 (41.7)	
Education level				0.484				0.003				0.257
High school	12 (25.5)	17 (36.2)	18 (38.3)		3 (13.6)	5 (22.7)	14 (63.6)		1 (20.0)	3 (60.0)	1 (20.0)	
Bachelor	13 (36.1)	9 (25)	14 (38.9)		13 (29.5)	14 (31.8)	17 (38.6)		0 (0.0)	2 (100)	0 (0.0)	
Graduate	32 (36.4)	31 (35.2)	25 (28.4)		32 (41.0)	30 (38.5)	16 (20.5)		4 (33.3)	2 (16.7)	6 (50.0)	
Smoking				0.094				0.067				0.159
No	38 (40.4)	28 (29.8)	28 (29.8)		37 (36.6)	37 (36.6)	27 (26.7)		5 (41.7)	3 (25.0)	4 (33.3)	
Yes	19 (24.7)	29 (37.7)	29 (37.7)		11 (25.6)	12(27.9)	20 (46.5)		0 (0.0)	4 (57.1)	3 (42.9)	
Alcohol drinking				0.076				0.901				0.227
No	43 (37.4)	32 (27.8)	40 (34.8)		40 (33.3)	40 (33.3)	40 (33.3)		3 (18.8)	7 (43.8)	6 (37.5)	
Yes	14 (25)	25 (44.6)	17 (30.4)		8 (33.3)	9 (37.5)	7 (29.2)		2 (66.7)	0 (0.0)	1 (33.3)	
Physical activity level				0.135				0.947				0.125
Low	30 (29.7)	32 (31.7)	39 (38.6)		32 (32.3)	33 (33.3)	34 (34.3)		3 (21.4)	4 (28.6)	7 (50.0)	
Moderate	22 (35.5)	22 (35.5)	18 (29.0)		15 (34.9)	15 (34.9)	13 (30.2)		1 (25.0)	3 (75.0)	0 (0.0)	
High	5 (62.5)	3 (37.5)	0 (0.0)		1 (50.0)	1 (50.0)	0 (0.0)		1 (100)	0 (0.0)	0 (0.0)	
Sun exposure, past 3 months				0.011				0.598				0.547
≤15min	24 (36.9)	14 (21.5)	27 (41.5)		17 (29.8)	17 (29.8)	23 (40.4)		4 (40.0)	2 (20.0)	4 (40.0)	
16-60 min	9 (20.0)	18 (40.0)	18 (40.0)		19 (33.9)	21 (37.5)	16 (28.6)		1 (14.3)	4 (57.1)	2 (28.6)	
>60min	24 (39.3)	25 (41.0)	12 (19.7)		12 (38.7)	11 (35.5)	8 (25.8)		0 (0.0)	1 (50.0)	1 (50.0)	

Sunscreen use				0.020				0.016				1.000
No	50 (30.9)	56 (34.6)	56 (34.6)		26 (40.0)	14 (21.5)	25 (38.5)		2 (22.2)	4 (44.4)	3 (33.3)	
Yes	7 (77.8)	1 (11.1)	1 (11.1)		22 (27.8)	35 (44.3)	22 (27.8)		3 (30.0)	3 (30.0)	4 (40.0)	
Chronic morbidity				0.000				0.010				0.386
No	45 (50.0)	27 (30.0)	18 (20.0)		37 (35.9)	40 (38.8)	26 (25.2)		3 (50.0)	2 (33.3)	1 (16.7)	
Yes	12 (15.0)	30 (37.5)	38 (47.5)		11 (26.8)	9 (22.0)	21 (51.2)		2 (15.4)	5 (38.5)	6 (46.2)	
Dietary vitamin D intake (µg)	3.03± 6.10	2.06±1.76	2.33±2.85	0.416	2.70±2.57	1.92±1.83	1.48±1.61	0.012[$]	1.49±0.62	1.87±1.81	2.24±2.53	0.804
Vitamin D supplements, past 3 months				0.241				0.825				0.602
No	46 (33.1)	43 (30.9)	50 (36.0)		39 (33.3)	41 (35.0)	37 (31.6)		3 (33.3)	4 (44.4)	2 (22.2)	
Yes	11 (34.4)	14 (43.8)	7 (21.9)		9 (33.3)	8 (29.6)	10 (37.0)		2 (20.0)	3 (30.0)	5 (50.0)	
25(OH)D_3 [4] (ng/mL)	30.64±17.10	26.38±11.63	21.48±10.31	0.003[$]	27.81±12.30	23.64±10.45	22.65±9.06	0.094	22.30 (.)	24.26 (18.71)	-	0.513
25(OH)D_3 Status[4]				0.187				0.052				1.000
optimal	19 (44.2)	14 (32.6)	10 (23.3)		16 (55.2)	8 (27.6)	5 (17.2)		1 (50.0)	1 (50.0)	0 (0.0)	
insufficiency	10 (25.6)	14 (35.9)	15 (38.5)		9 (22.0)	19 (46.3)	13 (31.7)		1 (33.3)	1 (33.3)	1 (33.3)	

Deficiency	17 (29.8)	15 (26.3)	25 (43.9)		14(32.6)	14(32.6)	15(34.9)		1 (33.3)	2 (66.7)	0 (0.0)	
Hypertension (mmHg)[&]				0.000			19 (44.2)	0.000				0.347
No	48 (41.7)	39 (33.9)	28 (24.3)		48 (35.8)	48 (35.8)	38 (28.4)		5 (35.7)	4 (28.6)	5 (35.7)	
Yes	9 (16.1)	18 (32.1)	29 (51.8)		0 (0.0)	1 (10.0)	9 (90.0)		0 (0.0)	3 (60.0)	2 (40.0)	
Impaired Fasting glucose(mg/dL)[&]				0.000				0.000				0.159
No	52 (44.1)	36 (30.5)	30 (25.4)		47 (35.1)	49(36.6)	38 (28.4)		5 (41.7)	4 (33.3)	3 (25.0)	
Yes	5 (9.4)	21 (39.6)	27 (50.9)		1 (10.0)	0 (0.0)	9 (90.0)		0 (0.0)	3 (42.9)	4 (57.1)	
Hypertriglycedemia (mg/dL)[&]				0.000				0.000				0.499
No	44 (50.0)	24 (27.3)	20 (22.7)		47 (37.9)	46 (37.1)	31 (25.0)		4 (33.3)	5 (41.7)	3 (25.0)	
Yes	13 (15.7)	33 (39.8)	37 (44.6)		1 (5.0)	3 (15.0)	16 (80.0)		1 (14.3)	2 (28.6)	4 (57.1)	
Hypercholesterolemia (mg/dL)[&]				0.151				0.001				0.347
No	43 (38.4)	34 (30.4)	35 (31.2)		41 (42.3)	33 (34.0)	23 (23.7)		0 (0.0)	2 (40.0)	3 (60.0)	
Yes	14 (23.7)	23 (39.0)	22 (37.3)		7 (14.9)	16 (34.0)	24 (51.1)		5 (35.5)	5 (35.7)	4 (28.6)	
LDL-c (mg/dL)[&]				0.668				0.002				0.342
Normal	24 (37.5)	19 (29.7)	21 (32.8)		25 (48.1)	19(36.5)	8 (15.4)		0 (0.0)	3 (60.0)	2 (40.0)	
High	33 (31.4)	37 (35.2)	35 (33.3)		23 (25.0)	30 (32.6)	39 (42.4)		5 (38.5)	4 (30.8)	4 (30.8)	
HDL-c (mg/dL)[&]				0.235				0.540				0.494
Normal	46 (36.5)	38 (30.2)	42 (33.3)		38 (33.3)	41 (36.0)	35 (30.7)		5 (33.3)	5 (33.3)	5 (33.3)	

Low	11 (34.4)	19 (42.2)	15 (33.3)		10 (33.3)	8 (26.7)	12 (40.0)		0 (0.0)	2 (50.0)	2 (50.0)	
CRP (mg/L)[&]				0.002				0.000				0.076
Moderate	25 (47.2)	20 (37.7)	8 (15.1)		34 (45.9)	30 (40.5)	10 (13.5)		3 (60.0)	2 (40.0)	0 (0.0)	
High	32 (27.1)	37 (31.4)	49 (41.5)		14 (20.0)	19 (27.1)	37 (52.9)		2 (14.3)	5 (35.7)	7 (50.0)	
Body mass index (kg/m^2)[&]				0.000				0.000				0.005
Normal	25 (89.3)	3 (10.7)	0 (0.0)		47 (54.7)	36 (41.9)	3 (3.5)		4 (80.0)	1 (20.0)	0 (0.0)	
Overweight	31 (37.3)	38 (45.8)	14 (16.9)		1 (2.9)	13 (37.1)	21 (60.0)		1 (12.5)	5 (62.5)	2 (25.0)	
Obese	1 (1.7)	16 (26.7)	43 (71.7)		0 (0.0)	0 (0.0)	23 (100.0)		0 (0.0)	1 (16.7)	5 (83.3)	
Waist circumference (cm)[&]				0.000				0.000				0.444
Healthy	51 (62.2)	28 (34.1)	3 (3.7)		42 (53.8)	30 (38.5)	6 (7.7)		1 (33.3)	2 (66.7)	0 (0.0)	
Unhealthy	6 (6.7)	29 (32.6)	54 (60.7)		6 (9.1)	19 (28.8)	41 (62.1)		4 (25.0)	5 (31.2)	7 (43.8)	
Waist-to-hip-ratio[&]				0.000				0.000				-
Healthy	35 (79.5)	9 (20.5)	0 (0.0)		34 (85.0)	4 (10.0)	2 (5.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Unhealthy	22 (17.3)	48 (37.8)	57 (44.9)		14 (13.5)	45 (43.3)	45 (43.3)		5 (26.3)	7 (36.8)	7 (36.8)	
Waist-to-height-ratio[&]				0.000				0.000				-
Healthy	11 (100)	0 (0.0)	0 (0.0)		22 (91.7)	2 (8.3)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Unhealthy	46 (28.8)	57 (35.6)	57 (35.6)		26 (21.7)	47 (39.2)	47 (39.2)		5 (26.3)	7 (36.8)	7 (36.8)	
Fat free mass (kg)	60.11±10.12	62.98±8.73	63.99±8.87	0.071	41.38±5.00	42.56±4.43	46.10±6.50	0.000[$], 0.004[#]	37.6 (6.45)	40.9 (4.4)	45.9 (4.7)	0.000[$#]

Skeletal muscle mass(kg)	33.64±5.08	35.67±5.21	36.16±5.38	0.029[$],	22.49±2.90	23.20±2.63	25.31±3.88	0.000[$], 0.004[#]	20.2 (3.67)	22.3 (3.1)	25.1 (1.8)	0.001[$#]
Fat mass (kg)	16.69±4.83	23.82±4.81	33.90±6.94	0.000[*], 0.000[$], 0.000[#]	15.50 (4.03)	19.60 (5.55)	31.80 (10.30)	0.000[*$#]	20.4 (2.6)	25 (8.1)	38.7 (7.4)	0.001[$#]
Body Fat Percentage (%)	22.29±5.22	27.47±4.70	34.54±4.52	0.000 [*$#]	27.33±4.18	31.55±4.40	41.74±5.12	0.000* [$#]	33.9 (4.05)	39.7 (6.2)	44.3 (6.0)	0.001[*#$]
Upper-to-lower body fat ratio[6]	1.93±0.27	2.17±0.18	2.20±0.22	0.000[*$]	1.60 (0.19)	1.73 (0.14)	1.87 (0.25)	0.000[*$#]	1.76 (0.41)	2.04 (0.27)	2.12 (0.16)	0.361

Values are means ±SDs /medians (interquartile ranges) for normally/non-normally distributed continuous variables, respectively and counts (percentages for categorical variables)

Excluding underweight participant (n=3)

[2] p-value pertains to differences within a group

[3] menopausal status (missing , n=1)

[4] In men and post menopausal women: excluding those taking Vitamin D supplements / in pre- menopausal women: excluding those taking Vitamin D supplements and oral contraceptives;
$25(OH)D_3$ status was defined as follows: A serum level of $25(OH)D_3$ <=20 ng/ml is considered to be vitamin D deficiency ; insufficiency is considered at a level between 21-29 ng/ml; optimal levels are ≥30 ng/ml / participants taking vitamin D supplements (n=72) and OC users (n=3) were excluded.

[&]: hypertension: BP ≥130/ 85 mmHg, impaired fasting blood glucose: FBG ≥100 mg/dL; hypertriglyceridemia: ≥ 150 mg/dL; hypercholesterolemia: ≥ 200 mg/dl ;high LDL-c levels: ≥ 100mg/dl; low HDL-c levels: < 40 mg/dL in men or < 50 mg/ dL in women; CRP levels: moderate : 1 -3 mg/L high : >3 mg/L; BMI : normal: 18.5 kg/m2 < BMI < 24.9 kg/m2, overweight: BMI > 25.0 kg/m2 < BMI < 29.9 kg/m2, obese: BMI ≥ 30.0 kg/m2; WC: unhealthy : WC ≥102 cm in men or ≥ 88 cm in women; WHR: unhealthy : ≥ 0.9 for men ≥ 0.85 for women; WHtR: unhealthy : > 0.5 for men and women.

*T1vs T2 , $ T1 vs T3, # T2vs T3

Table 2-b: Associations of sociodemographic, lifestyle, biochemical and adiposity characteristics with upper- to- lower body fat ratio among study participants[1]

Characteristic	Upper-to-lower body fat Ratio											
	Men (n=176)			P-value[2]	Premenopausal Women (n=146)[3]			P-value	Postmenopausal Women (n=19)			P-value
	Tertile 1 UTLBFR≤2.01	Tertile 2 2.02≤UTLBFR ≤2.20	Tertile 3 UTLBFR≥2.21		Tertile 1 ULBFR ≤ 1.65	Tertile 2 1.66≤ULBFR ≤ 1.79,	Tertile 3 ULBFR ≥1.80		Tertile 1 ULBFR ≤ 1.81	Tertile 2 1.82 ≤ULBFR ≤ 2.05	Tertile 3 ULBFR ≥2.06	
Age (years)	44.02±12.61	46.26±12.47	46.98±10.80	0.391	35.79±9.47	36.15±8.10	39.88±8.37	0.058[$]	57 .00 (5.00)	56.00 (10.50)	52.00 (10.00)	0.386
Marital status				0.144				0.041				0.480
Single/ Separated/ Divorced	22 (40.7)	19 (35.2)	13 (24.1)		25 (44.6)	18 (32.1)	13 (23.2)		2 (50.0)	0 (0.0)	2 (50.0)	
Married	34 (29.1)	38 (32.5)	45 (38.5)		23 (26.1)	30 (34.1)	35 (39.8)		4 (26.7)	6 (40.0)	5 (33.3)	
Monthly income ($)				0.422				0.333				0.737
< 2,250	14 (24.1)	20 (34.5)	24 (41.4)		11 (25.6)	14 (32.6)	18 (41.9)		1 (16.7)	2 (33.3)	3 (50.0)	
2,250- 4,000	12 (34.3)	11 (31.4)	12 (34.3)		16 (32.7)	15 (30.6)	18 (36.7)		0 (0.0)	0 (0.0)	1 (100.0)	
≥ 4,000	30 (38.5)	26 (33.3)	22 (28.2)		21 (40.4)	19 (36.5)	12 (23.1)		5 (41.7)	4 (33.3)	3 (25.0)	
Education level				0.664				40.041				0.425
High school	15 (31.9)	14 (29.8)	18 (38.3)		5 (22.7)	6 (27.3)	11 (50.0)		1 (20.0)	1 (20.0)	3 (60.0)	
Bachelor	9 (25.0)	15 (41.7)	12 (33.3)		10 (22.7)	15 (34.1)	19 (43.2)		0 (0.0)	2 (100.0)	0 (0.0)	
Graduate	32 (36.4)	28 (31.8)	28 (31.8)		33 (42.3)	27 (34.6)	18 (23.1)		5 (41.7)	3 (25.0)	4 (33.3)	
Smoking				0.065				0.002				0.109

No	36 (38.3)	33 (35.1)	25 (26.6)		42 (41.6)	33 (32.7)	26 (25.7)		5 (41.7)	5 (41.7)	2 (16.7)	
Yes	20 (26.0)	24 (31.2)	33 (42.9)		6 (14.0)	15 (34.9)	22 (51.2)		1 (14.3)	1(14.3)	5 (71.4)	
Alcohol drinking				0.088				0.165				1.000
No	44 (38.3)	35 (30.4)	36 (31.3)		42 (35.0)	36 (30.0)	42 (35.0)		5 (31.2)	5 (31.2)	6 (37.5)	
Yes	12 (21.4)	22 (39.3)	22 (39.3)		6 (25.0)	12 (50.0)	6 (25.0)		1 (33.3)	1 (33.3)	1 (33.3)	
Physical activity level				0.248				0.023				0.415
Low	27 (26.7)	34 (33.7)	40 (39.6)		26 (26.3)	39 (39.4)	34 (34.3)		4 (28.6)	4 (28.6)	6 (42.9)	
Moderate	25 (40.3)	21 (33.9)	16 (25.8)		20 (46.5)	9 (20.9)	14 (32.6)		2 (50.0)	2 (50.0)	0 (0.0)	
High	4 (50.0)	2 (25.0)	2 (25.0)		2 (100.0)	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	1 (100.0)	
Sun exposure, past 3 months				0.011				0.935				0.222
≤15min	22 (33.8)	29(44.6)	14 (21.5)		20 (35.1)	17 (29.8)	20 (35.1)		4 (40.0)	1 (10.0)	5 (50.0)	
16-60 min	10 (22.2)	16 (35.6)	19 (42.2)		17 (30.4)	20 (35.7)	19 (33.9)		2 (28.6)	3 (42.9)	2 (28.6)	
>60 min	24 (39.3)	12 (19.7)	25 (41.0)		11 (35.5)	11 (35.5)	9 (29.0)		0 (0.0)	2 (100.0)	0 (0.0)	
Sunscreen use				0.174				0.456				0.451
No	51 (31.5)	54 (33.3)	57 (35.2)		25 (38.5)	19 (29.2)	21 (32.3)		3 (33.3)	4 (44.4)	2 (22.2)	
Yes	5 (55.6)	3 (33.3)	1 (11.1)		23 (29.1)	29 (36.7)	27 (34.2)		3 (30.0)	2 (20.0)	5 (50.0)	
Chronic morbidity				0.891				0.283				0.594
No	31 (34.4)	29 (32.2)	30 (33.3)		34 (33.0)	38 (36.9)	31 (30.1)		3 (50.0)	1 (16.7)	2 (33.3)	
Yes	25 (31.2)	28 (35.0)	27 (33.8)		14 (34.1)	10 (24.4)	17 (41.5)		3 (23.1)	5 (38.5)	5 (38.5)	
Dietary vitamin D intake (μg)	2.80±6.13	2.58±2.98	2.05±1.66	0.595	2.32±2.45	1.99±2.11	1.80±1.65	0.480	1.40±0.33	2.41±2.73	1.92±1.86	0.669

Vitamin D supplements, past 3 months				0.553				0.872				0.621
No	43 (30.9)	47 (33.8)	49 (35.3)		39 (33.3)	38 (32.5)	40 (34.2)		4 (44.4)	2 (22.2)	3 (33.3)	
Yes	13 (40.6)	10 (31.2)	9 (28.1)		9 (33.3)	10 (37.0)	8 (29.6)		2 (20.0)	4 (40.0)	4 (40.0)	
25(OH)D_3[4] concentration ng/mL)	27.29±17.33	25.17±11.65	25.74±12.17	0.756	28.39±12.46	23.69±9.34	22.09±9.77	0.030[$]	37.97± 16.99	19.46 ± 1.16	26.20 ± 3.38	0.249
25(OH)D_3 Status[4]				0.918				0.004				0.021
optimal	12 (30.2)	13 (30.2)	17 (39.5)		18 (60.0)	7 (23.3)	5 (16.7)		2 (100.0)	0(0.0)	0(0.0)	
Insufficiency	11 (28.2)	15 (38.5)	13 (33.3)		9 (21.4)	18 (42.9)	15 (35.7)		0(0.0)	0(0.0)	3 (100.0)	
Deficiency	19 (33.3)	19 (33.3)	19 (33.3)		13 (28.3)	12 (26.1)	21 (45.7)		1 (33.3)	2 (66.7)	0(0.0)	
Hypertension (mmHg)&				0.226				0.219				0.431
No	40 (34.8)	41 (35.7)	34 (29.6)		46 (34.3)	46 (34.3)	42 (31.3)		5 (35.7)	3 (21.4)	6 (42.9)	
Yes	16 (28.6)	16 (28.6)	24 (42.9)		2 (20.0)	2 (20.0)	6 (60.0)		1 (20.0)	3 (60.0)	1 (20.0)	
Impaired fasting glucose(mg/dL)&				0.062				0.219				1.000
No	45 (38.1)	38 (32.2)	35 (29.7)		46 (34.3)	46 (34.3)	42 (31.3)		4 (33.3)	4 (33.3)	4 (33.3)	
Yes	11 (20.8)	19 (35.8)	23 (43.4)		2 (20.0)	2 (20.0)	6 (60.0)		2 (28.6)	2 (28.6)	3 (42.9)	
Hypertriglyceridemia (mg/dL)&				0.058				0.024				0.844

No	36 (40.9)	27 (30.7)	25 (28.4)		44 (35.5)	44 (35.5)	36 (29.0)		4 (33.3)	3 (25.0)	5 (41.7)	
Yes	20 (24.1)	30 (36.1)	33 (39.8)		4 (20.0)	4 (20.0)	12 (60.0)		2 (28.6)	3 (42.9)	2 (28.6)	
Hypercholesterolemia (mg/dL)&				0.396				0.311				1.000
No	39 (34.8)	39 (34.8)	34 (30.4)		36 (37.1)	29 (29.9)	32 (33.0)		2 (40.0)	1 (20.0)	2 (40.0)	
Yes	17 (28.8)	18 (30.5)	24 (40.7)		12 (25.5)	19 (40.4)	16 (34.0)		4 (28.6)	5 (35.7)	5 (35.7)	
LDL-c (mg/dL)&				0.258				0.012				1.000
Normal	25 (39.1)	22 (34.4)	17 (26.6)		24 (46.2)	18 (34.6)	10 (19.2)		1 (20.0)	2 (40.0)	2 (40.0)	
High	31 (29.5)	34 (32.4)	40 (38.1)		24 (26.1)	30 (32.6)	38 (41.3)		4 (30.8)	4 (30.8)	5 (38.5)	
HDL-c (mg/dl)&				0.018				0.091				0.079
Normal	45 (35.7)	46 (36.5)	35 (27.8)		41 (36.0)	40 (35.1)	33 (28.9)		5 (33.3)	3 (20.0)	7 (46.7)	
Low	11 (24.4)	11 (24.4)	23 (51.1)		7 (23.3)	8 (26.7)	15 (50.0)		1 (25.0)	3 (75.0)	0 (0.0)	
CRP[3] (mg/L)&				0.254				0.000				0.431
Moderate	22 (41.5)	16 (30.2)	15 (28.3)		34 (45.9)	26 (35.1)	14 (18.9)		3 (60.0)	1 (20.0)	1 (20.0)	
High	34 (28.8)	41 (34.7)	43 (36.4)		14 (20.0)	22 (31.4)	34 (48.6)		3 (21.4)	5 (35.7)	6 (42.9)	
Body mass index (kg/m^2)&				0.000				0.000				0.394
Normal	22 (78.6)	6 (21.4)	0 (0.0)		44 (51.2)	30 (34.9)	12 (14.0)		3 (60.0)	0 (0.0)	2 (40.0)	
Overweight	22 (26.5)	35 (42.2)	26 (31.3)		2 (5.7)	15 (42.9)	18 (51.4)		2 (25.0)	4 (50.0)	2 (25.0)	
Obese	12 (20.0)	16 (26.7)	32 (53.3)		2 (8.7)	3 (13.0)	18 (78.3)		1 (16.7)	2 (33.3)	3 (50.0)	
Waist circumference (cm)&				0.000				0.000				1.000

Healthy	39 (47.6)	28 (34.1)	15 (18.3)		41 (52.6)	25 (32.1)	12 (15.4)		1 (33.3)	1 (33.3)	1 (33.3)	
Unhealthy	17 (19.1)	29 (32.6)	43 (48.3)		7 (10.6)	23 (34.8)	36 (54.5)		5 (31.2)	5 (31.2)	6 (37.5)	
Waist-to-hip-ratio&				0.088				0.000				
Healthy	18 (40.9)	17 (38.6)	9 (20.5)		31 (77.5)	7 (17.5)	2 (5.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Unhealthy	38 (29.9)	40 (31.5)	49 (38.6)		17 (16.3)	41 (39.4)	46 (44.2)		6 (31.6)	6 (31.6)	7 (36.8)	
Waist-to-height-ratio&				0.000				0.000				
Healthy	10 (90.9)	1 (9.1)	0 (0.0)		21 (87.5)	3 (12.5)	0 (0.0)		0 (0.0)	0 (0.0)	0 (0.0)	
Unhealthy	46 (28.8)	56 (35.0)	58 (36.2)		27 (22.5)	45 (37.5)	48 (40.0)		6 (31.6)	6 (31.6)	7 (36.8)	
Fat free mass (kg)	58.34±9.97	61.82±7.38	66.77±8.71	0.000[$], 0.008[#]	41.89±6.32	42.58±4.44	45.49±5.60	0.005[$], 0.029[#]	39.25 (8.85)	44.5 (5.63)	43.8 (5.20)	0.302
Skeletal muscle mass(kg)	32.44±4.80	34.98±4.41	37.97±4.23	0.016[*] 0.000[$],0.003[#]	22.75±3.67	23.23±2.58	24.98±3.41	0.003[$], 0.025[#]	21.25 (4.95)	24.35 (3.43)	23.90 (3.00)	0.180
Fat mass (kg)	21.35±9.91	24.77±7.61	28.18±8.21	0.000[$]	15.20 (5.33)	20.55 (8.03)	27.35 (13.53)	0.000[*$#]	21.65 (9.55)	31.25 (7.85)	31.8 (18.50)	0.180
Body fat percentage (%)	26.55±7.77	28.29±6.69	29.41±6.15	0.086	28.53±6.45	33.77±6.12	38.11±6.91	0.000[*$], 0.004[#]	35.45 (6.90)	41.85 (4.45)	42.00 (11.3)	0.180
Visceral Fat Area (cm^2)	116.38±40.37	136.57±33.93	153.97±29.35	0.007*, 0.000[$], 0.022[#]	64.95 (22.88)	84.90 (26.95)	114.70 (54.28)	0.000[*$#]	111.45 (39.3)	155.70 (32.35)	159.6 (70.1)	0.180

Values are means ±SDs /medians (interquartile ranges) for normally/non-normally distributed continuous variables, respectively and counts (percentages for categorical variables)

[7] Excluding underweight participant (n=3)

[2] P-value pertains to differences within a group

[3] menopausal status (missing , n=1)

[4] In men and post menopausal women: excluding those taking Vitamin D supplements / in pre- menopausal women: excluding those taking Vitamin D supplements and oral contraceptives;
$25(OH)D_3$ status was defined as follows: A serum level of $25(OH)D_3$ <=20 ng/ml is considered to be vitamin D deficiency ; insufficiency is considered at a level between 21-29 ng/ml; optimal levels are ≥30 ng/ml / participants taking vitamin D supplements (n=72) and OC users (n=3) were excluded.

&: hypertension: BP ≥130/ 85 mmHg, impaired fasting blood glucose: FBG ≥100 mg/dL; hypertriglyceridemia: ≥ 150 mg/dL; hypercholesterolemia: ≥ 200 mg/dl ;high LDL-c levels: ≥ 100mg/dl; low HDL-c levels: < 40 mg/dL in men or < 50 mg/ dL in women; CRP levels: moderate : 1 -3 mg/L high : >3 mg/L; BMI : normal: 18.5 kg/m2 < BMI < 24.9 kg/m2, overweight: BMI > 25.0 kg/m2 < BMI < 29.9 kg/m2, obese: BMI ≥ 30.0 kg/m2; WC: unhealthy : WC ≥102 cm in men or ≥ 88 cm in women; WHR: unhealthy : ≥ 0.9 for men ≥ 0.85 for women; WHtR: unhealthy : > 0.5 for men and women;

*T1vs T2 , $ T1 vs T3, # T2vs T3

Table 3a: Correlation coefficients among serum 25(OH)D_3 concentration, adiposity and biochemical measures adjusted for age in Men

	Serum 25(OH) D_3 (mg/dl)	SPB (mm Hg)	DBP (mm Hg)	FG (mg/dl)	TG (mg/dl)	TC (mg/dl)	LDL-c (mg/dl	HDL-c (mg/dl)	CRP (mg/L)	BMI (kg/m^2)	WC (cm)	WHtR	WHR	FFM (kg)	SMM (kg)	FM (kg)	BFP (%)	ULBFR	VFA (cm^2)
Serum 25(OH) D_3 (mg/dl)	1.000 .	-0.063 (0.407)	-0.056 (0.465)	-0.079 (0.298)	-0.139 (0.068)	-0.220 (0.004)	-0.243 (0.001)	0.112 (0.142)	0.064 (0.398)	-0.074 (0.331)	-0.027 (0.720)	-0.114 (0.140)	-0.039 (0.607)	0.035 (0.654)	0.033 (0.670)	-0.134 (0.082)	-0.139 (0.071)	-0.009 (0.908)	-0.131 (0.089)
SPB (mm Hg)	-0.063 (0.407)	1.000 .	0.729 (0.000)	0.006 (0.939)	0.191 (0.011)	-0.003 (0.972)	-0.029 (0.703)	-0.184 (0.015)	0.029 (0.702)	0.339 (0.000)	0.336 (0.000)	0.249 (0.001)	0.267 (0.000)	0.248 (0.001)	0.230 (0.003)	0.333 (0.000)	0.241 (0.002)	0.231 (0.002)	0.332 (0.000)
DBP (mm Hg)	-0.056 (0.465)	0.729 (0.000)	1.000 .	-0.019 (0.801)	0.171 (0.024)	0.027 (0.719)	0.037 (0.633)	-0.211 (0.005)	0.151 (0.046)	0.374 (0.000)	0.357 (0.000)	0.270 (0.000)	0.299 (0.000)	0.293 (0.000)	0.277 (0.000)	0.354 (0.000)	0.261 (0.001)	0.232 (0.002)	0.320 (0.000)
FG (mg/dl)	-0.079 (0.298)	0.006 (0.939)	-0.019 (0.801)	1.000 .	0.105 (0.166)	0.008 (0.920)	-0.003 (0.972)	-0.084 (0.268)	0.017 (0.824)	0.236 (0.002)	0.247 (0.001)	0.175 (0.023)	0.226 (0.003)	0.153 (0.047)	0.157 (0.041)	0.197 (0.010)	0.162 (0.035)	0.183 (0.017)	0.217 (0.005)
TG (mg/dl)	-0.139 (0.068)	0.191 (0.011)	0.171 (0.024)	0.105 (0.166)	1.000 .	0.352 (0.000)	0.140 (0.065)	-0.452 (0.000)	0.352 (0.000)	0.344 (0.000)	0.291 (0.000)	0.333 (0.000)	0.298 (0.000)	0.113 (0.141)	0.130 (0.092)	0.363 (0.000)	0.291 (0.000)	0.272 (0.000)	0.353 (0.000)
TC (mg/dl)	-0.220 (0.004)	-0.003 (0.972)	0.027 (0.719)	0.008 (0.920)	0.352 (0.000)	1.000 .	0.918 (0.000)	0.105 (0.165)	0.115 (0.129)	0.073 (0.335)	0.086 (0.260)	0.134 (0.083)	0.102 (0.179)	-0.032 (0.628)	-0.018 (0.814)	0.146 (0.057)	0.137 (0.075)	0.126 (0.102)	0.129 (0.093)
LDL-c (mg/dl)	-0.243 (0.001)	-0.029 (0.703)	0.037 (0.633)	-0.003 (0.972)	0.140 (0.065)	0.918 (0.000)	1.000 .	0.004 (0.957)	0.101 (0.185)	0.038 (0.616)	0.063 (0.409)	0.085 (0.276)	0.063 (0.412)	-0.013 (0.870)	-0.001 (0.986)	0.110 (0.156)	0.101 (0.195)	0.134 (0.084)	0.100 (0.198)
HDL (mg/dl)	0.112 (0.142)	-0.184 (0.015)	-0.211 (0.005)	-0.084 (0.268)	-0.452 (0.000)	0.105 (0.165)	0.004 (0.957)	1.000 .	-0.324 (0.000)	-0.297 (0.000)	-0.280 (0.000)	-0.182 (0.018)	-0.230 (0.002)	-0.264 (0.001)	-0.261 (0.001)	-0.245 (0.001)	-0.159 (0.038)	-0.330 (0.000)	-0.126 (0.005)

CRP (mg/L)	**0.064 (0.398)**	**-0.029 (0702.)**	**0.151 (0.046)**	**0.017 (0.824)**	**0.352 (0.000)**	**0.115 (0.129)**	**0.101 (0.185)**	**-0.324 (0.000)**	**1.000 .**	**0.315 (0.000)**	**0.324 (0.000)**	**0.313 (0.000)**	**0.344 (0.000)**	**0.067 (0.387)**	**0.066 (0.395)**	**0.350 (0.000)**	**0.339 (0.000)**	**0.227 (0.003)**	**0.342 (0.000)**
BMI (kg/m^2)	**-0.074 (0.331)**	**0.339 (0.000)**	**0.374 (0.000)**	**0.236 (0.002)**	**0.344 (0.000)**	**0.073 (0.335)**	**0.038 (0.616)**	**-0.297 (0.000)**	**0.315 (0.000)**	**1.000 .**	**0.858 (0.000)**	**0.804 (0.000)**	**0.853 (0.000)**	**0.499 (0.000)**	**0.487 (0.000)**	**0.855 (0.000)**	**0.718 (0.000)**	**0.478 (0.000)**	**0.806 (0.000)**
WC (cm)	**-0.027 (0.720)**	**0.336 (0.000)**	**0.357 (0.000)**	**0.247 (0.001)**	**0.291 (0.000)**	**0.086 (0.260)**	**0.063 (0.409)**	**-0.208 (0.000)**	**0.324 (0.000)**	**0.858 (0.000)**	**1.000 .**	**0.638 (0.000)**	**0.869 (0.000)**	**0.562 (0.000)**	**0.544 (0.000)**	**0.843 (0.000)**	**0.678 (0.000)**	**0.476 (0.000)**	**0.815 (0.000)**
WHR	**-0.114 (0.140)**	**0.249 (0.001)**	**0.270 (0.000)**	**0.175 (0.023)**	**0.333 (0.000)**	**0.134 (0.083)**	**0.085 (0.276)**	**-0.182 (0.018)**	**0.313 (0.000)**	**0.804 (0.000)**	**0.638 (0.000)**	**1.000 .**	**0.850 (0.000)**	**-0.026 (0.736)**	**-0.026 (0.733)**	**0.830 (0.000)**	**0.885 (0.000)**	**0.309 (0.000)**	**0.777 (0.000)**
WHtR	**-0.039 (0.607)**	**0.267 (0.000)**	**0.299 (0.000)**	**0.226 (0.003)**	**0.298 (0.000)**	**0.102 (0.179)**	**0.063 (0.412)**	**-0.230 (0.002)**	**0.344 (0.000)**	**0.853 (0.000)**	**0.869 (0.000)**	**0.850 (0.000)**	**1.000 .**	**0.221 (0.004)**	**0.208 (0.006)**	**0.793 (0.000)**	**0.791 (0.000)**	**0.392 (0.000)**	**0.752 (0.000)**
FFM (kg)	**0.035 (0.654)**	**0.248 (0.001)**	**0.293 (0.000)**	**0.153 (0.047)**	**0.113 (0.141)**	**-0.032 (0.682)**	**-0.013 (0.870)**	**-0.264 (0.001)**	**0.067 (0.387)**	**0.499 (0.000)**	**0.562 (0.000)**	**-0.026 (0.736)**	**0.221 (0.004)**	**1.000 .**	**0.993 (0.000)**	**0.316 (0.000)**	**-0.037 (0.628)**	**0.473 (0.000)**	**0.338 (0.000)**
SMM (Kg)	**0.033 (0.670)**	**0.230 (0.003)**	**0.277 (0.000)**	**0.157 (0.041)**	**0.130 (0.092)**	**-0.018 (0.814)**	**-0.001 (0.986)**	**-0.261 (0.001)**	**0.066 (0.395)**	**0.487 (0.000)**	**0.544 (0.000)**	**-0.026 (0.733)**	**0.208 (0.006)**	**0.993 (0.000)**	**1.000 .**	**0.309 (0.000)**	**-0.062 (0.423)**	**0.498 (0.000)**	**0.344 (0.000)**
FM (kg)	**-0.134 (0.082)**	**0.333 (0.000)**	**0.354 (0.000)**	**0.197 (0.010)**	**0.363 (0.000)**	**0.146 (0.057)**	**0.110 (0.195)**	**-0.245 (0.001)**	**0.350 (0.000)**	**0.855 (0.000)**	**0.843 (0.000)**	**0.830 (0.000)**	**0.793 (0.000)**	**0.316 (0.000)**	**0.309 (0.000)**	**1.000 .**	**0.896 (0.000)**	**0.412 (0.000)**	**0.931 (0.000)**
BFP (%)	**-0.139 (0.071)**	**0.241 (0.002)**	**0.261 (0.001)**	**0.162 (0.035)**	**0.291 (0.000)**	**0.137 (0.075)**	**0.101 (0.195)**	**-0.159 (0.038)**	**0.339 (0.000)**	**0.718 (0.000)**	**0.678 (0.000)**	**0.885 (0.000)**	**0.791 (0.000)**	**0.316 (0.000)**	**-0.062 (0.423)**	**0.896 (0.000)**	**1.000 .**	**0.222 (0.004)**	**0.801 (0.000)**

ULBFR	**-0.009**	**0.231**	**0.232**	**0.183**	**0.272**	**0.126**	**0.134**	**-0.330**	**0.227**	**0.478**	**0.476**	**0.309**	**0.392**	**-0.037**	**0.498**	**0.412**	**0.222**	**1.000**	**0.471**
	(0.908)	**(0.002)**	**(0.002)**	**(0.017)**	**(0.000)**	**(0.102)**	**(0.084)**	**(0.000)**	**(0.003)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.628)**	**(0.000)**	**(0.000)**	**(0.004)**	**.**	**(0.000)**
VFA	**-0.131**	**0.332**	**0.320**	**0.217**	**0.353**	**0.129**	**0.100**	**-0.216**	**0.342**	**0.806**	**0.815**	**0.777**	**0.752**	**0.473**	**0.344**	**0.931**	**0.801**	**0.471**	**1.000**
(cm^2)	**(0.089)**	**(0.000)**	**(0.000)**	**(0.005)**	**(0.000)**	**(0.093)**	**(0.198)**	**(0.005)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**.**

Abbreviations: 25(OH)D3, 25-hydroxyvitamin D3; SBP; Systolic blood pressure, DBP, diastolic blood pressure; FG, fasting glucose; TG, triglyceride; TC, total cholesterol, ; LDL-c, low-density lipoprotein cholesterol, HDL-c: high-density lipoprotein cholesterol , CRP (c-reactive protein), BMI: body mass index, WC: waist circumference, WHR: waist to hip ratio, WHtR; waist to height ratio;, FFM: free fat mass; SMM: skeletal muscle mass, FM: fat mass; BFP: body fat percentage ; ULBFR: upper to lower body fat ratio, VFA :visceral fat area;

$P<0.05$ is considered to be indicative of statistical significance

Table 3b: Correlation coefficients among serum 25(OH)D_3 concentration, adiposity and biochemical measures adjusted for age in premenopausal women

	Serum 25(OH)D_3 (mg/dl)	SPB (mm Hg)	DBP (mm Hg)	FG (mg/dl)	TG (mg/dl)	TC (mg/dl)	LDL-c (mg/dl	HDL-c (mg/dl)	CRP (mg/L)	BMI (kg/m^2)	WC (cm)	WHR	WHtR	FFM (kg)	SMM (kg)	FM (kg)	BFP (%)	ULBFR	VFA (cm^2)
Serum 25(OH)D_3 (mg/dl)	1.000	-0.231 (0.005)	-0.185 (0.026)	-0.130 (0.120)	-0.195 (0.019)	-0.009 (0.915)	0.028 (0.735)	0.110 (0.190)	-0.128 (0.126)	-0.275 (0.001)	-0.292 (0.000)	-0.275 (0.001)	-0.292 (0.000)	-0.015 (0.855)	-0.013 (0.876)	-0.281 (0.001)	-0.287 (0.001)	-0.265 (0.001)	-0.318 (0.000)
SPB (mm Hg)	-0.231 (0.005)	1.000 .	0.795 (0.000)	0.126 (0.131)	0.234 (0.005)	0.088 (0.291)	0.034 (0.688)	-0.066 (0.429)	0.032 (0.701)	0.329 (0.000)	0.301 (0.000)	0.245 (0.003)	0.304 (0.000)	0.198 (0.018)	0.190 (0.023)	0.309 (0.000)	0.290 (0.000)	0.126 (0.132)	0.279 (0.001)
DBP (mm Hg)	-0.185 (0.026)	0.797 (0.000)	1.000 .	0.075 (0.371)	0.246 (0.003)	0.048 (0.564)	0.018 (0.828)	-0.129 (0.123)	0.153 (0.065)	0.377 (0.000)	0.325 (0.000)	0.297 (0.000)	0.351 (0.000)	0.189 (0.024)	0.186 (0.026)	0.349 (0.000)	0.332 (0.000)	0.157 (0.061)	0.355 (0.000)
FG (mg/dl)	-0.130 (0.120)	0.126 (0.131)	0.075 (0.371)	1.000 .	0.163 (0.050)	0.156 (0.060)	0.113 (0.176)	-0.076 (0.365)	0.240 (0.004)	0.321 (0.000)	0.288 (0.000)	0.202 (0.016)	0.274 (0.001)	0.190 (0.023)	0.191 (0.023)	0.336 (0.000)	0.327 (0.000)	0.149 (0.077)	0.308 (0.000)
TG (mg/dl)	-0.195 (0.019)	0.234 (0.005)	0.246 (0.003)	0.163 (0.050)	1.000 .	0.342 (0.000)	0.246 (0.003)	-0.301 (0.000)	0.306 (0.000)	0.391 (0.000)	0.389 (0.000)	0.437 (0.000)	0.431 (0.000)	0.113 (0.179)	0.124 (0.141)	0.433 (0.000)	0.446 (0.000)	0.366 (0.000)	0.441 (0.000)

TC	**-0.009**	**0.088**	**0.048**	**0.156**	**0.342**	**1.000**	**0.855**	**0.262**	**0.088**	**0.173**	**0.149**	**0.133**	**0.183**	**-0.190**	**-0.090**	**0.214**	**0.262**	**0.062**	**0.219**
(mg/dl)	**(0.915)**	**(0.291)**	**(0.564)**	**(0.060)**	**(0.000)**	**.**	**(0.000)**	**(0.001)**	**(0.295)**	**(0.037)**	**(0.074)**	**(0.113)**	**(0.028)**	**(0.286)**	**(0.286)**	**(0.010)**	**(0.002)**	**(0.465)**	**(0.009)**
LDL-c	**0.028**	**0.039**	**0.018**	**0.113**	**0.246**	**0.855**	**1.000**	**-0.138**	**0.169**	**0.206**	**0.199**	**0.129**	**0.219**	**-0.024**	**-0.024**	**0.229**	**0.257**	**0.129**	**0.221**
(mg/dl)	**(0.735)**	**(0.688)**	**(0.828)**	**(0.176)**	**(0.003)**	**(0.000)**	**.**	**(0.097)**	**(0.042)**	**(0.013)**	**(0.016)**	**(0.123)**	**(0.008)**	**(0.775)**	**(0.775)**	**(0.006)**	**(0.002)**	**(0.125)**	**(0.008)**
HDL (mg/dl)	**0.110**	**-0.066**	**-0.129**	**-0.076**	**-0.301**	**0.262**	**-0.138**	**1.000**	**-0.354**	**-0.288**	**-0.307**	**-0.281**	**-0.315**	**-0.195**	**-0.195**	**-0.270**	**-0.241**	**-0.304**	**-0.250**
	(0.190)	**(0.429)**	**(0.123)**	**(0.365)**	**(0.000)**	**(0.001)**	**(0.097)**	**.**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.001)**	**(0.000)**	**(0.020)**	**(0.020)**	**(0.001)**	**(0.004)**	**(0.000)**	**(0.003)**
CRP	**-0.128**	**0.032**	**0.153**	**0.240**	**0.306**	**0.088**	**0.169**	**-0.354**	**1.000**	**0.466**	**0.365**	**0.482**	**0.429**	**0.094**	**0.101**	**0.488**	**0.513**	**0.353**	**0.485**
(mg/L)	**(0.126)**	**(0.701)**	**(0.065)**	**(0.004)**	**(0.000)**	**(0.295)**	**(0.042)**	**(0.000)**	**.**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.263)**	**(0.229)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
BMI (kg/m^2)	**-0.275**	**0.329**	**0.377**	**0.321**	**0.391**	**0.173**	**0.206**	**-0.288**	**0.466**	**1.000**	**0.812**	**0.813**	**0.824**	**0.472**	**0.467**	**0.917**	**0.816**	**0.612**	**0.893**
	(0.001)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.037)**	**(0.013)**	**(0.000)**	**(0.000)**	**.**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
WC (cm)	**-0.292**	**0.301**	**0.325**	**0.3288**	**0.389**	**0.149**	**0.199**	**-0.307**	**0.365**	**0.812**	**1.000**	**0.641**	**0.932**	**0.485**	**0.475**	**0.799**	**0.676**	**0.556**	**0.773**
	(0.000)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.074)**	**(0.016)**	**(0.000)**	**(0.000)**	**(0.000)**	**.**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
WHR	**-0.275**	**0.245**	**0.297**	**0.202**	**0.437**	**0.133**	**0.129**	**-0.281**	**0.482**	**0.813**	**0.641**	**1.000**	**0.750**	**0.153**	**0.157**	**0.754**	**0.760**	**0.745**	**0.808**
	(0.001)	**(0.003)**	**(0.000)**	**(0.016)**	**(0.000)**	**(0.113)**	**(0.123)**	**(0.001)**	**(0.000)**	**(0.000)**	**(0.000)**	**.**	**(0.000)**	**(0.068)**	**(0.061)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**

WHtR	**-0.292**	**0.304**	**0.351**	**0.274**	**0.431**	**0.183**	**0.219**	**-0.315**	**0.429**	**0.824**	**0.932**	**0.750**	**1.000**	**0.253**	**0.248**	**0.793**	**0.760**	**0.541**	**0.771**
	(0.000)	**(0.000)**	**(0.000)**	**(0.001)**	**(0.000)**	**(0.028)**	**(0.008)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**.**	**(0.002)**	**(0.003)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**
FFM	**0.015**	**0.198**	**0.189**	**0.190**	**0.113**	**-0.092**	**-0.025**	**-0.189**	**0.094**	**0.472**	**0.485**	**0.153**	**0.253**	**1.000**	**0.997**	**0.332**	**0.038**	**0.247**	**0.338**
(kg)	**(0.855)**	**(0.018)**	**(0.024)**	**(0.023)**	**(0.079)**	**(0.276)**	**(0.766)**	**(0.024)**	**(0.263)**	**(0.000)**	**(0.000)**	**(0.068)**	**(0.002)**	**.**	**(0.000)**	**(0.000)**	**(0.656)**	**(0.003)**	**(0.000)**
SMM	**-0.013**	**0.190**	**0.186**	**0.191**	**0.124**	**-0.090**	**-0.024**	**-0.195**	**0.101**	**0.467**	**0.475**	**0.157**	**0.248**	**0.997**	**1.000**	**0.319**	**0.026**	**0.254**	**0.336**
(Kg)	**(0.876)**	**(0.023)**	**(0.026)**	**(0.023)**	**(0.141)**	**(0.286)**	**(0.775)**	**(0.020)**	**(0.229)**	**(0.000)**	**(0.000)**	**(0.061)**	**(0.003)**	**(0.000)**	**.**	**(0.000)**	**(0.757)**	**(0.002)**	**(0.000)**
FM	**-0.281**	**0.309**	**0.349**	**0.336**	**0.433**	**0.214**	**0.229**	**-0.270**	**0.488**	**0.917**	**0.799**	**0.754**	**0.793**	**0.332**	**0.319**	**1.000**	**0.940**	**0.613**	**0.934**
(kg)	**(0.001)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.010)**	**(0.006)**	**(0.001)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**.**	**(0.000)**	**(0.000)**	**(0.000)**
BFP (%)	**-0.287**	**0.290**	**0.332**	**0.327**	**0.446**	**0.262**	**0.257**	**-0.241**	**0.513**	**0.816**	**0.676**	**0.760**	**0.760**	**0.038**	**0.026**	**0.940**	**1.000**	**0.540**	**0.883**
	(0.001)	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.002)**	**(0.002)**	**(0.004)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.656)**	**(0.757)**	**(0.000)**	**.**	**(0.000)**	**(0.000)**
ULBFR	**-0.265**	**0.126**	**0.157**	**0.149**	**0.366**	**0.062**	**0.129**	**-0.304**	**0.353**	**0.612**	**0.556**	**0.745**	**0.541**	**0.247**	**0.254**	**0.613**	**0.540**	**1.000**	**0.679**
	(0.001)	**(0.032)**	**(0.061)**	**(0.077)**	**(0.000)**	**(0.465)**	**(0.125)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.003)**	**(0.002)**	**(0.000)**	**(0.000)**	**.**	**(0.000)**

VFA	**-0.318**	**0.279**	**0.355**	**0.308**	**0.441**	**0.219**	**0.221**	**-0.250**	**0.485**	**0.893**	**0.773**	**0.808**	**0.771**	**0.338**	**0.336**	**0.934**	**0.883**	**0.679**	**1.000**
(cm^2)	**(0.000)**	**(0.001)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.009)**	**(0.008)**	**(0.003)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	.

Abbreviations: 25(OH)D3, 25-hydroxyvitamin D3; SBP; Systolic blood pressure, DBP, diastolic blood pressure; FG, fasting glucose; TG, triglyceride; TC, total cholesterol, ; LDL-c, low-density lipoprotein cholesterol, HDL-c: high-density lipoprotein cholesterol , CRP (c-reactive protein), BMI: body mass index, WC: waist circumference, WHR: waist to hip ratio, WHtR; waist to height ratio;, FFM: free fat mass; SMM: skeletal muscle mass, FM: fat mass; BFP: body fat percentage ; ULBFR: upper to lower body fat ratio, VFA :visceral fat area.

$P<0.05$ is considered to be indicative of statistical significance

Table 3c: Correlation coefficients among serum 25(OH)D3 concentration, adiposity and biochemical measures in Postmenopausal women, adjusted for age.

	Serum 25(OH) D_3	SPB (mm Hg)	DBP (mm Hg)	FG (mg/dl)	TG (mg/dl)	TC (mg/dl)	LDL-c (mg/dl)	HDL-c (mg/dl)	CRP (mg/L)	BMI (Kg/m^2)	WC (cm)	WHR	WhtR	FFM (kg)	SMM (kg)	FM (kg)	BFP (%)	ULBFR	VF (cm^2)
Serum 25(OH) D_3	1.000 .	-0.204 (0.431)	-0.009 (0.971)	-0.103 (0.695)	-0.065 (0.806)	0.119 (0.648)	0.118 (0.653)	0.141 (0.591)	-0.142 (0.587)	-0.116 (0.537)	-0.210 (0.418)	-0.030 (0.908)	-0.184 (0.481)	-0.187 (0.473)	-0.226 (0.384)	-0.065 (0.804)	-0.063 (0.811)	-0.052 (0.843)	-0.082 (0.754)
SPB(mm Hg)	-0.204 (0.431)	1.000 .	0.647 (0.004)	0.713 (0.001)	0.378 (0.122)	0.109 (0.666)	0.087 (0.741)	-0.171 (0.498)	0.205 (0.414)	0.649 (0.004)	0.548 (0.019)	0.698 (0.001)	0.543 (0.020)	0.573 (0.013)	0.596 (0.009)	0.585 (0.011)	0.442 (0.066)	0.230 (0.359)	0.617 (0.006)
DBP(mm Hg)	-0.009 (0.971)	0.647 (0.004)	1.000 .	0.679 (0.002)	0.418 (0.084)	0.112 (0.658)	0.147 (0.573)	-0.285 (0.251)	0.502 (0.034)	0.560 (0.016)	0.540 (0.021)	0.458 (0.056)	0.516 (0.028)	0.587 (0.010)	0.595 (0.009)	0.480 (0.044)	0.294 (0.236)	-0.123 (0.628)	0.540 (0.021)
FG (mg/dl)	-0.103 (0.695)	0.713 (0.001)	0.679 (0.002)	1.000 .	0.324 (0.189)	-0.201 (0.424)	-0.159 (0.542)	-0.260 (0.298)	0.245 (0.328)	0.778 (0.000)	0.707 (0.001)	0.784 (0.000)	0.678 (0.002)	0.654 (0.003)	0.671 (0.002)	0.781 (0.000)	0.671 (0.002)	0.239 (0.339)	0.791 (0.000)
TG (mg/dl)	-0.065 (0.806)	0.378 (0.122)	0.418 (0.084)	0.324 (0.189)	1.000 .	0.167 (0.507)	0.076 (0.772)	-0.491 (0.039)	0.121 (0.634)	0.577 (0.012)	0.593 (0.009)	0.334 (0.175)	0.630 (0.005)	0.550 (0.018)	0.590 (0.010)	0.466 (0.051)	0.384 (0.116)	-0.054 (0.832)	0.483 (0.042)
TC(mg/dl)	-0.119 (0.648)	0.109 (0.666)	0.112 (0.658)	-0.201 (0.424)	0.167 (0.507)	1.000 .	0.931 (0.000)	0.200 (0.426)	-0.115 (0.651)	0.008 (0.976)	-0.161 (0.522)	-0.121 (0.631)	-0.105 (0.680)	-0.036 (0.886)	-0.010 (0.968)	-0.100 (0.692)	-0.152 (0.547)	-0.002 (0.992)	-0.085 (0.736)
LDL-c (mg/dl)	0.118 (0.653)	0.087 (0.741)	0.147 (0.573)	-0.159 (0.542)	0.076 (0.772)	0.931 (0.000)	1.0000 .	0.076 (0.772)	-0.093 (0.724)	0.050 (0.850)	-0.130 (0.619)	-0.073 (0.782)	-0.086 (0.743)	-0.009 (0.972)	0.000 (1.000)	-0.041 (0.877)	-0.034 (0.896	-0.044 (0.866)	-0.031 (0.906)
HDL (mg/dl)	0.141(0.591)	-0.171	-0.285	-0.260	-0.491	0.200	0.076	1.000	-0.016	-0.466	-0.485	-0.278	-0.506	-0.507	-0.508	-0.389	-0.305	0.098	-0.383

		(0.498)	(0.251)	(0.298)	(0.039)	(0.426)	(0.772)	.	(0.950)	(0.051)	(0.041)	(0.264)	(0.032)	(0.032)	(0.032)	(0.111)	(0.218)	(0.700)	(0.116)
CRP	-0.142	0.205	0.502	0.245	0.121	-0.115	-0.093	-0.016	1.000	0.172	-0.041	0.236	-0.077	0.188	0.166	0.194	0.120	0.058	0.272
(mg/L)	(0.587)	(0.414)	(0.034)	(0.328)	(0.634)	(0.651)	(0.724)	(0.950)	.	(0.494)	(0.872)	(0.345)	(0.762)	(0.455)	(0.509)	(0.442)	(0.636)	(0.820)	(0.276)
BMI	-0.161	0.649	0.560	0.778	0.577	0.008	0.050	-0.466	0.172	1.000	0.855	0.827	0.857	0.847	0.860	0.941	0.871	0.345	0.955
(kg/m^2)	(0.537)	(0.004)	(0.016)	(0.000)	(0.012)	(0.976)	(0.850)	(0.051)	(0.494)	.	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.161)	(0.000)
WC (cm)	-0.210	0.548	0.540	0.707	0.593	-0.161	-0.130	-0.485	-0.041	0.855	1.000	0.626	0.965	0.819	0.823	0.806	0.755	0.217	0.799
	(0.418)	(0.019)	(0.021)	(0.001)	(0.009)	(0.522)	(0.619)	(0.041)	(0.872)	(0.000)	.	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.388)	(0.000)
WHR	-0.030	0.698	0.458	0.784	0.334	-0.121	-0.073	-0.278	0.236	0.827	0.626	1.000	0.656	0.601	0.595	0.834	0.748	0.581	0.831
	(0.908)	(0.001)	(0.056)	(0.000)	(0.175)	(0.631)	(0.782)	(0.264)	(0.345)	(0.000)	(0.005)	.	(0.003)	(0.008)	(0.009)	(0.000)	(0.000)	(0.011)	(0.000)
WhtR	-0.184	0.543	0.516	0.678	0.630	-0.105	-0.086	-0.506	-0.077	0.857	0.965	0.656	1.000	0.718	0.735	0.745	0.714	0.183	0.765
	(0.481)	(0.020)	(0.028)	(0.002)	(0.005)	(0.680)	(0.743)	(0.032)	(0.762)	(0.000)	(0.000)	(0.003)	.	(0.001)	(0.001)	(0.000)	(0.001)	(0.467)	(0.000)
FFM	-0.187	0.573	0.587	0.654	0.550	-0.036	-0.009	-0.507	0.188	0.847	0.819	0.601	0.718	1.000	0.992	0.846	0.685	0.209	0.804
(kg)	(0.481)	(0.013)	(0.010)	(0.003)	(0.018)	(0.886)	(0.972)	(0.032)	(0.455)	(0.000)	(0.000)	(0.008)	(0.001)	.	(0.000)	(0.000)	(0.002)	(0.405)	(0.000)
SMM	-0.226	0.596	0.595	0.671	0.590	-0.010	0.000	-0.508	0.166	0.860	0.823	0.595	0.735	0.992	1.000	0.832	0.668	0.177	0.801
(Kg)	(0.384)	(0.009)	(0.009)	(0.002)	(0.010)	(0.968)	(1.000)	(0.032)	(0.509)	(0.000)	(0.000)	(0.009)	(0.001)	(0.000)	.	(0.000)	(0.002)	(0.482)	(0.000)
FM (kg)	-0.065	0.585	0.480	0.781	0.466	-0.100	-0.041	-0.389	0.194	0.941	0.806	0.834	0.745	0.846	0.832	1.000	0.941	0.473	0.978
	(0.804)	(0.011)	(0.044)	(0.000)	(0.051)	(0.692)	(0.877)	(0.111)	(0.442)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	.	(0.000)	(0.047)	(0.000)
BFP	-0.063	0.442	0.294	0.671	0.384	-0.152	-0.034	-0.305	0.120	0.871	0.755	0.748	0.714	0.685	0.668	0.941	1.000	0.455	0.940
(%)	(0.811)	(0.066)	(0.236)	(0.002)	(0.116)	(0.547)	(0.896)	(0.218)	(0.636)	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.002)		.	(0.058)	(0.000)

ULBFR	**-0.052**	**0.230**	**-0.123**	**0.239**	**-0.054**	**-0.002**	**-0.044**	**0.098**	**0.058**	**0.345**	**0.217**	**0.581**	**0.183**	**0.209**	**0.177**	**0.473**	**0.455**	**1.000**	**0.405**
	(0.843)	**(0.359)**	**(0.628)**	**(0.339)**	**(0.832)**	**(0.992)**	**(0.866)**	**(0.700)**	**(0.820)**	**(0.161)**	**(0.388)**	**(0.011)**	**(0.467)**	**(0.405)**	**(0.482)**	**(0.047)**	**(0.058)**	**.**	**(0.095)**
VF	**-0.082**	**0.617**	**0.540**	**0.791**	**0.483**	**-0.085**	**-0.031**	**-0.383**	**0.272**	**0.955**	**0.799**	**0.831**	**0.765**	**0.804**	**0.801**	**0.978**	**0.940**	**0.405**	**1.000**
(cm^2)	**(0.754)**	**(0.006)**	**(0.021)**	**(0.000)**	**(0.042)**	**(0.736)**	**(0.906)**	**(0.116)**	**(0.276)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.000)**	**(0.095)**	**.**

Abbreviations: 25(OH)D3, 25-hydroxyvitamin D3; SBP; Systolic blood pressure, DBP, diastolic blood pressure; FG, fasting glucose; TG, triglyceride; TC, total cholesterol, ; LDL-c, low-density lipoprotein cholesterol, HDL-c: high-density lipoprotein cholesterol , CRP (c-reactive protein), BMI: body mass index, WC: waist circumference, WHR: waist to hip ratio, WHtR; waist to height ratio;, FFM: free fat mass; SMM: skeletal muscle mass, FM: fat mass; BFP: body fat percentage ; ULBFR: upper to lower body fat ratio, VFA :visceral fat area.

$P<0.05$ is considered to be indicative of statistical significance

Table 4. Association between Suboptimal Vitamin D status and adiposity measures in men, as assessed by Multiple Logistic Regression Analyses ^

Independent Variables	OR	95% C.I.		P-value	R-Square
		Lower	Upper		
Waist Circumference (WC)					0.001
Model 1 ^^					
≤102 cm	1.000				
>102 cm	1.098	0.598	2.017	0.763	
Model 3 ^^^^					0.200-0.271
≤102 cm	1.000				
>102 cm	.729	0.321	1.653	0.449	
Waist-to-Hip Ratio (WHR)					0.008-0.010
Model 1 ^^					
<0.9	1.000				
≥ 0.9	1.500	0.748	3.010	0.254	
Model 3 ^^^^					0.191-0.259
<0.9	1.000				
≥ 0.9	2.296	0.854	6.176	0.100	
Waist-to-Height Ratio (WHtR)					0.004 - 0.005
Model 1 ^^					
≤ 0.5	1.000				
>0.5	0.571	0.146	2.233	0.421	
Model 3 ^^^^					0.231-0.313
≤ 0.5	1.000				
> 0.5	0.248	0.041	1.495	0.128	
Visceral Fat Area (VFA)					0.020-0.027
Model 1 ^^					
T1 (≤121.1 cm^2)	1.000				
T2 (121.2-151.6 cm^2)	1.074	0.512	2.255	0.850	
T3 (:>=151.7 cm^2)	1.953	0.895	4.265	0.093	
Model 3 ^^^^					0.177 - 0.241
T1 (≤121.1 cm^2)	1.000				
T2 (121.2-151.6 cm^2)	.894	.349	2.290	0.816	

T3 (:>=151.7 cm^2)	.959	.328	2.801	0.939	
Upper-to-lower body fat ratio (ULBFR)					0.002-0.003
Model 1 ^^					
T1 (≤ 2.01)	1.000				
T2 (2.02-2.20)	1.255	.585	2.691	0.560	
T3 (≥2.21)	1.140	.538	2.418	0.732	
Model 2 ^^^					0.003-0.004
T1 (≤ 2.01)	1.000				
T2 (2.02-2.20)	1.226	.567	2.653	0.604	
T3 (3:≥2.21)	1.123	.528	2.392	0.763	
Model 3 ^^^^					0.193-0.263
ULBFR					
T1 (≤ 2.01)	1.000				
T2 (2.02-2.20)	.757	.310	1.849	0.542	
T3 (3:≥2.21)	.634	.255	1.575	0.326	

^**:** Main Dependent Variable: Vitamin D status; Main Independent Variable: Adiposity Measure

^^: Model 1: Unadjusted

^^^: Model 2 adjusted for body fat percentage for ULBFR only.

^^^^: Model 3adjuted fo age, systolic blood pressure (SBP), physical activity (PA) level, triglycerides (TG), metabolic syndrome (MeTs), marital status, vitamin D supplement and sun exposure **(WC)**; age, SBP, PA level, TG, MeTs, vitamin D supplement and sun exposure,total cholesterol (TC) and vitamin D intake **(WHR/VFA)**; age, SBP, PA level, TG, MeTs, marital status, vitamin D supplement and sun exposure creatinine and vitamin D intake **(WHtR)**; age, SBP, PA level, TG, MeTs, marital status, vitamin D supplement and sun exposure and TC **(ULBFR).**

Table 5. Association between Suboptimal Vitamin D status and adiposity measures in premenopausal women, as assessed by Multiple Logistic Regression Analyses ^

Independent Variables	OR	95% C.I. Lower	95% C.I. Upper	P-value	R-Square
Waist Circumference (WC)					
Model 1 ^^					0.065-0.089
≤88 cm	1.000				
>88	3.083	1.471	6.465	0.003	
Model 3 ^^^^					0.356 -0.488
≤88 cm	1.000				
>88 cm	4.559	1.600	12.994	0.005	
Waist-to-Hip Ratio (WHR)					0.008 - 0.011
Model 1 ^^					
< 0.85	1.000	0.707	3.186	0.291	
≥ 0.85	1.501				0.330-0.453
Model 3 ^^^^					
≥ 0.85	4.545	1.279	16.147	0.019	
< 0.85	1.000				
Waist-to-Height Ratio (WHtR)					0.008-0.012
Model 1 ^^					
≤ 0.5	1.000				
>0.5	1.650	.678	4.013	0.269	
Model 3 ^^^^					0.309-0.425
≤ 0.5	1.000				
> 0.5	1.431	.449	4.562	0.545	
Visceral Fat Area (VFA)					0.033-0.046
Model 1 ^^					
T1 (≤72.4 cm^2)	1.000				
T2 (72.5-102.0 cm^2)	2.085	.909	4.785	0.083	
T3 (≥102.1 cm^2)	2.377	.991	5.698	0.052	
Model 3 ^^^^					0.361-0.495

T1 (≤72.4 cm^2)	1.000				
T2 (72.5-102.0 $cm^{2)}$	5.088	1.468	17.643	0.010	
T3 (≥102.1 cm^2)	8.646	1.702	43.909	0.009	
Upper-to-lower body fat ratio (ULBFR)					0.066-0.090
Model 1 ^^					
T1 (≤1.65)	1.000				
T2 (1.66-1.79)	2.319	1.006	5.343	0.048	
T3 (:≥1.80)	3.804	1.543	9.381	0.004	
Model 2 ^^^					0.071-0.097
T1 (≤1.65)	1.000				
T2 (1.66-1.79)	2.051	.852	4.942	0.109	
T3 (:≥1.80)	3.029	1.078	8.514	0.036	
Model 3 ^^^^					0.341-0.468
T1 (≤1.65)	1.000				
T2 (1.66-1.79)	2.326	.798	6.784	0.122	
T3 (:≥1.80)	3.789	1.022	14.053	0.046	

^: Main Dependent Variable: Vitamin D status; Main Independent Variable: Adiposity Measure
^^: Model 1: Unadjusted
^^^: Model 2 adjusted for body fat percentage for ULBFR only)
^^^^: Model 3: adjusted for age, systolic blood pressure (SBP), clinical diagnosis of a family member with depression or any other mental illness, physical activity (PA) level, HDL-c and vitamin D intake and vitamin D supplement **(WC)**; age, systolic blood pressure (SBP), HDL-c and vitamin D intake and vitamin D supplement and triglycerides (TG) **(WHR)**; age, SBP,clinical diagnosis of a family member with depression or any other mental illness, HDL-c, vitamin D intake, vitamin D supplement and breakfast **(VFA)**; age, body fat percentage, SBP, HDL-c, vitamin D intake and vitamin D supplement **(ULBFR)**.

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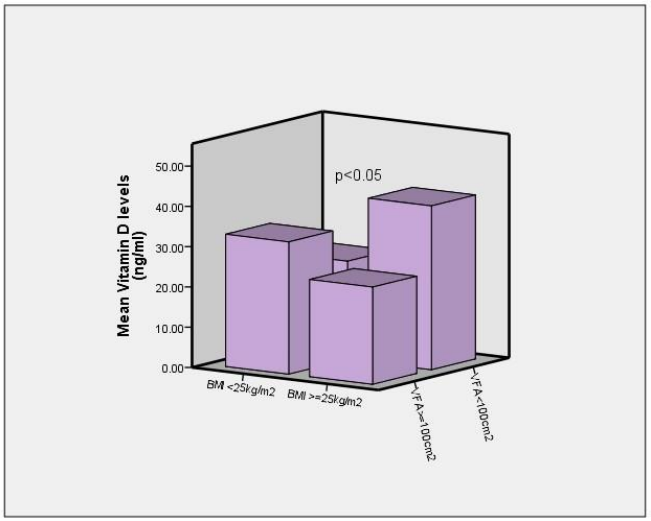

Figure 1a: serum 25 (OH) D_3 according to different VFA levels among men with similar BMI categories.

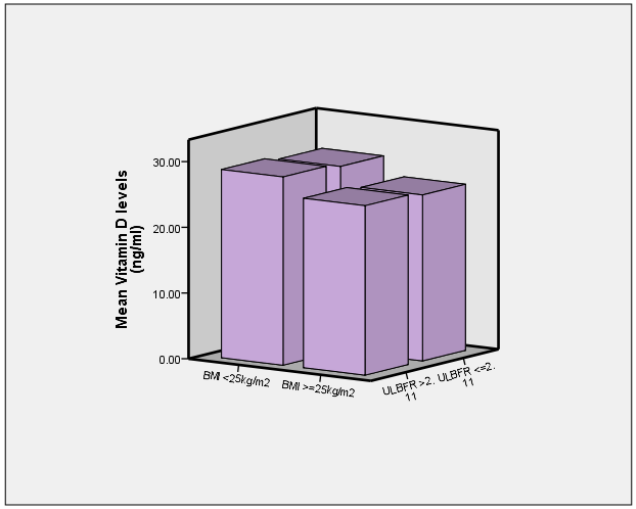

Figure 1b: serum 25 (OH) D_3 according to different ULBFR levels among men with similar BMI categories
..

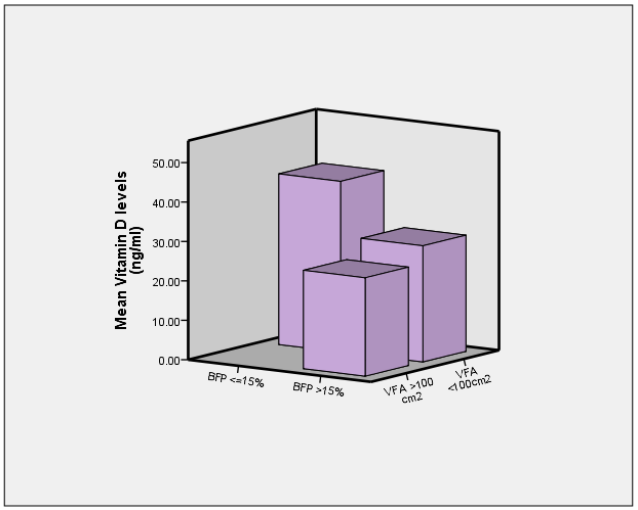

Figure1c: serum 25 (OH) D_3 according to different VFA levels among men with similar BFP categories.

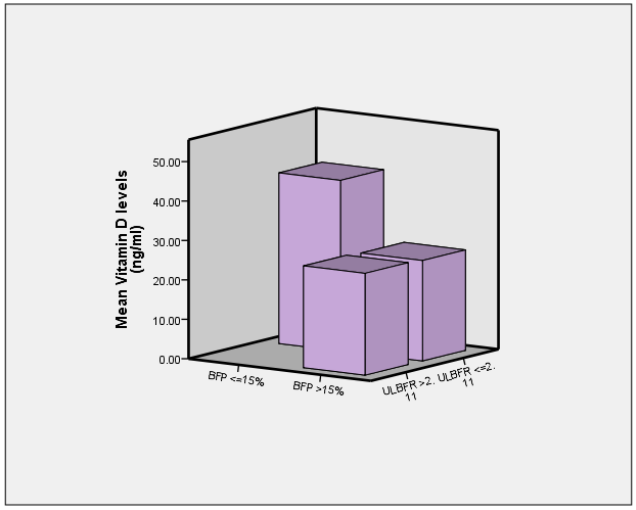

Figure 1d: serum 25 (OH) D_3 according to different ULBFR levels among men with similar BFP

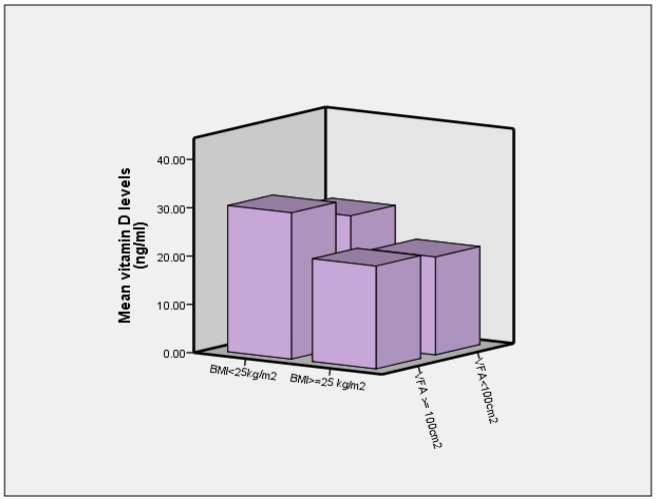

Figure2a: serum 25 (OH) D_3 according to different VFA levels among pre-menopausal women with similar BMI categories.

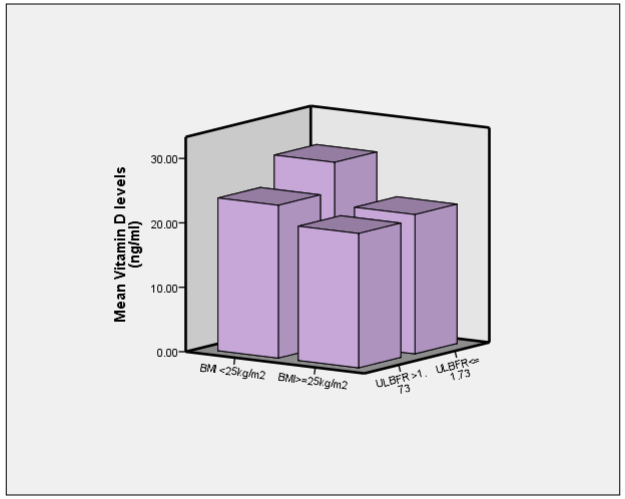

Figure2b: serum 25 (OH) D_3 according to different ULBFR levels among pre-menopausal women with similar BMI categories.

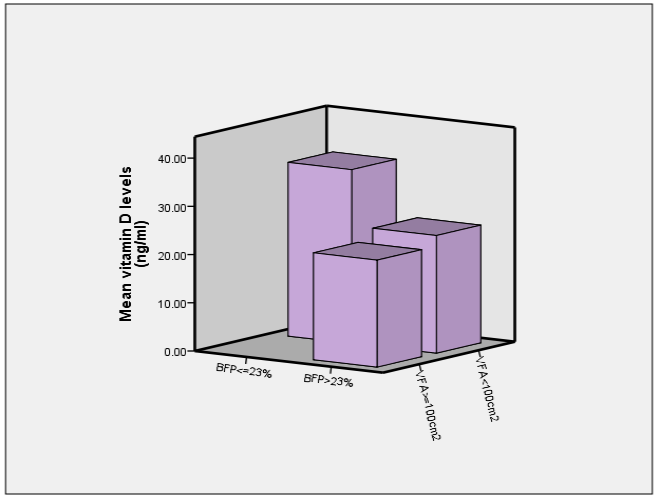

Figure2c: serum 25 (OH) D_3 according to different VFA levels among pre-menopausal women with similar BFP categories.

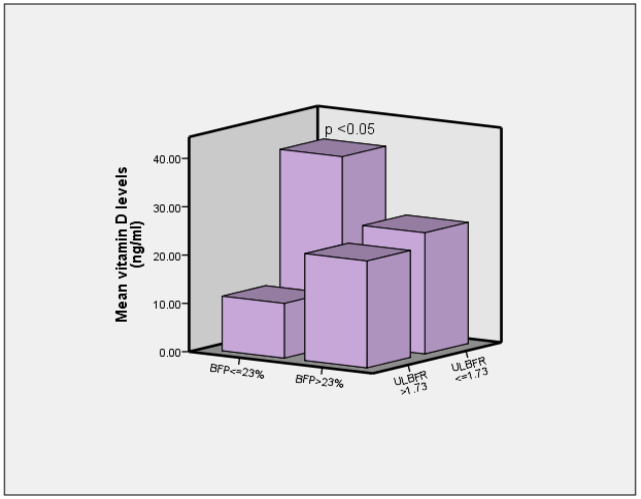

Figure2d: serum 25 (OH) D_3 according to different ULBFR levels among pre-menopausal women with similar BFP categories.

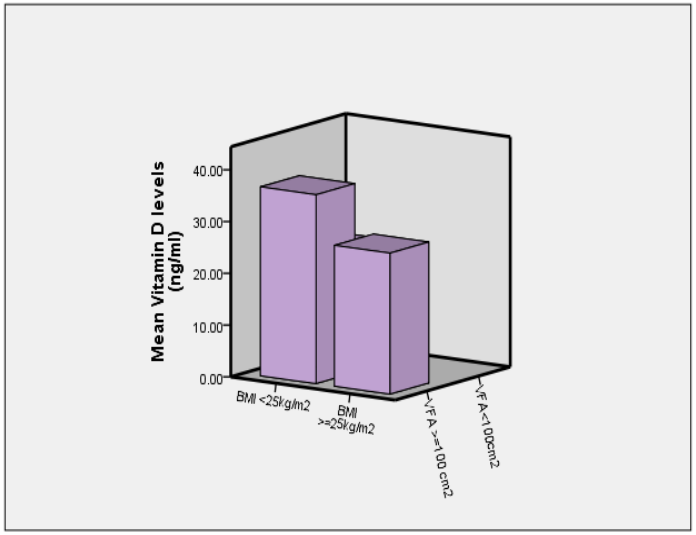

Figure 3a: serum 25 (OH) according to different VFA levels among post-menopausal women with similar BMI categories.

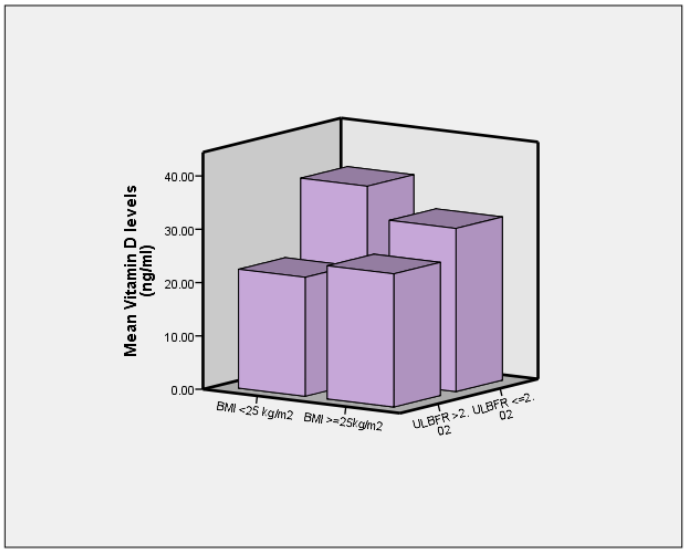

Figure 3b: serum 25 (OH) according to different ULBFR levels among post-menopausal women with similar BMI categories.

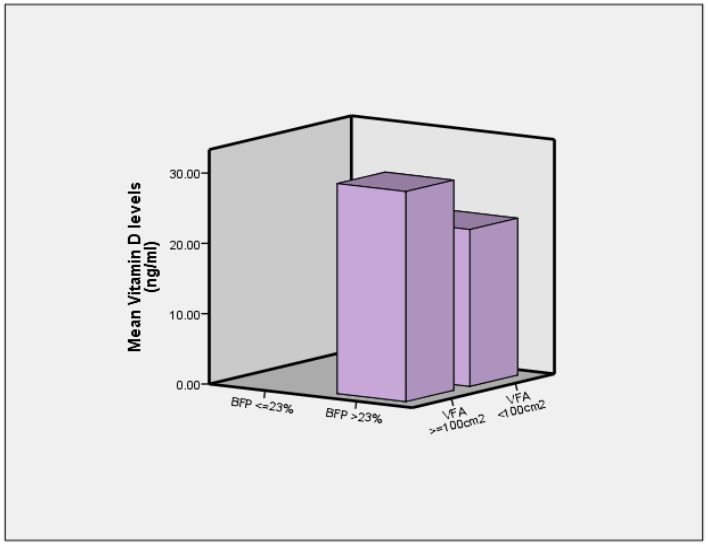

Figure 3c: serum 25 (OH) according to different VFA levels among post-menopausal women with similar BFP categories.

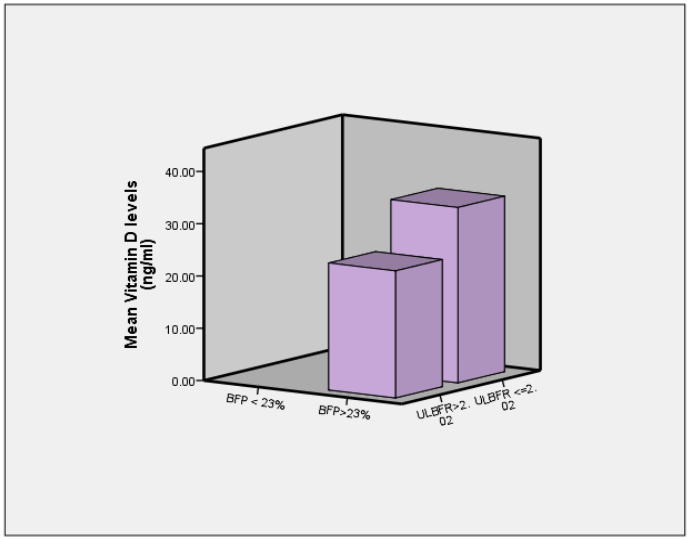

Figure 3d: serum 25 (OH) D_3 according to different ULBFR levels among post-menopausal women with similar BFP categories.

Appendixes

Subject Code: ---------- Interviewer Name: ---------- Faculty: ----------
Date of birth: ----/ -----/ ----- Date of Interview: -----/ -----/ -------- Time Required: ----------

(day/month/year) (day/month/year)

Personal Information

1. **Have you been recently diagnosed by a doctor with a <u>mental illness other than depression</u> [for instance any of anxiety disorders, bipolar disorder, eating disorders, , substance abuse/ dependence (alcoholic, drug)]?**

هل عانيت راوخم بسحب صي خشت بيبطلا تصخملا نم أيرابضطإ ليقع غير بةآكلا ، (،لققئلا ابرطضإ
،جالامز لاخلل فـي لكلأا ، ، انمالإد ـعل ةويدلأا أو لولاكد (

☐No
☐Yes, Specify disease: _____
If yes, have you been taking any medication?
↗No ↗Yes, Specify medication: _____

2. **Has any member of your family (parents, siblings) been diagnosed by a doctor with depression or any other mental illness (bipolar, schizophrenia…)?**

هل انيي عأحد نم دارفأ ائلةقلاع) هلالأا و أ ةوخلأا) نم لكاشم يةسفن (إضطرابإج ازملا ، امصف...(

☐No
☐Yes, Specify disease: _____

3. **Have you been recently diagnosed by a doctor with <u>depression</u>?**

هل انيتع ارخمؤ مذ تالاح بةئآ بسحب خيصشت طبيبلا ختصلام

☐No
☐Yes, Indicate if you have been taking any antidepressant medication?
☐ No ↗ Yes, Specify name of medication:

_____

4. **Do you make yourself sick (throw up) because you feel uncomfortably full?**

☐No ↗Yes

5. **Do you worry you have lost control over how much you eat?**
   ☐No ↗Yes

6. **Have you recently lost more than one stone (6.35kg) in a 3 month period?**
   ☐No ↗Yes

7. **Do you believe yourself to be fat when others say you are too thin?**
   ☐No ↗Yes

8. **Would you say that food dominates your life?**
   ☐No ↗Yes

9. **Have you had experienced any of the following stressful life events <u>during the past year</u>?**
   ☐No ↗ Yes (check all applicable answers)

☐ Loss of parent(s) due to death	☐ Serious conflicts with your intimate partner/ divorce
☐ Loss of a close family member due to death	☐ Serious financial difficulties
☐ Loss of a close friend due to death	☐ Serious job difficulties
↗Taking care of a family member with disability	↗ Other: Specify: ----------

10. **Please provide best estimate of the monthly Household Income (دخلالا يرشهلا قرسلأل) (i.e. income generated by all adults in the household) in $US:**
    ☐ Less than $1,250
    ↗ Between $1,250- $ 2,250
    ↗ Between $2,250- $4,000
    ↗ Between $4,000- $5,333
    ↗ More than $5,333

Thank you for taking the time to complete this survey.

Subject Code: ----------
--

Food Frequency Questionnaire: Vitamin D Intake

INSTRUCTIONS: Do your best to answer each question. State how often (if ever) you ate the following vitamin D-containing foods during the past 3 months, and then indicate the frequency, number of servings, & average portion size.

Food Item	**Never**	**Monthly**	**Weekly**	**Daily**	**Check Serving Size:** (mark one only)
EXAMPLE: Milk for drinking (including chocolate milk/ hot cocoa with milk)			10		● 125 ml (0.5 cup) Δ 250 ml (1 cup) Δ 375 ml (1.5 cup)
1.Milk for drinking (including chocolate milk/ hot cocoa with milk) Specify brand & type:					Δ 125 ml (0.5 cup) Δ 250 ml (1 cup) Δ 375 ml (1.5 cup)
2. Milk on cereal, in soups, pasta, and desserts (ex. sahlab,muhallabieh, custard, riz bi halib, ...) Specify brand & type:					Δ 60 ml (0.25 cup) Δ 125 ml (0.5 cup) Δ 250 ml (1 cup)
3. Soy or rice milk, or orange juice with added calcium and vitamin D Specify brand & type:					Δ 125 ml (0.5 cup) Δ 250 ml (1 cup) Δ 375 ml (1.5 cup)
4. Eggs and egg- based dishes (including yolk) (ex. Fried, hard boiled, omelette, quiche,…)					Δ 1 large Δ 1 medium Δ 1 small
5. Fish: including salmon (canned, smoked, & fresh), oysters, or other fish Specify type:					Δ 75 g (2.5 oz) Δ 150 g (5 oz) Δ 225 g (7.5 oz)

6. Margarine (ex. Crisco, Elle et Vire, Flora, etc.) Specify brand:				5 ml (1 tsp) 15 ml (1 tbsp) 45 ml (3 tbsp)
7. Yogurt Specify brand & type:				60 ml (0.25 cup) 125 ml (0.5 cup) 250 ml (1 cup) 30 g (1 oz) 60 g (2 oz) 90 g (3 oz)
8. Cheeses (including cheddar, mozzarella, cheese singles, parmesan, gouda, brie, feta, blue, chevre, ...) Specify brand/ type:				60 ml (0.25 cup) 125 ml (0.5 cup) 250 ml (1 cup) 30 g (1 oz) 60 g (2 oz) 90 g (3 oz)
9. Ice cream Specify brand/ type:				60 ml (0.25 cup) 125 ml (0.5 cup) 250 ml (1 cup)
Additional sources of vitamin D				
10. Fish liver oil (supplement)				15 ml (1 tbsp) 30 ml (2 tbsp) 45 ml (3 tbsp)
11. Vitamin D or multivitamin supplement Specify brand:				200 IU 400 IU 800 IU Other: ----------

Subject Code: ----------

Interviewer Name: ----------

Faculty: ----------

Date of birth: ----/ -----/ --------

(day/month/ year)

Date of Interview: -----/ -----/ --------

(day/month/year)

Time Required: --------

Background Questionnaire *(28 Q, 3 pages)*

Please check one box for each question where there are check boxes. If you do not wish to answer a question, please draw a line through it.

Medical history- I

1. **Have you been recently diagnosed by a doctor with any of the following <u>chronic</u> medical conditions?**

   □ No ↗ Yes (Check all applicable)

□ Heart attack (بقنو قبيلق) ; Heart failure (فشلبلقلا)	↗ Cancer (انطسرلا)
↗ Stroke (تةكلاسيقغاملاد)	□ Neurological disease (multiple sclerosis…) (ضمراأيف هازلاجيبصعلا) بلصتلا يحويللا ...)
↗ Hypertension (عاتفرإ غطض دملا)	□ Kidney disease (ضراماًبـلكلا)
↗ Diabetes (يسكرلا)	□ Liver cirrhosis (فيلت دكبلا)
□ Asthma (اللا(ربو	□ Thyroid gland disorders (تابراطضا دةغلا قيرقدلا)
□ Vitamin D deficiency	↗ Other: Specify: ----------

2. **If your answer is yes to question # 2, have you been taking any medication &/or supplement?**

   □ No

   □ Yes, Specify name of medication: _____

3. **Are you pregnant or breastfeeding?**

   □ No ↗ Yes

4. **Are you currently taking any oral contraceptive pills?**

□ No

□ Yes, Specify name: _____

5. **Have you previously taken oral contraceptive pills?**

   □ No

   □ Yes, Specify when: _____

6. **Do you have any physical disability (ةقاعإ ةيدسج)?**
   □ No
   □ Yes, Specify: _____

Sociodemographic, plus anthropometric measurements

7. **Gender**:
   □ Male ↗ Female

8. **Date of Birth:** ----------/ ---------/ ---------- (day/ month/ year)

9. **Body weight (kg)/Height (cm) (measured by researcher)** *(leave it empty)*

   Body weight (kg) _____
   Height (cm) _____

10. **Blood pressure measurement (mmHg):** *(leave it empty)* _____

11. **Waist circumference (cm):** *(leave it empty)* _____

12. **Body composition (total body fat %):** *(leave it empty)* _____

13. **Describe your permanent place of residence:**
    □ Urban ↗ Rural

14. **Marital status:**
    □ Single ↗ Separated
    □ Married ↗ Divorced

15. **Do you have children?**
    □ No
    □ Yes, How many? _____

16. **Indicate your level of education**
    □ High School (or equivalent) ↗ University graduate (Master's, Doctorate degree, or equivalent)
    □ University bachelor's degree (BA, BS)

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Lifestyle questions

17. How many meals do you have per day?

□ One ↗ Three

□ Two ↗ Four or more

18. How often do you have your meals?

□ Often ↗ Occasionally ↗ Rarely

19. How often do you have a breakfast?

□ Daily ↗ Occasionally ↗ Rarely

20. During the past 3 months, have you been taking any vitamin D supplement?

□ No ↗ Yes ↗ If yes, which supplement? *(Include dosage)* ----------

-

21. <u>If your answer is yes to Q#22</u>, then how often did you take the vitamin D supplement?

□ Daily ↗ Less than 1x/ week

□ Every other day

22. During the past 3 months, have you been taking <u>any other</u> vitamin or mineral supplement(s)?

□ No ↗ Yes ↗ If yes, which supplement? *(Include dosage)* ----------

-

23. <u>If your answer is yes to Q#24</u>, then how often did you take the supplement(s)?

□ Daily ↗ Less than 1x/ week

□ Every other day

24. Have you been recently following a special diet (مظان يذائغ اصخ)?

□ No

□ Yes, Specify: _____

25. In the past 3 months, on average, how much time per day was you exposed to direct sunlight (between 10:00 am- 4:00 pm)? *(Think about averaging weekdays & weekend days)*

□ 5 min or less □ 31 to 60 min

□ 5 to 15 min ↗ More than 1 hour

□ 16 to 30 min

26. How often do you use sunscreen?

□ Rarely/ Never □ Sometimes □ Often

27. Do you smoke?

□ Daily
□ Occasional

↗ Former daily
↗ Former occasional
↗ Never smoked

28. Do you drink alcohol?

□ Never/ Occasionally
□ 1-2 drinks per week

↗ 1-2 drinks per day
↗ More than 2 drinks per day

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard (back garden) work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____days per week

   ⌋ No vigorous physical activities ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____minutes per day

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis?
   Do not include walking.

   _____days per week

   ⌋ No moderate physical activities ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

   _____minutes per day

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____days per week

⌋ No walking □ ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____minutes per day

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____hours per day

This is the end of the questionnaire, thank you for participating.

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