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The Association of Vitamin D Insufficiency/Deficiency with Metabolic Syndrome, Quality of Life and Depression in Postmenopausal Women

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ABSTRACT

Objective: This cross-sectional study aimed to assess the association of vitamin D insufficiency/deficiency with metabolic syndrome risk factors, quality of life, and depression in postmenopausal women aged 50 years and older. **Materials and Metods:** The study was conducted with women (n=165) who attended a handicraft course **i**n Bursa Province, Turkey, in March 2019**.** At the initial visit, blood samples were obtained from the individuals, and the study continued with 150 participants whose serum 25-hydroxyvitamin D (25(OH)D) levels lower than 30 ng/mL and met the research criteria. At the second visit, the subjects were questioned about their general characteristics, quality of life, and depression. In addition to the questionnaire, metabolic syndrome was defined according to the diagnostic criteria of the International Diabetes Federation, and waist circumference and blood pressure measurements were made for each participant. **Results:** The prevalences of vitamin D insufficiency and deficiency in the participants were 21.3% and 78.7, respectively. When compared to the women with vitamin D insufficiency, those with vitamin D deficiency displayed a significantly higher metabolic syndrome prevalence (46.6% vs 18.8%), waist circumference, blood pressure, and fasting blood glucose levels, and significantly lowered high density lipoprotein cholesterol levels (P<0.05). Furthermore, the differences observed between the women with vitamin D deficiency/insufficiency for physical function, energy level/vitality, mental and general health, which are sub parameters of the quality of life scale, and depression and anxiety scores, were also statistically significant (P<0.05). **Conclusion:** It was concluded that low vitamin D levels in postmenopausal women may be associated with metabolic syndrome**,** low quality of life, and depression.

Keywords: Vitamin D, Cholesterol, Waist Circumference, Depression, Anxiety.

Postmenopozal Kadınlarda D vitamini Eksikliği/Yetersizliğinin Metabolik Sendrom, Yaşam Kalitesi ve Depresyon ile İlişkisi

ÖZ

Amaç: Bu kesitsel çalışmada, 50 yaş ve üstü postmenopozal kadınlarda D vitamini eksikliği/yetersizliğinin metabolik sendrom risk faktörleri, yaşam kalitesi ve depresyon ile ilişkisinin araştırılması amaçlandı. **Gereç ve Yöntem:** Bu çalışma, Mart 2019'da Bursa'da bir el sanatları kursuna katılan kadınlarla (n=165) gerçekleştirildi. İlk ziyarette bireylerden kan örnekleri alındı ve serum 25-hidroksivitamin D [25(OH)D] seviyesi 30 ng/mL'den düşük olan ve araştırma kriterlerini karşılayan 150 kadın ile çalışmaya devam edildi. İkinci ziyarette bireylerin genel özellikleri, yaşam kalitesi ve depresyon durumları sorgulandı. Anketlere ek olarak, Uluslararası Diyabet Federasyonu'nun tanı kriterlerine göre metabolik sendrom tanımlandı ve her katılımcı için bel çevresi ve tansiyon ölçümleri yapıldı. **Bulgular:** Katılımcıların %21,3'ünde D vitamini yetersizliği ve %78,7'sinde D vitamini eksikliği vardı. D vitamini yetersizliği olan kadınların D vitamini eksikliği olan kadınlara kıyasla metabolik sendrom prevalansı (%18,8'e karşılık %46,6), bel çevresi ve açlık kan şekeri anlamlı derecede düşük ve yüksek yoğunluklu lipoprotein kolesterol düzeyleri anlamlı derecede yüksek bulundu **(**P<0.05). Ayrıca, D vitamini eksikliği/yetersizliği olan kadınların yaşam kalitesi ölçeğinin alt parametreleri olan fiziksel fonksiyonu, enerji düzeyi/canlılık, ruh sağlığı ve genel sağlık durumu ile depresyon ve anksiyete puanları arasında gözlene farklar da istatistiksel olarak anlamlı bulundu (P<0.05). **Sonuç:** Postmenopozal kadınlarda düşük D vitamini düzeylerinin metabolik sendrom, düşük yaşam kalitesi ve depresyon ile ilişkili olabileceği sonucuna varıldı.

Anahtar Kelimeler: D Vitamini, Kolesterol, Bel Çevresi, Depresyon, Anksiyete.

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INTRODUCTION

The most significant influence of vitamin D, among the fat-soluble vitamins, is on calcium, phosphorus metabolism, and bone mineralization (Marsman et al., 2018). Although there is no consensus on optimal vitamin D levels, deficiency has been described as having a 25-hydroxyvitamin D [25(OH)D] level < 20 ng/mL, whereas insufficiency refers to a level ranging between 20 - 30 ng/mL, with a level of > 30 ng/mL adopted as sufficient by most specialists (Perez-Lopez, Chedraui & Pilz 2020).

Vitamin D plays an important role in musculoskeletal health. Vitamin D status may also be associated with metabolic syndrome (MetS), obesity, insulin resistance, diabetes, cardiovascular disease, immune responses to various cancers, and death (Chiang, Stanczyk & Kanaya, 2018; Haimi & Kremer, 2017; Kaur et al., 2019). Also, studies have shown that there may be an association between vitamin D deficiency and mood disorders. Recent research has shown a negative association between vitamin D levels and depressive disorders (Musazadeh, Keramati, Ghalchi, 2023). Besides, some recent studies proposed that vitamin D status and quality of life (QoL) are positively correlated. However, available data is inconsistent due to differences in the populations studied and the QoL assessment tools (Tepper et al., 2016).

This study purposed to evaluate the relation between vitamin D deficiency with MetS markers [waist circumference (WC), fasting blood glucose, blood pressure (BP), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C) levels, and low-density lipoprotein cholesterol (LDL-C) levels], depression, and QoL in postmenopausal women aged 50 and over.

MATERIALS AND METHODS

Subject characteristics

The population of the research consisted of all women (n=165) aged 50 and over (between 50 and 70 years of age, mean 55.26 ± 5.11) who attended a handicraft course in Bursa Province, Turkey, in March 2019. No sample selection was made from the population, and women who were in the course on the days when the research was conducted and agreed to participate in the research were included. Five participants did not return to the study following the initial visit, and 10 participants did not meet the inclusion criteria, resulting in 150 subjects completing the study.

Inclusion criteria were (i) postmenopausal females aged 50 and over; (ii) vitamin D deficiency or insufficiency; and (iii) no disease with poor prognosis in the short term. Exclusion criteria were (i) premenopausal females; (ii) individuals with a cognitive impairment that would not allow them to complete the study; and (iii) participation in a clinical trial during the three months preceding the entry into the study.

Study design

A cross-sectional study design was used to examine the effects of insufficient or deficient levels of vitamin D on MetS risk factors, depression, and QoL. Postmenopausal women aged 50 and over were visited on two separate occasions. After verbal information was given about the study at the first visit, the written consent of the women, who met the inclusion criteria, was obtained. Then for biochemical analysis, blood samples were collected from each participant. The second part of the study was proceeded with women with vitamin D levels below 30 ng/mL. At the second visit, the subjects were asked to fill in questionnaires to assess their physical activity, sun exposure, QoL, and depression. MetS was determined according to the International Diabetes Federation (IDF) diagnostic criteria (IDF, 2006), including abdominal obesity (WC ≥ 80 cm) plus two of the following criteria: hyperglycemia (fasting blood glucose ≥ 100 mg/dL), hypertriglyceridemia (TG ≥ 150 mg/dL), HDL-C < 50 mg/dL, and hypertension (BP ≥ 130/85 mmHg). In addition, WC and BP were both measured following the relevant standards.

Procedures

Questionnaires

Health Status Questionnaire: This is a screening questionnaire used to check for the sociodemographic characteristics of individuals, inclusion criteria or any health issues that might impact a study's findings.

Sun Exposure Questionnaire: The level of sun exposure and the capacity of clothing to inhibit vitamin D synthesis were determined using a validated questionnaire (Atli, Gullu, Uysal & Erdogan, 2005).

The participants were divided into four groups based on the criteria used to determine their level of exposure to the sun (Group 1A-4A) and the ability of their garments to prevent sunlight (Group 1B-4B).

Group 1A: Women who were not exposed to direct sun.

Group 2A: Women who were exposed to the sun, except for the period between 11.00 and 15.00 hours.

Group 3A: Women who were continuously exposed to the sun between 11.00 and 15.00 hours.

Group 4A: Women who were in the sun all day.

Group 1B: Women whose daily clothes exposed their head, face, neck, arms, hands, and legs and who bathed in the sun wearing a bathing suit for at least a week in the summer.

Group 2B: Women whose daily clothes exposed their face, head, neck, arms, and legs.

Group 3B: Women whose daily clothes exposed their face, neck, hands, and occasionally arms.

Group 4B: Women who wore skin-covering daily clothes.

Physical Activity Questionnaire: The physical activity levels of the individuals were evaluated by using the International Physical Activity Questionnaire-short form (IPAQ-SF) (Craig et al., 2003). Severe physical activity duration, moderate physical activity duration, walking, and sitting time in the last seven days were questioned with the IPAQ. In the evaluation of physical activities, the criterion was that each activity should be done for at least 10 minutes a time. The results were used to calculate energy consumption in metabolic equivalent minutes per week (MET-min/week). According to the IPAQ scoring system, the MET min/week for a certain activity is calculated by multiplying the MET value of that activity (8.0 for severe, 4.0 for moderate, and 3.3 for walking) by the hours spent. Based on the IPAQ recommended cut-off values, the scores of each individual were divided into low, moderate, and high levels of physical activity.

QoL Questionnaire: QoL of the individuals was determined by the Short Form-36 Health Survey Questionnaire (SF-36). This form is composed of 36 questions in eight subscales, including general health perceptions, mental health, physical functioning, social functioning, vitality, bodily pain, and role limitations caused by physical health problems or emotional issues. Scores range from 0 to 100, where higher scores indicate better health (Koçyiğit, Aydemir, Fişek, Ölmez & Memiş, 1999; Ware & Sherbourne, 1992).

Depression Questionnaire: Psychological annoyance of the women was assessed by the 14-item Hospital Anxiety and Depression Scale (HADS). It consists of two subscales, anxiety and depression. Higher scores indicate more severe anxiety and depression (Zigmond & Snaith, 1983).

Waist circumference (WC) measurements

WC was measured in centimeters using non-stretchable plastic tape in lightly clothed, standing, and normally breathing subjects at a level midway between the lower rib margin and the iliac crest. Measurements were taken twice on the left side of the body, and the mean of the two values was used.

Blood pressure (BP)

Systolic (SBP) and diastolic blood pressures (DBP) were measured twice using a mercury sphygmomanometer in a sitting position on the right arm after a 10-minute rest. The average of the two measurements was used for analysis.

Laboratory measurements

Ten milliliters of blood were collected from the antecubital vein of each participant, in the seated position, according to the standard protocol, following fasting of at least eight hours for the biochemical assays. Blood specimens were transferred to the laboratory in an opaque container to prevent exposure to light and were centrifuged at 3500 rpm for 5 min. The serum was separated and analyzed immediately after being extracted. Serum 25(OH)D concentrations (deficient: < 20 ng/mL; insufficient: > 20 to < 30 ng/mL; normal: > 30 ng/mL) was analyzed using an immunofluorescence method on an Afias-i-chroma (BODITECH-South Korea) device. Fasting blood glucose, TG, LDL-C, and HDL-C levels were analyzed by a photometric method using biochemistry kits (Randox Laboratories Limited, United Kingdom) and a fully automatic autoanalyzer (2000, BT-Italy).

Statistical analysis

SPSS 21.0 software was used to analyze the data obtained in this study. Pearson's chi-square test was used for the comparison of categorical variables. One-way analysis of variance (ANOVA) was used for the comparison of numerical variables with a normal distribution (post-hoc Tukey test when variances were equal for paired comparisons and Tamhane's T2 test when variances were not equal), whilst the Kruskal-Wallis test was used for the comparison of numerical variables that did not show a normal distribution (Mann-Whitney U test for paired comparisons). Spearman's correlation test was used to determine the correlation between numerical variables. The statistical significance level was set at $p<0.05$.

Ethical considerations

The study protocol was confirmed by the Ethics Committee of Bursa *Uludag University,* Faculty of Medicine (Approval No.: 2019-4/17). Written and verbal assent was obtained from each woman who agreed to participate in the study.

RESULTS

A total of 150 women, 32 (21.3%) of whom had vitamin D insufficiency and 118 (78.7%) of whom had vitamin D deficiency, participated in the study. The distribution of the general features of the women accordingly to vitamin D insufficiency and deficiency is shown in Table 1. The mean age was 55.3 years, with a minimum of 50 and a maximum of 70 years. The vitamin D-deficient group was older than the vitamin D-insufficient group ($p=0.027$). The three groups were homogeneous for the following three variables: marital status ($p=0.194$), smoking habit (0.111), and alcohol consumption ($p=1.000$).

The serum 25 (OH) vitamin D concentration of the women was significantly correlated with the duration of sun exposure and clothing style ($p=0.000$) (Table 2).

A statistically significant association was found between the serum 25 (OH) vitamin D levels of women and their physical activity levels ($p=0.004$). Women with vitamin D deficiency were found to be less physically active (Table 3).

Statistically significant differences were found between the serum 25 (OH) vitamin D levels of the women and their mean general health ($p=0.022$), mental health ($p=0.021$), physical function ($p=0.007$), and vitality ($p=0.040$) scores from the SF-36 QoL scale sub-parameters. However, no statistically significant difference was found for the mean pain ($p=0.678$), social function ($p=0.531$), physical role limitation ($p=0.699$), and emotional role limitation scores ($p=0.286$) (Table 4).

The depression and anxiety scores of the women with vitamin D insufficiency were 5.28 ± 3.51 and 6.21 ± 3.11, respectively. On the other hand, the depression and anxiety scores of the women with vitamin D deficiency were 7.32 ± 3.08 and 8.27 ± 4.42, respectively. The serum 25(OH)D levels and mean

depression (p=0.008) and anxiety (p=0.028) scores of the women were determined to significantly differ (Table 5).
According to IDF criteria, the risk of MetS exists in 18.8% of women with vitamin D insufficiency and 46.6% of women with vitamin D deficiency. Thereby, the risk of MetS was more common in the women with vitamin D deficiency (p=0.004). WC (p=0.001), BP (p=0.008), and fasting blood glucose levels (p=0.034) were higher in the vitamin D-deficient group. HDL-C levels (p=0.009) were higher in the group with vitamin D insufficiency. There was no significant difference between the two groups for triglyceride levels (p=0.659) (Table 6).

Table 1. The distribution of the general characteristics of the postmenopausal women based on vitamin D deficiency and insufficiency.

General features	25(OH)D level (ng/mL)						
	< 20 (n = 118)		20-30 (n = 32)		Overall (n = 150)		
	n	%	n	%	n	%	P
Aged							
50-54	67	56.8	24	75.0	91	60.7	0.153
55-59	24	20.3	5	15.6	29	19.3	
60-64	14	11.9	3	9.4	17	11.3	
65-70	13	11.0	0	0.0	13	8.7	
Mean age (years±SD)	55.72±5.31		53.59±3.90		55.26±5.11		
Min-max	50-70		50-63		50-70		0.027
Marital status							
Married	104	88.1	31	96.9	135	90.0	0.194
Divorced/widow	14	11.9	1	3.1	15	10.0	
Smoking habit							
Smoker	35	29.7	5	15.6	40	26.7	0.011
Non-smoker	83	70.3	27	84.4	110	73.3	
Alcohol consumption							
Drinker	7	5.9	1	3.1	8	5.3	1.000
No-drinker	111	94.1	31	96.9	142	94.7	

Table 2. The association of vitamin D status with sun exposure and clothing style in postmenopausal women.

Sunlight exposure	25(OH)D level (ng/mL)						
	< 20 (n = 118)		20-30 (n = 32)		Overall (n = 150)		
	n	%	n	%	n	%	P
Duration of sun exposure							
Group 1A	110	93.2	12	37.5	122	81.3	0.000
Group 2A	8	6.8	20	62.5	28	18.7	
Group 3A	0	0	0	0	0	0	
Group 4A	0	0	0	0	0	0	
Clothing style							
Group 1B	0	0.0	5	1.1	5	3.3	0.000
Group 2B	39	33.1	19	59.4	58	38.7	
Group 3B	5	4.2	0	0	5	3.3	
Group 4B	74	62.7	8	25	82	54.7	

Table 3. The association of vitamin D status and physical activity.

Physical activity	25(OH)D level (ng/mL)						
	< 20 (n = 118)		20-30 (n = 32)		Overall (n = 150)		
	n	%	n	%	n	%	P
Highly active (≥ 3000 MET-min/week*)	0	0	3	9.4	3	2	0.004
Moderately active (600-3000 MET-min/week*)	82	69.5	23	71.9	105	70	
Low active (< 600 MET-min/week*)	36	30.5	6	18.8	42	28	

*Metabolic equivalent minutes per week

Table 4. The association of vitamin D status and quality of life (QoL.

SF-36 QoL scale*	25(OH)D level (ng/mL)				
	< 20 (n = 118)		20-30 (n = 32)		
	X±SD	Min-max	X±SD	Min-max	P
General health	55.46±18.73	5-90	63.12±16.10	10-85	0.022
Mental health	56.40±20.50	4-100	66.15±12.69	56-96	0.021
Physical functioning	70.46±26.07	10-100	84.06±15.78	40-100	0.007
Social functioning	77.86±21.01	25-100	80.46±20.56	37.5-100	0.531
Energy level/vitality	48.51±19.50	0-90	57.03±17.45	30-95	0.040
Pain	68.91±25.89	0-100	72.73±15.80	50-100	0.678
Role constraints due to physical problems	66.10±42.55	0-100	74.21±30.77	0-100	0.699
Role constraints due to emotional problems	63.55±41.80	0-100	72.91±37.33	0-100	0.286

*Short Form-36 Health Survey Questionnaire (SF-36)

Table 5. The association of vitamin D status with depression and anxiety.

HAD scale*	25(OH)D level (ng/mL)				
	< 20 (n = 118)		20-30 (n = 32)		
	X±SD	Min-max	X±SD	Min-max	P
Depression	7.32±3.08	0-15	5.28±3.51	0-12	0.008
Anxiety	8.27±4.42	1-17	6.21±3.11	1-11	0.028

*Hospital Anxiety and Depression Scale

Table 6. The association of vitamin D status and metabolic syndrome based on IDF diagnostic criteria.

MetS* & components	25(OH)D level (ng/mL)						
	< 20 (n = 118)		20-30 (n = 32)		Overall (n = 150)		
	n	%	n	%	n	%	P
MetS (IDF)*							
Yes	55	46.6	6	18.8	61	40.7	0.004
No	63	53.4	26	81.3	89	59.3	
WC (cm)**							
≥ 80	113	95.8	25	78.1	138	92.0	0.001
< 80	5	4.2	7	21.9	212	8.0	
Triglyceride (mg/dL)							
≥ 150	38	32.2	9	28.1	47	31.3	0.659
< 150	80	67.8	23	71.9	103	68.7	
HDL-C (mg/dL)							
< 50	52	44.1	6	18.8	58	38.7	0.009
≥ 50	66	55.9	26	81.3	92	61.3	
BP (mm Hg)							
≥ 130/85	44	37.3	4	12.5	48	32.0	0.008
< 130/85	74	62.7	28	87.5	102	68.0	
Fasting blood glucose (mg/dL)							
≥ 100	37	31.4	4	12.5	41	27.3	0.034
< 100	81	68.6	28	87.5	109	72.7	

*Metabolic syndrome according to the diagnostic criteria of the International Diabetes Federation (IDF)
**Waist circumference

DISCUSSION

Serum vitamin D status has been studied on all continents and in many countries. Globally vitamin D deficiency and insufficiency affect more than one billion people (Tepper et al., 2016). Although also common among the elderly, pregnant women, adolescents, middle-aged adults, and even children, deficiency of vitamin D is more common in postmenopausal women, most probably as a result of the scarcity of natural food sources rich in vitamin D, inadequate exposure to sunlight, reduced vitamin D synthesis in the skin due to the aging process, decreased intestinal absorption, and natural hypoestrogenism in the postmenopausal period

(Cheng et al., 2014; Tayem, Alotaibi, Hozayen & Hassan, 2019; Valladares et al., 2019). It is estimated that 32.1% of postmenopausal women living in the European Union have vitamin D deficiency (<20 ng/mL). Besides, it was reported that the vitamin D deficiency status of postmenopausal women living in India, China, and the USA was 53.3%, 72.1%, and 53%, respectively (Tayem et al., 2019). Our study demonstrated that, of the female subjects, 21.3% and 78.8% had vitamin D insufficiency and deficiency, respectively. Our results were consistent with previous studies that showed a higher incidence of vitamin D deficiency in postmenopausal women.

Smoking exposes individuals to a mixture of dangerous chemicals that are involved in the pathogenesis of various diseases (Mousavi, Amini, Heydarpour, Chermahini & Godderis, 2019). Specifically, the association of smoking with serum vitamin D concentrations is not clear (Jiang et al., 2016). Some studies (Jiang et al., 2016; Lokki, Heikkinen-Eloranta, Öhman, Heinonen, Surcel & Nielsen 2020) suggest that smokers have lower serum vitamin D levels than non-smokers, while other studies (Grimnes et al., 2010; Lee & Longo, 2016) suggest the opposite. On the other hand, some researchers have not observed any significant association between these two parameters (Kimlin et al., 2007; McKinney, Breitkopf, Berenson, 2008). The present study showed a important association between the vitamin D vitamin status of the subjects and their smoking habits. Our findings on the smoking status of women is consistent with previous studies that have shown smoking to be associated with lower serum vitamin D levels in postmenopausal women (Cheng et al., 2014).

Excessive alcohol consumption can alter serum vitamin D status. Various researches have reported that chronic alcohol consumption may be related with a decrease in serum 25(OH)D levels (Carlson et al., 2017; Wijnia et al., 2013). They have revealed that low vitamin D concentrations in alcohol-dependent individuals can be caused by many factors, including limited sunlight exposure, malnutrition, malabsorption, and a direct effect of alcohol on vitamin metabolism (Wijnia et al., 2013). In our study, no significant relationship was found between the vitamin D status of women and their alcohol consumption habits. It is considered that this may be due to only few of the subjects having declared to drink alcohol.

Worldwide, dietary vitamin D intake has been reported to be below the recommendations. Because very few foods, such as fatty fish such as salmon, sardines, fish liver oil, mushrooms and eggs, are rich in vitamin D and these foods are not part of the daily diet. Therefore, since the most effective source of vitamin D is sunlight, less exposure to sunlight is considered the main determinant of vitamin D deficiency. This study showed that 37.5% of the women with vitamin D insufficiency and 93.2% of the women with vitamin D deficiency were not exposed to the sun. Furthermore, a skin-covering clothing style due to environmental, psychological, religious and cultural factors, also affects vitamin D synthesis in the skin (Al-Yamata, AlOtaibi, Al-Bader & Al-shoumer, 2019). The association of low vitamin D levels with skin-covering garments has been shown in Turkey and also some middle-east countries with adequate sunlight, including Egypt, Jordan, Kuwait, and Lebanon. Several reports demonstrated that skin-covering garments wearing was associated with low vitamin D levels (Al-Yamata et al., 2019; Buyukuslu et al., 2014). The present study showed that 25% of the women with vitamin D insufficiency and 62.7% of the women with vitamin D deficiency dressed in skin-covering garments. These findings suggest that wearing skin-covering garments and reduced exposure to sunlight may be major risk factors for vitamin D deficiency.

The findings of our study show that as physical activity decreases, serum vitamin D levels decrease. Decreased physical activity is associated with lower vitamin D levels, as decreased physical activity outdoors often results in decreased skin exposure to sunlight (Brock et al., 2010; Wang et al., 2018). The findings of this study tend to support this association. Similarly, in a previous study conducted in Turkish women with osteoporosis, those with vitamin D levels below 20 ng/mL were found to have significantly lower physical activity levels than those with vitamin D levels above 20 ng/mL (Basaran, Guzel, Coskun-Benlidayi & Güler-Uysal, 2007). Another study it was reported that increased physical activity is related with decreased vitamin D deficiency/insufficiency frequency (Kaur et al., 2019). Thus, exercise can maintain the vitamin D status and increase skin exposure to sunlight (Brock et al., 2010). A sedentary lifestyle and attending indoor courses reduce the exposure of women to sunlight. Therefore, increasing physical activity would induce positive effects and increase serum vitamin D levels.

It is necessary to assess treatments for their potential biological effects and consequences for an individual's QoL. Many scales have been developed to evaluate the QoL for general and disease-specific purposes (Hoffmann, Senior & Mager, 2015). Recent studies have shown a positive correlation between QoL and vitamin D levels, yet available data is inconsistent due to differences in the populations studied and the quality-of-life assessment scales used (Civelek, Pekyavas, Cetin, Cosar & Karatas, 2014; Ecemis & Atmaca, 2012; Feng et al., 2016; Motsinger, Lazovich, MacLehose, Torkelson & Robien, 2012). Nevertheless, the findings of our study also support this positive correlation. In the present study, the mean physical function, energy level/vitality, general health scores, and mental health scores of SF-36 QoL scale sub-parameters were found to be significantly lower in the women with vitamin D deficiency. However, no statistically significant difference was found for the pain, social function, role limitations caused by emotional or physical problems. This was attributed to the women participating in the present study being 50 and over, as well as to their accompanying health problems due to advancing age.

Depression is a common mental illness, which is prolonged or recurring, and significantly reduces an individual's ability to function in daily life (Huang, Wang & Hu, 2016). It is conjectural that more than 300 million people globally are affected by depression (Vellekkatt & Menon, 2019), and one in four older adults has a mental illness such as anxiety or depression (Motsinger et al., 2012). It is also increasingly recognized that symptoms of depression are present at subclinical levels in healthy populations (Huang et al., 2016). Many researches have shown that low level of vitamin D are related with the risk of depression (Boulkrane et al., 2020; Ersoy & Ersoy, 2017; Musazadeh et al., 2023). Similar to literature reports, the present study revealed significantly higher depression and anxiety scores in vitamin D deficient women. The presence of vitamin D receptors in multiple areas in the brain, which affect depression, and significant immunoreactivity for 1α-hydroxylase in most of these regions, further support this association (Ersoy & Ersoy, 2017).

MetS is a cluster of clinical conditions posing a cardiometabolic risk, including obesity, insulin resistance, hypertension, and dyslipidemia (Alaklabi & Alsharairi, 2018; Wang et al., 2018). The etiology of MetS is complex and affected by several factors, including smoking, alcohol intake, increasing age, unhealthy diet, obesity, and lack of exercise. Vitamin D deficiency can also be considered as a risk factor for MetS (Alaklabi & Alsharairi, 2018). Many researches have shown a reverse relationship between MetS and serum vitamin D levels (Al-Dabhani et al., 2017; Liu et al., 2020; Wang et al., 2018). Similarly, in this study, we found that vitamin D deficiency was importantly related with an increased risk of MetS in postmenopausal women, based on IDF criteria.

The preceding research results on the relation of serum vitamin D levels with MetS components are inconsistent. While some researches have shown vitamin D levels to be associated with all MetS (Yahyaoui et al., 2019) components, some others have revealed an association with some MetS components (Liu et al., 2020; Sarmiento-Rubiano et al., 2018). In the current study, it was observed that WC, BP, HDL-C levels, and fasting blood sugar levels, all which are components of MetS, were associated with vitamin D deficiency. However, no significant association was determined for triglyceride level, another component of MetS. The findings of this study support the hypothesis that heavily obese individuals are at risk for serum vitamin D deficiency. Different theories have been proposed to explain the association between obesity and vitamin D deficiency. Firstly, it has been suggested that obese individuals are less exposed to sunlight due to limited outdoor activity arising from social acceptance problems and have limited vitamin D synthesis in the skin due to a more loose clothing style that covers a large part of their body compared to slim individuals. In addition, vitamin D is an essential determinant of serum parathyroid hormone (PTH) level. High concentrations of PTH increase lipogenesis and may contribute to weight gain. Other related hypotheses are based on the assumption that hepatic steatosis, which develops with obesity, decreases 25(OH)D synthesis in the liver, and high circulating leptin and interleukin-6 levels inhibit 25(OH)D synthesis by affecting vitamin D receptors. In addition, vitamin D metabolites can be retained in adipose tissue. Therefore, it has been suggested that cholecalciferol, taken in the diet or synthesized in the dermal, is partially sequestered by body fat before being transported to the liver for initial hydroxylation. Thus, obesity may be a direct result of vitamin D deficiency and/or a cause of vitamin D deficiency (Pereira-Santos et al., 2015).

In several different studies, researchers have shown a relationship between low vitamin D status and high blood pressure (hypertension) (Latic & Erben, 2020). The deficiency of vitamin D can induce hypertension by increasing the activity of the renin-angiotensin system, causing endothelial dysfunction and leading to hyperparathyroidism (He & Hao, 2019; McMullan, Borgi, Curhan, Fisher & Forman, 2017).

Vitamin D also regulates glucose metabolism by enhancing insulin secretion and action. Human and animal studies have shown a strong correlation between decreased insulin secretion and vitamin D deficiency (Wimalawansa, 2018). Some researchers have found that vitamin D levels are significantly correlated with blood lipid levels, positively correlated with HDL-C levels, and negatively associated with triglyceride levels (Liu et al., 2020). In our study, we found a significantly inverse association between vitamin D levels and HDL-C levels. But, no relation was observed with triglyceride levels. While the effects of vitamin D on lipid metabolism are known, the potential mechanisms are yet to be elucidated. In various studies, it has been reported that vitamin D plays indirect and direct roles in the lipid profile by affecting lipid metabolism (Faraji & Alizadeh, 2020). Factors such as age, gender, menopausal status, exposure to less sunlight, skin-covering garments, and lower physical activity level may cause differences between studies and complicate the interpretation of their results.

This study has several limitations. First, because the study design was cross-sectional, a cause-effect relationship could not be established between serum vitamin D and MetS, QoL, and depression. Second, the effect of seasonal factors on the results could not be evaluated because the study was conducted in the winter season. Third, we did not have detailed food consumption records to calculate dietary vitamin D intake. Finally, this study is a single-center study with a relatively small sample size. The relationship we found between vitamin D and MetS, QoL and depression is valid for postmenopausal women and may differ in different gender, age and ethnic groups. Therefore, we cannot generalize our results. Therefore, larger, prospective studies are needed on this subject.

As a result, the findings of the present study support a positive association between vitamin D deficiency and the presence of MetS in postmenopausal women. MetS components, such as WC, fasting blood glucose levels, HDL-C, and BP, were detected to be related with serum vitamin D levels. Decreased exposure to sunlight, skin-covering, concealing clothing style due to religious factors, and decreased physical activity limit vitamin D synthesis in the skin. Serum vitamin D level and the health-related QoL were found to be positively correlated. Sufficient vitamin D levels can contribute to the protection of the musculoskeletal system and increase the quality of life.

Serum vitamin D levels must be measured regularly in postmenopausal women to maintain optimal levels. To remedy vitamin D deficiency and insufficiency, it is crucial to prioritize and implement strategies such as increasing exposure to sunlight, consuming natural foods high in vitamin D, using nutritional vitamin D supplements, and employing dietary supplementation. In order to establish optimal vitamin D levels in society, the Ministry of Health, the Ministry of Agriculture and Forestry, and health professionals need to collaborate.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Author Contributions

Plan, design: SCK, AY; **Material, methods and data collection:** SCK, GS, SB; **Data analysis and comments:** SCK, AY, GS, SB; **Writing and corrections:** SCK, AY.

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