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Vitamin D Status of the Adult Population in Bali and Its Relationship to Anthropometry and Body Fat: A Cross-Sectional Study

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Abstract Introduction: In both children and adults, obesity is frequently correlated with low levels of vitamin D. The metabolic syndrome and insulin resistance have both been linked to people with low vitamin D levels. Low vitamin D levels and a higher prevalence of vitamin D deficiency were found in obese individuals, according to several epidemiological and clinical research. Objective: This study aims to determine the status of vitamin D in the population of Buleleng, Bali, and its relationship with body fat composition. Method: Cross-sectional research with a total of 50 subjects who satisfied the inclusion and exclusion criteria was conducted. Data analysis used independent t-test and one-way ANOVA to test the differences between groups. The Pearson correlation test is used to analyze the relationship between variables. Result: Of all these subjects, 7 people (14%) had normal serum levels of vitamin D (25 (OH) D), 15 people (30%) were insufficient, and 28 people (56%) were deficient. Analysis of vitamin D levels in each subgroup, such as sex, waist circumference (WC), visceral fat, subcutaneous fat, and body mass index (BMI), found significant differences in vitamin D levels ($p < 0.05$). Although there was no significant difference in vitamin D levels in the normal, high, and very high body fat groups ($p=0.063$), there was a significant inverse relationship between vitamin D levels and body fat ($p=0.000$). There is also a significant inverse correlation between levels of vitamin D and BMI, body weight, WC, body fat, visceral fat, and subcutaneous fat ($p<0.05$). Conclusion: The prevalence of vitamin D deficiency is still high. Vitamin D levels significantly inversely correlate with BMI, body weight, waist circumference, body fat, visceral fat, and subcutaneous fat.

Keywords Obesity, Vitamin D, BMI, Waist Circumference, Body Fat

1. Introduction

Low levels of vitamin D (VD) are frequently linked to obesity in both children and adults. This condition is consistent across different ethnic and geographical regions [1]. Individuals with high VD levels have been linked to metabolic syndrome and insulin resistance [2]. Due to the increasing prevalence of obesity and VD deficiency, these two global health issues have become some of the most prominent examples of the rising tide of public health concerns. It has been estimated that by 2035, around 370 million individuals will be obese, and around 10 million will suffer from VD deficiency [3]. Studies conducted on various populations in the U.S. revealed that the incidence of VD deficiency among obese individuals was 3.09 times higher than controls. On the other hand, among inactive individuals, the figure was two times higher [4]. Meanwhile, the prevalence of VD deficiency in China is 69%, and in South Korea, it is 47% for men and 65% for women. Various predictors that cause this are lack of physical activity, living in urban areas, and a family history of cardiovascular disease (CVD) and diabetes [5]. The meta-analysis and systematic review findings revealed that the VD deficiency rate in obese individuals was 35% higher than in controls [6]. According to Octavius et al [7], the prevalence of VD deficiency in Indonesian pregnant women is 63%. In Indonesia, pregnant women run the risk of developing VD deficiency. This condition can result in a variety of consequences, including early labor and preeclampsia. Pregnant women should get the necessary vitamin D supplements. In Indonesia, VD deficiency affects 90% of newborns and 13% of infants aged 6 months [8]. There is currently no evidence supporting the link between VD deficiency and obesity in Indonesia.

Although the association between VD concentrations and obesity is well recognized, the precise processes by which this link may be explained remain unknown. Obese people had lower VD levels and a higher frequency of VD deficiency, according to several epidemiological and clinical research. A lack of VD can result in a variety of diseases, including cardiovascular morbidity, metabolic syndrome, and type 2 diabetic mellitus (T2DM) [9]. VD deficiency does not only occur in obesity but can also be found in postmenopausal women. Research on 78 postmenopausal women in Granada, Spain, found that 80% of the subjects had VD deficiency [10]. There is a negative correlation between serum VD levels and body fat percentage ($p = 0.010$), BMI ($p=0.0420$), WC ($p=0.003$), and waist-to-hip ratio ($p<0.001$) in obese Chinese adults living in urban areas [11]. The study, which was conducted on 154 men aged 20 to 40, showed that those with low serum VD levels were more prone to have an enlarged waist circumference. Dual-Energy X-ray Absorptiometry (DEXA) was used to determine an inverse relationship between serum VD levels and truncal fat mass [3]. However, a study of 379 children aged 2-14 years in Iran found that there was a significant but weak inverse correlation between VD deficiency and BMI, but not the WC. This study also found that a prevalence of VD deficiency was 40.6% and insufficiency was 11.9% [12]. A cross-sectional study conducted in Singapore on 114 subjects (59 males and 55 females) who measured body fat using three techniques, namely bioelectrical impedance analysis, BOD POD body composition measurement, and DEXA, discovered a negative relationship between VD deficiency (20 ng/ml) and body fat percentage [13]. Another study found an inverse correlation between VD deficiency and most anthropometric tests (WC, waist-to-hip ratio, body fat percentage) except for BMI [14, 15]. Different results were found by Karatas et al, who conducted a study on 287 subjects, of which 73 subjects were non-obese as controls. In that investigation, a strong inverse connection was discovered between VD deficiency and BMI. However, no significant association was found between the low level of VD and the body fat percentage or WC [16].

The results of anthropometric and body fat assessments remain inconsistent when linked to VD deficiency. The link between VD status and obesity may also vary depending on the ethnicity and gender of the individuals [15]. In Bali, Indonesia, no research has been conducted that describes VD status. Also, there has never been a study linking VD deficiency with anthropometry and body fat. This research aimed to determine and explain the VD status of the population in Bali, as well as its relationship with anthropometry and body fat composition. This research will also look into the link between VD status, blood glucose levels, and liver function.

2. Method

A cross-sectional design with correlational quantitative descriptive research was used in this study. The subjects in this study were healthy and obese residents of Buleleng Regency. Buleleng is one of the areas in Bali. Subjects are chosen using multi-stage random sampling that fits the inclusion and exclusion criteria. The inclusion criteria for this study were (1) male or female aged 20-50 years, (2) willing to take part in the study and give their informed consent, (3) cooperative and residing in Buleleng. The study's exclusion criteria were (1) pregnant women, (2) ascites, (3) currently taking vitamin D routinely, (4) refusing to be a subject, (6) uncooperative, (7) not having a history of hypertension. This study includes 50 samples. This sample is by the minimum sample selection. The number of samples (n) in this study was as follows: n = 15-20 samples per independent variable [17]. The minimum sample size is 20 because there is only one independent variable.

Vitamin D status uses criteria from the Endocrine Society, less than 20 ng/ml (<50 nmol/l) deficiency, 20-30 ng/ml (50-75 nmol/l) insufficiency, and >30 ng/ml (>75 nmol/l) sufficiency. For waist circumference based on the criteria specified by the Indonesia Ministry of Health, the risk of mortality increases and abdominal obesity if the males have a waist circumference > 90 cm while females have a waist circumference > 80 cm. BMI uses classification according to Asia Pacific Guidelines: underweight (< 18.5), normal (18.5-22.9), overweight (23-24.9), and obese (≥ 25).

Examine 25 (OH) D levels using the fluorescence immunoassay method with the Ichroma II instrument. The SGOT/SGPT, liver function test, uses the IFCC2 method, without pyridoxal-5-phosphate 370C, with the automated biochemistry analyzer Mispa CX-4 Analyze. Blood glucose examination uses the glucose oxidase-PAP method with the Agappe Mispa CX 4 Autolyzer. Measuring body composition and weight using the Tanita BC-587 body fat analyzer [18]. Height was measured using a GEA HT721 height meter and waist circumference using an Onemed OD 235 measuring tape. Blood tests were carried out at the Buleleng General Hospital.

For continuous data, the descriptive analysis included mean and standard deviation, and for categorical data, it included percentages, which was used to estimate vitamin D status in obese and normal-weight patients. The Pearson correlation test was performed to examine the association between serum vitamin D levels and BMI, waist circumference, body fat composition, blood sugar, and liver function. Different tests used independent t-test and one-way ANOVA. IBM SPSS 24 was used to analyze the data.

The Research Ethics Commission of the Faculty of Medicine at Ganesha University of Education has given this study ethical approval No: 034/UN48.24.11/LT/2023.

3. Result

A cross-sectional study on 50 obese and healthy population subjects was conducted in Buleleng, 26 male (52%) and 24 female (48%). Of all these subjects, 7 people (14%) had normal VD level, 15 people (30%) were insufficient and 28 people (56%) were deficient. For body fat percentage, only 4 people (8%) had normal body fat, 19 people (38%) had high body fat, and 27 people (54%) had very high body fat. For visceral fat, 13 people (26%) had normal visceral fat, 16 people (32%) had high visceral fat, and 21 people (42%) were very high. Of the body mass index variables, 9 people (18%) had a normal body mass index, 13 people (26%) were overweight, and 28 people (56%) were obese. For waist circumference, 6 people (12%) had a low risk of metabolic disease, and 44 (88%) had a high risk. Table 1 shows data on subject characteristics and vitamin D level.

Table 2 describes each variable: age, body weight, BMI, body fat, subcutaneous fat, visceral fat, WC, SGOT, SGPT, blood glucose, and vitamin D (25 (OH)D) levels. The lowest VD level found in this study was 10.40 ng/ml, and the highest was 38.40 ng/ml, with a mean of 20.34 and a standard deviation of 6.94

Table 3 compares VD levels according to age, body fat, sex or gender, visceral fat, BMI, WC, and occupation. The levels of VD were measured in this study, aged 20-29 years (18.60 ± 6.32), aged 30-39 years (20.33 ± 5.53), and aged 40-50 (22.59 ± 8.92) with a P value of 0.279 meaning that there was no distinction VD levels according to age. Meanwhile, according to gender, the levels of VD in men (26.69 ± 8.11) and in women (17.80 ± 4.25), with a p-value (0.011), mean that there is an average difference in VD levels between male and female subjects. According to the body fat variable, subjects who have normal body fat have levels of VD (27.89 ± 7.83), whereas subjects who have high levels of body fat (20.35 ± 7.62), and very high levels of body fat (19.22 ± 5.78), with a p-value of 0.063 meaning that there is no difference in the average VD levels in terms of body fat. Subjects who have normal visceral fat have average VD levels (26.28 ± 8.46), those who have high visceral fat (17.26 ± 3.78), and those who have very high visceral fat (19.00 ± 5.65), with p-value 0.001, meaning that from the visceral fat category the VD levels differ between the subgroups. Then, a post hoc test was carried out and found significant differences between subjects with normal visceral fat and subjects who had high (p = 0.007) and very high (p = 0.033) visceral fat.

Table 1. Vitamin D status and subject characteristics

Characteristics	n	Percentage (%)
Sex		
Male	26	52
Female	24	48
Vitamin D		
Sufficiency	7	14
Insufficiency	15	30
Deficiency	28	56
Body Fat		
Normal	4	8
High	19	38
Very High	27	54
Visceral Fat		
Normal	13	26
High	16	32
Very High	21	42
Body Mass Index		
Normal	9	18
Overweight	13	26
Obese	28	56
Waist Circumference		
Low Risk	6	12
High Risk	44	88

Table 2. Description of each variable

1	Minimum	Maximum	Mean±SD
Age	20	49	33.92 ±8.66
Body Weight	49.40	156	84±21.48
Height	143.50	183.50	163.67±10.12
Body Mass Index	19.90	57.70	31.37±7.59
Body Fat	15.80	59.25	33.84±7.88
Subcutaneous Fat	10.90	53.40	28.31±10.14
Visceral Fat	3.00	35.60	14.72±7.35
Waist Circumference	74.00	133	101.22±13.67
SGOT	10.30	65.90	23.90±10.87
SGPT	9.90	134.10	34.74±24.98
Blood Glucose	84	147	106.58±6.04
25 (OH) D	10.40	38.40	20.34±6.94

Table 3. Comparison of vitamin D levels according to age, sex, body fat, BMI, WC, visceral fat, and occupation

Variable	Subgroup	Mean±SD	P value
Age (year)	20-29	18.60±6.32	0.279
	30-39	20.33±5.53	
	40-50	22.59±8.92	
Sex	Male	26.69±8.11	0.011*
	Female	17.80±4.25	
Body Fat (%)	Normal	27.89±7.83	0.063
	High	20.35±7.62	
	Very High	19.22±5.78	
Visceral Fat	Normal	26.28±8.46	0.001**
	High	17.26±3.78	
	Very High	19.00±5.65	
Body Mass Index (kg/m^2)	Normal	29.91±6.02	0.000**
	Overweight	17.13±4.97	
	Obese	18.75±5.26	
Waist Circumference (cm)	Low risk	30.02±4.73	0.000*
	High Risk	19.02±6.12	
Occupation	Housekeeper	23.55±7.43	0.172
	Student	15.98±3.35	
	Office worker	21.07±7.65	
	Lecture	20.30±4.53	
	Cleaning Service	18.92±5.65	
	Self Employee	24.12±8.59	

significance value (p <0.05), t-test*, one-way Anova**

When viewed from the body mass index variable, subjects with normal BMI have levels of VD (29.91 ± 6.02), overweight (17.13 ± 4.97), and obese (18.75 ± 5.26), with a p-value <0.0001 meaning that there is a significant difference in the VD levels of the three categories. Then, post hoc tests were carried out and found significant differences between subjects with normal BMI and overweight (p <0.0001) and obese (p<0.0001). However, there was no significant difference between overweight and obese participants (p=1,000). For the waist circumference subgroup, the average VD level in low-risk subjects was (30.02 ± 4.73) and high risk was (19.02 ± 6.12), with p-value <0.0001, meaning that there was a significant difference between the two groups. For the occupation subgroup, subjects who work as housekeepers have an average level of VD (23.55 ± 7.43), student (15.98 ± 3.35), office worker (21.07 ± 7.65), lecture (20.30 ± 4.53), cleaning services (18.92 ± 5.65), and self-employee (24.12 ± 8.59), with a p-value of 0.172 implying that there is no change in VD levels seen from occupation.

The results of the association between VD levels and body composition, liver function, and blood glucose are shown in Table 4. Using the Pearson correlation, the results showed that the correlation between VD levels and BMI (p=0.004), body weight (p=0.014), waist circumference, body fat, visceral fat (p = 0.036), and subcutaneous fat (p <0.0001) was significant. Meanwhile, the variables of height, SGOT, SGPT, and blood glucose were not significantly related.

Table 4. Relationship between vitamin D levels and BMI, height, body weight, WC, body fat, visceral fat, and subcutaneous fat, SGOT, SGPT, blood glucose

Variable	r	P value
Body Mass Index (kg/m^2)	-0.405	0.004*
Body Weight (kg)	-0.347	0.014*
Height (cm)	0.109	0.451
Waist Circumference (cm)	-0.503	0.000*
Body Fat (%)	-0.570	0.000*
Visceral fat	-0.297	0.036*
Subcutaneous Fat (%)	-0.509	0.000*
Blood Glucose (mg/dL)	-0.101	0.487
SGOT (U/L)	0.005	0.971
SGPT (U/L)	-0.105	0.470

significance value (p <0.05), Pearson correlation test*

4. Discussion

Based on the findings of the research, it can be seen that the incidence of deficiency of VD levels in Bali, especially in Buleleng Regency, is quite high. Of the 50 subjects studied, 43 (86%) had a deficiency in serum levels of VD. The average level of VD in this study was (20.34 ± 6.94) with a minimum level of 10.40 ng/ml and a maximum of 38.40 ng/ml. After conducting a subgroup analysis, it was found that the average VD level in overweight and obese subjects was lower than in subjects with normal BMI, and a significant difference was found (p<0.0001). Significant differences were also found in subjects with normal waist circumference and abdominal obesity (p<0.0001). Our study is in accordance with the meta-analysis and systematic review conducted by Santos et al [6], which found that the prevalence of VD deficiency was 35% greater in obesity and 24% in overweight. A high prevalence of VD deficiency in obesity was also discovered by another study in Bangladesh [9]. VD deficiency also tends to happen in populations with higher BMI than in populations in the United Kingdom, Finland, Germany, Sweden, Canada, and the United States [19]. Vitamin D deficiency is 3.36 times more likely to occur in obese subjects compared to those with a normal BMI. Asian race and black skin have the greatest possibility of experiencing vitamin D deficiency compared to other races [20]. In obese abdominal patients in Kuala Lumpur, the incidence of VD deficiency is 2.57 times greater than that of non-obese [21]. The low VD levels in obesity may be caused by the volumetric dilution theory; VD is distributed over a larger volume in obese people, namely fat, liver, and muscle, so that the 25(OH)D serum concentration becomes low [1]. Sequestration in adipose tissue can also cause VD deficiency. In the mechanism of sequestration in adipose tissue, VD, as a fat-soluble vitamin, is entrapped or sequestered in adipose tissue. VD metabolism is increased in obesity, possibly due to increased uptake by adipose tissue [22].

This study also found significantly different levels of VD (p=0.011) between male subjects (26.69 ± 8.11) and females (26.69 ± 8.11). This is consistent with studies by Moy and Bulgiba [21] on adult subjects in Kuala Lumpur, which found that VD deficiency is related to gender, wherein women are likely to experience VD deficiency 8.68 times greater than men. A study in healthy Egyptian women concluded that women who wore headscarves had an average lower VD content (16.7 ng/dl) than women who did not wear headscarves (23 ng/dl). The study also found that lack of sun exposure led to VD deficiency. The study also discovered a high prevalence of VD deficiency [23]. Research on women in Brazil at the age of 35 years and over found that women exposed to more sunlight tend to have higher VD levels [24]. The lower levels of VD in females compared to males in this study may be due to a combination of factors, including the fact that Balinese females cover their skin to prevent it from darkening when exposed to the sun. However, no research has been conducted in Indonesia or Bali on this topic. However, women in China also tend to maintain white skin by protecting direct sunlight exposure to the skin by wearing sunscreen and clothing [25]. A higher prevalence of VD deficiency in women than in men was discovered in Singaporean research. This is probably not due to how they dress but possibly due to the use of sunscreen in women, the increased sequestration of VD in adipose tissue and the higher body fat percentage in women [13].

This study also found significant p<0.05 differences between each subgroup's visceral fat, BMI, and WC variables. Although in the subgroup analysis, no differences existed in the percentage of body fat in each group, a significant correlation was found between VD levels and body fat (p<0.0001). There was a significant correlation between VD levels and BMI, body weight, WC, visceral fat, and subcutaneous fat (p<0.05). According to a study conducted in Lebanon on 344 subjects aged 20-74 years, 68.3% had VD levels <30 ng/ml. Additionally, there was a significantly negative correlation between VD levels, body fat, and WC, although there was no correlation with BMI [15]. A population study in Italy using 200 subjects discovered a significantly inverse correlation between VD levels and WC but not BMI [26]. Several hypotheses cause low levels of VD in obesity, such as a diet lacking in VD, a sedentary lifestyle, and decreased 25 (OH) D synthesis in the liver in obesity caused by secondary hyperparathyroidism. The increase in parathyroid hormone (PTH) increases lipogenesis caused by the influx of calcium into adipocytes. Volumetric dilution, sequestration of VD in adipose tissue, and increased VD catabolism in adipose tissue are other factors that contribute to low VD in obese people [26,27,28].

The weakness of this research was that a cross-sectional study was used to conduct it, where measurements were taken at one time, so it could not explain the causal relationship between variables. The sample used is also quite small, so further research is needed with a larger sample size. A larger sample coverage is needed, not only in one district but in the population of one province. In this study, nutritional intake or diet and sun exposure were also not measured in the subjects. Examination of body fat only uses BIA, even though the gold standard examination of body fat is by magnetic resonance imaging, computed tomography, and dual-energy x-ray absorptiometry, but these examinations are impractical, expensive, and risky radiation.

The benefit of this research is that it is the first study conducted in Bali, Indonesia, to examine the VD status of both obese and normal-weight individuals, and it also looked into the correlation between VD status and body composition, blood sugar levels, and liver function. To address the issue of VD deficiency in the community, both in obese and normal-weight people, and to lower the risk of disease brought on by VD deficiency, the government can use this research as a resource, especially in the field of public health.

5. Conclusions

This study indicates that there is still a high incidence of VD deficiency. Out of 50 subjects, only 7 subjects (14%) have sufficient levels of VD. Average VD levels were lower in women than men, with a significant difference. There is a significantly inverse relationship between VD levels and BMI, body weight, WC, body fat, visceral fat and subcutaneous fat. Further research is needed using a larger sample and also associated with nutritional intake and sun exposure. It would be better to use a body fat examination with a gold-standard examination

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