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ASSOCIATION BETWEEN VITAMIN D DEFICIENCY AND CENTRAL OBESITY AMONG SUDANESE ADULTS: A CROSS-SECTIONAL STUDY

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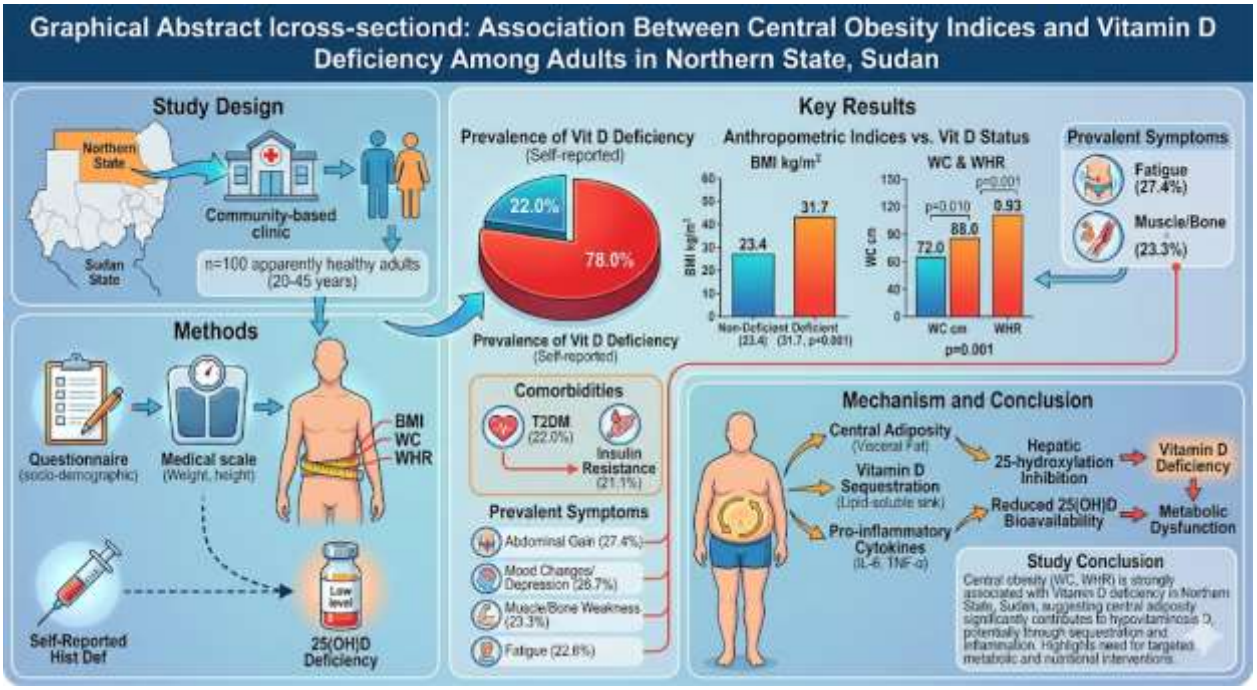
ABSTRACT

Background: Hypovitaminosis D and central obesity are major interconnected public health concerns in the Middle East and North Africa (MENA) region. Conventional anthropometric measurements may not adequately capture regional variations in visceral fat distribution and their relationship with vitamin D status.

Objective: To assess the association between clinical anthropometric indicators of general and central obesity and vitamin D deficiency among adults in Northern State, Sudan.**Methods:** A community-based cross-sectional study was conducted among 100 apparently healthy adults aged 20–45 years in Northern State, Sudan. Socio-demographic characteristics, medical history, and anthropometric measurements, including weight, height, body mass index (BMI), waist circumference (WC), hip circumference (HC), and waist-to-hip ratio (WHR), were collected. Information regarding previous vitamin D deficiency status was also obtained. Data were analyzed using SPSS version 28 through descriptive statistics and Chi-square tests.**Results:** The prevalence of self-reported historical vitamin D deficiency was 78.0%. Participants with vitamin D deficiency exhibited significantly higher indicators of both general and central obesity compared with non-deficient participants. Mean BMI was significantly elevated among the deficient group (31.7 ± 5.94 kg/m² vs. 23.4 kg/m², $P < 0.001$). Similarly, WC (88.0 cm vs. 72.0 cm, $P = 0.010$) and WHR (0.93 vs. 0.72, $P = 0.001$) were markedly higher among vitamin D-deficient individuals. Endocrine-related comorbidities were also common, including type 2 diabetes mellitus (22.0%) and insulin resistance (21.1%).

Conclusion: Vitamin D deficiency was strongly associated with both general and central obesity indicators, particularly WC and WHR, among adults in Northern State, Sudan. These findings suggest that central adiposity may contribute substantially to hypovitaminosis D in this population and highlight the need for targeted metabolic and nutritional interventions.

KEYWORDS: Body mass index; Central obesity; Insulin resistance; Vitamin D deficiency; Waist circumference; and Waist-to-hip ratio.



INTRODUCTION

Vitamin D is a crucial fat-soluble secosteroid hormone essential for bone mineralization, calcium homeostasis, and a wide array of extra-skeletal physiological processes, including immunomodulation, cardiovascular health, and metabolic regulation [1]. Despite abundant year-round solar irradiance in equatorial and desert regions, hypovitaminosis D has paradoxically emerged as a sweeping public health crisis across the Middle East and North Africa (MENA) territories, influenced by genetic susceptibility, lifestyle factors, and limited sun exposure behaviors [2]. Vitamin D deficiency has also been increasingly linked with osteoporosis and several chronic metabolic disorders [3]. Concurrently, global obesity rates have risen sharply, marked by distinct structural variations in adipose tissue deposition across different populations. Obesity is currently recognized as a chronic, multifactorial disease associated with profound metabolic and cardiovascular complications [4,5]. While total body mass index (BMI) remains the conventional screening tool for general obesity, it fails to differentiate between peripheral subcutaneous fat and visceral adiposity. Emerging clinical evidence highlights central obesity—clinically mapped via Waist Circumference (WC) and Waist-to-Hip Ratio (WHR)—as an independent and reliable predictor of insulin resistance, systemic inflammation, cardiometabolic syndrome, and obesity-related morbidity [5,6]. Recent evidence further suggests that not all obesity phenotypes confer equal metabolic risk, with visceral adiposity exerting more detrimental endocrine and inflammatory effects than generalized adiposity [7]. In African populations, and particularly within East Africa, unique hereditary metabolic phenotypes frequently present as central, truncal adiposity rather than peripheral gluteofemoral fat deposition. The intersection between this localized fat accumulation and circulating 25-hydroxyvitamin D [25(OH)D] concentrations remains under-researched. Visceral adipose tissue is highly biologically active and serves both as a physical sink for lipid-soluble vitamin D storage and as a source of pro-inflammatory cytokines that may impair hepatic vitamin D metabolism and endocrine regulation [6,7]. Furthermore, obesity-associated vitamin D deficiency has been implicated in skeletal fragility and altered fracture risk despite increased body mass [8]. Therefore, understanding the interaction between anthropometric indices and vitamin D status is essential for developing targeted preventive interventions in high-risk populations. This investigation aims to evaluate the correlation between general and central anthropometric parameters and clinical vitamin D status among adults aged 20 to 45 years in Northern State, Sudan, while exploring the broader public health implications of this metabolic relationship.

MATERIALS AND METHODS

Study Design and Sampling

A descriptive community-based cross-sectional study was conducted to investigate the association between vitamin D status, central obesity indicators, and related metabolic risk factors among adults in Northern State, Sudan. Data collection was performed in both urban and rural communities to ensure variability in the study population. Participants were recruited using a non-probability convenience sampling technique.

The minimum required sample size was calculated using the standard formula for estimating sample size in an infinite population:

$$n = \frac{Z^2 p(1-p)}{E^2}$$

Where:

- (Z = 1.96), corresponding to a 95% confidence level
- (p = 0.5), assuming maximum population variability
- (E = 0.10), representing a 10% margin of error

The calculated minimum sample size was 96.04 participants, which was rounded to 100 participants to improve representativeness and compensate for incomplete responses.

Inclusion and Exclusion Criteria
Inclusion criteria:

Adults aged 20–45 years who were permanent residents of Northern State, Sudan, and who voluntarily agreed to participate in the study were included.

Exclusion criteria:
Pregnant or lactating women, individuals receiving treatment or supplementation for severe renal, hepatic, or endocrine disorders within the previous three months, and individuals with physical conditions that could interfere with accurate anthropometric measurements were excluded from the study.

Data Collection and Procedures
Data were collected using a pre-tested structured questionnaire administered by trained field workers. The questionnaire consisted of five sections covering socio-demographic characteristics, medical history, anthropometric measurements, lifestyle practices, and dietary habits using a localized food frequency approach.
Anthropometric measurements were obtained according to standardized procedures using calibrated equipment:

Body Mass Index (BMI): Calculated as weight in kilograms divided by height in meters squared [9].

$$BMI = \frac{Weight\,(kg)}{Height\,(m)^2}$$

Waist Circumference (WC): Measured at the midpoint between the lower rib margin and the iliac crest using a non-elastic measuring tape [10].
Waist-to-Hip Ratio (WHR): Calculated by dividing waist circumference by hip circumference [11].

$$WHR = \frac{Waist\,Circumference}{Hip\,Circumference}$$

Statistical Analysis
Data entry, cleaning, and statistical analyses were performed using IBM SPSS Statistics version 28. Descriptive statistics were expressed as frequencies, percentages, means, and standard deviations (Mean ± SD). Chi-square (χ^2) tests were applied to assess associations between categorical variables. A *P-value of* < 0.05 was considered statistically significant throughout the analysis [12].

RESULTS

Table 1. Sociodemographic Characteristics of the Study Participants (N = 100)

Variable	Category	N	Percent
Gender	Male	27	27%
	Female	73	73%
Age (years)	20–30	36	36%
	31–40	30	30%
	41–45	34	34%
Marital Status	Single	42	42%
	Married	58	58%
Educational Level	Primary	2	2%
	Secondary	18	18%
	University/Higher Education (Bachelor's)	62	62%
	Postgraduate Studies (Master's/PhD)	18	18%

Table 1 presents the sociodemographic characteristics of the study participants (N=100). Females constituted the majority of the study population, accounting for 73% of participants, while males represented 27%. Regarding age distribution, participants aged 20–30 years formed the largest proportion (36%), followed closely by those aged 41–45 years (34%) and 31–40 years (30%), indicating a relatively balanced representation across adult age categories. In terms of marital status, more than half of the participants were married (58%), whereas 42% were single. Educational attainment was

generally high among the study population, with the majority holding university or higher education degrees (62%). Additionally, 18% had completed postgraduate studies (Master's or PhD), while smaller proportions had secondary education (18%) or primary education only (2%). Overall, the findings suggest that the study population was predominantly female, relatively young to middle-aged, and highly educated.

Table 2. Distribution of Participants According to Vitamin D Deficiency History, Vitamin D Supplement Use, and Obesity Status

Variable	Category	N	Percent
History of Vitamin D Deficiency	Yes	78	78.0%
	No	20	20.0%
	Maybe	2	2.0%
Vitamin D Supplement Use	Yes	74	74.0%
	No	26	26.0%
Obesity/Abdominal Fat Accumulation Status	Yes	70	70.0%
	No	24	24.0%
	Maybe	6	6.0%

Table 2 summarizes participants' history of vitamin D deficiency, vitamin D supplement use, and obesity or abdominal fat accumulation status. A high proportion of participants (78.0%) reported a previous history of vitamin D deficiency, while 20.0% reported no history of deficiency and 2.0% were uncertain about their status. Regarding supplementation practices, the majority of participants (74.0%) indicated current or previous use of vitamin D supplements, whereas 26.0% reported no supplement use. In relation to obesity and abdominal fat accumulation, 70.0% of participants reported having obesity or noticeable abdominal fat accumulation, while 24.0% denied this condition and 6.0% were unsure. Overall, the findings indicate a high prevalence of both self-reported vitamin D deficiency and obesity-related conditions among the study population, suggesting a potential association between metabolic health status and vitamin D deficiency.

Table 3. Anthropometric Measurements and Their Association with Vitamin D Deficiency Among Study Participants

Variable	Mean ± SD	No Vitamin D Deficiency	Vitamin D Deficiency	*P value*
Weight (kg)	81.12 ±17.68	60.2	87.0	*<0.001*
Height (cm)	164.61 ±5.33	162.1	165.3	*0.040*
Body Mass Index (kg/m²)	29.87 ± 5.94	23.4	31.7	*<0.001*
Waist Circumference (cm)	84.52 ±14.63	72.0	88.0	*0.010*
Hip Circumference (cm)	92.03 ±18.32	82.0	95.0	*0.001*
Waist-to-Hip Ratio	0.88 ± 0.15	0.72	0.93	*0.001*

Table 3 presents the comparison of anthropometric measurements between participants with and without vitamin D deficiency. The findings demonstrate significant differences in nearly all anthropometric indicators according to vitamin D status. Participants with vitamin D deficiency had a markedly higher mean body weight compared with non-deficient participants (87.0 kg vs. 60.2 kg; $P < 0.001$). Similarly, the mean body mass index (BMI) was substantially elevated among vitamin D-deficient individuals (31.7 kg/m²) compared with those without deficiency (23.4 kg/m²), indicating a strong association between obesity and vitamin D deficiency ($P < 0.001$). Measures of central obesity also differed significantly between the two groups. Waist circumference was significantly greater among vitamin D-deficient participants (88.0 cm) than among non-deficient participants (72.0 cm; $P = 0.010$). In addition, hip circumference was higher in the deficient group (95.0 cm vs. 82.0 cm; $P = 0.001$). Waist-to-hip ratio (WHR), an important indicator of abdominal fat distribution, was also significantly elevated among participants with vitamin D deficiency (0.93 vs. 0.72; $P = 0.001$). Although the difference in height between the groups was statistically significant (165.3 cm vs. 162.1 cm; $P = 0.040$), the variation was relatively small compared with the substantial differences observed in obesity-related parameters. Overall, the findings indicate that vitamin D deficiency was strongly associated with increased general and central adiposity among the study participants.

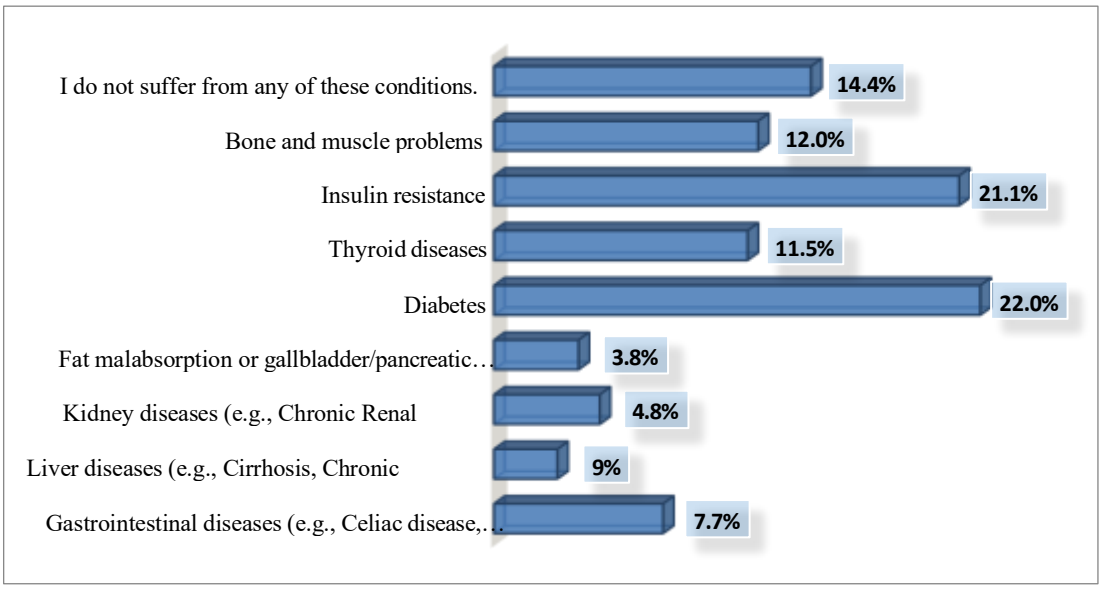


Figure 1: Percentage distribution of associated medical conditions

Figure 1 illustrates the percentage distribution of self-reported clinical symptoms among the vitamin D-deficient participants. The most prevalent symptom reported by the cohort was abdominal weight gain, accounting for 27.4% of responses. This was closely followed by psychological and neurological manifestations, with mood changes or depression reported by 26.7% of participants. Classical musculoskeletal symptoms were also highly visible, as 23.3% of individuals experienced muscle and bone weakness, while persistent fatigue was documented in 22.6% of cases. These findings highlight that the deficiency in this population presents with a prominent combination of visceral adiposity markers, metabolic features, and structural/neurological symptoms.

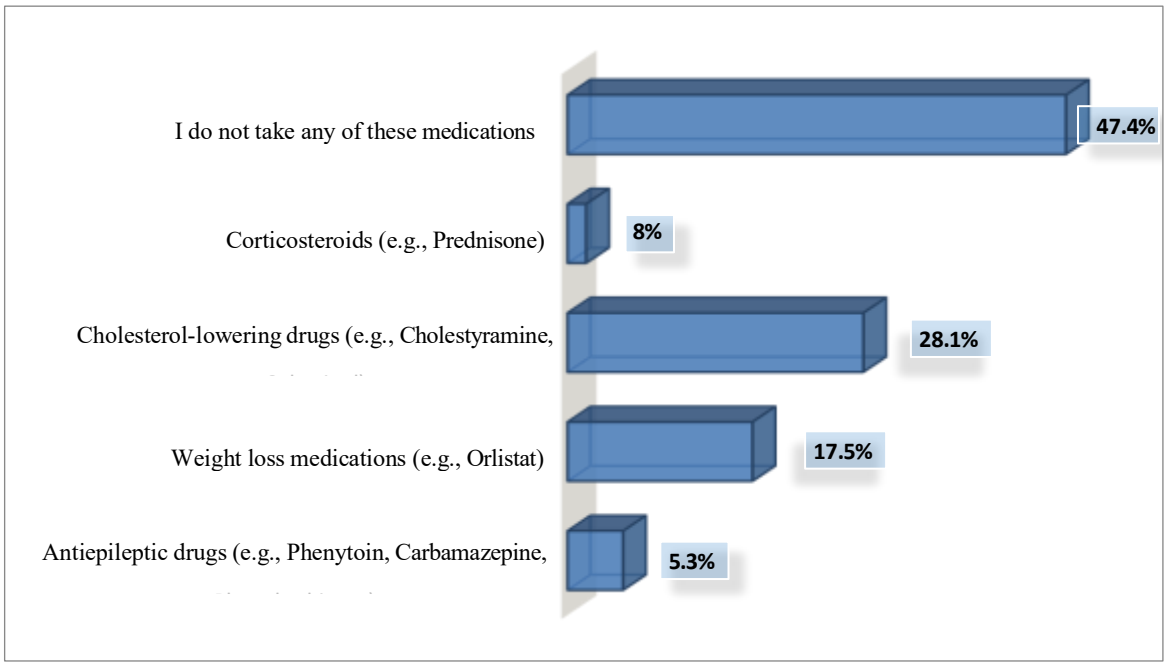


Figure 2: Percentage distribution of participants according to medication use

Figure 2 highlights the percentage distribution of study participants according to their concurrent use of specialized medications. Close to half of the studied cohort (47.4%) reported no exposure to the tracked treatments. Among those utilizing prescription therapies, antiepileptic drugs, such as Phenytoin, Carbamazepine, or Phenobarbitone, represented the most prevalent class at 28.1%. This was followed by weight loss medications (e.g., Orlistat) at 17.5%, corticosteroids (e.g., Prednisone) at 8.0%, and cholesterol-lowering drugs (e.g., Cholestyramine or Colestipol) at 5.3%. Monitoring these pharmaceutical profiles is structurally important given the documented capacity of these drug classes to accelerate hepatic catabolism or limit intestinal assimilation of fat-soluble vitamin D.

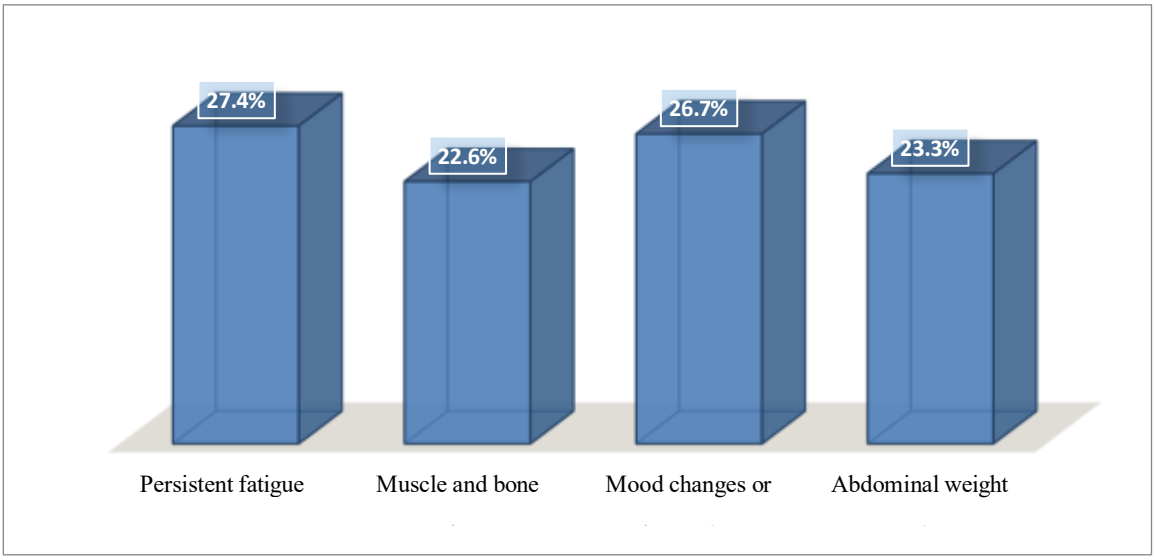


Figure 3: Percentage distribution of Vitamin D deficiency symptoms.

The self-reported clinical symptom configurations among the vitamin D-deficient sub-population are illustrated in **Figure 3.** Visceral fat accumulation, specifically progressive abdominal weight gain, stood as the leading clinical complaint reported by 27.4% of deficient individuals. Psychological and neurological impacts were nearly as prominent, with mood changes or depression accounting for 26.7% of participant selections. Furthermore, the classic musculoskeletal hallmarks of hypovitaminosis D were well-represented, with muscle and bone weakness noted in 23.3% of cases, while chronic, persistent fatigue was documented in 22.6% of the deficient respondents.

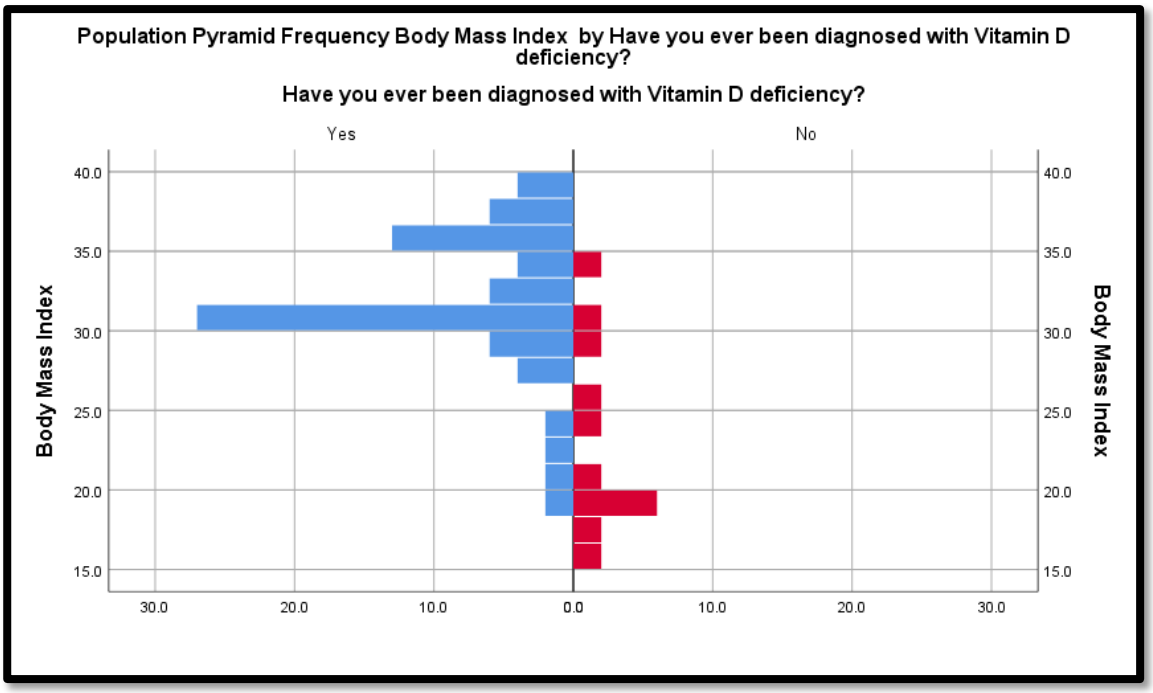


Figure 4: Percentage distribution of BMI across the diagnosis of vitamin D deficiency

Figure 4 illustrates the percentage distribution and structural shift of Body Mass Index (BMI) classifications stratified by clinical vitamin D status. The data demonstrates a highly significant, non-overlapping phenotypic separation between the two groups ($P < 0.001$). Participants without vitamin D deficiency clustered in the healthy reference range, maintaining a lean mean BMI of 23.4 kg/m2. Conversely, the vitamin D-deficient cohort demonstrated an obvious shift toward advanced weight categories, exhibiting a mean BMI of $31.7 \neq 5.94$ kg/m^2. This distribution visually confirms that general obesity parameters track alongside depleted circulating 25-hydroxyvitamin D pools within this population sample.

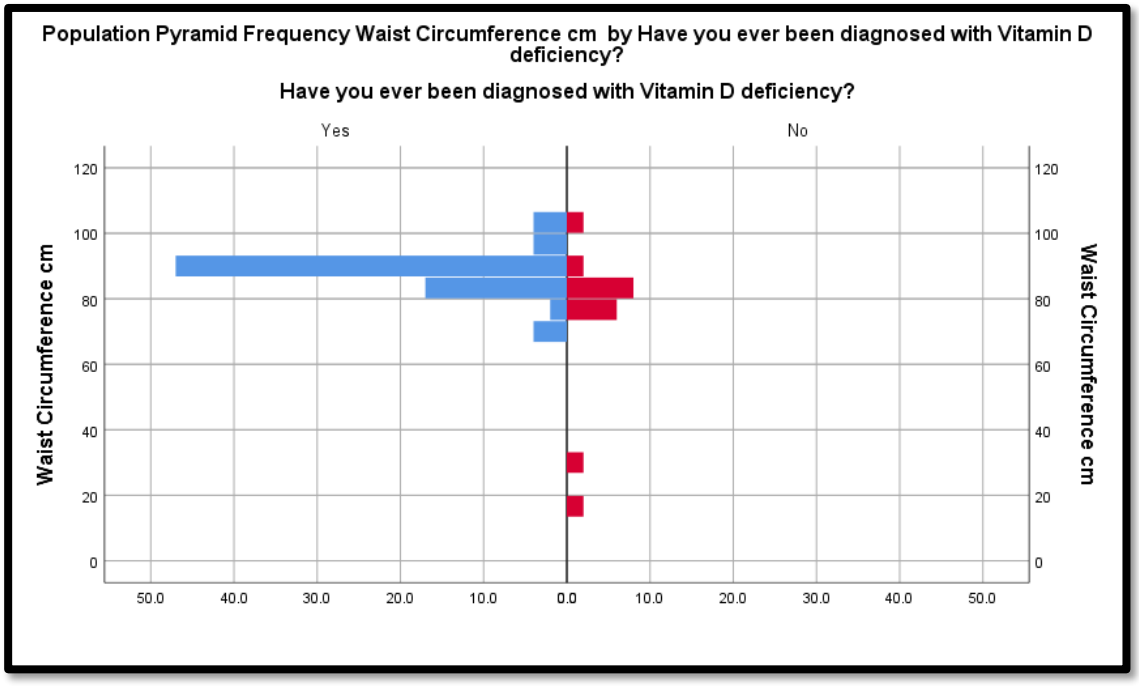


Figure 5: Percentage distribution of waist circumference by diagnosis of vitamin D deficiency.

Figure 5 shows the percentage distribution of waist circumference (WC) measurements according to vitamin D status, highlighting the role of visceral adiposity independent of total body mass. Consistent with the study's primary objective, markers of central truncal adiposity were significantly greater among participants with vitamin D deficiency (*P = 0.010*). The non-deficient group exhibited a leaner central fat distribution, with a mean waist circumference of 72.0 cm. In contrast, the vitamin D-deficient group had a significantly higher mean waist circumference of 88.0 cm. This increase was accompanied by a significantly elevated waist-to-hip ratio (WHR) (0.93 vs. 0.72; *P = 0.001*). Figure 5 clearly demonstrates that greater abdominal fat accumulation is strongly associated with vitamin D deficiency, suggesting that central adiposity is an important metabolic marker of hypovitaminosis D among East African adults.

DISCUSSION

The present study was designed to assess the association of adiposity indices with hypovitaminosis D among adults aged 20-45 years in Northern State, Sudan. The results showed a very high prevalence of vitamin D deficiency (78.0%), which was a major public health concern, similar to reports from countries in the Middle East and North Africa (MENA) region [1,2]. The study also identified significant correlations between vitamin D deficiency and measures of both general and central obesity. Participants with vitamin D deficiency had significantly higher BMI, waist circumference (WC), and waist-to-hip ratio (WHR) than non-deficient participants, indicating that central adiposity may be an important factor in reduced vitamin D status. The mean BMI was 31.7 ± 5.94 kg/m2 among vitamin D-deficient participants compared to 23.4 kg/m2 among non-deficient individuals (*P < 0.001*). Similarly, WC (88.0 cm vs 72.0 cm; *P = 0.010* and WHR 0.93 vs 0.72; P = 0.001 were significantly increased in the deficient group, suggesting close relationships between abdominal adiposity and decreased circulating 25-hydroxyvitamin D. Several international studies have supported the inverse association between circulating 25(OH)D concentrations and markers of central obesity [3,4]. Previous reports have demonstrated that abdominal adiposity is an independent predictor of lower vitamin D levels [5, 6]. One explanation for this association may be the fat-soluble nature of vitamin D. Vitamin D and its metabolites are stored well in adipose tissue, especially in people with excess body fat, thus decreasing bioavailability in systemic circulation [7,8]. This may, therefore, contribute to volumetric dilution and sequestration of vitamin D in lipid-rich tissues and, thus, limit hepatic 25-hydroxylation and circulating serum concentrations [8,13]. An important finding of the present study was that measures of central obesity were more strongly associated with vitamin D deficiency than BMI alone. In many Western populations, general obesity as measured by BMI is generally viewed as the main determinant of vitamin D deficiency [14,15]. However, current findings suggest that WC and WHR may be more indicative of metabolic risk in this East African population. This difference could be explained by regional metabolic and genetic factors, as populations of North-East African ancestry have been shown to have a higher propensity for visceral fat deposition even with a moderate total body weight [16,17]. Visceral adipose tissue is metabolically active and is associated with increased secretion of pro-inflammatory cytokines such as tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) [18,19]. These inflammatory mediators may affect hepatic vitamin D metabolism by decreasing the expression of enzymes involved in vitamin D hydroxylation pathways [20,21]. The high prevalence of endocrine and metabolic disorders among study participants adds further validation to the clinical significance of the obesity-vitamin D association. The most common diagnoses were Type 2 diabetes mellitus (22.0%), insulin resistance (21.1%), and thyroid disorders (11.5%). These results are in line with

previous evidence that vitamin D deficiency and visceral obesity are synergistically involved in impaired glucose metabolism and metabolic dysfunction [21, 22]. Vitamin D has been shown to be involved in pancreatic β-cell function, calcium signaling, insulin secretion, and insulin sensitivity [23, 24]. Thus, deficiency may contribute to the development of insulin resistance, metabolic syndrome, and cardiometabolic disease. Furthermore, some participants reported symptoms often associated with hypovitaminosis D, such as fatigue, general weakness, musculoskeletal pain, and progressive weight gain [25, 26].

These results further highlight the clinical importance of vitamin D deficiency in the studied population and the necessity of early preventive and therapeutic measures [27]. The overall findings indicate the importance of an integrated public health strategy that tackles obesity and metabolic risk factors in addressing vitamin D deficiency in Northern State, Sudan. Lifestyle modification, nutritional education, increased safe sun exposure, weight management, and vitamin D supplementation may help reduce the burden of metabolic disease in the region.

CONCLUSION

The present study found a significant association between central obesity indicators, particularly waist circumference and waist-to-hip ratio and vitamin D deficiency among adults in Northern State, Sudan. The results suggest that visceral adiposity may contribute significantly to lower circulating vitamin D concentrations via sequestration and inflammatory-related metabolic pathways. The high prevalence of associated metabolic disorders such as type 2 diabetes mellitus and insulin resistance also highlight the clinical and public health significance of this relationship. These findings support the need for inclusion of assessment of central obesity in routine metabolic health screening programs and the importance of combined intervention programs such as weight management, nutritional counseling, vitamin D screening, and supplementation. Approaches like these could help reduce long-term cardiometabolic complications and improve population health outcomes in Sudan and similar regional settings.

Ethical considerations

Participation was voluntary, and verbal informed consent was obtained from all participants before data collection. Confidentiality and privacy were maintained throughout the study by excluding all personal identifiers from the collected data.

Conflict of Interest:

The authors declare no conflicts of interest in this manuscript.

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Authors' Contributions

Braa Ahmed Abdelsalam and Abrar Abdalwahid contributed to the conceptualization of the study and anthropometric data collection. Azhari A. Mohammed Nour and Mohamed Awad Elkarim Mohamad Ibrahim contributed to the study design and statistical analysis. Alshebli Ahmed and Sara Elkheir Mustafa Fadul contributed to data organization and literature review. Wisal A. Babiker and Soltan J. Algamdi contributed to data interpretation and manuscript editing. Mohammed A. Shanwaz and Ali A. Zaeri contributed to methodology review and technical supervision. Ali Mahzari, Khalid Eltahir Khalid Kheiralla and Nawal M.Osman contributed to manuscript revision and validation of the study findings. Motasim Jawi contributed to overall project supervision and final approval of the manuscript. All authors read and approved the final version of the manuscript.

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