Original Article

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Association between Zinc and Vitamin D Intake and Obesity among Women: A Cross-Sectional Analysis of NHANES 2017-2018

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Abstract

Background: *Micronutrient intake, particularly zinc and vitamin D, has been hypothesized to influence obesity risk through metabolic and inflammatory pathways. However, evidence on these associations in women remains limited and mixed. The current study aimed to examine the relationship between zinc and vitamin D intake and obesity among adult women using nationally representative data.*

Methods: *We conducted a cross-sectional analysis of 1,043 adult women from the NHANES 2017–2018 dataset. Obesity was defined as body mass index (BMI) $\geq$30 kg/m^2. Zinc and vitamin D intake was categorized as adequate or inadequate based on dietary guidelines (zinc >8 mg/day; vitamin D >15 mcg/day). Logistic regression models estimated adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for the association between micronutrient intake and obesity. The models were adjusted for diabetes, exercise status, age, Hispanic origin, smoking, and other comorbidities.*

Results: *Vitamin D intake >15 mcg/day was associated with higher odds of obesity in the unadjusted analysis (OR = 1.37; 95% CI: 1.05–1.78; $p = 0.02$), but it was not statistically significant after adjustment (adjusted OR = 1.28; 95% CI: 0.95–1.71; $p = 0.09$). Zinc intake of >8 mg/day was not significantly associated with obesity (adjusted OR = 1.38; 95% CI: 0.33–5.86; $p = 0.66$). Key predictors of higher obesity risk included the presence of diabetes (adjusted OR = 2.13; 95% CI: 1.48–3.07; $p < 0.01$) and comorbidities >1 (adjusted OR = 2.33–2.37 across models; $p < 0.01$). Protective factors included physical activity (adjusted OR = 0.62; 95% CI: 0.47–0.81; $p < 0.01$), Hispanic ethnicity (adjusted OR = 0.82; 95% CI: 0.74–0.92; $p < 0.01$), and increasing age (adjusted OR = 0.99 per year; 95% CI: 0.98–0.99; $p < 0.01$). Smoking and total fat intake were not significantly associated with obesity.*

Conclusions: *In this cross-sectional analysis of U.S. women, neither zinc nor vitamin D intake was significantly associated with obesity after adjustment for confounders. Diabetes, comorbidities, exercise, and Hispanic ethnicity emerged as important predictors of obesity. These findings highlight the multifactorial nature of obesity and underscore the need for longitudinal research using biomarker-based assessments of nutrient status to better understand these relationships.*

Introduction

Obesity is a major global public health epidemic that affects a significant number of women, with serious implications such as cardiovascular disease, diabetes, and metabolic disorders (Cooper et al., 2021; Piché et al., 2020). The role of nutritional deficiencies in the etiology of obesity has been previously investigated (Kobylińska et al., 2021), and zinc and vitamin D have been identified as critical micronutrients in metabolic processes that may influence weight management (Argano et al., 2023; Chapela et al., 2024; Olechnowicz et al., 2017).

Zinc has been demonstrated to regulate inflammation and appetite, which are essential in the pathogenesis of obesity (Abdollahi et al., 2019; Franco & Canzoniero, 2024). Khorsandi et al. (2019) proposed that zinc supplementation in obese women may improve inflammatory markers, such as IL-6 and C-reactive protein. Additionally, evidence suggests that people with obesity may have zinc deficiency associated with unbalanced diets and metabolic issues (Marreiro et al., 2006). On the other hand, vitamin D may play a role as a potential regulator of fat storage and metabolic function, although its specific role in obesity management remains poorly understood (Bennour et al., 2022). Furthermore, Orces (2019) showed that obese individuals are 1.3 times more likely not to use vitamin D supplements and are 24% less likely to take them.

These findings underscore a knowledge gap regarding the role of zinc and vitamin D intake in women with obesity. An improved understanding of these associations could provide insights into effective nutritional interventions aimed at reducing obesity rates. This study aimed to explore whether zinc and vitamin D supplementation have an impact on obesity in women. We hypothesized that these supplements could contribute to weight regulation and thus reduce obesity risk.

Materials and Methods

Study design

A cross-sectional study to explore the association between zinc and vitamin D intake as independent factors and obesity in adult women.

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Data source

Data for this study were drawn from the National Health and Nutrition Examination Survey (NHANES) 2017-2018 cycle, a biennial survey by the Centers for Disease Control and Prevention (CDC) that provides comprehensive health, dietary, and lifestyle data from a nationally representative sample of the United States population. NHANES collects data through interviews, physical exams, and laboratory tests for analyzing health-related factors across diverse populations. To prepare the data for analysis, several steps were taken to refine the sample. Initially, only female participants were retained, resulting in the removal of 4,557 observations. The sample was further restricted to adults aged 18 years and older, leading to the exclusion of an additional 1,681 observations. Next, participants with missing data for Body Mass Index (BMI) were excluded, eliminating 205 observations. Subsequently, cases with missing zinc intake values were excluded, and 286 observations were removed. Participants with missing vitamin D intake values were removed, resulting in the deletion of 1,442 observations, giving 1,043 participants. Ultimately, participants who did not wish to respond or were uncertain about their diabetes status were excluded, resulting in the elimination of 41 patients. Following this data refinement, the final analytical sample comprised adult women with complete data on BMI, zinc intake, and vitamin D intake, along with other pertinent variables such as age, patient's origin, comorbidities, smoking status, and diet. This sample was used in all subsequent analyses (Figure 1).

Exposure description

The primary exposures examined in this study were zinc and vitamin D intake. Zinc intake was measured using a 24-hour dietary recall in which participants reported all foods and beverages consumed within the previous day. Vitamin D intake was measured based on a 30-day average daily vitamin D supplement consumption, providing a slightly longer-term view of intake than zinc (Ahluwalia et al., 2016). Both these variables were addressed as categorical, defining adequate intake thresholds of vitamin D if values were >15 mcg/day (Bouillon, 2017) and zinc >8 mg/day (Brnić et al., 2016) before conducting sensitivity analysis to secure the same outcomes. These categorical variables were used throughout all logistic regression analyses.

Outcome description

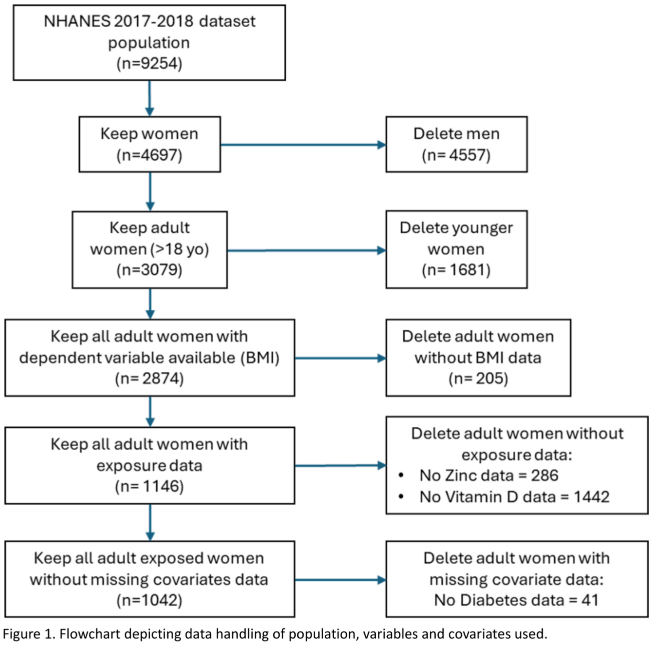

Figure 1: *Flowchart depicting data handling for the population, variables, and covariates used.*

The outcome variable, obesity, was defined as a dichotomous variable based on BMI. Participants were classified as "obese" if their BMI was 30 or higher and "not obese" if their BMI was below 30 (Weir & Jan, 2023). BMI was calculated from self-reported weight and height data that were subsequently validated during the NHANES physical examination to increase accuracy.

Statistical analysis

Logistic regression models were used to evaluate the associations between obesity and primary exposure, zinc, and vitamin D intake. Univariate logistic regression analyses were conducted separately to assess the independent associations of vitamin D and zinc intake with obesity. Furthermore, these were adjusted for potential confounding variables, including: exercise status (categorized as engaging or not engaging in vigorous and/or moderate exercise), diabetes diagnosis, age, Hispanic origin, smoking status (defined as having smoked at least 100 cigarettes in their lifetime), and the presence of one or more comorbidities (such as cardiovascular disease, arthritis, and other conditions listed in the NHANES database). Sensitivity analyses were conducted to account for possible differences in outcomes after dichotomizing the vitamin D and zinc variables, demonstrating no changes in the statistical significance for both variables and models of interest. Finally, to evaluate model fit and linearity assumptions in logistic regression, the Hosmer-Lemeshow test was used ($p = 0.1741$), indicating a good global fit between predicted and observed probabilities. Additionally, the ROC curve showed an area under the curve (AUC) of 0.6757, reflecting moderate discriminative capacity. These results indicate that the model is appropriate for describing the relationship between the predictor variables and obesity.

To address the potential issue of collinearity, we conducted a collinearity analysis using the Variance Inflation Factor (VIF). If the VIF value was equal to or higher than 5, collinearity was considered to exist. To further examine this, separate logistic regression models were fitted, followed by a linear regression analysis that included only the independent variables to compute VIF values. The collinearity analysis demonstrated that no collinearity existed between the variables. VIF values ranged from 1.01 to 1.13 in the zinc model and from 1.01 to 1.11 in the vitamin D model. Odds ratios (ORs) with 95% confidence intervals (CIs) were used to quantify the strength and significance of the associations between predictors and obesity. Statistical analyses were performed using Stata/BE 18.5 (StataCorp LLC, Texas, USA), and a p-value of < 0.05 was considered statistically significant.

Results

After initial cleaning and filtering, the final analysis included 1,043 observations of adult women with complete data on BMI, vitamin D, zinc intake, and self-reported diabetes diagnosis by a physician. Table 1 describes the sociodemographic characteristics of the study population.

Vitamin D

A logistic regression model was used to evaluate the association between vitamin D intake and obesity in women. The findings indicated that higher vitamin D levels were associated with a trend toward higher odds of obesity, although this association only reached statistical significance in the univariate analysis. After adjusting for confounders, vitamin D intake higher than 15 mcg per day did not reach statistical significance (Table 2,4). Diabetes status was significantly associated with >2-fold increase odds of obesity, as was the presence of 1 or more comorbidity; Exercise status showed a protective effect with individuals engaging in exercise having a 48% decrease in odds of obesity; Increasing age was associated with a small decrease in obesity risk; and being of Hispanic origin was linked to reduced odds of obesity. The presence of comorbidities significantly increased the likelihood of obesity by 2-fold. No statistically significant association was found between smoking status (having smoked at least 100 cigarettes) and obesity, nor was there a significant association with total fat intake.

Table 2 displays the adjusted odds ratios, 95% CIs, and p-values from logistic regression analysis evaluating predictors of obesity, with a focus on vitamin D intake among women. While vitamin D intake showed a trend toward increased odds of obesity, the result did not reach statistical significance. Diabetes and comorbidities were significant risk factors, whereas exercise and Hispanic origin provided protective effects. No significant associations were found between smoking status and total fat intake.

Key Findings of Zinc

A subsequent logistic regression model was used to analyze the association between zinc intake and obesity, adjusting for the same potential confounders. Zinc intake was not significantly associated with obesity in the univariate or multivariate analysis. The adjusted model highlighted similar trends in the vitamin D model, with diabetes status and the presence of comorbidities remaining strong predictors of obesity, with a 2-fold risk increase. Exercise continued to exhibit a protective effect, whereas age was inversely associated with a higher BMI. Hispanic origin remained a protective factor, and no significant association was observed between smoking status or total fat intake and obesity in this model (Table 3,4).

Table 4 presents the results of logistic regression analysis examining predictors of obesity with zinc and vitamin D intake as primary exposure. Zinc intake was not significantly associated with obesity risk. Diabetes and comorbidities emerged as strong predictors, whereas exercise and Hispanic origin were protective factors. Similar to the vitamin D model, smoking status and total fat intake were not significant predictors.

Discussion

Using data from the NHANES 2017-2018 dataset, our findings indicate that higher vitamin D intake was associated with a trend toward an increased likelihood of obesity, although this association did not reach statistical significance. Conversely, zinc intake was not significantly associated with obesity status. Additionally, the study highlighted that diabetes, age, comorbidities, and exercise status were important predictors of obesity risk.

The literature on vitamin D and its association with obesity is controversial. Our findings regarding vitamin D align with other articles that state no association between calcitriol and BMI. Aydin and Goktas Aydin (2024) analyzed men and women retrospectively, the meta-analysis by Oussaada et al. (2024) investigated a population treated with vitamin D, and Yao et al. (2015) specifically examined postmenopausal women; all of them did not find a significant association between these two factors. However, other studies have reinforced the negative association between them. (Lee et al., 2023; Avila Castillo et al., 2023; Yao et al., 2015; Mai et al., 2012).

Zinc intake in obesity is a less explored topic, and limited data are available. Nevertheless, few studies have suggested an association between lower zinc serum levels and obesity (Hernández-Mendoza et al., 2022; Rios-Lugo et al., 2020). This association could not be corroborated in our study, which could be explained by reliance on self-reported dietary data, introducing measurement error (information bias). In addition, considering the limited number of participants meeting the zinc intake thresholds, our power to detect an effect could be compromised.

This study's strengths include the use of a large, nationally representative sample from the NHANES database, which ensures representación of different communities across the US. We also accounted for several potential confounders, including exercise status, diabetes, comorbidities, ethnicity, and age. However, limitations should be acknowledged. Since the

Variable	Obese	Non-obese	p-value	Overall
Age, Mean ± SD (years)	58.7 ± 16.3	47.1 ± 17.5	<0.01	54.8 ± 17.5
Vitamin D Intake, IQR (mcg/day)	25 (38.4)	25 (40)	0.03	25 (40)
Zinc Intake, median + IQR (mg/day)	0.13 (0.83)	0.14 (0.72)	0.87	0.14 (0.73)
Hispanic ethnicity			<0.01	
Mexican American (n, %)	60 (13.9)	56 (9.2)		116 (11.1)
Other Hispanic (n, %)	32 (7.4)	62 (10.2)		94 (9.0)
Non-Hispanic White (n, %)	179 (41.5)	240 (39.3)		419 (40.2)
Non-Hispanic Black (n, %)	123 (28.5)	100 (16.4)		223 (21.4)
Other Race, including Multi-Racial (n, %)	37 (8.6)	152 (25.0)		190 (18.2)
Marital Status			0.99	
Married (n, %)	201 (46.9)	319 (54.2)		520 (51.1)
Widowed (n, %)	69 (16.1)	72 (12.2)		141 (13.9)
Divorced (n, %)	64 (14.9)	75 (12.7)		139 (13.7)
Separated (n, %)	20 (4.7)	22 (3.7)		42 (4.1)
Never married (n, %)	42 (9.8)	65 (11.0)		107 (10.5)
Living with partner (n, %)	32 (7.5)	36 (6.1)		68 (6.7)
Refused (n, %)	1 (0.2)	0 (0)		1 (0.1)
Educational level			0.93	
Less than 9th grade (n, %)	30 (7.0)	35 (5.9)		65 (6.4)
9-11th grade (includes 12th grade with no diploma) (n, %)	41 (9.6)	35 (5.9)		76 (7.5)
High School Graduated/GED or equivalent (n, %)	94 (21.9)	114 (19.4)		208 (20.4)
Some College or AA degree (n, %)	158 (36.8)	206 (35.0)		364 (35.8)
College graduate or above (n, %)	105 (24.5)	199 (33.8)		304 (29.9)
Refused (n, %)	1 (0.23)	0 (0)		1 (0.1)
Annual Family Income			0.96	
$ 0 – 19.999 (n, %)	89 (20.7)	104 (17.0)		193 (18.5)
$ 20.000 —44.999 (n, %)	117 (27.2)	144 (23.6)		261 (25.1)
$ 45.000 – 74.999 (n, %)	74 (17.2)	102 (16.7)		176 (16.9)
$ 75.000 – 99.999 (n, %)	33 (7.7)	55 (9.0)		88 (8.5)
$ >100.000 (n, %)	70 (16.2)	143 (23.4)		213 (20.4)
Refused (n, %)	48 (11.1)	63 (10.3)		111 (10.7)
Length of stay in U.S.			0.35	
0 –<5 years (n, %)	5 (1.2)	15 (2.5)		20 (2.0)
5 – <10 years (n, %)	8 (1.9)	20 (3.3)		28 (2.7)
10 – <20 years (n, %)	12 (2.8)	48 (7.9)		60 (5.8)
20 – <30 years (n, %)	28 (6.5)	41 (6.7)		69 (6.6)
>30 years (n, %)	37 (8.6)	83 (13.6)		120 (11.5)
Refused/Don't know (n, %)	341 (79.1)	404 (66.1)		745 (73.4)

Table 1: *Demographic characteristics of study population.*

Variable	Univariate regression		
	Crude OR	95% CI	*p*-value
Vitamin D >15 mcg/day	1.37	1.05 – 1.78	0.02

Table 2: *Univariate analysis of Vitamin D.*

Variable	Univariate regression		
	Crude OR	95% CI	*p*-value
Zinc >8 mg/day	1.13	0.30 – 4.25	0.85

Table 3: *Univariate analysis of Zinc.*

Variable	Multivariate regression for Vitamin D Adjusted OR	95% CI	p-value	Multivariate regression for Zinc Adjusted OR	95% CI	p-value
Vitamin D >15 mcg/day	1.28	0.95 – 1.71	0.09	N/A	N/A	N/A
Zinc >8 mg/day	N/A	N/A	N/A	1.38	0.33 – 5.86	0.66
Age (in years)	0.99	0.98 – 0.99	<0.01	0.99	0.98 – 0.99	<0.01
Presence of DM	2.13	1.48 – 3.07	<0.01	2.13	1.48 – 3.07	<0.01
Physical activity (moderate/rigorous)	0.62	0.47 – 0.81	<0.01	0.62	0.48 – 0.82	<0.01
Hispanic ethnicity	0.82	0.74 – 0.92	<0.01	0.82	0.74 – 0.92	<0.01
Comorbidity >1	2.33	1.64 – 3.29	<0.01	2.37	1.68 – 3.35	<0.01
Smoking (>100 cig/life)	0.78	0.59 – 1.04	0.09	0.78	0.59 – 1.04	0.09
Total fat intake	1.01	0.99 – 1.02	0.25	1.00	0.99 – 1.02	0.32

Table 4: *Logistic regression analysis of obesity predictors and their associated risk factors.*

database consists of U.S. self-reported data, zinc values were measured through 24-hour dietary recall, whereas vitamin D values were based on supplement use in the last 30 days. Due to missing data from self-reported information and differences in the measurement of variables, conducting a combined analysis is challenging because of temporal inconsistencies that could complicate comparisons. One of the limitations of this study is that these findings cannot be extrapolated to other populations outside of the US. In addition, self-reported dietary data for vitamin D and zinc intake may be an inadequate marker, being also subject to recall bias and inaccuracies. Additionally, our inability to adjust for certain potential confounders is limited, as it is a public database not designed specifically for our research question. Finally, the cross-sectional nature of the study design prevents the inference of causality and might not reflect long-term habits. Moreover, the relatively small number of participants with high zinc intake may have limited our ability to detect associations.

Our findings improve our understanding of the link between vitamin D, zinc, and obesity in women. Although micronutrient supplementation may influence metabolic processes, it alone may not be sufficient as a strategy for obesity management. Interventions should consider a broader metabolic context, including the presence of comorbidities and lifestyle factors such as exercise and dietary patterns. Longitudinal studies are needed to evaluate the chronic impact of vitamin D and zinc supplementation on obesity risk over time. Investigating potential interactions among genetic predispositions, micronutrient intake, and lifestyle factors may further clarify their role in obesity management. Overall, this study underscores the complexity of obesity as a multifactorial condition and highlights the need for a holistic approach that goes beyond single-nutrient supplementation to effectively address obesity risk.

Conclusion

This study examined the association between zinc and vitamin D intake and obesity among women, using data from the NHANES 2017-2018 dataset. The analysis indicates that there is no statistically significant correlation between zinc intake and obesity. However, the limited sample size of women meeting adequate zinc intake levels, combined with the potential for recall bias in self-reported data, may have had an impact on this outcome. The data suggest a trend toward an increased risk of obesity associated with vitamin D intake; however, this did not reach statistical significance. This finding is in accordance with the mixed results of previous studies, which suggested that the role of vitamin D supplementation in obesity management may be complex or limited.

The presence of comorbidities and diabetes were identified as significant predictors of obesity, whereas physical exercise and Hispanic ethnicity were associated with protective effects. These findings highlight the complex, multifactorial etiology of obesity, reinforcing the need for multidisciplinary management strategies that integrate a range of interventions beyond single-nutrient supplementation.

The study's limitations include the use of self-reported dietary data, the cross-sectional nature of the design, which limits the ability to draw causal inferences, and the absence of sufficient control for all potential confounding variables. These factors must be taken into account when analyzing the results. Further research must be conducted using longitudinal studies in order to evaluate the chronic impact of micronutrient intake and to examine the interactions between lifestyle, genetic predispositions, and micronutrient status in relation to obesity risk.

Supplementary Materials

STATA Codes

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Conflicts of Interest

The authors declare no conflict of interest.

References

Abdollahi, S., Toupchian, O., Jayedi, A., Meyre, D., Tam, V., & Soltani, S. (2020). Zinc Supplementation and Body Weight: A Systematic Review and Dose–Response Meta-analysis of Randomized Controlled Trials. Advances in Nutrition, 11(2), 398–411. https://doi.org/10.1093/ADVANCES/NMZ084

Ahluwalia, N., Dwyer, J., Terry, A., Moshfegh, A., & Johnson, C. (2016). Update on NHANES Dietary Data: Focus on Collection, Release, Analytical Considerations, and Uses to Inform Public Policy. Advances in Nutrition (Bethesda, Md.), 7(1), 121–134. https://doi.org/10.3945/an.115.009258

Argano, C., Mirarchi, L., Amodeo, S., Orlando, V., Torres, A., & Corrao, S. (2023). The Role of Vitamin D and Its Molecular Bases in Insulin Resistance, Diabetes, Metabolic Syndrome, and Cardiovascular Disease: State of the Art. International Journal of Molecular Sciences, 24(20), 15485. https://doi.org/10.3390/IJMS242015485

Avila Castillo, A., Hagemann, T., Hoffmann, A., Baber, R., Biemann, R., Wirkner, K., Krupka, S., Stumvoll, M., Blüher, M., & Klöting, N. (2023). Associations between vitamin D, immunoglobulin E concentrations, and obesity. Frontiers in Nutrition, 10, 1147407. https://doi.org/10.3389/fnut.2023.1147407

Aydin, A., & Goktas Aydin, S. (2024). A Case-Control Study of the Correlation Between Blood Parameters and Obesity. Cureus, 16(9), e69809. https://doi.org/10.7759/cureus.69809

Bennour, I., Haroun, N., Sicard, F., Mounien, L., & Landrier, J. F. (2022). Vitamin D and Obesity/Adiposity—A Brief Overview of Recent Studies. Nutrients, 14(10), 2049. https://doi.org/10.3390/NU14102049

Bouillon R. (2017). Comparative analysis of nutritional guidelines for vitamin D. Nature Reviews Endocrinology, 13(8), 466–479. https://doi.org/10.1038/nrendo.2017.31

Brnić, M., Wegmüller, R., Melse-Boonstra, A., Stomph, T. J., Zeder, C., Tay, F. M., & Hurrell, R. F. (2016). Zinc Absorption by Adults Is Similar from Intrinsically Labeled Zinc-Biofortified Rice and from Rice Fortified with Labeled Zinc Sulfate. The Journal of Nutrition, 146(1), 76–80. https://doi.org/10.3945/JN.115.213421

Chapela, S. P., Martinuzzi, A. L. N., Llobera, N. D., Ceriani, L., et al. (2024). Obesity and Immunity: From Mechanisms to Clinical Implications. HIV & AIDS Review. International Journal of HIV-Related Problems: Acta Dermatovenerologica Alpina, Pannonica et Adriatica / Slovenian Association for Infectious Diseases and Tropical Medicine and Allergology and Clinical Immunology, 35(1). https://doi.org/10.1080/09540105.2024.2381725

Cipriani, C., Pepe, J., Piemonte, S., Colangelo, L., Cilli, M., Minisola, S., & Romagnoli, E. (2014). Vitamin D and its relationship with obesity and muscle. International Journal of Endocrinology, 2014, 841248. https://doi.org/10.1155/2014/841248

Cooper, A. J., Gupta, S. R., Moustafa, A. F., & Chao, A. M. (2021). Sex/Gender Differences in Obesity Prevalence, Comorbidities, and Treatment. Current Obesity Reports, 10(4), 458–466. https://doi.org/10.1007/s13679-021-00453-x

Cunha, T. A., Vermeulen-Serpa, K. M., Grilo, E. C., Leite-Lais, A., et al. (2022). Zinc and its associations with adiposity and metabolic health: A mini-review. Journal of Trace Elements in Medicine and Biology, 71, 126940. https://doi.org/10.1016/j.jtemb.2022.126940

Fonseca de Oliveira, L., Guimarães de Azevedo, L., da Mota Sant'Anna, M., & Guimarães, M. R. (2019). Obesity and its relation to female reproduction: A review. Journal of Women's Health and Gender-Based Medicine / Women's Health Issues & Care, 20(2), 1–10. https://doi.org/10.1007/s11154-019-09527-7

Franco, C., & Canzoniero, L. M. T. (2024). Zinc homeostasis and redox alterations in obesity. Frontiers in Endocrinology, 14, 1273177. https://doi.org/10.3389/FENDO.2023.1273177

Fregni and Ben Illigens Critical Thinking in Clinical Research: Chapter 16: Observational studies. In: Oxford University Press 2018.

Hao L, Lu A, Gao H, Niu J, Prabahar K, Seraj S. S., Pan Y. The "Obesity Paradox" in Vitamin D Status and Its Association with Cardiometabolic Diseases. Clinical Therapeutics. 2023;45(10):1411-1425. doi:10.1016/j.clinthera.2023.07.009. Epub 2023 Aug 17. PMID: 37598056.

Hernández-Mendoza, H., Martínez-Navarro, I., Hernández-Ochoa, R., & Valdés-Ramos, R. (2022). Association between zinc levels and obesity: A systematic review. Journal of Trace

Elements in Medicine and Biology, 73, 127002. https://doi.org/10.1016/j.jtemb.2022.127002

Gu, K., Xiang, W., Zhang, Y., Sun, K., & Jiang, X. (2019). The association between vitamin D and obesity in adults: a systematic review and meta-analysis of observational studies. European Journal of Nutrition, 58(7), 2971–2982. https://doi.org/10.1007/s00394-018-1876-x

Khorsandi, H., Nikpayam, O., Yousefi, R., Parandoosh, M., Hedayati, M., & Alavian, S. M. (2019). The effects of zinc supplementation on inflammation and oxidative stress in overweight/obese adults: A systematic review and meta-analysis of randomized controlled trials. Diabetology & Metabolic Syndrome, 11, 101. https://doi.org/10.1186/S13098-019-0497-8

Kobylińska, M., Antosik, K., Decyk, A., & Kurowska, K. (2021). Obesity and nutrition in women—Is it possible? Obesity Facts, 15(1), 19. https://doi.org/10.1159/000519503

Lee, J. H., Kim, Y. A., Kim, Y. S., Lee, Y., & Seo, J. H. (2023). Association between Vitamin D and Obesity in Women: A Cross-Sectional Study. Nutrients, 15(13), 3043. https://doi.org/10.3390/nu15133043

Mai, X. M., Chen, Y., Camargo, C. A., Jr, & Langhammer, A. (2012). Cross-sectional and prospective cohort study of serum 25-hydroxyvitamin D level and obesity in adults: the HUNT Study. American Journal of Epidemiology, 175(10), 1029–1036. https://doi.org/10.1093/aje/kwr456

Marreiro, D. N., Geloneze, B., Tambascia, M. A., Lerário, A. C., Halpern, A., Cozzolino, S. M. F., & Biagio, R. M. (2003). Expression of insulin receptor in subcutaneous adipose tissue and its relation to zinc nutritional status in humans. Biological Trace Element Research, 112(2), 109–118. https://doi.org/10.1385/bter:112:2:109

Olechnowicz, J., Tinkov, A., Skalny, A., & Suliburska, J. (2018). Zinc status is associated with fat mass in obese children. Journal of Physiological Sciences : JPS, 68(1), 19. https://doi.org/10.1007/S12576-017-0571-7

Orces C. (2019). The Association between Body Mass Index and Vitamin D Supplementation among Adults in the United States. Cureus, 11(9), e5721. https://doi.org/10.7759/cureus.5721

Oussaada, S. M., Akkermans, I., Chohan, S., Limpens, J., Twisk, J. W., & Jazet, I. M. (2024). Vitamin D supplementation and body weight: a systematic review and meta-analysis of randomized controlled trials. Clinical Nutrition (Edinburgh, Scotland), 43(11), 99–105. https://doi.org/10.1016/j.clnu.2024.08.031

Piché, M. E., Tchernof, A., & Després, J. P. (2020). Obesity Phenotypes, Diabetes, and Cardiovascular Diseases. Circulation Research, 126(11), 1477–1500. https://doi.org/10.1161/CIRCRESAHA.120.316101

Rios-Lugo, M. J., Madrigal-Arellano, C., Gaytán-Hernández, D., Hernández-Morales, H., & Cruz Hernández, J. J. (2020). Serum Zinc Levels and Obesity: A Systematic Review and Meta-Analysis. Biological Trace Element Research, 198(1), 51–57. https://doi.org/10.1007/s12011-020-02060-8

Weir, C. B., & Jan, A. (2023). BMI Classification Percentile And Cut Off Points. In StatPearls. Treasure Island (FL): StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK541070/

Yao, Y., Zhu, L., He, L., Duan, Y., Liang, W., Nie, Z., Jin, Y., & Zhao, X. (2015). A meta-analysis of the relationship between vitamin D deficiency and obesity. European Review for Medical and Pharmacological Sciences, 19(24), 4196–4206.

Zavros, A., Giannaki, C. D., Aphamis, G., Roupa, Z., & Andreou, E. (2022). The role of micronutrients in obesity pathophysiology and management: A narrative review. International Journal of Food Properties, 20(4), 643–671. https://doi.org/10.1080/19390211.2022.2072044