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The role of vitamin D supplementation in improving health outcomes among different ethnic groups

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Abstract: The study investigates the association between vitamin D supplementation and the risk of diabetes and depression across diverse ethnic groups in the USA, using NHANES 2015–2018 data. The analysis reveals significant ethnic disparities in the protective effects of vitamin D supplementation. Mexican Americans who took supplements had a reduced risk of diabetes (OR = 1.389, 95% CI: 1.142–1.690), while African Americans showed a reduced risk of depression (OR = 1.286, 95% CI: 1.021–1.620). These findings suggest that vitamin D supplementation may benefit these populations, likely due to genetic and environmental factors. The study underscores the need for personalised public health strategies that account for ethnic differences and baseline vitamin D levels, advocating for a tailored supplementation approach to mitigate health disparities related to diabetes and depression in high-risk groups.

Keywords: vitamin D supplementation; diabetes; depression; ethnic disparities; National Health and Nutrition Examination Survey; NHANES; protective effects.

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1 Introduction

Vitamin D, a crucial fat-soluble vitamin, is essential in various physiological functions, including regulating calcium and phosphorus levels, bone health, and immune system support (Holick, 2007). Vitamin D is primarily obtained through exposure to sunlight, but it can also be sourced from certain foods and supplements. Despite its importance, vitamin D deficiency is a widespread issue affecting every region globally (Mithal et al., 2009). In the USA, vitamin D deficiency is prevalent, with an estimated 41% of the population experiencing insufficient levels, particularly among African Americans (82%), Hispanics (69%), and older adults (Forrest and Stuhldreher, 2011). This deficiency is influenced by factors such as limited sun exposure, darker skin pigmentation, obesity, and dietary habits that lack sufficient vitamin D-rich foods (Holick, 2017).

- Significance of the study: this study is particularly important because about 41% of the U.S population has insufficient vitamin D levels and vitamin D deficiency is associated with a broad spectrum of health complications. Given the high prevalence of vitamin D deficiency and its potential health ramifications, the need for targeted public health interventions, especially vitamin D supplementation, becomes evident.
- Objective: this study aims to explore the effects of vitamin D supplementation in improving health outcomes among different ethnic groups, with a particular focus on its potential to mitigate the burden of depression and diabetes.

1.1 Factors leading to vitamin d deficiency

One of the primary causes of vitamin D deficiency is insufficient exposure to sunlight. The synthesis of vitamin D in the skin requires ultraviolet B (UBV) radiation from the sun, which is influenced by geographical location, time of the year, and individual lifestyle. Populations living at higher latitudes, where the sunlight is less intense during winter months, are at higher risk of vitamin D deficiency (Holick, 2007). Additionally, lifestyle factors such as spending more time indoors, wearing protective clothing, or the use of sunscreen can further reduce the skin's ability to produce vitamin D (Mithal et al., 2009). Skin pigmentation plays a major role in vitamin D synthesis. Thus, individuals with darker skin pigmentation requires more sun exposure to produce sufficient vitamin D as melanin, the pigment responsible for skin colour, act as natural sunscreen by absorbing UVB radiation, thereby reducing the synthesis of vitamin D (Powe et al., 2000). As individual age, their skin's ability to synthesise vitamin D declines. This reduction is due to decreased concentrations of 7-dehydrocholesterol in the skin, which is a precursor necessary for the production of vitamin D upon exposure to UVB, thus, order populations are susceptible to vitamin D deficiency (Ginde et al., 2009).

In many populations, dietary intake of vitamin D is insufficient to meet the body's needs. Few foods naturally contain significant amounts of vitamin D, with fatty fish, like salmon and mackerel among the best sources. Fortified foods can help, but dietary sources alone are not enough to prevent deficiency (Holick, 2007). Obesity is another factor that contributes to vitamin D deficiency. Vitamin D is fat-soluble, meaning it is stored in adipose tissue, in obese individuals, the vitamin D may be become sequestered in fat cells, reducing its availability in the bloodstream for physiological functions (Wortsman et al., 2000).

Vitamin D undergoes two hydroxylation processes, first in the liver and then in the kidneys to become active form, calcitriol. Chronic liver or kidney diseases can impair these processes, leading to lower active vitamin D levels even if sun exposure and dietary intake are adequate (Mithal et al., 2009).

1.2 Effects of imbalanced vitamin D levels

The key is to have or achieve balance level or sufficient level of vitamin D, as too low and too high levels do have effects on physiological activities.

Vitamin D deficiency has been associated with a wide array of health problems, including osteoporosis, cardiovascular diseases, autoimmune disorders, and infectious diseases (Pludowski et al., 2013). Moreover, emerging evidence suggests that vitamin D plays a significant role in mental health, particularly in the pathogenesis of depression. Depression is a major global health concern, characterised by persistent sadness, loss of interest in activities, and a range of cognitive and physical symptoms that can impair daily functioning (American Psychiatric Association, 2013). In the USA, depression affects approximately 18.4% of adults, with women being twice as likely to suffer from depression as men (Lee et al., 2023). Several studies have identified a correlation between low serum levels of vitamin D and an increased risk of depression, (Anglin et al., 2013), particularly in populations at higher latitudes and among individuals with limited sun exposure (Mithal et al., 2009). The proposed mechanisms for this relationship include the role of vitamin D in the regulation of neurotransmitters, such as serotonin, and its anti-inflammatory and neuroprotective properties (Berk et al., 2007). Meta-analysis and reviews of randomised controlled trials have provided mixed results. Still, some have demonstrated that vitamin D supplementation may help reduce depressive symptoms, particularly in individuals with baseline vitamin D deficiency (Spedding, 2014).

In addition to its potential role in mental health, vitamin D deficiency is also implicated in the development and progression of type 2 diabetes, a chronic metabolic disorder characterised by insulin resistance and hyperglycemia (‘Standard of Medical Care in Diabetes 2014,’2013). Type 2 diabetes is a significant public health issue in the USA, affecting approximately 14.7% of the adult population, with higher prevalence rates among African Americans, Hispanics, and Native Americans (National Diabetes Statistics Report, 2024). The role of vitamin D in glucose metabolism and insulin sensitivity has been a topic of considerable research interest. Vitamin D receptors are present in pancreatic beta cells, which are responsible for insulin secretion, and in various tissues involved in glucose metabolism (Chiu et al., 2004). Studies have shown that individuals with low levels of vitamin D are at an increased risk of developing diabetes, and supplementation with vitamin D may improve insulin sensitivity and glycemic control, thereby reducing the risk of diabetes (Pittas et al., 2007).

However, excessive vitamin D intake can lead to hypercalcemia, a condition characterised by abnormally high calcium levels in the blood. Symptoms of hypercalcemia includes nausea, vomiting, weakness and frequent urination (Holick, 2007). Hypercalcemia can lead to kidney damage due to excessive deposit of calcium in the kidneys leading to nephrocalcinosis and impaired kidney function (Jones, 2008).

The high prevalence of vitamin D deficiency in the USA, coupled with its association with adverse health outcomes such as depression and diabetes, underscores the need for targeted public health interventions. Vitamin D supplementation presents a promising

strategy for improving health outcomes, particularly in populations at risk of deficiency. However, the effectiveness of supplementation may vary across different ethnic groups due to variations in baseline vitamin D levels, genetic factors, and cultural practices (Pludowski et al., 2013). This research aims to explore the role of vitamin D supplementation in improving health outcomes among different ethnic groups, with a particular focus on its potential to mitigate the burden of depression and diabetes. By examining the impact of vitamin D supplementation on these health outcomes, this study seeks to provide evidence-based insights that can inform public health strategies and clinical practices to reduce health disparities and improve the well-being of diverse populations.

2 Research methodology

The data for the study was downloaded from the National Health and Nutrition Examination Survey (NHANES) website. NHANES is a program that assesses the health and nutritional status of adults and children in the USA. This unique survey, conducted by the National Centre for Health Statistics (NCHS) under the Centre for Disease Control and Prevention (CDC), combines interviews and physical examinations to gather comprehensive health data. The NHANES program, initiated in the early 1960s, transitioned to a continuous survey in 1999, with each cycle covering two years examining a nationally representative sample of about 5,000 individuals from various counties across the country, with 15 counties visited each year. This sampling method ensures that the survey accurately represents the diverse US population (NHANES, 2015–2018).

The NHANES interview includes questions on demographics, socioeconomic status, diet, and health, while the examination involves medical, dental, physiological measurements, and laboratory tests by trained medical personnel. The findings from NHANES are crucial for determining the prevalence of major diseases and risk factors, assessing nutritional status, and setting national health standards. This data is instrumental in epidemiological studies, health science research, and developing public health policies, programs, and services, thereby enhancing the nation's health knowledge and promoting disease prevention (NHANES, 2015–2018).

The study used two survey cycles, the 2015–2016 and 2017–2018 survey cycles, making it a four-year study. In 2015–2016, NHANES selected 15,327 individuals from 30 different survey locations. Out of those selected, 9,971 completed the interview, and 9,544 underwent the examination. In 2017–2018, the survey selected 16,211 individuals from 30 different locations. Of those selected, 9,254 completed the interview, and 8,704 were examined. The data were saved and opened using SPSS version 29.0. The variables of interest were merged by the respondent sequence number 'SEQN' within a survey cycle by 'Add Variables' and the two survey cycles were combined by 'SEQN' by 'add cases'. Glycohemoglobin (LBXGH) which is hemoglobin A1C blood level was used to classify diabetes status and LBXVIDMS was used for the Vitamin D serum level. Below is a table summary of variables used in the study (NHANES, 2015–2018).

Before filtering and cleaning databased on the selected variables, 19,225 participants were selected for use. Among these, 11.1% reported being Mexican American, 7.2% identified as Other Hispanics, 32.3% as White, 22.1% as African American, 11.5% as

Asian, and 5.9% as Other Races. The gender distribution was nearly even, with 49,1% male and 50.9% female participants. The mean age of the participants was 33 years.

For our study, we employed a research methodology that utilised a complex sampling design, which combined clustered sampling, sample weighting, and stratified sampling. This multifaceted approach is effective for uncovering patterns in large survey datasets and ensures that the results accurately reflect the demographic composition of the population. By adopting this complex sampling technique with stratification, the study aimed to enhance the representativeness and precision of the outcomes, providing a comprehensive representation of the USA population. This method allows us to draw more reliable and generalisable conclusions from our data, ensuring that the findings are both robust and reflective of the broader population demographics.

Table 1 Illustrates the original variables in NHANES recorded to new variable

Variable name	*Variable label*	*Original variable name*	*Variable classification*	*Responses categorised as*
A1C_Diabetes	Diabetic	LBXGH	Dependent	A1 < 5.6: '1'= 'no'
				A1C > 5.6: '2'= 'yes'
Depression_Status	Depression	DPQ020	Dependent	'0' = 'no'
				'1' = 'yes'
Age_Group	Age group	RIDAGEYR	Independent	1 = 18–39
				2 = 40–59
				3 = 60–79
				4 = 80+
Gender	Gender	RIAGENDR	Independent	1 = 'Male
				2 = 'Female'
Race	Race	RIDRETH3	Independent	1 = Mex. American
				2 = Other Hispanics
				3 = White
				4 = African American
				5 = Asian
				6 = Other races
VitaminD_Deficient	VitaminD deficient	LBXVIDMS	Independent	Deficient '0' = 'yes'
				Deficient '1' = 'no'
VitaminD_Sup.	VitaminD Sup	DSQTVD	Independent	Supplement '1'= 'yes'
				Supplement '2'= 'no'

The missing values, if present in any of the datasets were eliminated using the likewise deletion to ensure a consistent base case. With the help of the SEQN, the participants who have variables of interest were identified. The main focus of the study was to know how Vitamin D supplementation impacts type 2 diabetes and depression among different ethnic groups in the USA. A1C levels of less than 5.6 were coded as 'no' meaning no

diabetes and A1C greater than 5.6 was coded as 'yes' meaning participants have diabetes or are at risk of diabetes.

Vitamin D supplementation was coded as 'yes' for those who take the supplement and 'no' for those who do not. Depression was coded as 'no' for participants who answered, 'not at all' to the questions 'feeling down, depressed, or hopeless' and 'yes' for participants who answered, 'several days, more than half the days, and nearly every day' to the questions 'feeling down, depressed, or hopeless.' The sample weight was calculated based on the NHANES criteria to reflect the four years covered by the study to use in designing the study plan for the complex sample analyses.

In preliminary analyses, descriptive statistics were performed to show the frequency of gender, age group, vitamin D supplementation status, diabetes status, depression status, and the frequency of the different ethnicities. Cross-tabulation was done to show the distribution of diabetes status and depression status across vitamin D supplementation status while adjusting for age, gender, and race. The cross-tabulation was used to analyse the chi-square test to indicate whether there is a statistically significant association between the variables of interest.

The relationship between vitamin D supplementation status and each health outcome, i.e., diabetes status and depression were examined using logistic regression analysis. The dependent variables were binary measures, categorising participants into two groups, see Table 1 for details. The logistic regression analysis shows the odd ratios for ethnicity and vitamin D supplementation status in predicting diabetes status and depression while adjusting for age groups and gender. All analyses were performed with SPSS 29.0.

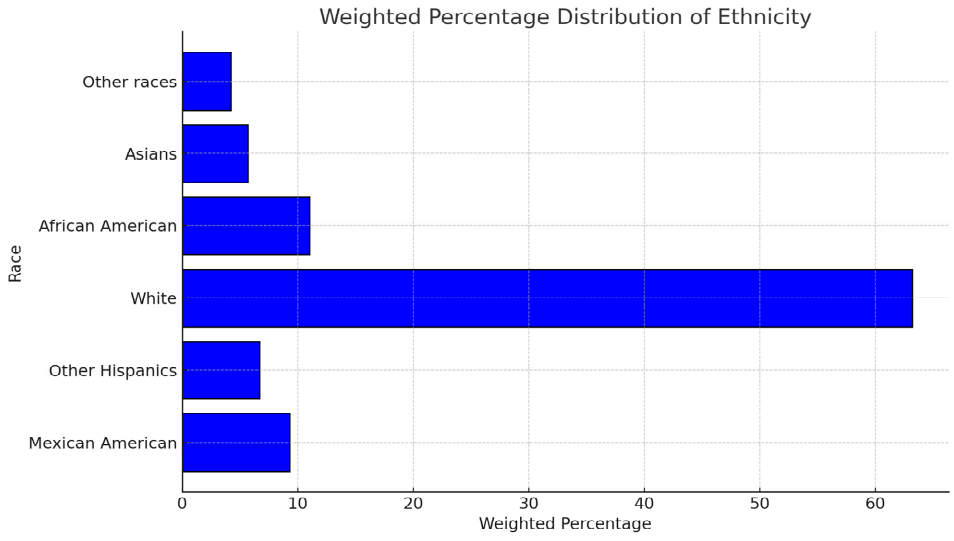
3 Results

After cleaning and excluding missing data, descriptive statistics showed that 9,811 participants (age range: 18-80 years) with complete data were used for this study. The demographic breakdown revealed that the majority of participants identified as white (34.7%), followed by African American (21.6%), Mexican American (16.2%), Asians (11.8%), other Hispanics (11%), and Other Races (4.6%). The average age of participants was 44.5 years, and slightly more than half (51.4%) were female. In terms of health statistics, a significant portion of the sample, 34.4% were found to be at risk of diabetes/diabetes, 23.3% were found to be depressed, and 39.9% reported taking vitamin D supplements. 65% of participants were under 60 years old, Table 2 shows the weighted statistics of age bracket and Figure 1 shows the weighted statistics of ethnicity.

Table 2 Weighted percentage of age bracket

Variable		*Weighted percent*
Age bracket	18–39	37.3%
	40–59	34.6%
	60–79	23.6%
	80+	4.5%

Figure 1 Weighted percentage distribution of ethnicity/race (see online version for colours)



Chi-square tests indicated a strong association between age and diabetes, gender and diabetes, race and diabetes, vitamin D supplementation and diabetes, gender and depression, and race and depression, with a p-value of < 0.001 as shown in Table 3.

Table 3 Test of independence

Cross-tabulation: tests of independence					
	Chi-square	*Adjusted F*	*df1*	*df2*	*Sig.*
Age * diabetes	1538.748	224.953	2.244	67.319	< 0.001
Gender * diabetes	3.598	3.682	1	30	0.065
Race * diabetes	119.387	18.129	3.926	117.786	< 0.001
vitDsup * diabetes	73.474	23.786	1	30	< 0.001
Age * depression	13.920	1.774	2.530	75.886	0.168
Gender * depression	57.662	35.098	1	30	< 0.001
Race * depression	40.879	6.724	3.219	96.562	< 0.001
vitDsup * depression	10.994	3.452	1	30	0.073

The cross-tabulation of diabetes shows significant associations between age brackets ($p < 0.001$) indicating substantial differences in diabetes prevalence across different age groups. Race ($p < 0.001$), suggesting that diabetes risk varies significantly across racial groups. Vitamin D supplementation ($p < 0.001$) shows that supplementation status significantly affects diabetes. Gender with a p-value of 0.065 indicates marginally non-significant, suggesting that gender might not be a strong independent factor for diabetes. Similarly, the cross-tabulation of depression shows gender and race have significant associations with depression suggesting gender differences in depression risk, likewise, depression is influenced by race.

Analyses of interaction effects show significance in the interaction of vitamin D supplements and age ($p < 0.001$), race ($p < 0.001$), and gender (p 0.005) indicating that

the impact of vitamin D supplementation on diabetes significantly varies by race and across age brackets and differs by gender. Why for depression, the interaction effects of vitamin D supplementation and race, and vitamin D supplementation and gender show significant interaction indicating that the impact of vitamin D supplementation on depression varies by race and differs by gender as depicted in Table 4.

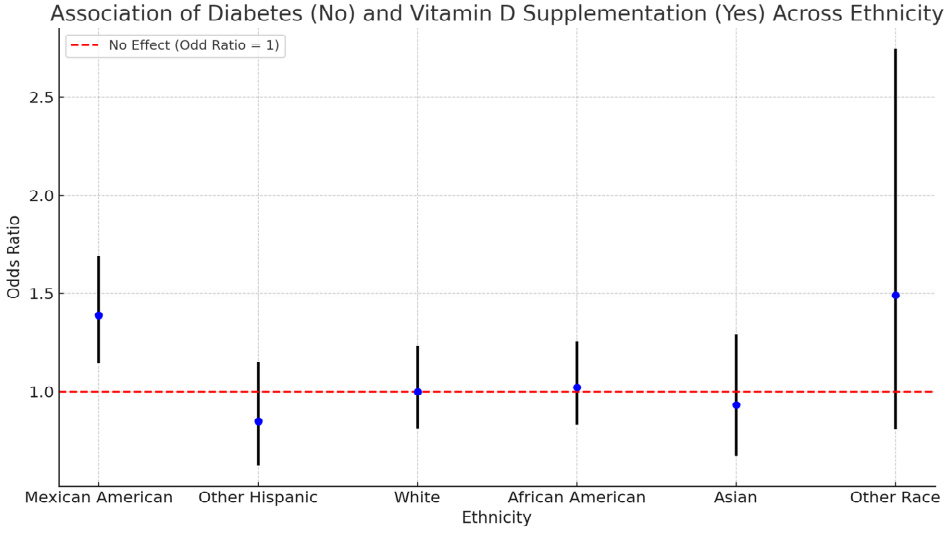
Table 4 Interactive effects of Vitamin D supplementation

Interaction effects of vitamin D supplementation, age, gender and race on diabetes and depression

	Diabetes		*Depression*	
Intercept	*< 0.001*		*< 0.001*	
Interaction	Wald F	Sig.	Wald F	Sig.
VitDsup*age	266.880	< 0.001	0.587	0.738
VitDsup*gender	6.424	0.005	26.963	< 0.001
VitDsup*race	22.807	< 0.001	4.744	0.001

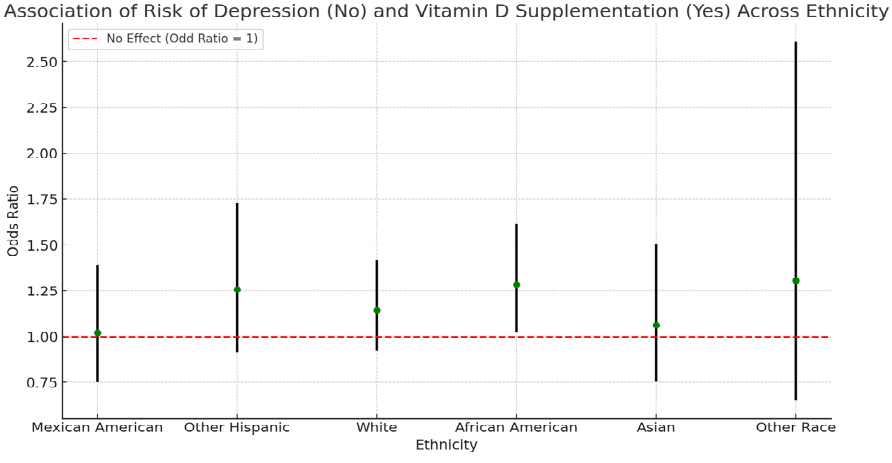
Logistic regression was performed for diabetes and depression across ethnic groups to provide insights into the impact of vitamin D supplementation when controlling for other variables. For diabetes, the odd ratios suggested that individuals who take vitamin D supplements have higher odds of not having diabetes compared to those who do not take the supplements across ethnic groups however, significance was only established in Mexican Americans, indicating that, among Mexican Americans, vitamin D supplementation is significantly associated with reduced likelihood of having diabetes. The narrow confidence interval (CI) indicates that the estimate is precise, providing a high level of confidence in the association. The odds ratio and CI for the relationship between vitamin D supplementation and diabetes across ethnic groups are shown in Figure 2.

Figure 2 Effects of vitamin d supplementation on diabetes across ethnicity (see online version for colours)



For depression, the odd ratios suggest that individuals who take vitamin D supplements have higher odds of not having depression across all ethnic groups, however, significance was only seen in the African American population (OR:1.286, CI: 1.021–1.620), suggesting a protective effect of vitamin D supplementation against depression and that the result is statistically significant. This suggests that vitamin D supplementation may be associated with a reduced likelihood of depression in this population. The odds ratio and CI for the relationship between vitamin D supplementation and depression across ethnic groups are shown in Figure 3.

Figure 3 Effects of vitamin d supplementation on depression across ethnicity (see online version for colours)



4 Discussion

Our analysis using NHANES data demonstrates that vitamin D supplementation significantly impacts health outcomes, particularly diabetes and depression, across different ethnic groups.

4.1 Vitamin D supplementation and diabetes across ethnic groups

Our study highlights significant ethnic disparities in the association between vitamin D supplementation and the reduced risk of diabetes. The odds ratios in Figure 2 indicate that vitamin D supplementation has a positive association with a reduced risk of diabetes among some ethnic groups, while others show weaker or no significant associations.

For Mexican Americans, the odds ratio (OR = 1.389, 95% CI: 1.142–1,690) suggests a significant protective effect of vitamin D supplementation against diabetes. This finding aligns with previous studies that have demonstrated the role of vitamin D in improving insulin sensitivity and glucose metabolism, particularly in populations at higher risk for diabetes, such as Mexican Americans and other minorities (Palomer et al., 2007). This is particularly relevant for Mexican Americans, who, due to genetic and environmental factors, are at higher risk for both vitamin D deficiency and diabetes. Supplementation in this group may help reduce the incidence of diabetes by improving glucose metabolism.

Other studies have demonstrated vitamin D deficiency was associated with an increased risk of diabetes, particularly among individuals with darker skin tone (Afzal et al., 2013; Ames et al., 2021). This supports the observed disparity in the protective effects of Vitamin D supplementation, particularly for Mexican Americans and African Americans.

In contrast, the association between vitamin D supplementation and diabetes risk was weaker among other ethnic groups even with high odds of reducing the risk of diabetes with supplementation. For African Americans, the odds ratio was 1.023 suggesting odds for reduced risk of diabetes but the association was not statistically significant. This may be due to the complex interaction between vitamin D metabolism and genetic factors in African Americans. Research has shown that African Americans often have lower serum levels of 25-hydroxyvitamin D due to differences in vitamin D-binding protein, which may limit the effectiveness of standard supplementation doses (Powe et al., 2013). The odds ratio for whites (OR = 1.001, 95% CI: 0.812–1.235) also suggests a negligible effect of vitamin D supplementation though the association is not significant. This finding is consistent with research indicating that while vitamin D supplementation can be beneficial for individuals with vitamin D deficiency, its effects are less pronounced in those with adequate baseline levels of vitamin D (Pittas et al., 2006). Whites, generally having higher baseline levels of vitamin D due to greater sun exposure, lighter skin tone Ames et al (2021), and dietary intake, may not experience as strong a benefit from supplementation in reducing diabetes risk. The non-significant association between vitamin D supplementation and diabetes risk across ethnicities apart from Mexican Americans suggests that genetic and environmental factors across different populations may be responsible as vitamin D plays a role in modulating the immune system that influences insulin secretion and sensitivity (Manson et al., 2012).

4.2 Vitamin D supplementation and depression across ethnic groups

Our analysis reveals ethnic disparities in the protective effects of vitamin D supplementation against depression. The odds ratio for African Americans who take vitamin D supplements is 1.286 (95% CI: 1.021–1.620), suggesting a significantly higher likelihood of being free from depression compared to those who do not take vitamin D supplements. Various studies support this finding, one such study by Ganji et al. (2010) focused on the relationship between serum vitamin D levels and depression across different ethnic groups, finding that vitamin D deficiency was more strongly associated with depression in African Americans and Hispanics than in Whites. This suggests that supplementation may be more critical for these groups in mitigating depression risk. Similarly, a system review by Spedding (2014) found that vitamin D supplementation was associated with reduced depressive symptoms, but effects varied by population. The review highlighted those individuals with the greatest deficiencies benefited the most, supporting the argument that targeted interventions are needed for populations with low baseline levels of vitamin D, such as African Americans. Powe et al. (2013) suggested that disparity in vitamin D levels is due to differences in Vitamin D-binding proteins. Forest and Stuhldreher (2011) attribute this disparity to melanin levels reducing vitamin D synthesis from sunlight. Since African Americans are prone to vitamin D deficiency due to high melanin, consequently, vitamin D supplementation may be particularly effective in reducing depression risk in this population.

In contrast, other ethnic groups see Figure 3, exhibited odds ratios close to and above 1, indicating a negligible association between vitamin D supplementation and depression

risk. This suggests that other factors, such as cultural or dietary differences may play a more significant role in influencing depression risk in these populations. These findings are consistent with studies suggesting dietary intake of vitamin D-rich foods, combined with higher levels of physical activity, may reduce the need for supplementation in some ethnic groups (Ganji et al., 2010). Though vitamin D supplementation has been shown to reduce the risk of depression in African Americans, its effects are less pronounced in populations with higher baseline levels of vitamin D due to a combination of diet, lifestyle, genetics, and greater exposure to sunlight, which may explain the less pronounced effect of supplementation in other groups especially whites (Schneider et al., 2000).

4.3 Implications for public health interventions

Findings from our study indicate that public health strategies targeting vitamin D supplementation to reduce diabetes risk and depression risk should be tailored to account for ethnic differences. Minorities, especially Mexican Americans and African Americans, who showed the most significant benefit from vitamin D supplementation, may be an important target for public health interventions aimed at reducing diabetes in Mexican Americans and reducing the risk of depression in African Americans through supplementation. Additionally, routine screening for vitamin D deficiency could help identify individuals at greater risk for diabetes and depression, particularly in ethnic groups with lower baseline levels.

For minority ethnic groups, the study suggests that standard D supplementation doses may not be sufficient to reduce the risk of diabetes and depression significantly. Public health strategies should consider individualised supplementation recommendations based on baseline vitamin D status, with higher doses potentially needed for ethnic groups such as African Americans and Hispanics to achieve optimal serum levels.

5 Conclusions

Our study of NHANES data on vitamin D supplementation's effects on depression and diabetes reveals significant insights into the potential protective role of vitamin D across different ethnic groups. For both depression and diabetes, vitamin D supplementation appears to offer notable benefits, particularly for populations that are more prone to vitamin D deficiency, such as African Americans and Mexican Americans. These populations often exhibit higher baseline risks for both conditions due to genetic, environmental, and socioeconomic factors and vitamin D supplementation may help mitigate these risks by improving metabolic functions, mood regulation, and insulin sensitivity.

However, the effects of vitamin D supplementation are not uniform across all ethnicities. The efficacy of supplementation tends to be more pronounced in those with lower baseline vitamin D levels. In contrast, individuals with higher baselines, such as Whites and Asians, show weaker or no significant effect.

These findings emphasise the need for personalised public health interventions that consider ethnicity and baseline vitamin D status when designing supplementation strategies. Targeted approaches that focus on screening for vitamin D deficiency and administering appropriate doses of supplementation could significantly reduce the

prevalence of depression and diabetes, especially in high-risk groups. Future research should continue to investigate the complex interactions between vitamin D metabolism, ethnicity, and chronic disease prevention to further optimise these interventions.

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References

Afzal, S., Bojesen, S.E. and Nordestgaard, B.G. (2013) 'Low 25-hydroxyvitamin D and risk of type 2 diabetes: a prospective cohort study and metaanalysis, *Clinical Chemistry*, Vol. 59, pp.381–391, https://doi.org/10.1373/clinchem.2012.193003.

American Psychiatric Association, DSM-5 Task Force (2013) *Diagnostic and Statistical Manual of Mental Disorders: DSM-5™*, 5th ed., American Psychiatric Publishing, Inc. https://doi.org/10.1176/appi.books.9780890425596.

Ames, B.N., Grant, W.B. and Willett, W.C. (2021) 'Does the high prevalence of vitamin D deficiency in African Americans contribute to health disparities?', *Nutrients*, Vol. 13, p.499, https://doi.org/10.3390/nu13020499.

Anglin, R.E.S., Samaan, Z., Walter, S.D. and McDonald, S.D. (2013) 'Vitamin D deficiency and depression in adults: systematic review and meta-analysis', *The British Journal of Psychiatry*, Vol. 202, pp.100–107, https://doi.org/10.1192/bjp.bp.111.106666.

Berk, M., Sanders, K.M., Pasco, J.A., Jacka, F.N., Williams, L.J., Hayles, A.L. and Dodd, S. (2007) 'Vitamin D deficiency may play a role in depression', *Medical Hypotheses*, Vol. 69, pp.1316–1319, https://doi.org/10.1016/j.mehy.2007.04.001.

Chiu, K.C., Chu, A., Go, V.L.W. and Saad, M.F. (2004) 'Hypovitaminosis D is associated with insulin resistance and β cell dysfunction', *American Journal of Clinical Nutrition*, Vol. 79, pp.820–825, https://doi.org/10.1093/ajcn/79.5.820.

Forrest, K.Y.Z. and Stuhldreher, W.L. (2011) 'Prevalence and correlates of vitamin D deficiency in US adults', *Nutrition Research*, Vol. 31, pp.48–54, https://doi.org/10.1016/j.nutres.2010.12.001.

Ganji, V., Milone, C., Cody, M.M., McCarty, F. and Wang, Y.T. (2010) Serum vitamin D concentrations are related to depression in young adult US population: the third national health and nutrition examination survey', *International Archives of Medicine*, Vol. 3, p.29, https://doi.org/10.1186/1755-7682-3-29.

Ginde, A.A., Mansbach, J.M. and Camargo, C.A. (2009) 'Association between serum 25-hydroxyvitamin d level and upper respiratory tract infection in the third national health and nutrition examination survey', *Archives of Internal Medicine*, Vol. 169, p.384, https://doi.org/10.1001/archinternmed.2008.560.

Holick, M.F. (2007) 'Vitamin D deficiency', *New England Journal of Medicine*, Vol. 357, pp.266–281, https://doi.org/10.1056/nejmra070553.

Holick, M.F. (2017) The vitamin D deficiency pandemic: approaches for diagnosis, treatment and prevention', *Reviews in Endocrine and Metabolic Disorders*, Vol. 18, pp.153–165, https://doi.org/10.1007/s11154-017-9424-1.

Jones, G. (2008) 'Pharmacokinetics of vitamin D toxicity', *American Journal of Clinical Nutrition*, Vol. 88, pp.582S–586S, https://doi.org/10.1093/ajcn/88.2.582s.

Lee, B., Wang, Y., Carlson, S.A., Greenlund, K.J., Lu, H., Liu, Y., Croft, J.B., Eke, P.I., Town, M. and Thomas, C.W. (2023) 'National, state-level, and county-level prevalence estimates of adults aged ≥18 years self-reporting a lifetime diagnosis of depression – United States, 2020', *MMWR Morbidity and Mortality Weekly Report*, Vol. 72, pp.644–650, https://doi.org/10.15585/mmwr.mm7224a1.

Manson, J.E., Bassuk, S.S., Lee, I-M., Cook, N.R., Albert, M.A., Gordon, D., Zaharris, E., MacFadyen, J.G., Danielson, E., Lin, J., Zhang, S.M. and Buring, J.E. (2012) 'The VITamin D and OmegA-3 TriaL (VITAL): Rationale and design of a large randomized controlled trial of vitamin D and marine omega-3 fatty acid supplements for the primary prevention of cancer and cardiovascular disease', *Contemporary Clinical Trials*, Vol. 33, pp.159–171, https://doi.org/10.1016/j.cct.2011.09.009.

Mithal, A., Wahl, D.A., Bonjour, J-P., Burckhardt, P., Dawson-Hughes, B., Eisman, J.A., Fuleihan, G.E-H., Josse, R.G., Lips, P. and Morales-Torres, J. (2009) 'Global vitamin D status and determinants of hypovitaminosis D', *Osteoporosis International*, Vol. 20, pp.1807–1820, https://doi.org/10.1007/s00198-009-0954-6.

National Diabetes Statistics Report (2024) *Diabetes* [online] https://www.cdc.gov/diabetes/php/data-research/index.html.

National Health and Nutrition Examination Survey Homepage (NHANES) (n.d.) [online] https://www.cdc.gov/nchs/nhanes/index.htm.

National Health and Nutrition Examination Survey (NHANES) (2015–2018) US Department of Health and Human Services [online] https://www.cdc.gov/nchs/nhanes/ (accessed 16 August 2024).

Palomer, X., González-Clemente, J.M., Blanco-Vaca, F. and Mauricio, D. (2007) 'Role of vitamin D in the pathogenesis of type 2 diabetes mellitus', *Diabetes Obesity and Metabolism*, Vol. 10, pp.185–197, https://doi.org/10.1111/j.1463-1326.2007.00710.x.

Pittas, A.G., Dawson-Hughes, B., Li, T., Van Dam, R.M., Willett, W.C., Manson, J.E. and Hu, F.B. (2006) 'Vitamin D and calcium intake in relation to type 2 diabetes in women', *Diabetes Care*, Vol. 29, pp.650–656, https://doi.org/10.2337/diacare.29.03.06.dc05-1961.

Pittas, A.G., Lau, J., Hu, F.B. and Dawson-Hughes, B. (2007) 'The role of vitamin D and calcium in type 2 diabetes. A systematic review and meta-analysis', *The Journal of Clinical Endocrinology and Metabolism*, Vol. 92, pp.2017–2029, https://doi.org/10.1210/jc.2007-0298.

Pludowski, P., Holick, M.F., Pilz, S., Wagner, C.L., Hollis, B.W., Grant, W.B., Shoenfeld, Y., Lerchbaum, E., Llewellyn, D.J., Kienreich, K. and Soni, M. (2013) 'Vitamin D effects on musculoskeletal health, immunity, autoimmunity, cardiovascular disease, cancer, fertility, pregnancy, dementia and mortality – a review of recent evidence', *Autoimmunity Reviews*, Vol. 12, pp.976–989, https://doi.org/10.1016/j.autrev.2013.02.004.

Powe, C.E., Evans, M.K., Wenger, J., Zonderman, A.B., Berg, A.H., Nalls, M., Tamez, H., Zhang, D., Bhan, I., Karumanchi, S.A., Powe, N.R. and Thadhani, R. (2013) 'Vitamin D–binding protein and vitamin D status of Black Americans and White Americans', *New England Journal of Medicine*, Vol. 369, pp.1991–2000, https://doi.org/10.1056/nejmoa1306357.

Schneider, B., Weber, B., Frensch, A., Stein, J. and Fritz, J. (2000) 'Vitamin D in schizophrenia, major depression and alcoholism', *Journal of Neural Transmission*, Vol. 107, pp.839–842, https://doi.org/10.1007/s007020070063.

Spedding, S. (2014) 'Vitamin D and depression: a systematic review and meta-analysis comparing studies with and without biological flaws', *Nutrients*, Vol. 6, pp.1501–1518, https://doi.org/10.3390/nu6041501.

Standards of Medical Care in Diabetes – 2014 (2013) *Diabetes Care*, Vol. 37, pp.S14–S80, https://doi.org/10.2337/dc14-s014.

Wortsman, J., Matsuoka, L.Y., Chen, T.C., Lu, Z. and Holick, M.F. (2000) 'Decreased bioavailability of vitamin D in obesity', *American Journal of Clinical Nutrition*, Vol. 72, pp.690–693, https://doi.org/10.1093/ajcn/72.3.690.