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Research Article

Impact of Dietary Vitamin Intake on Obesity in Native American Adolescents

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Abstract

Background: The overall obesity rates in the United States have been increasing but adolescent rates have been gaining momentum at an alarming rate compared to other age groups. However, these statistics consider the United States population as a whole and fail to recognize ethnic minority groups such as Native Americans who have adolescent obesity rates 12.9% above the 2015 national average. This study analyzed the dietary vitamin intake values of Native American adolescents in relation to their body fat mass categories.

Methods: Our study's population was drawn from grades 9 through 12 and consisted of 183 Native American adolescents ages 14-18, representing 43 tribes across the USA. Dietary intake data was obtained using the Harvard School of Public Health Youth Adolescent Questionnaire (HSPHYAQ), a semi-quantitative food frequency questionnaire that estimates macronutrients and micronutrients from foods in the participants' diet. The completed surveys were prepared for scanning by The Harvard T.H. Chan School of Public Health Nutrition Department.

Results: All body fat mass categories were deficient in vitamins D, E, K, B4, B5 & B9. Obese females were shown to be generally more deficient than normal females.

Conclusion: Within the Native American population in the United States, adolescents were found to have micronutrient deficiencies and higher rates of obesity compared to national figures.

Impact Statement: Conducted amongst a population group with higher-than-average rates of child and adolescent obesity, this study discovered that there were only four vitamins in which all BMI groups met the adequate dietary intake for, meaning that even the normal weight range group often had an inadequate dietary vitamin intake.

INTRODUCTION

In the past few decades, the overall U.S. obesity rates have increased dramatically, and now current research is showing a positive correlation between obesity and the increased prevalence of chronic diseases [1-4]. Many of the chronic diseases which plague and overburden the U.S. healthcare system include diabetes mellitus, hypertension, cardiovascular diseases, stroke, and some cancers; all of which can be mitigated through dietary and lifestyle changes [5,6]. In 2017 it was estimated that the U.S. healthcare system spent $315.8 billion on treatments related to obesity [7]. In addition to adult obesity rates, the National Center for Health Statistics reported in 2018 that adolescents ages 12-19 years had a national obesity rate of 25.4%, up 1.3% from the previous year [3,8]. The period of adolescence is extremely important developmentally because biological predictors of cardiovascular disease such as increased levels of glucose, triglycerides, LDL cholesterol, and decreased levels of HDL cholesterol are established [9]. Additionally, adolescence is when behavior patterns are established that influence physical and emotional health moving into adulthood [10]. The overall adolescent obesity rates in the United States have been gradually increasing and require immediate attention. However, national statistics surveys reporting obesity rates can fail to highlight the full extent of the obesity epidemic by neglecting to include data regarding high-risk sub-populations such as Native American adolescents [1]. The data published by the National Center for Health and Statistics in 2020 reporting a 25.4% obesity rate showed Mexican American boys having the highest sub-categorical rate at 29.2% [1]. However, our own previous research published in 2016 presents statistical data absent from many national statistics surveys that shows an obesity rate of 38.3% in a sample of Native American adolescents at Sherman Indian High School; with males having an obesity rate of 35.4% and females having an astounding 41.7% obesity rate [11]. The inclusion of Native American obesity rates in national statistics may be less frequent due to differences in reporting guidelines between local, state, and tribal governments. However, restricting the data to broad ethnic categories masks critical points of extreme disparities that may require special attention. Researchers trying to understand the disparity in Native American obesity rates have assessed several different approaches and hypotheses to both combat the epidemic and understand its origins.

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There are a few hypotheses that offer insight as to how there can be such a large disparity between Native American and national adolescent obesity rates. One theory identifies food insecurity as a major catalyst. Food insecurity is defined as having a "Limited or uncertain ability to acquire or consume an adequate quality or sufficient quantity of food in socially acceptable ways" [12]. According to Jernigan et al. [13], the geographic isolation of many tribes has caused members to become heavily reliant on cheaper non-nutritive food options found at local convenience stores [13]. In another research study conducted by Sowerwine et al., Native Americans in the Klamath River Basin were found to have a food insecurity rate of 76.7%, more than three times higher than the national Native American rate of 25% and more than six times the national non-Native American rate of 12.3% [14]. Additionally, a study conducted by Porter et al. [6], found that tribal members of the Wind River Indian Reservation in Wyoming had a 65% food insecurity rate which was associated with obesity rates 70% higher than the national average and hypertension rates more than twice the national average [6]. These studies show how food insecurity differences within various tribal lands may influence the higher prevalence of obesity.

Another hypothesis identified genetic variation as a contributing factor to higher obesity rates. According to Acuña-Alonzo, et al. [15], people with high Native American genetic ancestory were more likely to have a gene variant exclusive to Native Americans. The *R230C* variant of the ATP-binding cassette transporter A1 gene (*ABCA1*) found in Native Americans is associated with low baseline levels of high-density lipoprotein cholesterol (HDL-C) which is essential in regulating cholesterol efflux [15]. In another genetic variation study a research team found that Brazilians with a large Native American genetic ancestry had lower baseline levels of vitamin B_{12} and folate, elucidating that those genetic abnormalities may in fact play a role in metabolic differences between various ethnicities. However, the same research team conducted micronutrient intervention on 20 children and adolescents over 6 weeks and found that Native Americans were the most responsive ethnic group to micronutrient intervention. The intervention resulted in lower LDL levels and increased gene expression of proteins related to lipid and glucose metabolism when compared to European and African subjects [9]. Another study conducted by Caro-Gomez et al. [16] examined the genes of an admixed Colombian Native American population and found that subjects with greater Native American ancestry had a subtle predisposition to decreased pancreatic β-cell functioning, a signature trait of type 2 diabetes. Moreover, the same research team suggested that the forced adoption of western dietary patterns rich in simple carbohydrates, fats, and processed foods has served as a catalyst for metabolic dysfunction and obesity [16]. This information has prompted a call to action in many tribal communities in an effort to tackle the growing obesity epidemic in Native American populations.

With increased awareness and new research data, the emergence of programs focused on reducing Native American adolescent obesity rates and increasing daily micronutrient intake from whole foods have taken flight. One program called The Tribal Health and Resilience in Vulnerable Environments (THRIVE) program sought to challenge long standing Native American food insecurity rates in Oklahoma by: increasing tribal awareness of major issues; increasing the accessibility of nutrient dense food at convenience stores; and reducing the cost of healthy foods. THRIVE was successful in creating collaboration between local governments, commerce, and health departments to increase accessibility and reduce the price of healthy foods in local stores [13]. In an intervention study conducted by Guerendiain et al. [17], dietary intervention of antioxidant fat-soluble vitamins and carotenoids like α-tocopherol (vitamin E), retinol (vitamin A), lycopene, and β-carotene was shown to influence several genes associated with lipid metabolism and fat storage. Obese individuals have a higher need for antioxidants due to higher levels of free-radicals which accompanies obesity. Therefore, adequate dietary intake of micronutrients becomes increasingly more important the higher an individuals' body fat mass is [11,17]. These findings along with the research conducted by Coelho-Landell et al. [9], and Acuña-Alonzo, et al. [15], support the idea of a strong correlation between increased micronutrient intake and lower obesity rates. The previously mentioned data serves as the foundation for our interest of conducting this study to better understand the higher than average Native American adolescent obesity rates in the United States.

In our two previous studies, we used the HSPHYAQ to analyze dietary intake values of antioxidants, minerals, and macronutrients. We then compared that data with the subjects' anthropometric measurements to look for correlations to obesity [11,18,19]. The purpose of this study was to analyze the data from the HSPHYAQ to estimate the dietary vitamin intake in Native American adolescents and look for associations with obesity. The estimated consumption of all eight water-soluble and four fat-soluble vitamins were analyzed and compared to the national DRI standards.

METHODS & MATERIALS

Study participants

This research was a cross-sectional and epidemiological study that analyzed and estimated the dietary vitamin intakes of Native American adolescent students within BMI categories. The subjects were from the off-reservation Sherman Indian High School located in Riverside, California. Sherman Indian High School was selected because the student population represented 43 different Native American tribes from across the United States and served as a sample of the national Native American adolescent population. The subjects were between the ages of 14-18 years and were dispersed between school grades 9-12 and consisted of 183 participants [18,19]. Students were considered residents of the campus and were provided three meals a day plus snacks by the school with no restriction on personally procured snacks. Students were assigned living quarters at one of the four on-site dormitories which served as the locations for weekly anthropometric measurements over the course of eight weeks [11]. The study was conducted by California Baptist University professionals, each member participating in a mandatory orientation session where they were given guidance on how each assessment phase would be conducted; training on Native

American culture; and training on the guidelines and applications for all quantitative measurements to ensure continuity among the team members.

Data Collection and Analysis

Baseline anthropometric data from each subject was gathered each week for 8 weeks. Measures of height (m), weight (kg), waist circumference (cm); and skinfold (mm) measurements of the triceps and calves were taken in accordance with National Institute of Health (NIH) standardized protocols [20]. From these data a BMI (kg/m^2) value was assigned to each subject calculated from the arithmetic mean of all their measures. Each subject (n=183) was assigned to one of four BMI classification categories according to the National Health and Nutrition Examination Survey III (NHANES III) guidelines. Subjects were classified as underweight (<18.5), normal (18.5-24.9), overweight (25-29.9), or obese (≥30.0). The normal and obese categories were then further divided into gender groups ultimately yielding four test categories: normal males, obese males, normal females, and obese females.

Dietary intake data was obtained using the HSPHYAQ on a weekly basis. Weekly sessions were scheduled at each of the four dormitories over an 8-week period for collection of anthropometric and dietary data. The completed surveys were sent to the Harvard T.H. Chan School of Public Health's Department of Nutrition where a total intake value for each vitamin was generated for each subject. The mean intake values for all subjects in each of their respective test categories (normal male, obese male, normal female and obese female) were then calculated for each vitamin.

Statistical Analysis

Analysis of the anthropometric and dietary vitamin intake data was conducted at California Baptist University using R-3.1.0 statistical software [11]. The vitamin intake values for each BMI category were then compared to the Dietary Reference Intakes (DRIs): Recommended Dietary Allowance (RDA) or Adequate Intake (AI) for each vitamin according to the guidance from the Institutes of Medicine and National Institutes of Health Office of Dietary Supplements (Table 1). Daily Value (DV) was based on a 2000 kcal/day diet. The 12 vitamins essential to the human body include the four fat-soluble (vitamins A, D, E, and K) vitamins and eight water-soluble (vitamins B_1, B_2, B_3, B_4, B_5, B_6, B_9, and B_{12}) [21,22]. The Student's T-test was utilized to find statistical significance between means expressed as mean ± standard error of the mean (SEM). The significance testing was set at p-value <0.05. The data were compared across the BMI (underweight, normal, overweight, and obese) and gender categories to DRI values.

RESULTS

Comparisons of vitamin intake among the normal male, obese male, normal female and obese female BMI categories were performed using a two-tailed t-test assuming unequal variances with significance testing set at a p-value <0.05. Significance testing was conducted between each of the BMI categories and between genders. Comparing the vitamin intake data in this way allowed the research team to clearly identify intake differences between BMI categories and genders.

FAT SOLUBLE VITAMINS

Vitamin A

The RDA for males is 3000IU/day (900µg/day RAE) while the recommended intake for females are 2333IU/day (700µg/day RAE). Vitamin A is important in maintaining healthy vision and skin. Additionally, the antioxidant β-carotene has been associated with lower levels of adipose tissue accumulation in humans [17]. Common sources include animal meat, fortified milk products, and eggs; but can also be found in plants rich in β-carotene such as broccoli, cantaloupe, and carrots. Normal BMI males (3887.87 ± 739.22IU/day; 129.6% DV) and obese BMI males (3825.67 ± 1098.70IU/day; 127.5% DV) had comparable reported intake values. However, normal BMI females (8583.69 ± 2623.41IU/day; 367.9% DV) averaged an intake significantly

Table 1:

	Males			Females		
Vitamin	**Daily RDA/AI**	**Normal**	**Obese**	**Daily RDA/AI**	**Normal**	**Obese**
A	3000IU	3887.87 ± 739.22	3825.67 ± 1098.70	2333IU	8583.69 ± 2623.41	2325.62 ± 498.60
D	600IU	135.15 ± 0.60	93.52 ± 0.61	600IU	35.94 ± 0.19	59.62 ± 0.37
E	15IU	3.81 ± 0.54	4.45 ± 0.69	15IU	4.22 ± 1.32	3.65 ± 0.92
K	120µg	38.34 ± 5.36	30.07 ± 4.29	75µg	63.48 ± 35.53	38.07 ± 14.56
B_1	1.2mg	1.37 ± 0.14	1.41 ± 0.12	1mg	1.05 ± 0.15	1.24 ± 0.11
B_2	1.3mg	1.48 ± 0.18	1.50 ± 0.14	1.1mg	1.48 ± 0.33	1.17 ± 0.13
B_3	16mg	14.17 ± 1.63	15.75 ± 1.41	14mg	16.23 ± 3.22	13.03 ± 1.19
B_4	550µg	211.51 ± 90.33	182.14 ± 158.69	400µg	92.24 ± 205.39	156.27 ± 169.56
B_5	5mg	4.44 ± 0.45	4.76 ± 0.49	5mg	3.41 ± 0.67	3.25 ± 0.49
B_6	1.3mg	1.26 ± 0.12	1.46 ± 0.19	1.2mg	1.61 ± 0.33	1.29 ± 0.15
B_9	400µg	238.41 ± 20.74	247.89 ± 35.22	400µg	203.55 ± 32.89	186.34 ± 20.48
B_{12}	2.4µg	3.36 ± 0.41	3.27 ± 0.20	2.4µg	3.75 ± 1.07	2.82 ± 0.29
C	75mg	111.73 ± 19.45	89.28 ± 18.22	65mg	57.85 ± 10.40	77.08 ± 18.12

more (p = 0.043) than obese BMI females (2325.62 ± 498.60IU/day; 99.7% DV), Figure 1A. Therefore all categories had adequate dietary intake of vitamin A.

Vitamin D

In this study Ergocalciferol (D_2) and Cholecalciferol (D_3) levels were combined together to represent vitamin D which has an RDA of 600IU/day. Vitamin D is important in bone mineralization and absorption of phosphorus & calcium from the digestive tract. Common sources include egg yolks, oily fish, and synthesis from sunlight exposure. Normal BMI females had significantly (p = 0.004) more inadequate intake values when compared to normal BMI males. Normal BMI males (135.15 ± 0.60IU/day; 22.5% DV) and obese BMI males (93.52 ± 0.61IU/day; 15.6% DV) also had inadequate dietary intake values of vitamin D but had a greater intake overall than the female categories. Normal BMI females (35.94 ± 0.19IU/day; 6% DV) and obese BMI females (59.62 ± 0.37IU/day; 9.9% DV) both had inadequate intake values (Figure 1B). Therefore all categories had inadequate dietary intake for vitamin D.

Vitamin E

The RDA for α-tocopherol (vitamin E) is 15IU/day for males and females. Vitamin E acts as a powerful antioxidant that can reduce free radical damage and some research shows it can help protect against diabetes and heart disease. Common sources include polyunsaturated vegetable oils, fatty meats, leafy greens, whole grains, liver, and nuts but the main source for the subjects was from potato chips and nuts [17,19]. Normal BMI males (3.81 ± 0.54IU/day; 25.4% DV) and obese BMI males (4.45 ± 0.69IU/day; 29.7% DV) both had inadequate intake values. Normal BMI females (4.22 ± 1.32IU/day; 28.1% DV) had a slightly better intake value than obese BMI females (3.65 ± 0.92IU/day; 24.3% DV) but both were still inadequate (Figure 1C). Therefore all categories had inadequate dietary intake of vitamin E.

Vitamin K

The Phylloquinone (vitamin K_1) AI is 120µg/day for males and 75µg/day for females. In this study we did not include vitamin K_2 (Menaquinone) or the K_1 supplemental form Menadione. Vitamin K is important for blood clotting and bone proteins. Common sources include liver, dark-green leafy vegetables, and cabbage but the main source in the subjects' diet came from hamburger lettuce and carrots. Normal BMI males (38.34 ± 5.36µg/day; 31.9% DV) had a slightly greater intake values than obese BMI males (30.07 ± 4.29µg/day; 25% DV) however both failed to meet the AI. Normal BMI females (63.48 ± 35.53µg/day; 52.9% DV) had an intake values greater than obese BMI females (38.07 ± 14.56µg/day; 31.7% DV) however both failed to meet the AI (Figure 1D). Therefore all four categories had inadequate dietary intake of vitamin K1.

WATER-SOLUBLE VITAMINS

Vitamin B_1

Thiamine (vitamin B_1) RDA is 1.2mg/day for males and 1mg/

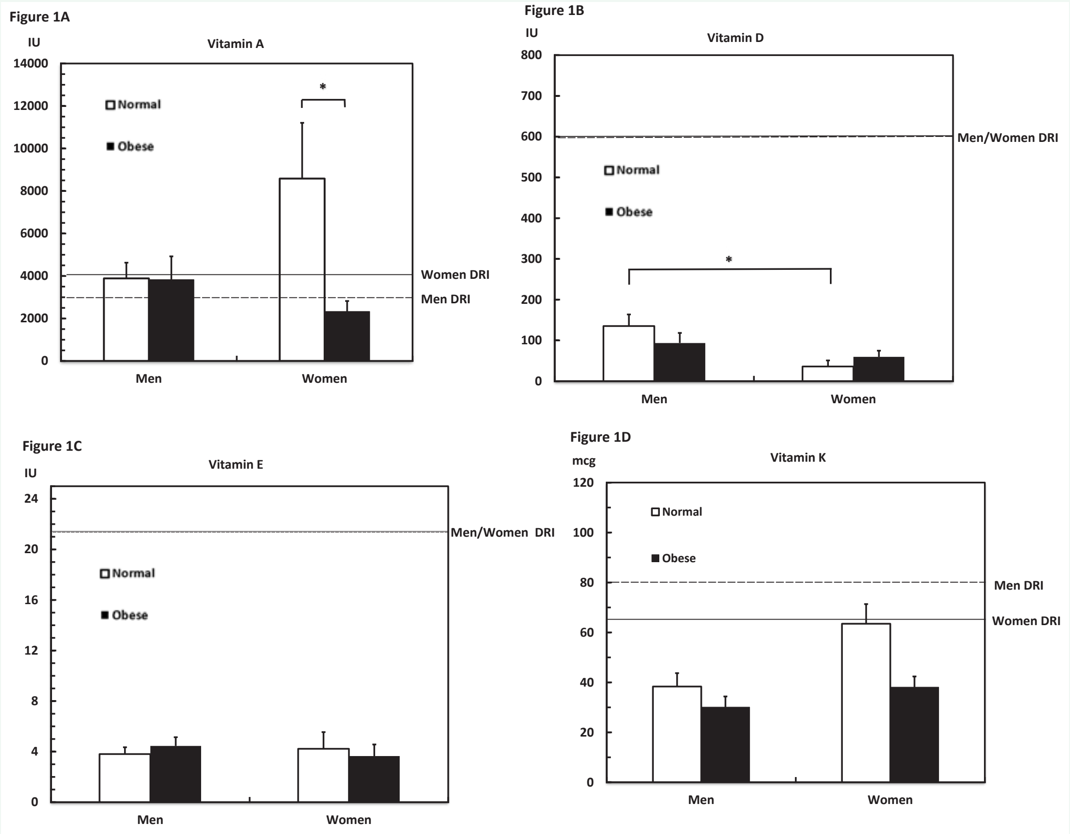

Figure 1A-D

day for females. Vitamin B_1 is needed in the coenzyme thiamine pyrophosphate (TPP) for energy metabolism [23]. Vitamin B_1 can be found in whole grains, fortified foods, squash, and lean pork chops. Normal BMI males (1.37 ± 0.14mg/day; 114.2% DV) and obese BMI males (1.41 ± 0.12mg/day; 117.5% DV) were comparable in reported intake values. Obese BMI females (1.24 ± 0.11mg/day; 124% DV) had an intake greater than normal BMI females (1.05 ± 0.15mg/day; 105% DV) (Figure 2A). Therefore all four categories had adequate intake of vitamin B_1.

Vitamin B_2

Riboflavin (vitamin B_2) RDA for males is 1.3mg/day and 1.1mg/day for females. Vitamin B_2 is part of the coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD) used in energy metabolism. Common sources include milk products, fortified foods, whole grains, and liver [23]. Normal BMI males (1.48 ± 0.18mg/day; 113.9% DV) and obese BMI males (1.50 ± 0.14mg/day; 115.4% DV) had similar reported intake values. Normal BMI females (1.48 ± 0.33mg/day; 134.6% DV) had slightly better intake values than obese BMI females (1.17 ± 0.13mg/day; 106.4% DV) but both met the RDA (Figure 2B). Therefore all four categories had adequate intake of vitamin B_2.

Vitamin B_3

Niacin (vitamin B_3) RDA for males is 16mg/day while the female RDA is 14mg/day. Vitamin B_3 is part of the coenzymes nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). Common sources include milk, whole grains, nuts, and protein-containing foods. One important note on vitamin B_3 is that 70% of the vitamin in corn is bound up by complex carbohydrates and the high levels of the amino acid leucine in corn disrupts tryptophan's conversion to niacin reducing vitamin B_3 bioavailability. This may be noteworthy considering corn and corn products are cheap and may be a major part of traditional Native American diets [23]. The only category to reach the RDA was the normal BMI female category. Normal BMI males (14.17 ± 1.63mg/day; 88.6% DV) and obese BMI males (15.75 ± 1.41mg/day; 98.4% DV) had inadequate dietary intake values. Normal BMI females (16.23 ± 3.22mg/day; 116% DV) had a greater intake value than obese BMI females (13.03 ± 1.19mg/day; 93.1% DV) (Figure 2C). Therefore only the normal female category had adequate dietary intake of vitamin B_3.

Vitamin B_4

Biotin (vitamin B_4) AI for males is 550µg/day while the AI for women is 400µg/day. Vitamin B_4 has an important role as a coenzyme in the Krebs Cycle, gluconeogenesis, fatty acid synthesis, and plays a role in catabolizing fatty acids & amino acids. Common sources include fish, liver, whole grains, eggs, and small amounts produced by GI bacteria [23]. Normal BMI males (211.51 ± 90.33µg/day; 38.5% DV) had a greater dietary intake value than obese BMI males (182.14 ± 158.69µg/day; 33.1% DV). Normal BMI females (92.24 ± 205.39µg/day) had a lower intake

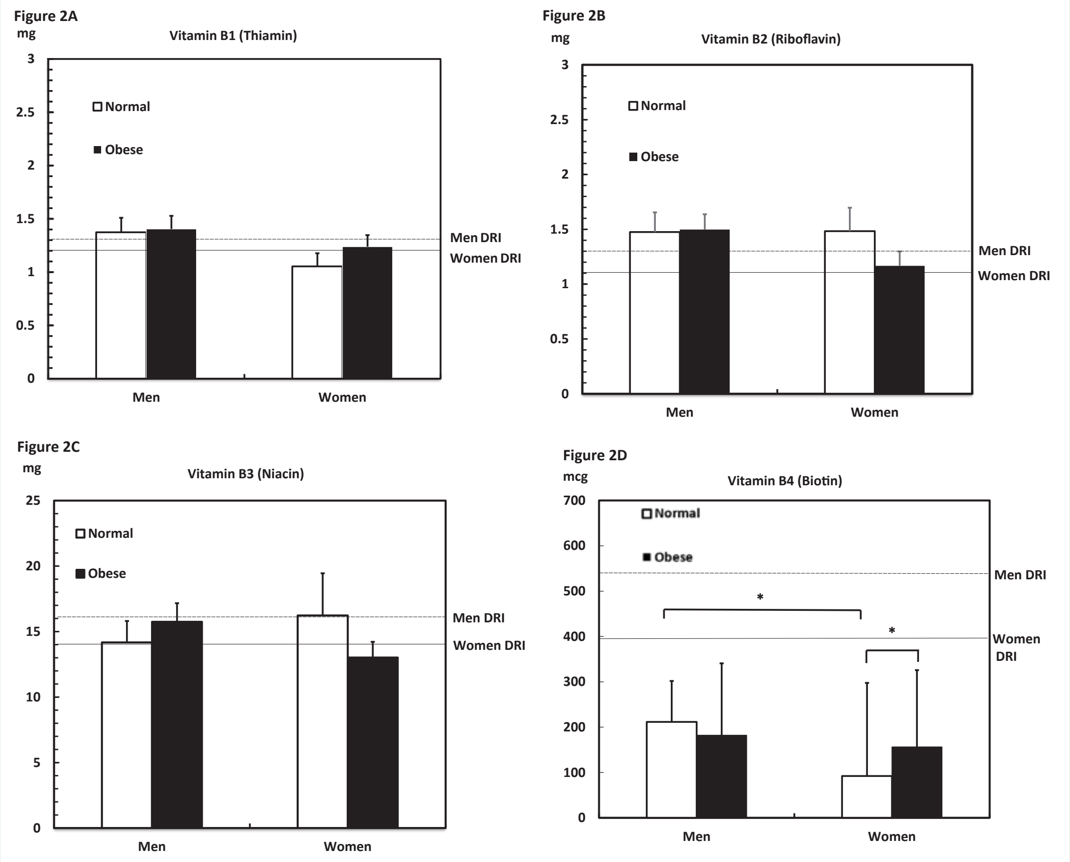

Figure 2A-D

value when compared to obese BMI females (156.27 ± 169.56µg/day) however both categories had inadequate intake values (Figure 2D). Therefore all categories had inadequate dietary intake for vitamin B_4.

Vitamin B_5

The Pantothenic Acid (vitamin B_5) AI is 5mg/day for both males and females. Vitamin B_5 forms part of the structure of coenzyme A in the Krebs Cycle for energy metabolism. Common sources include chicken, beef, tomatoes, liver, potatoes, broccoli, and whole grains [23]. Normal BMI males (4.44 ± 0.45mg/day; 88.8% DV) and obese BMI males (4.76 ± 0.49mg/day; 95.2% DV) both had inadequate dietary intake values. Normal BMI females (3.41 ± 0.67mg/day; 68.2% DV) intake values were comparable to obese BMI females (3.25 ± 0.49mg/day; 65% DV). Obese BMI males had a vitamin intake level significantly ($p = 0.032$) higher than obese BMI females. (Figure 2E). Therefore all categories had inadequate dietary intake for vitamin B_5.

Vitamin B_6

Pyridoxine (vitamin B_6) RDA is 1.3mg/day for males while the female RDA is 1.2mg/day. Vitamin B_6 converts tryptophan to niacin and serotonin and forms part of the coenzymes pyridoxal phosphate (PLP) and pyridoxamine phosphate (PMP) needed for amino acid and fatty acid metabolism. Common sources include starchy vegetables, meats, fish, poultry, legumes, and fortified foods [23]. Normal BMI males (1.26 ± 0.12mg/day; 96.9% DV) had an inadequate dietary intake value while obese BMI males (1.46 ± 0.19mg/day; 112.3% DV) had an intake value above the RDA. Normal BMI females (1.61 ± 0.33mg/day; 134.2% DV) had a greater dietary intake value than obese BMI females (1.29 ± 0.15mg/day; 108% DV) however both had adequate dietary intake values (Figure 2F). Therefore only obese BMI males and normal BMI females had adequate dietary intake values of vitamin B_6.

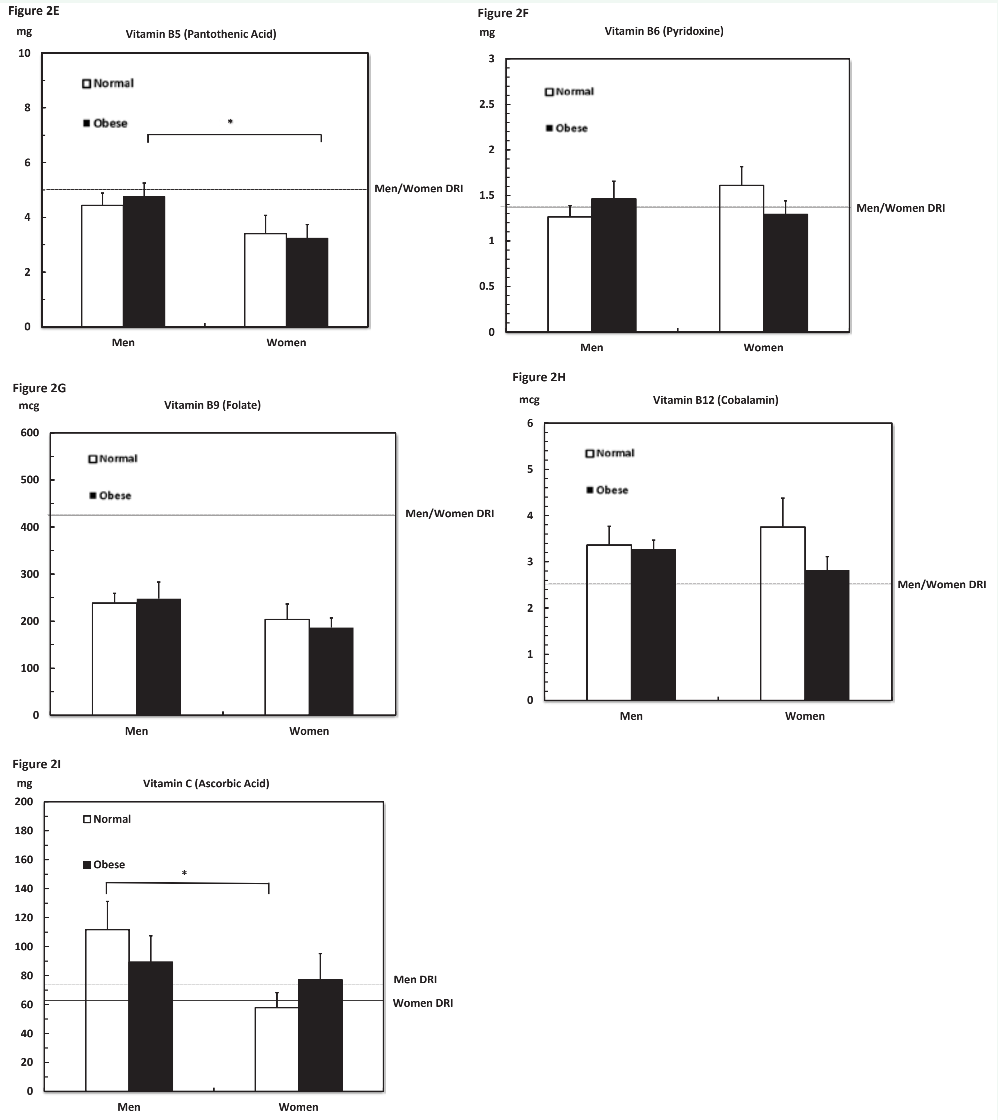

Figure 2E-I

Vitamin B_9

Folate (vitamin B_9) RDA is 400µg/day for both males and females. Vitamin B_9 is important for DNA synthesis and new cell formation. Common sources include fortified grains, legumes, seeds, liver, and fortified grains [23]. The normal BMI males (238.41 ± 20.74µg/day; 59.6% DV) had a comparable intake to obese BMI males (247.89 ± 35.22µg/day) however both had inadequate dietary intake values. Normal BMI females (203.55 ± 32.89µg/day; 50.9% DV) had a slightly greater intake value than obese BMI females (186.34 ± 20.48µg/day; 46.6% DV) however both had inadequate dietary intake values (Figure 2G). Therefore all four categories had inadequate dietary intake values of vitamin B_9.

Vitamin B_{12}

Cobalamin (vitamin B_{12}) RDA is 2.4 µg/day for both males and females. Vitamin B_{12} is used in new cell formation, reforms the folate coenzyme, and helps catabolize amino acids and fatty acids. Common sources include animal products and fortified foods [23]. Normal BMI males (3.36 ± 0.41µg/day; 140% DV) had a slightly greater intake value than obese BMI males (3.27 ± 0.20µg/day; 136.3% DV) and both had adequate dietary intake values. Normal BMI females (3.75 ± 1.07µg/day; 156.3% DV) had a greater dietary intake value than obese BMI females (2.82 ± 0.29µg/day; 118% DV) (Figure 2H). Therefore, all four categories had adequate dietary intake values of vitamin B_{12}.

Vitamin C

Ascorbic Acid (vitamin C) RDA is 75mg/day for males and 65mg/day for females. Vitamin C has many functions including acting as an antioxidant reducing free radical damage, helping in iron absorption, and amino acid metabolism [17]. Common sources include citrus fruit, dark green vegetables, lettuce, and tomatoes [23]. Normal BMI males (111.73 ± 19.45mg/day; 149% DV) had a greater intake value than obese BMI males (89.28 ± 18.22mg/day; 119% DV) and both had adequate dietary intake values. Obese BMI females (77.08 ± 18.12mg/day; 118.6% DV) had a greater dietary intake value than normal BMI females (57.85 ± 10.40mg/day; 89% DV) (Figure 2I). Therefore only the normal BMI female category had inadequate dietary intake values of vitamin C.

DISCUSSION

The data collected from the subjects' HSPHYAQ showed inadequate dietary intake values in many (D, E, K, B_4, B_5 and B_9) of the vitamins for all BMI categories. Adequate vitamin intake values for all BMI categories were found for only four vitamins (A, B_1, B_2, and B_{12}). Furthermore, our research hypothesis that obese subjects would be significantly more deficient in dietary vitamin intake was only marginally validated. Obese female subjects had consistently lower intake values than normal females except for vitamins D, B_4, and C. Overall, the major findings of the study showed inadequate dietary vitamin intake in Native American adolescents across the country. This may be a factor in the higher prevalence of obesity compared to national rates. Similar findings were also seen in our previous research that showed Native American subjects were more likely to have inadequate dietary mineral and antioxidant intake values [11,19]. Furthermore, our data which showed that all subjects came from low socioeconomic households supports and expands upon the research findings of Porter et al., Sowerwine et al., and Jernigan et al. [6,13,14]. Our research also supports the claims that unhealthy habits may be learned and reinforced from parents and the community; and that bad eating habits early in life can set a child on a pathway towards obesity [5,6,8-10,13].

This study is not without its limitations. Our research did not include blood serum analysis of vitamin levels or gene sequencing. This limitation restricts our ability to contribute to other research that suggests variants like the *R230C* gene can compromise lipid metabolism and increase Native American susceptibility to obesity [9,15,16]. Other limitations of our study include understanding that the data from the questionnaires were dependent on the honesty, memory, and food quantity estimations of the subjects. Additionally, the questionnaire did not consider other factors that have been known to influence obesity including estimates of physical activity, screen time, and mental health disorders such as bulimia nervosa, depression, and avoidant/restrictive food intake disorder (ARFID). Moreover, our study did not design, implement, or evaluate a program to test the effectiveness of food education and healthy food accessibility interventions on reducing obesity rates to support other researchers [9,13]. All of these factors may be working together to increase the prevalence of obesity within Native American adolescents. However, more research needs to be done in validating whether Native Americans have unique micronutrient needs compared to other ethnic groups or whether programs such as THRIVE can be implemented in other tribal communities. Our suggestion for future research is to include blood serum micronutrient analyses, genetic analysis, mental health screening, and assessing the efficacy of intervention programs focused on environmental changes and food education.

CONCLUSION

Our original hypothesis was that obese Native American adolescents would be significantly deficient in dietary vitamin intake compared to their normal BMI peers. Our study revealed that there is an inadequate vitamin intake for normal and obese adolescents in both genders. However, the obese female category was shown to be more deficient than the normal female category in many of the vitamins. This study has contributed data showing a higher rate of obesity, lower intake of dietary micronutrients, and high number of low socioeconomic households within the Native American adolescent population in the United States.

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DECLARATIONS

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Conflicts of interest

The authors declare no conflict of interest regarding funding, employment, patents or personal financial interests that could undermine the objectivity, integrity or perceived value of any publication.

Availability of data and material

Available upon requests.

Code availability

Available upon requests.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

Informed consent was obtained from all individual participants and authors included in the study.

REFERENCES

1. Craig M Hales, Margaret D Carroll, Cheryl D Fryar, Cynthia L Ogden. Prevalence of Obesity Among Adults and Youth: United States, 2015-2016. NCHS Data Brief. 2017; (288): 1-8.
2. Palmer MK, Toth PP. Trends in Lipids, Obesity, Metabolic Syndrome, and Diabetes Mellitus in the United States: An NHANES Analysis (2003-2004 to 2013-2014). Obesity. 2019; 27: 309-14.
3. Fryar C, Carroll M, Afful J. Prevalence of Overweight, Obesity, and Severe Obesity Among Children and Adolescents Aged 2-19 Years: United States, 1963-1965 Through 2017-2018. Centers for Disease Control and Prevention. National Centers for Health Statistics Health E-Stats. 2020.
4. Carroll MD, Navaneelan T, Bryan S. Centers for Disease Control and Prevention (DHHS/PHS). Prevalence of Obesity among Children and Adolescents in the United States and Canada. NCHS Data Brief. Number 211. Centers for Disease Control and Prevention 2015.
5. Kelley MN, Lowe JR. Strong Cultural Identity Effects Stress Levels among Native American Youth at Risk for Obesity. J Cult Divers. 2018; 25: 127-31.
6. Porter CM, Wechsler AM, Hime SJ, Felix Naschold. Adult health status among native american families participating in the growing resilience home garden study. Prev Chronic Dis. 2019; 16: E113.
7. Biener A, Cawley J, Meyerhoefer C. The High and Rising Costs of Obesity to the US Health Care System. J Gen Intern Med. 2017; 32: 6-8.
8. Bullock A, Sheff K, Moore K, Spero Manson. Obesity and Overweight in American Indian and Alaska Native Children, 2006-2015. Am J Public Health. 2017; 107: 1502-7.
9. Coelho-Landell CA, Salomão RG, Almada Mordv, Mariana Giaretta Mathias, Roseli Borges Donega Toffano, Elaine Hillesheim, et al. Metabo groups in response to micronutrient intervention: Pilot study. Food Sci Nutr. 2019; 8: 683-93.
10. Dhauvadel AS, Wagle S, Bhandari TR. Effects of nutrition education program in intention change for consuming healthy food among adolescents: A School-based study. J Sci Soc. 2019; 46: 41-5.
11. Perez M, Knisley B, Crosby G, Shasha Zheng, M. Margaret Barth. Obesity Prevalence and Dietary Intake of Antioxidants in Native American Adolescents. Int J Publ Health Sci. 2016; 5: 222-227.
12. Boyle M. Community Nutrition in Action: An Entrepreneurial Approach, 7th edn. Cengage Learning Ltd: Boston, Massachussettes, USA, 2016.
13. Jernigan VBB, Williams M, Wetherill M, Tori Taniguchi, Tvli Jacob, Tamela Cannady, et al. Using community-based participatory research to develop healthy retail strategies in Native American-owned convenience stores: The THRIVE study. Prev Med Rep. 2018; 11: 148-53.
14. Sowerwine J, Mucioki M, Sarna-Wojcicki D, Lisa Hillman. Reframing food security by and for Native American communities: a case study among tribes in the Klamath River basin of Oregon and California. Food Security. 2019; 11: 579-607.
15. Acuña-Alonzo V, Flores-Dorantes T, Kruit J, Teresa Villarreal-Molina, Olimpia Arellano-Campos, Tábita Hünemeier, et al. A functional ABCA1 gene variant is associated with low HDL-cholesterol levels and shows evidence of positive selection in Native Americans. Hum Mol Genet. 2010; 19: 2877-85.
16. Caro-Gomez MA, Naranjo-González CA, Gallego-Lopera N, María Victoria Parra-Marín, Diana María Valencia, Edgar Gerardo Arcos, et al. Association of Native American ancestry and common variants in ACE, ADIPOR2, MTNR1B, GCK, TCF7L2 and FTO genes with glycemic traits in Colombian population. Gene. 2018; 677: 198-210.
17. Guerendiain M, Mayneris-Perxachs J, Montes R, Gemma López-Belmonte, Miguel Martín-Matillas, Ana I Castellote, et al. Relation between plasma antioxidant vitamin levels, adiposity and cardio-metabolic profile in adolescents: Effects of a multidisciplinary obesity programme. Clin Nutr. 2017; 36: 209-17.
18. Dai H, Ramirez G, Zheng S. Dietary Minerals Measurement in Normal Versus Obese Native American Adolescents. J Racial Ethn Health Disparities. 2020; 7: 769-75.
19. Dai H, Song R, Barth M, Shasha Zheng. Dietary Nutrient Intake and Obesity Prevalence among Native American Adolescents. Int J Publ Health Sci. 2018; 7: 114-119.
20. Executive summary of the clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. J Am Diet Assoc 1998; 158: 1855-67.
21. A Catharine Ross, Joann E Manson, Steven A Abrams, John F Aloia, Patsy M Brannon, Steven K Clinton, et al. The 2011 Dietary Reference Intakes for Calcium and Vitamin D: What Dietetics Practitioners Need to Know. J Am Diet Assoc. 2011; 111: 524-7.
22. Dietary Reference Intakes (DRIs): Recommended Dietary Allowances and Adequate Intakes, Vitamins. National Institutes of Health Office of Dietary Supplements. 2011; 25:127-31.
23. Whitney E, Rolfes S. Understanding Nutrition, 15th edn. Cengage Learning Ltd: Boston, Massachussettes, USA, 2019.