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Trends in vitamin D intake from food sources among adults in the Minneapolis St Paul, MN Metropolitan area, 1980–82 through 2007–2009

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Abstract

Background—Changes in eating habits could potentially be contributing to vitamin D insufficiency among US adults.

Objective—Describe secular trends in vitamin D intake from food sources over the past twenty five years.

Design—Trends in dietary vitamin D intake from 1980–1982 to 2007–2009 were examined using data collected from the Minnesota Heart Survey (MHS), a surveillance study of trends in risk factors for cardiovascular disease among probability samples of adults aged 25–74 years in the Minneapolis-St Paul, MN metropolitan area. Surveys were conducted in 1980–1982, 1985–1987, 1990–1992, 1995–1997, 2000–2002, and 2007–2009. One twenty-four hour recall was collected from survey participants during each survey period.

Results—Results indicate that vitamin D intake from food sources decreased between 1980–1982 and 2007–2009 among males, with age-adjusted mean vitamin D intake decreasing from 7.24 mcg/day in 1980–1982 to 6.15 mcg/day in 2007–2009 (p for trend <0.001). A decrease was

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also observed among females (4.77 mcg/day in 1980–1982 in comparison to 4.53 mcg/day in 2007–2009; p for trend <0.001).

Conclusions—Results suggest that vitamin D intake from food sources has been on the decline over the past twenty five years among males and females, potentially contributing to vitamin D insufficiency.

Introduction

In recent years there has been growing awareness that vitamin D insufficiency is a nutritional problem among US adults. Results from the 2000–2004 National Health and Nutrition Examination Survey (NHANES) indicate that more than 10% of adult males and 15% of adult females have moderate to severe vitamin D insufficiency, defined as serum levels of $25(OH)D_3$ <37.5 nmol/L)(1).

Changes in eating habits could potentially be contributing to vitamin D insufficiency among US adults. Numerous studies have documented major shifts in the dietary practices of Americans over the past several decades (2–20). Of relevance to vitamin D is the downward trend in fluid milk consumption that has occurred over the past several decades (7, 20). Since milk is one of the predominant food sources of vitamin D in the United States (21) it could be speculated that vitamin D intake from food sources has likewise been on the decline.

It is possible that vitamin D intake from food sources has remained constant or increased due to dietary changes and/or shifts in food fortification practices. Results reported in 2004 from an unofficial local marketplace survey indicated that few vitamin D fortified food products were available in many of the food product categories for which vitamin D fortification is allowed in the U.S. For example, only a few yogurts and margarines in the marketplace were found to be fortified with vitamin D(22). It is possible that in recent years more vitamin D fortified products have entered the marketplace. For example, anecdotal evidence suggests a number of yogurt (23, 24) and margarine (24) brands are now fortified with vitamin D.

To our knowledge trends in vitamin D intake from food sources among adults in the U.S. have not previously been examined. To address this important issue trends from 1980–1982 to 2007–2009 were examined using data collected from the Minnesota Heart Survey (MHS), a surveillance study of trends in risk factors f or cardiovascular disease among probability samples of adults in the Minneapolis-St Paul, MN metropolitan area. Trends in vitamin D intake from food sources were examined separately for males and females. Furthermore, trends by age, education level, and body mass index (BMI) were examined.

It is important to note that historical trends in vitamin D intake from food sources may not be examined using NHANES data because this nutrient was only recently added to the food and nutrient database used to analyze dietary data collected in that survey. Thus, data from regional surveys such as the Minnesota Heart Survey must be relied on to evaluate historical trends in vitamin D intake from food sources in the U.S.

Methods

MHS design

Detailed information on the MHS study design has been published previously (25). In short, a two-stage cluster sampling, random selection of household clusters and subsequent random selection of households within each cluster was conducted using a sampling frame constructed from census maps. In the first sampling stage in 1980–1981, 40 household clusters were randomly selected from 704 household clusters of approximately 1,000 households within the seven-county metropolitan area. Growth in new housing was small enough during the 1980's that the 40 original clusters continued to represent the Twin Cities. However, to accommodate considerable new growth by 1995 and thereby maintain representativeness of the sample for the Twin Cities population, the original clusters were supplemented with four new clusters randomly selected from among 10 high-growth clusters. High growth was defined as a 2.5 fold or greater increase in cluster size in the original 704 clusters, based on changes in the number of households from the 1980 to the 1990 census.

In the second sampling stage, a proportion of households (5–10% across surveys) were randomly selected from the original 40 clusters after removing the households selected in previous study periods. Households were selected from the four new clusters without replacement in the survey periods of 2000–2002 and 2007–2009. In the second annual survey comprising the 1995–1997 sample, new sampling was stopped due to budget constraints; therefore, 26 of the 44 clusters were not represented in that survey; statistical balance was achieved by bootstrap estimation for these 26 clusters in that survey year.

An introductory letter was mailed to selected households, and then a trained interviewer visited the households for a household enumeration and a home interview. In the 1980–1981 survey cycle all age-eligible individuals in a household were asked to participate. One individual in each household was randomly selected for the study during the 1981–1982, 1985–1987 and 1990–1992 survey years. For the 1995–1997 through 2007–2009 survey periods, all age-eligible individuals in each selected household were asked to participate in the study to ensure a random sample of the Twin Cities for sex-specific analyses. The age-eligibility criterion was ages 25 to 74 years for the 1980–1982 and 1985–1987 survey periods, whereas it was changed to ages 25 to 84 years in the 2000–2002 and 2007–2009 survey periods.

Study participants were asked to attend a local clinic visit for collection of physiologic measures and a 15–45 minute home interview for data collection of socio-demographic characteristics, medical history, smoking status, and health knowledge, attitudes, and beliefs. In the clinic using standard procedures, height was measured in stocking feet and weight was measured using a calibrated balance-beam scale. Body mass index (BMI) was calculated as weight (kg) divided by a square of height (m). To measure food and nutrient intake, a 24-hour dietary recall was collected during the clinic visit. Clinic visit examinations were conducted at home for those who could not or did not want to travel to the clinic. Overall response rates to complete both home interview and clinic visit surveys ranged from 60% to 69% across the six survey periods among adult participants. Those who completed the survey were slightly more likely to be married, employed, better educated, and non-smokers compared to non-respondents.

Written consent was obtained from all study participants. Consent and data collection procedures for each survey were approved by the University of Minnesota Research Subjects' Protection Programs Institutional Review Board.

Dietary intake assessment

A systematic 50% sample of participants who completed the clinic visit surveys were administered a 24-hour dietary recall, except for the 2000–2002 survey period in which all clinic visit survey participants were asked for a 24-hour dietary recall.

Most dietary data collection procedures remained the same throughout the survey years. Interviewers trained and certified by the University of Minnesota Nutrition Coordinating

Center collected dietary data. During each survey period the 24-hour dietary recalls were collected using a multiple pass approach. The multiple pass approach utilized included the following four information collection steps: 1.) obtain listing of all foods and beverages consumed; 2.) review listing for completeness and correctness; 3.) collect detailed information about each food and beverage reported including amount consumed and any additions to the food (e.g. sugar added to coffee); and 4.) review detailed information for completeness and correctness. Three-dimensional food models were used to help estimate portion sizes. The only major change in dietary data collection procedures was the introduction of a computerized data-entry method in the 1995–1997 survey. Prior to that survey a manual (paper and pencil) method was used, with the computerized method used for all subsequent surveys. A comparability study in which approximately 100 participants completed both a computerized and manual (paper and pencil) recall showed that differences in total caloric intake (3.2 kcal) and percentage of calories from fat (1.1%) between the computerized and the manual methods were not significant ($p>0.05$).

Vitamin D Intake Estimates

Nutrient intake estimates were calculated using the University of Minnesota Nutrition Coordinating Center Food and Nutrient Database (26). This Database is expanded and updated on an ongoing basis, with a new version released annually. The expansion and update work has two foci. One focus is updating and expanding nutrients and other food components in the database. The other focus relates to keeping the foods in the database comprehensive and up-to-date with the marketplace.

Vitamin D was added to the NCC Food and Nutrient Database in 1984. Since then vitamin D values for foods in the database have been updated on an ongoing basis with new and better composition data incorporated as it has become available.

Vitamin D values included in the Database are compiled from various sources. The USDA National Nutrient Database for Standard Reference is the preferred source as it reflects U.S. foods and fortification practices. Because the Standard Reference does not provide vitamin D values for many foods in the NCC Food and Nutrient Database, other sources of data are utilized including scientific literature, manufacturers’ information, non-U.S. food composition tables, and U.S. fortification standards.

As a result of use of a variety of data sources and application of standard imputation procedures (27), there were no missing vitamin D values for foods in the version of the NCC Food and Nutrient Database used to calculate vitamin D intake estimates for survey participants. Consequently, vitamin D intake estimates reported in this paper represent intake from all food sources including foods that naturally contain vitamin D such as fish, meats, mushrooms, and eggs.

To obtain vitamin D intake estimates from 24-hour dietary recall data collected from MHS survey participants using the most complete and accurate food composition information available, a procedure within NDSR that automatically recalculates nutrient intake estimates using the most current version of the NCC Food and Nutrient Database available was utilized. Using this procedure vitamin D intake estimates for dietary recalls from each survey period (1980–82 through 2007–09) were calculated using the most current version of the Database available. This recalculation process is possible due to the time-related design of the NCC Food and Nutrient Database. In brief, so that the recalculation process is possible the following rules are followed in maintaining and updating the Database: 1.) Foods that exit the marketplace (become no longer available) are kept in the Database, but are flagged as ‘deactivated’; 2.) A new nutrient string identification code and nutrient string are assigned to a food when it has been reformulated in such a way that its nutrient composition changes significantly. The old nutrient string identification code and nutrient string are kept in the Database, but flagged as 'deactivated'; 3.) When a nutrient is added to the Database (e.g. addition of vitamin D in 1984), composition values are assigned to both deactivated and active foods and nutrient strings in the Database; and 4.) When better or more complete nutrient composition data becomes available for incorporation in the Database, updates are made to both deactivated and active foods and nutrient strings.

Statistical analysis

Only those study participants aged 25–74 years with a completed 24-hour dietary recall were included in analyses for this study. All analyses were conducted using SAS software package (SAS Inc, Cary, NC).

A generalized linear mixed model (PROC MIXED) was used to compare vitamin D intake estimates from the 1980–1982 through 2007–2009 survey periods. Neighborhood cluster was included as a random effect term in these models to correct for the design effects, which inflated the variance of sample means compared to what they would have been if considered independent (without the neighborhood cluster). To examine consistency of trends in vitamin D intake across demographic variables such as age and education level, analyses were conducted stratified by these factors. Because of the well established differences between males and females in nutrient requirements and food intake, all analyses examining trends in vitamin D intake were conducted stratified by sex.

Results

The demographic characteristics of participants by survey period are described in Table 1. To summarize, for each survey period somewhat more females than males participated. More than half of the participants had some education beyond high school with this percentage increasing over time (e.g. 57% in 1980–1982 versus 83% in 2007–2009). In accord with the Minneapolis St Paul, MN metropolitan area, most participants were white. Reflecting demographic trends in the community, over time a growing proportion were non-white. About 55% of participants had a BMI of 25 or higher in the 1980–1982 survey, and this proportion increased over time to 70.2% in the 2007–2009 survey.

Among males mean vitamin D intake from food sources was found to be significantly lower in 2007–2009 (6.15 mcg/day in age-adjusted analysis) compared to 1980–1982 (7.24 mcg/day in age-adjusted analysis) (p for trend <0.001)(Table 2). Results were generally similar across the age, education, and body mass index categories examined. When analyses were conducted adjusted for both age and energy intake results were similar to those from the age-adjusted analysis (data not shown).

Among females a significant downward trend in vitamin D intake was also observed (p for trend <0.001) (Table 3). Mean vitamin D intake from food sources was 4.53 mcg/day in 2007–2009 compared to 4.77 mcg/day in 1980–1982 (Table 3). Results were generally similar across the age, education, and body mass index categories examined. When analyses were conducted adjusted for both age and energy intake a more somewhat more sizeable decline in vitamin D intake appeared to occur (4.35 mcg/day in 2007–2009 compared to 4.94 mcg/day in 1980–1982) (Table 4). This finding was generally consistent across the age, education level, and body mass index categories examined.

For both males and females vitamin D intake trends across survey periods appeared to follow a somewhat non-linear pattern with intake levels generally declining between 1980–1982 and 1990–92; increasing between 1990–92 and 1995–97; and then declining between 1995–97 and 2000–2002 (Tables 2–4)

Discussion

Results suggest that vitamin D intake from food sources has declined over the past twenty five years among adult males and females with the magnitude of the decline appearing to be greater among males. Because this is the first study to examine trends in vitamin D intake from food sources in a population based sample of adults it is not possible to corroborate these findings with those of others. It is interesting to note though that study findings are somewhat consistent with reported trends in the serum 25-hydroxyvitamin D status of the US population (1). Looker et al. compared ser um 25(OH) D concentrations of participants in NHANES III (1988–1991 and 1991–1994 phases combined) and NHANES 2000–2004 (2000, 2001–2002, and 2003–2004 survey periods combined). Results from age-standardized and assay adjusted analysis indicated that mean serum 25 (OH) D concentrations were significantly lower in NHANES 2000–2004 compared to NHANES III in all the male groups examined except Mexican American males surveyed in April-October. In contrast, among females a decrease was seen in only one of the groups examined (non-Hispanic black females surveyed in April–October). It has been noted that findings by Looker et al. may need to be reevaluated in the near future due to concerns with assay variability in NHANES since 2000 (28).

Among males the magnitude of the decrease in mean vitamin D intake observed between 1980–1982 and 2007–2009 was sizeable, with the difference in means (−1.09 mcg/day) close to the amount of vitamin D found in 8 fluid ounces of vitamin D fortified milk. It is important to note that mean Vitamin D intake from food sources among males in 2007–2009 (6.15 mcg/day) was well below both the Recommended Daily Allowance (RDA) and Estimated Average Requirement (EAR) levels for adult males of 15 mcg/day and 10 mcg/day respectively (29). Consequently, it may be concluded that a substantial proportion of males are consuming less vitamin D from dietary sources than their requirement.

Among females a smaller decrease in mean vitamin D intake from food sources was observed between 1980–1982 and 2007–2009 (−0.24 mcg/day). However, at both time points mean vitamin D intake from food sources was well below the RDA and EAR levels for adult females. For example, in 2007–2009 vitamin D intake among females averaged 4.53 mcg/day, less than one-half of the EAR (10 mcg/day) and RDA (15 mcg) levels for adult females (29).

Several methodological issues must be considered in interpreting study findings. First, the source of dietary information in this study was a 24-hour dietary recall. Underreporting of food intake is a pervasive problem with this methodology (30) and therefore may have resulted in under-estimates of vitamin D intake. Trends should not be affected, however, if it can be assumed that the magnitude of underreporting remained constant over time. Only one recall was collected from each survey participant. Consequently, the distribution of dietary intakes in a population should not be characterized from the standard deviations presented in the tables. As a result of this limitation the proportion of survey participants with usual vitamin D intake below the EAR or above the recommended Upper Level (UL) for this nutrient may not be estimated. In the 1995–97 survey period a major change in the dietary data collection procedures was implemented when a computerized data-entry method was introduced, replacing a more labor intensive paper and pencil method in which dietary recall information was recorded on paper for subsequent entry into Nutrition Data System for nutrient analysis. It is possible that that the spike in vitamin D intake from food sources that occurred in 1995–1997 among both males and females are artifacts of this change in methodology. Dietary supplement use was not assessed in a comprehensive nor consistent manner across the survey periods. Consequently, trends in vitamin D intake from dietary supplements could not be examined. It was not possible to identify specific changes in dietary habits that contributed to vitamin D intake changes due to limitations in the food data files available for analysis from earlier survey periods. A final issue to consider is generalizability of findings. Because participants in this study were adult, predominantly white men and women residing in the Minneapolis-St. Paul Metropolitan area, strictly interpreted the study findings should be generalized only to similar men and women.

In conclusion, results suggest that vitamin D intake from food sources has been on the decline among adult males and females. This is a concerning trend given that more than 10% of adult men and 15% of adult women in the U.S. have moderate to severe vitamin D insufficiency (1). Further research is needed to identify specific changes in eating habits that may be contributing to declining vitamin D intake from food sources. Results from such an analysis may be useful in evaluating the adequacy of vitamin D food fortification practices in the U.S.

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References

1. Looker A, Pfeiffer C, Lacher D, Schleicher R, Picciano M, Yetley E. Serum 25-hydroxyvitamin D status of the US population: 1988– 1994 compared with 2000– 2004. Am J Clin Nutr. 2008; 88:1519–1527. [PubMed: 19064511]
2. Popkin B, Siega-riz A, Haines P, Jahns L. Where's the fat? Trends in U.S. diets 1965–1996. Prev Med. 2001; 32(3):245–254. [PubMed: 11277682]
3. Popkin B, Siega Riz A, Haines P. A comparison of dietary trends among racial and socioeconomic groups in the United States. N Eng J Med. 1996; 335:716–720.
4. Popkin B, Zizza C, Siega-Riz A. Who is leading the change?: U.S. dietary quality comparison between 1965 and 1996. Am J Med. 2003; 25:1–8.
5. Putnam J. American eating habits changing: Part 1. Meat, dairy, and fat and oils. Food Review. 1993; 16(3):2–11.
6. Putnam J. American eating habits changing: Part 2. Grains, vegetables, fruit, and sugars. Food Review. 1994; 17(2):36–47.
7. Putnam J. U.S. food supply providing more food and calories. FoodReview. 1999; 22(3):2–12.
8. Kant A, Graubard B, Kumanyika S. Trends in black-white differentials in dietary intakes of U.S. adults, 1971–2002. Am J Prev Med. 2007; 32(4):264–272. [PubMed: 17383557]
9. Wright J, Kennedy Stephenson J, Wang C, McDowell M, Johnson C. Trends in intake of energy and macronutrients- United States, 1971--2000. MMWR. 2004; 53(04):80–82. [PubMed: 14762332]
10. Nielsen S, Popkin B. Patterns and trends in food portion sizes, 1977–1998. JAMA. 2003; 289:450–453. [PubMed: 12533124]
11. Nielsen S, Siega Riz A, Popkin B. Trends in energy intake in U.S. between 1977 and 1996: Similar shifts seen across age groups. Obes Res. 2002; 10(5):370–378. [PubMed: 12006636]
12. Kant A, Graubard B. Eating out in America, 1987–2000: Trends and nutritional consequences. Prev Med. 2004; 38(2):243–249. [PubMed: 14715218]
13. Kant A, Graubard B. Secular trends in patterns of self-reported food consumption of adult Americans: NHANES 1971–1975 to NHANES 1999–2002. Am J Clin Nutr. 2006; 84:1215–1223. [PubMed: 17093177]
14. Briefel R, Johnson C. Secular trends in dietary intake in the United States. Annu Rev Nutr. 2004; 24:401–431. [PubMed: 15189126]
15. Wilkinson Enns C, Goldman J, Cook A. Trends in food and nutrient intakes by adults: NFCS 1977–78, CSFII 1989–91, and CSFII 1994–95. Fam Econ Nutr Rev. 1997; 10(4):2–15.

16. Albertson A, Tobelman R, Marquardt L. Estimated dietary calcium intake and food sources for adolescent females: 1980–92. J Adol Health. 1997; 20:20–26.

17. Harnack L, Lee S, Schakel SF, Duval S, Luepker RV, Arnett DK. Trends in the trans-fatty acid composition of the diet in a metropolitan area: the Minnesota Heart Survey. J Am Diet Assoc. 2003; 103(9):1160–1166. [PubMed: 12963944]

18. Lee S, Harnack L, Jacobs DR Jr, Steffen LM, Luepker RV, Arnett DK. Trends in diet quality for coronary heart disease prevention between 1980–1982 and 2000–2002: The Minnesota Heart Survey. J Am Diet Assoc. 2007; 107(2):213–222. [PubMed: 17258957]

19. Lin, B.; Frazao, E. Away-From-Home Foods Increasingly Important to Quality of American Diet. Washington, DC: United States Department of Agriculture Economic Research Service; 1999 January.

20. Bowman S. Beverage choices of young females: changes and impact on nutrient intakes. J Am Diet Assoc. 2002; 102:1234–1239. [PubMed: 12792618]

21. Calvo M, Whiting S. Prevalence of vitamin D insufficiency in Canada and the United States: importance to health status and efficacy of current food fortification and dietary supplement use. Nutr Rev. 2003; 61:107–113. [PubMed: 12723644]

22. Calvo M, Whiting S, Barton C. Vitamin D fortification in the United State and Canada: current status and data needs. Am J Clin Nutr. 2004; 80 suppl:1710A–1716S.

23. Hobson K. Which yogurts have vitamin D? These 17 yogurt products do. US News & World Report. 2010 April 16. Posted at http://health.usnews.com/health-news/blogs/on-fitness/2009/04/16/which-yogurts-have-vitamin-d-these-17-yogurt-products-do_print.html.

24. Schepers A. Bread spread or functional food? Choose margarine wisely. LexisNexis. 2009 April 1. at http://www.allbusiness.com/consumer-products/food-beverage-products-oils-fats/13336092-1.html.

25. Luepker R, Jacobs D, Gillum R, Folsom A, Prineas R, Blackburn H. Population risk of cardiovascular disease: The Minnesota Heart Survey. J Chronic Dis. 1985; 38:671–682. [PubMed: 4019704]

26. Schakel S, Sievert Y, Buzzard M. Sources of data for developing and maintaining a nutrient database. J Am Diet Assoc. 1988; 88:1268–1271. [PubMed: 3171020]

27. Schakel S, Buzzard I, Gebhardt S. Procedures for estimating nutrient values for food composition databases. J Food Comp Anal. 1997; 10:102–114.

28. Looker A, Pfeiffer C, Lacher D, Schleicher R, Picciano M, Yetley E. Letter to the Editor: Data advisory with regard to NHANES serum 25-hydroxyvitamin D data. Am J Clin Nutr. 2009; 90:695. [PubMed: 19571227]

29. Committee to Review Dietary Reference Intakes for Vitamin D and Calcium. Washington DC: Institute of Medicine of the National Academies; 2010. Food and Nutrition Board. Dietary Reference Intakes for Calcium and Vitamin D. Report No.: Prepublication Copy: Uncorrected Proofs

30. Black A, Prentice A, Goldberg G, Jebb S, Bingham S, Livingstone M, et al. Measurements of total energy expenditure provide insights into the validity of dietary measurements of energy intake. J Am Diet Assoc. 1993; 93:572–579. [PubMed: 8315169]

Table 1

Number (%) of participants aged 25 to 74 with 24-hour dietary recall data by sex, age group, education level, and ethnicity: MHS 1980–1982 through 2007–2009

	1980–1982 (n=1659) % (n)	**1985–1987 (n=2273) % (n)**	**1990–1992 (n=2488) % (n)**	**1995–1997 (n=1841) % (n)**	**2000–2002 (n=2757) % (n)**	**2007–2009 (n=1502) % (n)**
Sex						
Male	48.1 (798)	48.1 (1100)	45.9 (1141)	46.7 (860)	46.1 (1271)	46.3 (696)
Female	51.9 (861)	51.9 (1173)	54.1 (1347)	53.3 (981)	53.9 (1486)	53.7 (806)
Age Group						
25–39	45.2 (749)	43.8 (995)	44.3 (1103)	35.3 (649)	33.6 (925)	25.6 (384)
40–54	30.3 (503)	31.8 (722)	33.0 (822)	38.1 (701)	41.5 (1143)	39.4 (592)
55–74	24.5 (407)	24.5 (556)	22.6 (563)	26.7 (491)	25.0 (689)	35.0 (526)
Education level						
Vocational or college education	57.6 (946)	63.4 (1442)	68.9 (1713)	72.1 (1328)	75.3 (2077)	82.8 (1243)
High school or less	43.0 (713)	36.6 (831)	31.2 (775)	27.9 (513)	24.7 (680)	17.2 (259)
Ethnicity						
White	96.0 (1592)	96.0 (2181)	95.1 (2366)	93.8 (1727)	89.9 (2479)	90.4 (1357)
Nonwhite	4.0 (67)	4.0 (92)	4.9 (122)	6.2 (114)	10.1 (279)	9.7 (145)
Body mass index						
< 25	45.4 (753)	38.6 (877)	38.5 (958)	31.9 (568)	32.1 (885)	29.8 (448)
25.0–29.9	37.9 (628)	40.2 (914)	38.3 (953)	38.8 (714)	35.5 (978)	36.9 (554)
≥30	16.8 (278)	21.2 (482)	23.2 (577)	30.4 (559)	32.4 (894)	33.3 (500)

Table 2

Age-adjusted mean intake of vitamin D (mcg/day) for males in the Minneapolis-St. Paul metropolitan area aged 25 to 74, 1980–1982 through 2007–2009

	1980–1982 Mean (SD)	**1985–1987 Mean (SD)**	**1990–1992 Mean (SD)**	**1995–1997 Mean (SD)**	**2000–2002 Mean (SD)**	**2007–2009 Mean (SD)**	**p for trend**
All males	7.24 (0.24)	6.60 (0.21)	6.07 (0.21)	7.41 (0.23)	6.07 (0.26)	6.15 (0.27)	<0.001
Age							
25–39	7.89 (0.38)	6.83 (0.36)	6.71 (0.33)	7.89 (0.42)	6.62 (0.36)	5.63 (0.52)	0.003
40–54	6.92 (0.38)	6.51 (0.32)	5.87 (0.30)	7.13 (0.33)	5.85 (0.26)	6.32 (0.36)	0.02
55–74	5.58 (0.44)	6.34 (0.38)	5.40 (0.39)	7.04 (0.39)	5.71 (0.35)	6.05 (0.39)	0.05
Education level							
Vocational or college	7.28 (0.29)	6.44 (0.25)	5.99 (0.25)	7.58 (0.27)	6.19 (0.23)	6.15 (0.29)	<0.001
High school or less	7.17 (0.32)	6.98 (0.29)	6.38 (0.31)	6.87 (0.43)	5.67 (0.33)	6.21 (0.49)	0.01
Body mass index							
< 25	7.67 (0.45)	7.05 (0.42)	6.51 (0.41)	8.16 (0.53)	5.84 (0.41)	6.28 (0.59)	0.005
25.0–29.9	7.33 (0.31)	6.48 (0.27)	6.12 (0.27)	7.18 (0.31)	6.17 (0.28)	6.14 (0.36)	0.008
≥30	6.39 (0.49)	6.39 (0.39)	5.59 (0.36)	7.18 (0.36)	6.07 (0.29)	6.09 (0.37)	0.06

Table 3

Age-adjusted mean intake of vitamin D (mcg/day) for females in the Minneapolis-St. Paul metropolitan area aged 25 to 74, 1980–1982 through 2007–2009

	1980–1982 Mean (SD)	**1985–1987 Mean (SD)**	**1990–1992 Mean (SD)**	**1995–1997 Mean (SD)**	**2000–2002 Mean (SD)**	**2007–2009 Mean (SD)**	**p for trend**
All females	4.77 (0.15)	4.31 (0.13)	4.19 (0.12)	5.54 (0.14)	4.49 (0.12)	4.53 (0.16)	<0.001
Age							
25–39	5.25 (0.25)	4.91 (0.22)	4.47 (0.21)	5.79 (0.26)	4.67 (0.22)	4.37 (0.33)	<0.001
40–54	4.68 (0.26)	4.01 (0.22)	4.16 (0.20)	4.98 (0.22)	4.39 (0.17)	4.41 (0.24)	0.02
55–74	4.13 (0.31)	3.75 (0.27)	3.75 (0.26)	6.06 (0.29)	4.31 (0.25)	4.66 (0.28)	<0.001
Education level							
Vocational or college	4.82 (0.22)	4.36 (0.18)	4.36 (0.16)	5.49 (0.18)	4.65 (0.15)	4.55 (0.18)	<0.001
High school or less	4.69 (0.22)	4.24 (0.20)	3.87 (0.21)	5.68 (0.26)	4.08 (0.23)	4.60 (0.38)	<0.001
Body mass index							
< 25	4.75 (0.20)	4.39 (0.19)	4.33 (0.18)	5.92 (0.23)	4.72 (0.19)	4.55 (0.26)	<0.001
25.0–29.9	4.93 (0.31)	4.32 (0.24)	3.99 (0.23)	5.22 (0.26)	4.30 (0.22)	4.75 (0.29)	0.005
≥30	4.66 (0.37)	4.12 (0.28)	4.16 (0.26)	5.27 (0.26)	4.37 (0.21)	4.28 (0.28)	0.02

Table 4

Age and energy-adjusted mean intake of vitamin D (mcg/day) for females in the Minneapolis-St. Paul metropolitan area aged 25 to 74, 1980–1982 through 2007–2009

	1980–1982 Mean (SD)	1985–1987 Mean (SD)	1990–1992 Mean (SD)	1995–1997 Mean (SD)	2000–2002 Mean (SD)	2007–2009 Mean (SD)	p for trend
All females	4.94 (0.14)	4.48 (0.12)	4.35 (0.09)	5.29 (0.13)	4.36 (0.11)	4.36 (0.15)	<0.001
Age							
25–39	5.24 (0.23)	5.07 (0.20)	4.59 (0.19)	5.51 (0.24)	4.51 (0.21)	4.22 (0.31)	<0.001
40–54	4.86 (0.24)	4.12 (0.20)	4.33 (0.19)	4.75 (0.21)	4.36 (0.16)	4.24 (0.22)	0.12
55–74	4.33 (0.29)	3.99 (0.26)	3.94 (0.25)	5.89 (0.28)	4.11 (0.23)	4.48 (0.27)	<0.001
Education level							
Vocational or college	4.94 (0.20)	4.52 (0.17)	4.52 (0.15)	5.37 (0.17)	4.53 (0.13)	4.36 (0.17)	<0.001
High school or less	4.87 (0.21)	4.39 (0.19)	3.99 (0.21)	5.29 (0.25)	3.91 (0.22)	4.44 (0.36)	<0.001
Body mass index							
< 25	4.84 (0.19)	4.49 (0.18)	4.43 (0.17)	5.52 (0.22)	4.70 (0.18)	4.46 (0.24)	0.002
25.0–29.9	5.22 (0.29)	4.49 (0.23)	4.23 (0.21)	5.09 (0.24)	4.04 (0.19)	4.41 (0.22)	0.003
≥30	4.89 (0.36)	4.38 (0.27)	4.32 (0.25)	5.10 (0.25)	4.24 (0.19)	4.13 (0.27)	0.05