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A Thesis

Submitted to the Graduate College of Bowling Green State University
in partial fulfillment of the requirements for the degree of

MASTERS OF FAMILY AND CONSUMER SCIENCES

May 2010

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ABSTRACT

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Americans of all ages, races, and genders have insufficient to deficient levels of serum 25-hydroxy vitamin D₃ (25(OH)D₃). Americans choose to take vitamin D supplements to combat low serum vitamin D levels, meet physiological needs and prevent diseases. The purpose of this research was to study the racial, gender, age, income, and education level differences in the prevalence of vitamin D supplement intake and mean amount of vitamin D supplement taken in the American population from the file, Dietary Supplement Questionnaire, NHANES 2001-2002, 2003-2004, 2005-2006 data. The statistical software, SUDDAN was used to control the weights of the samples.

The data of 21,455 participants included in the sample, 2 years of age and older derived from the surveys were analyzed in this study to assess vitamin D supplement intake by Americans. According to the analysis, 33.7% (n=5,467) of the respondents reported consuming a vitamin D supplement. In this study, a higher percent of vitamin D supplement takers were females [37.7%], non-Hispanic whites [38.5%], elderly [53.3% of 71-85 years], college graduates [50%], and household incomes greater than $65,000 [41.6%]. The lowest percent of vitamin D supplement takers were males [29.7%], Mexican-Americans [19.2%], adolescents [16.6%], people with less than high school education [20.7%], and those with household incomes less than $20,000 [22.7%].

The groups that took the highest mean amount of vitamin D supplements were females [413.2 ± 9.7 IU], non-Hispanic whites [391.1 ± 6.8 IU], the elderly [485 ± 16.1 IU], high school graduates [426.4 ± 14.1], and household incomes greater than $65,000 [393 ± 9.5 IU]. The groups who took the least amount of vitamin D supplements were males [359.9 ± 7.1 IU],
In conclusion, the American population groups most likely to take a vitamin D supplement are women, elderly, non-Hispanic whites, college graduates, and incomes >$65,000. The groups most likely to take the highest mean amount are women, non-Hispanic whites, elderly, high school education, and incomes >$65,000.
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CHAPTER I: INTRODUCTION

Statement of Problem

It is known that many Americans have inadequate levels of serum 25-hydroxy vitamin D$_3$ (25(OH)D$_3$) and some population groups are at higher risk of developing vitamin D deficiency (1-13). The causes of vitamin D deficiency may be multiple; challenge of sufficient vitamin D intake from dietary sources, lack of sun exposure, and/or low metabolism (1-13). Age, skin pigmentation (11), use of sunscreens, season with less sun and distance from the equator, all affect the skin’s ability to synthesize vitamin D from its precursor, 7-dehydrocholesterol (12,14,16). Increased skin pigmentation reduces vitamin D$_3$ synthesis in skin by as much as 99%, because melanin is extremely efficient in absorbing UVB radiation (17). In addition, vitamin D deficiency is a major problem in elderly people, because of their low dietary intake, decreased skin stores of 7-dehydrocholesterol, and low exposure to sunlight (16).

For most American adults, the primary source of vitamin D is diet. However, the data from NHANES 1999-2000 showed that the total vitamin D intake from food sources across all ages was only 3.8-6.9 µg or 152-276 IU per day (3). This minimal amount is related to the fact that few foods contain vitamin D naturally, and these foods are not eaten on a regular basis by the American population (3,14). In the United States, 40% - 60% of the food intake of vitamin D is supplied by fortified milk (3). Consequently, society’s decrease in milk consumption has contributed to the decrease in vitamin D status as reported from National Health and Nutrition Examination and Survey (NHANES) III and NHANES 2003-2004 (15). The AI for vitamin D of 5 µg (200 IU) daily is set for infants over the age of 6 months, children, adolescents, and adults aged 19 to 50 years, including women who are pregnant and lactating (18). For individuals aged
51-70 years, the AI for vitamin D is 10 ug (400 IU), and for individuals over the age of 71 years, the AI is increased to 15 ug (600 IU) daily (15).

The role of vitamin D in bone metabolism is well-known. Vitamin D together with parathyroid hormone (PTH) acts to maintain homeostasis of blood calcium concentration. It does this by increasing absorption of calcium and phosphorous in the intestine, which increases reabsorption at the distal renal tubule and stimulates bone resorption in response to low blood calcium levels. Vitamin D is an important nutrient in the prevention of rickets in children, and its adult counterpart osteomalacia (19). In addition, other benefits are being elucidated including healthy cardiac and neuromuscular function, resistance to infection, protection against malignant diseases, improved insulin secretion, glucose tolerance, and blood pressure (11-16, 20-22).

Vitamin D deficiency appears to be a wide-spread, but unrecognized condition (23). There seems to be a very high prevalence of vitamin D deficiency in the United States. According to data collected from NHANES III, 10% of women aged 60-79 years living in northern United States have serum 25(OH)D values below 37 nmol/L. Approximately 77% of the same group of women, have serum 25(OH)D values below 80 nmol/L (7). Elderly had below-optimal average plasma vitamin D levels of 71-86 nmol/L, when living in a community dwelling, and 53-45 nmol/L for patients in nursing homes and in homes for the elderly. Geriatric patients had a mean 25(OH)D level of 45-71 nmol/L. Hip fracture patients had a mean plasma vitamin D of 32 nmol/L in the United States (11).

Research that showed low level of serum 25(OH)D in the elderly may be due to low dietary intakes and low sun exposure (1-13, 16). Vitamin D’s role in bone metabolism and increased incidence of osteoporosis among elderly prompted attention to vitamin D nutrition for the elderly (6, 19). In 1999, the Modified Food Guide Pyramid for individuals 70 years and older was
published, in order to emphasize their unique nutrient needs. It is common that older adults and elderly have a difficult time consuming adequate amounts of vitamin D from their diet. Older adults are more likely not to meet their AI (15 ug/day or 600 IU) for vitamin D (6). A specific addition to the Food Guide Pyramid was the flag placed at the top of the pyramid, emphasizing the need of getting nutrients specifically from supplementation for vitamin D, calcium and vitamin B12 (6).

Frequent reports on the low levels of serum vitamin D among Americans by health professionals as well as media prompted the serum vitamin D level check (6, 24-30). Supplement recommendations for vitamin D is growing, in response to the emerging research of vitamin D deficiency not only in the elderly, but in all age groups (2,4-13,15, 20, 21). Specifically, recommended intake of pediatric vitamin D has risen from 200 IU per day to 400 IU per day, for babies 2 months old through adolescence (4). The National Osteoporosis Foundation recommends that adults under 50 years old get 400-800 IU of vitamin D₃ daily, and that adults 50 and over get 800-1,000 IU of vitamin D₃ daily (30).

Significance of the Study

Currently, vitamin D supplement intake among Americans of all age groups is unknown (1,2,9). The National Health and Nutrition Examination and Survey (NHANES) collected information on dietary supplements intakes by the Dietary Supplement Questionnaire. Finding out who takes a vitamin D supplement and how much vitamin D was taken among Americans is important from the standpoint of vitamin D deficiency prevention as well as over-consumption. The data from three cycles of NHANES 2001-2002, 2003-2004 and 2005-2006 provided good sample size and recent information for this imperative research.
Objectives of the Study

The purposes of this study were to determine the number of Americans who took vitamin D supplements and how much they took. The two overall objectives of this study were:

1. To compare vitamin D supplement intake among various groups in relation to gender, age, race/ethnicity, education, and household income in term of the percentage of vitamin D takers in each group

2. To quantify and compare the amount of vitamin D supplement taken by the above groups.
CHAPTER II: REVIEW OF THE LITERATURE

Vitamin D Supplements

Data collected from the National Health and Nutrition Survey, What We Eat in America, survey indicated that approximately 50% of Americans take dietary supplements; thus, the total dietary intake of vitamin D must be partially supplied by supplements (1, 2). Many residents of the United States rely on diet to provide sources of vitamin D (3,22). Yet, varying age, ethnic, and genders groups have different reasons for consuming lower amounts of vitamin D than is recommended for prevention of disease. Therefore, vitamin D supplements are necessary to reduce the risk of vitamin D deficiency complications in different populations (6, 15, 24, 25, 27).

The main forms of vitamin D are found as cholecalciferol (vitamin D3) and ergocalciferol (vitamin D2). One study recently reported that supplementation with vitamin D3 increased the serum 25(OH)D levels higher than vitamin D2 supplementation, but others examinations have demonstrated equal contribution to circulating vitamin D (10). A comparison study of vitamin D2 and vitamin D3, described vitamin D2 to be only 30% to 50% as effective as vitamin D3 in serum 25(OH)D concentrations (11). In a single dose response study of 100,000 IU of vitamin D3, patients’ 25(OH)D was raised from 75 nmol/L to 100 nmol/L and remained above 80 nmol/L for 70 days after ceasing supplementation (12). What’s more, vitamin D3 is the form of vitamin D that the National Osteoporosis Foundation states as the best to support bone health (13).

Some of the commonly used vitamin supplements in the United States such as Centrum, Walgreen’s, and Osco multivitamin use vitamin D2 as their source of vitamin D (2). Multivitamins typically contain 400 IU vitamin D2. Supplements containing vitamin D only are available in various amounts including 400, 1000, 2000, 4000, 5000, 50000 IU vitamin D2 in a capsule or 8000 IU vitamin D2/mL. In Canada, Europe, Japan, and India, vitamin D3 is available
as a pharmaceutical (10, 11). Vitamin D supplements are widely prescribed for individuals with renal disease, because these individuals’ kidneys are typically unable to synthesize calcitriol. Usually, Rocaltrol (Hoffman-LaRoche) is the oral calcitriol supplement and Calciject (Abbott Laboratories) is given intravenously to individuals with renal disease. Another dietary supplement, Calderol, provides 25(OH)D$_3$ to individuals with organ malfunction (14,15).

In the past, research has looked at various variables when studying the use of vitamin D supplementation and the patient response in order to raise the serum levels to be preventive against disease. Extensive research of a serum 25(OH)D has exhibited protective benefits when concentrations are 80 nmol/L or higher (5, 7, 9, 16, 17). Furthermore, an oral intake of 55 ug/day (2200 IU) of vitamin D has been shown to successfully raise 25(OH)D to necessary levels. For a vitamin D deficient person, supplementing 150 IU of vitamin D will increase the 25(OH)D levels by approximately 1 ng/mL. Some clinical recommendations for vitamin D deficient individuals are 1,000 IU daily, if their serum 25(OH)D is 25-32 ng/mL, 2,000 IU daily with a 15-25 ng/mL serum 25(OH)D, and 3,000 IU daily for serum 25(OH)D below 15 ng/mL (9). Additionally, it takes more than three to six months for a vitamin D supplement before a plateau of circulating 25(OH)D concentration is achieved, thus it is necessary to supplement for long periods of time to show significant increases in serum 25(OH)D (5).

During vitamin D supplementation, high baseline 25(OH)D concentrations show small percent increases in serum 25(OH)D concentrations when compared to insufficient or deficient vitamin status. One study suggested that for a baseline 25(OH)D concentration above 50 nmol/L (20 ng/mL), only 800 IU vitamin D or more per day for 5 months was effective in raising the serum 25(OH)D level (11).
Recently, many different studies have shown the benefits of adequate vitamin D intake. On the other hand, deficiency in vitamin D appears to be deleterious to one's health. It seems that vitamin D deficiency causes impaired muscle function and muscle weakness, which are, however, reversible following vitamin D supplementation. To prevent falls and fractures among weak elderly individuals in nursing homes or other geriatric institutions, supplementation is important. There is good evidence to support general supplementation with 20 µg (800 IU) of vitamin D in combination with 1000-1200 mg calcium (18). Not only will supplementation raise plasma 25(OH)D, it will suppress plasma parathyroid hormone, reduce bone turnover, improve muscle force, improve bone strength, and prevent fractures. A randomized control trial on vitamin D in 65-85 years olds supplemented with 800 IU of vitamin D a day increased serum 25(OH)D from 50 nmol/L to 80 nmol/L, and reduced fracture risk by 33% (10, 19). The reduction in fracture rate observed with vitamin D treatment can also be partially explained by a decrease in body sway and the risk of falling (20). Yet, vitamin D alone without calcium has no significant effect on the risk of falling (21). The National Osteoporosis Foundation recommends that adults under 50 years old get 400-800 IU of vitamin D₃ daily, and that adults 50 and over get 800-1,000 IU of vitamin D₃ daily (13).

It has been suggested that optimal vitamin D levels in postmenopausal women is achieved by consuming 600-800 IU of vitamin D supplement per day (17). In a two year study of postmenopausal women, an administered dose of 500 mg calcium resulted in a 68% increase in calcium absorption when serum levels of vitamin D were increased from 50 nmol/L to 80 nmol/L (22). However, for postmenopausal African American women, raising 25(OH)D concentration higher than 75 nmol/L requires a dose of 2800 IU of vitamin D supplementation for baseline value of higher than 45 nmol/L, and 4000 IU for baseline values less than 45 nmol/L.
due to the lower effect of sunlight on vitamin D production in their darker skin pigmentation (14).

A variety of other populations have seen benefit in vitamin D supplementation as well. For example, there have been several studies that look at the relationship between vitamin D and cancer. A four year study of with 1100 IU supplements of vitamin D a day raised 25(OH)D, and was correlated to lower incidence of cancer (23). Additionally, people with congestive heart failure who took a 50 µg vitamin D supplement had increased anti-inflammatory cytokine IL-10 and prevented the increase of proinflammatory cytokine TNF-alpha. Supplementation of vitamin D is also able to manage serum concentrations of PTH, a hormone that may contribute to impaired cardiac function (5).

Additionally, a maternal intake of 4000 IU of vitamin D a day or more is sufficient to ensure adequate nutritional vitamin D status for both mothers and nursing infants. The American Academy of Pediatrics recommends that newborn infants should not be exposed to the sun during the first 6 months of life, which does not allow the production of vitamin D₃ in their skin from ultraviolet rays. Supplementing pregnant and lactating mothers with vitamin D will prevent rickets and hypovitaminosis D in infants, especially in darkly pigmented individuals who have higher needs (6).

Vitamin D Structures

Vitamin D is a fat soluble vitamin that plays very important roles in the body. The two major forms of vitamin D are vitamin D₂ (ergocalciferol) and vitamin D₃ (cholecalciferol). The active form of vitamin D is calcitriol (1,25-(OH)₂D₃). Calcitriol acts similarly to a steroid hormone. Vitamin D₃ is synthesized endogenously in the skin from 7-hydrocholesterol, mediated by
ultraviolet B radiation. Ergocalciferol, on the other hand, is plant derived and is formed exogenously by irradiation of ergosterol (10).

![Figure 1: ergocalciferol](image1)

![Figure 2: cholecalciferol](image2)

![Figure 3: calcitriol](image3)

**Vitamin D Sources**

*Food sources of vitamin D*

For most American adults, their primary source of vitamin D is from dietary sources (3). Although, the data from NHANES 1999-2000 presented the total vitamin D intake from food sources across all ages was only 3.8-6.9 ug per day. This very small amount is due to the fact that few foods contain vitamin D naturally, and the ones that do are usually not eaten on a regular basis by the American population. Naturally, vitamin D is found mainly in foods of animal origin, such as liver, beef, veal, eggs, and oily fish, such as salmon, herring, tuna, and sardines, including cod liver oil (3, 14). A recent study showed that wild-caught salmon had an average of 500-1000 IU vitamin D in 100 grams; whereas, farm-raised salmon only contained 100-250 IU
vitamin D per 100 grams (30). Since humans do not form adequate supplies of vitamin D from the sunlight alone, many people must depend on vitamin D from the diet (12).

Therefore, fortification of foods has been a safe and effective way to increase vitamin D in the general population (4). Traditional foods that have been fortified with vitamin D include milk, margarine, and enriched grain and cereal products (18, 24). In the United States, 40% - 60% of the total daily food intake of vitamin D is contributed by fortified milk (4). Dairy products that vitamin D is sometimes added to is yogurt and American cheese slices and macaroni products (1). Just as cow’s milk is fortified with vitamin D, so are dairy alternatives, including soy and rice milks. Consumption of dairy products plays an important role in the daily intake of vitamin D, because it is the group containing the largest food source of this particular nutrient (Moore et al, 2004). Consequently, society’s decrease in milk consumption is a contributing factor to the decrease in vitamin D status reported from NHANES III and NHANES 2003-2004 (6).

**Sunlight**

Since vitamin D is not widespread in the food chain, it is good that 80-90% of the body’s requirement comes from exposure to the sun (17). During skin exposure to sunlight, specifically ultraviolet B (UVB) radiation, some epidermal cutaneous reservoir of 7-dehydrocholesterol is converted to previtamin D₃ by photochemical activation in the stratum germinativum (24, 26). This previtamin D₃ is thermally isomerized within 2 to 3 days into vitamin D₃, also called cholecalciferol. Cholecalciferol diffuses from the skin into the blood, with transport in the blood (1). Vitamin D is deposited in the adipose tissue, but it is not large enough or sufficiently regulated to prevent seasonal variations in plasma concentrations 25(OH)D and PTH (24). Yet,
age, skin pigmentation, both natural and caused by sunburn (18), use of sunscreens, and distance from the equator all affect the skin’s ability to undergo this transformation to vitamin D (21).

Seasonal Differences

The skin’s ability to convert 7-dehydrocholesterol into vitamin D$_3$, due to the reduced zenith angle of the sun; and increased path length of sunlight through the atmosphere, decreases the effective level of UVB energy with North and South distance from the seasonally varying latitude. It is important to note that ultraviolet light of the appropriate wavelength (285-310 nm) is completely absorbed by glass, so in order to receive the full benefit from the sunlight to transform 7-dehydrocholesterol into vitamin, one must be outside (25). Anything that diminishes the transmission of solar UVB radiation to the earth’s surface or anything that interferes with the penetration of UVB radiation into the skin will affect the cutaneous synthesis of vitamin D$_3$ (11).

It has been suggested that at high levels of illumination, high intensity florescent lights can provide a minimal amount of ultraviolet light, such that eight hours exposure has about the same effect as a 15-min walk in the sun (25). Thus, the dependence on dietary sources of vitamin D peaks during the winter months at temperate latitudes and among people with limited skin exposure to sunshine (24).

Throughout evolution, humans have depended on the sun for their vitamin D requirement. A likely reason that melanin pigmentation evolved was to permit humans who migrated from south to north to make enough vitamin D in their skin to satisfy their requirements (7). The recommendation of avoidance of all sun exposure by clothing and sunscreen to prevent skin cancer has put the world’s population at risk of vitamin D deficiency (4, 11). It has been shown that the effect of sunscreen greatly reduces the effect of vitamin D conversion from
sunlight. Wearing a sunscreen with an SPF 8 decreases the vitamin D production by 85% and a SPF 15 decreases vitamin D production by 99% (7, 26).

A study examined the conversion of 7-dehydrocholesterol to vitamin D due to sunshine; in different seasons for one hour at noon. The study was conducted in Boston, which is 42 degrees north latitude. The results showed that during the months of January, February, November, and December, there was no conversion to vitamin D. In the spring and summer months, there was more conversion, the peak in June and July (28).

The more ultraviolet radiation in the lower latitudes is directly associated with more vitamin D that can be produced, and few incidences of vitamin D deficiency. Thus, epidemiologic studies have suggested a possible link to lower incidences of breast, colon, prostate, and ovarian cancers and non-Hodgkin lymphoma.

Skin Pigmentation

Ultraviolet absorption is also reduced by melanin, so that short-term irradiation of dark skin produces a slower and smaller rise in plasma D$_3$ than comparable irradiation of light skin in the winter and summer months (9, 25). Melanin absorbs UVB radiation very efficiently, and, thus increased skin pigmentation markedly reduces vitamin D$_3$ in skin by 99%. African Americans with very dark skin have an SPF of 15, and, thus their ability to make vitamin D in their skin reduces by as much as 99%. A lower milk intake related to lactose intolerance adds to the explanation why African Americans who live in a temperate climates are vitamin D deficient. However, Africans living near the equator are not deficient, because of the higher flux of UVB photons makes the vitamin D$_3$ synthesis is more efficient (11).

Following the exodus from Africa, the northern latitudes were inhabited by fair-skinned people with increased ability to make use of the limited amount of UVB despite the need for
clothing. By contrast, dark-skinned recent immigrants from Palestine, Pakistan and India to Northern Europe may develop severe vitamin D deficiency with proximal myopathy because of the limited effect of sunshine and low dietary vitamin D intake (18). Even today, dark-skinned agriculture workers in tropical latitudes have serum 25(OH)D levels three times those of light skinned adults in Europe and North America (21).

In addition to decreased production of vitamin D₃ in individuals with darker pigmented skin, lactose intolerance primarily in African Americans, Asians and Mexican Americans lowers their dairy intake. Consequently, vitamin D intake is reduced as well. Recent studies report low vitamin D intakes among different race and ethnicity groups (27). Despite recent efforts to increase vitamin D intake through appropriate fortification, dietary guidance and advice on vitamin D supplements would be beneficial for these population groups.

Recommended Intakes

Research has shown the appropriate adequate intake (AI) for vitamin D is not well understood. The most current adequate intake allowance of vitamin D, recommended in 1997, is considered to be too low (16, 29). The latest recommendations suggest an AI for vitamin D of 5 ug (200 IU) daily for infants over the age of 6 months, children, adolescents, and adults aged 19 to 50 years, including women who are pregnant and lactating. On the other hand, the elderly have a much higher AI. For individuals aged 51-70 years, the vitamin D need is 10 ug (400 IU), and for individuals over the age of 71 years, the AI is increased to 15 ug (600 IU) daily (15). The adequate intake (AI) of vitamin D was based on the amount of obtainable by sunlight, which in the United States is measured at 1.5 IU/cm²/hour during the winter and 6 IU/cm²/hour during the summer (30).
In 1941, the RDA for vitamin D was set at 400 IU. This original RDA was based on one teaspoon of cod liver oil, which has 400 IU of vitamin D. At the time, not much scientific research went into creating this RDA, it was simply enough to prevent the onset of rickets. The serum level of vitamin D shown to prevent rickets/osteomalacia is about 25 nmol/L. So, the reference range for normal blood range of 25(OH)D is between 37-120 nmol/L. In 1997, the current AI was based on functional indicators of vitamin D’s blood levels. Thus, an individual’s serum 25(OH)D, the form of vitamin D that circulates in the blood stream after it has undergone its first hydroxylation in the liver, is used to determine adequate vitamin D. So, there needs to be a lot more research to determine, if there is a higher need in order to raise the RDA. The US DRI panel concluded that there was insufficient evidence to set estimated average requirement (EAR), which is the foundation for setting recommended dietary allowance (RDA), because contributions of vitamin D from the sun and from food were too difficult to measure (16).

**Biological roles of vitamin D in the human body**

The canonical scheme of vitamin D begins with obtaining it from either the diet or through the skin by UVB rays from the sun (16). Vitamin D undergoes hydroxylation in the liver to become circulating form of 25(OH)D. The second hydroxylation of vitamin D occurs in the kidney to become the active hormonal form of 1,25(OH)₂D₃. Then, the active form of vitamin D performs its function at tissues by the endocrine functions. Endocrine functions of vitamin D, 1,25-dihydroxyvitamin D₃, generate biological responses in the immune, pancreas, cardiovascular, muscle, and brain systems as well as skeletal system (29). Vitamin D also has autocrine functions, which originate at the second hydroxylation, which can occur in almost any tissue in the body to convert active form of vitamin D as needed (18).
About 85% of circulating vitamin D in the body conducts autocrine functions. Specific autocrine functions include cell proliferation, cell differentiation, apoptosis, immune response and inflammation. These roles of vitamin D are indicative measures of cancer. In autocrine action, almost every tissue in the body has vitamin D receptors (brain, breast, prostate, colon, gastrointestinal tract). Furthermore, over 200 genes within each cell are related to vitamin D response element (18).

The major functions of vitamin D in the body include ATP-dependent calcium uptake by sarcoplasmic reticulum in muscle, beta-cell function for insulin secretion, gene expression and gene transcription for coding proteins. Vitamin D also acts together with the parathyroid hormone (PTH) to maintain homeostasis of blood calcium concentration, as well as increased absorption of calcium and phosphorous in the intestine and distal renal tubule. Vitamin D is an important nutrient in the prevention of rickets, and its adult counterpart osteomalacia. The involvement of vitamin D in cell differentiation, proliferation and growth in a variety of different tissues may even inhibit cancer cell proliferation and growth (31). A study disclosed a connection between vitamin D status and muscle function in the elderly, women with postmenopausal osteoporosis and among dark-skinned immigrants (18). The best way to measure a person’s vitamin D status is to measure serum 25(OH)D concentration (11). Vitamin D functions in non-skeletal diseases include osteoarthritis and rheumatoid arthritis, falls and neuromuscular function, multiple sclerosis, fibromyalgia, type 1 diabetes, insulin sensitivity, cardiovascular disease, periodontal disease, various cancers, tuberculosis, and hypertension (16, 23).
Relationship between vitamin D and calcium

Vitamin D plays a pivotal endocrine role in the action of PTH, calcium absorption, fractures and falls (29). Thus, vitamin D is critical to maintain calcium homeostasis and skeletal metabolism throughout the lifecycle. With any insufficiency in calcium absorption, either from low calcium intake or low status, there will be a fall in extracellular calcium circulation, thus triggering an increase in PTH which will be released to increase the hydroxylation of circulating vitamin D in the kidney and produce increased circulating active form of the vitamin in order to increase intestinal calcium absorption from baseline. This is a closed-circuit loop, so when calcium is sufficient, it will shut off. So PTH at a constant level is an indicator of homeostasis, the point at which the PTH level “bottoms out” defines the point at which adaptation is no longer needed. The role of vitamin D in enhancing calcium absorption and keeping serum calcium within range is necessary to support cardiac function, neuromuscular function and many other metabolic activities (21).

More specifically, vitamin D affects bone health by facilitating the input of calcium from the diet to meet the needs of bone mineralization and to balance obligatory losses. In order to achieve normal blood calcium concentration (17), vitamin D directs the mobilization of calcium and phosphorus from bone. Vitamin D also influences osteoblast-directed production of osteoclast (bone resorption) and or osteoblast (bone formation) activity mediated bone resorption. Additionally, vitamin stimulates the synthesis of variety of proteins involved in modeling, remodeling, and bone mineralization (32). It has been shown that vitamin D and calcium given together as a dietary supplement may increase bone mineral density and decreased amount of fractures. For an individual to receive the best protection against bone loss, it is ideal for a maintenance of serum 25(OH)D levels at or above 80 nmon/L. A study of vitamin D and
calcium absorption determined a threshold of 80 nmol/L of serum 25(OH) D, when no further calcium absorption will occur (33).

**Vitamin D and Cancer**

There have been several studies that look the relationship between vitamin D and cancer. In a randomized control trial of four years, the participants who receiving calcium and vitamin D therapy (1100 IU a day) raised their serum 25(OH)D levels from approximately 72nmol/L to 96 nmol/L, and 99% were cancer free (23). It has also been shown that with higher serum vitamin D levels, there is a relative decrease in prostate cancer. In a 13 year longitudinal study of 19,000 men, only 149 had prostate cancer. That particular study showed that men with 25(OH)D levels below the median of 70% were more likely to develop prostate cancer than those above (34)

**Assessment of Vitamin D Status**

Currently, the most accurate estimation of vitamin D status is based on the serum levels of 25(OH)D (29). These blood levels of vitamin D are measured in the clinical setting as 1ng/mL; which is equivalent to 2.5 nmol/L, the reference used in research. Research in vitamin D has shown that serum 25(OH)D levels below 80 nmol/L (32 ng/mL) are not adequate for optimal health (5, 7, 9, 16, 17). The plasma 25(OH)D concentration is a useful vitamin D biomarker, because it has a long half-life in the circulation, and its concentration is not under tight homeostatic control. Plasma 25(OH)D reflects vitamin D supply and usage over a period of time. Concentrations of 25(OH)D above 30 ng/mL is considered to be sufficient. Vitamin D insufficiency is defined as the lowest threshold value 21-29 ng/mL for plasma 25(OH)D, which prevents secondary hyperparathyroidism, increased bone turnover, bone mineral loss, or seasonal variations in plasma PTH. Vitamin D deficiency is defined as values less than 20 ng/mL (11).
As serum levels of vitamin increase, incidence of disease or risk of disease state decreases (35). Current research has indicated serum 25(OH)D levels are necessary to prevent certain disease states (5, 6, 23, 34). The optimal blood level of vitamin D for calcium endocrine related functions is 80 nmol/L. Raising serum 25(OH)D from 50 nmol/L to 80 nmol/L or higher improves calcium absorption and neuromuscular function, as well as reduces the risk of fractures and falls (10, 19). Some studies have even suggested that blood values of vitamin D below 80 nmol/L to be considered a deficient state (35).

Vitamin D deficiency

Vitamin D deficiency appears to be a wide-spread, but unrecognized condition (20). There appears to be a very high prevalence of vitamin D deficiency in the United States. According to data collected form NHANES III, 10% of women aged 60-79 living in northern states have serum 25(OH)D values below the lab-cut off of 37 nmol/L. Approximately 77% of the same group of women, have serum 25(OH)D values below 80 nmol/L.

In the United States, the population groups that are most likely to consume the recommended levels of vitamin D are children, adolescents, male teenagers, and young male adults. Conversely, the lowest dietary intakes of vitamin D were reported by female teenagers and female adults. The highest intakes of vitamin D from food sources were reported by male teenagers. Nevertheless, a majority of Americans are not obtaining adequate levels of vitamin D. Less than 10% of older adults (51-70 years old) and no more than 2% of the elderly (older than 70 years old) met vitamin D requirements from food sources alone. These decreases in vitamin D intake paralleled the increased vitamin D requirements associated with aging (27).

The elderly represents one population group that typically has insufficient vitamin D intake and receives low sun light exposure (36) because of changes in lifestyle factors such as
clothing and outdoor activity (18). Although vitamin D-containing dietary supplements increased the percentage of populations meeting the AI by 10% to 25%, up to 90% of older individuals still did not consume adequate amounts of vitamin D (27).

The prevalence of vitamin D deficiency based on skin pigmentation is greater in darker skinned individuals than lighter skinned individuals. In the data collected from NHANES III, the average circulating vitamin D, 25(OH)D in darker-skinned, African American women 60 years and older is about 40 nmol/L, compared to 75 nmol/L of light skinned Caucasian women 60 years and older (37).

**Rickets**

Vitamin D deficiency in children causes a condition called rickets. In the past, rickets occurred in children who had little exposure to sunlight. Most of the bone mineralization occurs after birth, and calcification requires vitamin D, and a lack of this vitamin D causes the bones to remain soft. In vitamin D deficient infants, their epiphyseal cartilage continues to grow and enlarge without replacement by bone matrix and minerals. Symptoms of rickets include bowed legs, enlargement of the ends of long bones which cause knees to knock, curving of the spine, and pelvic and thoracic deformities (24). This condition was thought to be cured by milk fortification. Yet, recently there have been reports of rickets in darkly pigmented infants who are breastfed, who have very limited sun exposure and were born to women who had little sun exposure. The DRI for pregnancy of 400 IU of vitamin D a day appear to be inadequate to provide the mother and her child with sufficient vitamin D to prevent disease (6).

**Osteomalacia and other vitamin D deficiency disorders**

In adults, vitamin D deficiency will precipitate and exacerbate both osteopenia and osteoporosis (11). Osteomalacia is a vitamin D deficiency in adults resulting in failure of bones.
This defect results from changes in calcium and phosphorus absorption and excretion. The lack of vitamin D contributes to impaired calcium absorption. Bone turnover occurs; the bone matrix is preserved, but re-mineralization is impaired. The bone matrix becomes progressively demineralized, producing radiographic changes and resulting in bone pain, aches and pains in the joints and muscles (11). Impaired vitamin D absorption may occur in disorders characterized by fat malabsorption, such as tropical sprue and Crohn’s disease. Disorders affecting the parathyroid, liver or kidney will impair synthesis of the active form of the vitamin. People on anticonvulsant drug therapy may develop an impaired response to vitamin D and exhibit problems with calcium metabolism (38). Additionally, because vitamin D is fat soluble, it is readily taken up by the fat cells. Thus, it is believed that in obese individuals, vitamin D is sequestered by a large body of fat causing a vitamin D deficiency (11).

Osteoporosis

Osteoporosis is a debilitating disease of the bones. Osteoporosis, or porous bone, is a disease characterized by loss of bone mass and structural deterioration of bone tissue (13). It is a condition of bone fragility that afflicts more than 25 million Americans and costs the economy of the United States approximately $13.8 billion per year. It costs patients their independence and decreases their quality of life. In patients with osteoporosis, improved nutritional status decreases fractures and associated morbidity, as well as saves health care dollars (17). On average, osteoporosis is four times more likely to occur in women than in men (13).

Fragile bones in the patients with osteoporosis are more likely to break; these breaks are known as fractures, and occur typically in the hip, spine, and wrist. Fractures of the hip and spine almost always lead an individual to hospitalization and may require a major operation.
Consequences of osteoporosis debilitate a person's ability to walk and may cause prolonged or permanent disability (13).

Studies show that people with low levels of vitamin D have lower bone density or bone mass, leading to osteoporosis and bone fractures (10). In order for vitamin D to be protective for bone health, individuals must have a serum value of 25(OH)D equal to 75 nmol/L or higher (30 ng/mL or higher). If an individual has osteoporosis, their plasma vitamin D will be low. Some healthcare providers prescribe extra vitamin D (usually vitamin D$_2$) for osteoporosis patients to increase blood levels. Desired clinical outcomes of medical nutrition therapy for patients with osteoporosis is to raise or maintain levels of serum 25(OH)D, specifically to 80-150 nmol/L. Desired behavioral outcomes of medical nutrition therapy for patients with osteoporosis are increased intake of foods with vitamin D and increased exposure to sun (17).

Vitamin D status in older adults and the elderly

According to NHANES 2003-2004, men over the age of 70 years had vitamin D intake of 8.1 ug/day and women 70 years and older had vitamin D intake of 8.0 ug/day (8). The main factors that contribute to vitamin D deficiency in elderly people are low intake, decreased skin stores of the vitamin D precursor, 7-dehydrcholesterol and low exposure to sunlight. Reduced vitamin D status due to age and increased latitude are the main reason for deficient levels of vitamin D found in elderly people in Northern countries (21). It has been shown that vitamin D deficiency is common among community-dwelling elderly in the developed countries at higher latitudes, among institutionalized elderly, geriatric patients and in patients with hip fractures. At higher latitudes, yearly injections of vitamin D in the autumn could prevent the fall in plasma 25(OH)D during winter. Intramuscular route seems at present to be less attractive for vitamin D administration (18).
A comparison study in Caucasian patients of young and older people measured the vitamin D levels in surgically obtained skin. The results of the study showed that vitamin D levels rose quickly in the young sample and the older sample had a more blunted response. In the patients studied, there was a 50% decrease in precursor for vitamin D in the ages 18 to 80 years (39). Consequently, aging reduces synthesis of cholecalciferol in the skin and reduces the activity of the renal 1-hydroxylase in response to PTH (36). The dermal production of vitamin D following a standard exposure to UVB light decreases with age, because of atropic skin changes with a reduced amount of its precursor (18). A 70 year old has about 25% of the 7-dehydrocholesterol that a young adult does and thus has a 75% reduced capacity to make vitamin D$_3$ in the skin (11).

In 1999, the Modified Food Guide Pyramid for individuals 70 years and older, in order to emphasize their unique nutrient needs. It is common that older adults and elderly have a difficult time consuming adequate amounts of vitamin D from their diet. Older adults are more likely not to meet their AI (15 ug/day) for vitamin D (8). Studies have shown that this may not be sufficient to maintain bone health and serum levels in older adults. A specific addition was the flag placed at the top of the pyramid, symbolizing awareness of the potential need to consider supplementation of vitamin D, vitamin B-12 and calcium (8).

In patients with hip fractures, vitamin D status was poor among Americans. Elderly living in a community dwelling have an average vitamin D plasma level of 71-86 nmol/L. Elderly who live in assisted living and nursing homes have mean vitamin D plasma level of 45-53 nmol/L. The lowest serum vitamin D was found in geriatric patients, who had a mean level of 45-71 nmol/l. Hip fracture patients had a mean plasma vitamin D of 32 nmol/L in the United States (18). When vitamin D deficient elderly were given a diet containing 400 IU of vitamin D
for 10 weeks in a study, results showed an increase in 25(OH)D₃ to 80 nmol/L. The results of this study indicated that a daily intake of 400 IU of vitamin D with diet must be recommended for elderly people to prevent hypovitaminosis D and to reduce the risk of bone loss and fracture (40).
CHAPTER III: SUBJECTS AND METHODS

Data Collection

The data used in this study came from the NHANES 2001-2002, 2003-2004, and 2005-2006, which were conducted by the US Department of Health and Human Services and US Department of Agriculture and the National Center for Health Statistics (NCHS), a division of the Centers for Disease Control and Prevention (CDC).

Subjects

The subjects for this study were participants of 2 years of age and older with exclusions made for those under the age of 2 years, if they had cancer, heart, kidney and or liver disorders and subjects who were pregnant and breastfeeding. These exclusions were made, because this research is intended for apparently healthy population and at certain life stages. After making the exclusions, 21,455 respondents remained in the data set. The ages were grouped by developmental stages of life: 2-5 years, 6-12 years, 13-17 years, 18-30 years, 31-50 years, 51-70 years, and 71-85 years. The oldest recorded person taking vitamin D supplements was 85 years old. The different race/ethnic groups were Mexican-Americans, non-Hispanic Blacks, and non-Hispanic Whites. To determine the mean amount of vitamin D taken, only participants who had taken a vitamin D supplement in the past 30 days were included.

Design

The goal of this research was to study vitamin D supplement intake among Americans. This study sought how gender, age, race/ethnicity, educational level, and household income level was related to the vitamin D supplement intake. Specifically, the percentage of Americans who took vitamin D supplements and the amount of the vitamin D supplement taken measured in International Units (IU) in those specific groups were calculated.
The dietary supplement data was found in the file of Dietary Supplement Questionnaire of the NHANES database. The “name of the supplement” (DSDSUPP) recorded that contained vitamin D as an ingredient included “vitamin D only,” “vitamin and mineral combinations (calcium and vitamin D),” and “vitamin combination (vitamin A and vitamin D).”

To determine if the participant took a vitamin D supplement, first it had to be determined that the participant took a dietary supplement. Therefore, the answer to the question DSD101, “Have you used or taken any vitamins, minerals or other dietary supplements in the past 30 days? Include prescription and non-prescription supplements,” must have been “[1] yes.” Also, to ensure respondents had taken a vitamin D supplement specifically, the DSDINGID “ingredient ID number,” must have been [1000385], which corresponds with the ingredient vitamin D. The following names were found during the Dietary Supplement Questionnaire assessment on respondent’s dietary supplement product labels, and were “considered vitamin D and were therefore classified as the vitamin ingredient [DSDINGID = 1000385]”: calciferol, cholecalciferol, ergocalciferol, and calcitriol.

The participant’s dietary supplement was required to have the “ingredient name,” DSDINGR, be vitamin D. The vitamin D supplement would have been recorded as “[1] vitamin,” in the “ingredient category,” DSDUNIT. The “number vitamins in the product,” DSDCNTV, was also recorded in the Dietary Supplement Questionnaire, as either a “[2-14] multivitamin,” or in a “[1] single vitamin supplement”.


The “serving size quantity,” DSDSERVQ was recorded from the product supplements fact panel. For example, “serving size quantity,” of vitamin D supplements on a product label of vitamin D tablets, would be “[1] serving size is one tablet,” or “[2] serving size is two tablets.”

The Dietary Supplements Questionnaire recorded vitamin D supplements as DSDUNIT “ingredient unit.” Ingredient units were “mg,” “IU,” and “mcg.” For this study, vitamin D supplements were measured only as International Units (IU). Hence, in analysis the conversion factors for IU were applied: 40 IU of vitamin D is equal to 1 mcg of vitamin D; and 40,000 IU vitamin D is equal to 1 mg vitamin D. The most common “ingredient quantity in one serving,” DSDQTY recorded for vitamin D were 400 and 200, as well as 20, 50, 60, 65, 100, 125, 130, 133, 134, 135, 200, 250, 312, 500, 815, and 50,000 were also quantities of vitamin D recorded.

The estimates of mean vitamin D supplement intake for this research were taken from the Dietary Supplement Questionnaire in the NHANES 2001-2002, 2003-2004, 2005-2006 survey. The following questions are about the amount of dietary supplement (vitamin D) a respondent took: “For how long have you been taking this product or similar type of product?” DSD090, which was recorded in days [1-29200]. DSD103 “In the past 30 days, on how many days did you take product?” which was answered in number of days from [1-30]. Also, “On the days that you took product, how much did you usually take on a single day?” DSD122Q, which as answered numerically; [0.06-48]. In this study, any DSD122Q > [50] were excluded and DSD103 > [30] were excluded.
The education levels were divided into five groups. The information from DMDEDUC2 “What is the highest grade or level of school {you have/SP has} completed or the highest degree {you have/s/he has} received?” Educational groups included less than a “[1] 9th grade education,” “[2] 9th – 11th grade (includes 12th grade with no diploma),” “[3] high school graduate/GED or equivalent,” “[4] some college education or AA degree,” and “[5] college graduate or above.”


Only respondents age 20 and older were used for the comparison of education. The amount of vitamin D supplement intake are reported as “crude” (unadjusted) value as well as adjusted value, which were controlled for gender, age, race/ethnicity and annual income level. Annual household income level was correlated well with education level, therefore, only income level was controlled.

Statistical Methods

The data were analyzed using the SUDAAN program. This statistical software program specifically analyzes data from complex sampling designs, such as NHANES which is a stratified, multistage and probability design. The statistical analysis was completed at the Bowling Green State University Center for Business Analytics.
Analysis of variance was used to compare the mean amount of vitamin D supplement intake per day. If analysis of variance found differences, then Tukey’s multiple comparison procedure was used to determine where the differences were. Both the analysis of covariance and Tukey’s multiple comparison procedure were run with $p<0.05$ showing statistical significance.

In addition, analysis of covariance was used to compare vitamin D supplement intake among the various groups, age, gender, ethnicity, income, and education, adjusting for the remaining demographic variables. Again, if differences were found, Tukey’s multiple comparison procedure was run with a $p<0.05$ level of statistical significance.

Data sets were created to determine the mean vitamin D intake in IU, and the percentage of the American population who took vitamin D supplements. In order for that to happen, all the necessary variables from the numerous files of the Dietary Supplement Questionnaire and Demographic Variables and Sample Weights from NHANES 2001-2002, 2003-2004, 2005-2006 had to be merged. One major task presented was to keep only respondents who took a vitamin D supplement. For each 2-year cycle, we followed the following format in creating the data set:

1. First, the variables DSDINGID (Ingredient ID), DSDINGR (Ingredient name), and DSDBCCAT (Blend Component Category) from the data set DSQ5_X1 were read in. From this data set, only those with DSDINGID = 10000385 were kept, which is the Ingredient ID for Vitamin D. In fact, there were no observations with DSDINGID = 10000385.

2. The next variables read were DSDSUPID (Supplement ID), DSDSUPP (Supplement name), DSDINGID, DSDINGR, DSDQTY (Ingredient quantity), DSDUNIT (Ingredient unit), and DSDCAT (Ingredient category) from the data set DSQ4_X1. Again, from this data set we kept only those with DSDINGID = 10000385, which is the Ingredient ID for Vitamin D.
3. Next, the variables read were DSDSUPID, DSDSUPP, DSDSERVQ (Serving size quantity), DSDSERVU (Serving size unit), DSDSERVA (Alternate serving size), and DSDCNTV (Count of vitamins in supplement) from data set DSQ3_X. The data sets were merged with DSQ4_X by DSDSUPID and DSDSUPP. Once these data sets were merged, any observations from DSQ3_X that were not matched with observations in DSQ4_X that contained Vitamin D were dropped. Thus, this combined data set kept only those supplements that contained Vitamin D.

4. The following variables were read next, SEQN (Sequence number), DSDSUPID, DSDSUPP, DSD090 (How long supplement has been taken in days), DSD103 (Days supplement taken in past 30 days), DSD122Q (Quantity of supplement taken per day), and DSD122U (dosage form) were read from data set DSQ2_X. This data set was then merged with the previously merged data set by DSDSUPID and DSDSUPP. Again, any observations from DSQ2_X that were not matched with observations in the merged DSQ4_X and DSQ3_X data set that contained Vitamin D, were dropped. Thus, this combined data set kept only those individuals who took supplements that contained Vitamin D.

5. The 3 cycles were combined. Then the following corrections to the data set were made: If DSDUNIT=4 (4 = mcg) then DSDQTY=DSDQTY*40. If DSDUNIT=1 (1 = mg) or DSDUNIT=21 (21 = unknown) then DSDQTY=missing. If DSD103 > 30 (supplement taken more than 30 days in the last 30 day) then DSD103 = missing. If DSDQTY > 3000 then DSDQTY = missing. If DSD122Q > 50 (Quantity of supplement taken per day) then DSD122Q = missing.

6. To find the total amount of Vitamin D taken per supplement, the following equation was used: multiply DSD103 x DSDSERVQ x DSDQTY. Then sum the total amount of Vitamin
D taken per supplement over all the supplements taken per individual. Finally, divide this total by 30 to get the amount of Vitamin D taken per day.
### Variables for Vitamin D Supplement Thesis: Racheal Sommerville


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<td>DSQ2_B, DSQ2_C, and DSQ2_D</td>
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<td>Dosage Form</td>
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### Extraneous Variables: Control These Variables

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<td>Answer Guide</td>
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<tr>
<td></td>
<td></td>
<td>1000 ng = 1 mcg</td>
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<td></td>
<td></td>
<td>1 mg = 1000 mcg</td>
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<tr>
<td></td>
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<td>1000 mg = 1 gram</td>
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<table>
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<tr>
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<td>Vitamin D Liquid</td>
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CHAPTER IV: RESULTS

Table 1 shows the percent of population who took vitamin D supplements. After the exclusions, 21,455 respondents remained in the NHANES 2001-2002, 2003-2004, and 2005-2006 data set. According to the Dietary Supplement Questionnaire, 33.7% (n=5,467) of the respondents who remained in the three NHANES cycles reported consuming a vitamin D supplement (not a random sample). In the first cycle examined, NHANES 2001-2002, 31.5% (n=1,839) took a vitamin D supplement. In the second cycle, NHANES 2003-2004, 34.1% (n=1,771) took a vitamin D supplement. Lastly, in the third cycle examination, NHANES 2005-2006, 35.5% (n=1,857) took a vitamin D supplement.

Table 1: Percent of Population Taking Vitamin D Supplement

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<td>0.0000</td>
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<td>28.3</td>
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<td>13-17 years</td>
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<tr>
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<td>23.0</td>
<td>35.8</td>
<td>0.0000</td>
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<td>30.9</td>
<td>41.0</td>
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Within the sample of participants, 29.7% (n=2,482) of the males who took vitamin D, and 37.7% (n=2,985) of the females took a vitamin D supplement (Table 1). Significant differences existed between males and females within all race/ethnicities [p<0.05] and ages 18-85 years. Further, significantly more women took vitamin D supplements than men did [p<0.05]. Among non-Hispanic whites, 43.2% (n=1,764) of females and 33.9% (n=1,400) of males took vitamin D supplements [p=0.0000]. In non-Hispanic blacks 20.8% (n=577) of females, and 17.9% (n=519) of males took vitamin D [p=0.0134]. Within the Mexican-Americans 21.6% (644) of females and 17.2% (n=563) of males took a vitamin D supplement [p=0.0017].

Figure 4: Gender and Ethnicity Differences: Percent (%) of Population Taking Vitamin D Supplement
For the race/ethnicity groups (Fig. 4), 6,283 participants were classified as Mexican-Americans (Mexicans); 6,493 were classified as non-Hispanic blacks (blacks); and 8,679 were classified as non-Hispanic whites (whites). There were significant differences between non-Hispanic white, non-Hispanic black and Mexicans-American participants who took vitamin D supplements \(p=0.0000\). Considerably more whites took vitamin D than blacks or Mexicans. Of the whites, 38.5% \(n=3,164\) took a vitamin D supplement, 19.4% \(n=1,096\) black participants, and 19.2% \(n=1,207\) of the Mexican-American participants took vitamin D. These same race/ethnicity differences existed within all the males participants \(p=0.0000\) and all the females participants of the sample \(p=0.0000\).

Age was a significant factor in vitamin D supplement intake \(p=0.0000\) (Fig. 5). In the age groups of 2-5 years, 6-12 years, 13-17 years, 18-30 years, 31-50 years, 50-70 years, and 71-85 years took 39% \(n=762\), 27.8% \(n=796\) 16.6% \(n=475\), 25.5% \(n=721\), 35.4% \(n=1,125\), 46.3% \(n=1,036\), and 53.3% \(n=522\) took a vitamin D supplement, respectively. The age group 13-17 years had the smallest percentage of their sample take a vitamin D supplement, 16.6% \(n=475\). The age group 71-85 years had the largest percentage of their sample take a vitamin D supplement, 53.3% \(n=522\). The results illustrated that with advancing age, the percentage of people who took vitamin D supplements increased, which was true in males of all age groups and females of all age groups \(p=0.0000\).

Also, in the age group 18-30 years, significantly fewer males 22.65% \(n=314\) took a vitamin D supplement than females, 28.9% \(n=407\) \(p=0.0024\). In the age group 31-50 years, 31.3% \(n=525\) of males and 39.8% \(n=600\) of females took a vitamin D supplement \(p=0.0000\). In the age group 51-70 years, 38.9% \(n=422\) of males and 52.8% \(n=614\) of females
took a vitamin D supplement \[p= 0.0000\]. In the age group 71-85 years, 43.6% \(n=205\) of males and 59.0% \(n=347\) of females took a vitamin D supplement \[p= 0.0010\].

Figure 5: Gender and Age Differences: Percent (%) of Population Taking Vitamin D Supplement

![Graph showing Influence of Age on Vitamin D Supplement Intake](image)

When comparing age with gender with the vitamin D intake, the results of this study showed that between the ages of 2-17 years old, there were no significant difference between men and women \[p >0.05\]. In the age group 2-5 years, 6-12 years, and 13-17 years, 39.9% \(n=385\) of males and 38.1% \(n=377\) of females \[p=0.5302\], 27.3% \(n=388\) of males and 28.3% \(n= 408\) of females \[p= 0.7003\], 15.9% \(n=243\) of males and 17.35% \(n=232\) of females \[p=0.3515\] took vitamin D supplements, respectfully.

Further, at each income level group, significantly more women took vitamin D supplements than men (Fig. 6). In the income groups “less than $20,000,” “$20,000-34,999,”
“$35,000-64,999,” and “greater than $65,000”: 22.7% (n=1094), 29.5% (n=1012), 35.7% (n=1438), and 41.6% (n=1719) took vitamin D supplements, respectively. In the income group “less than $20,000,” “$20,000-34,999,” “$35,000-64,999,” and “greater than $65,000”: 18% (n=441) of males and 26.7% (n=653) of females [p= 0.0000], 23% (n=438) of males and 35% (n=574) of females [p=0.0000], 30.9% (n=671) of males and 41% (n=767) of females [p= 0.0000], and 39.1% (n=840) of males and 44.4% (n=879) of females [p= 0.0035], took vitamin D supplements, respectively.

Figure 6: Gender and Income Differences: Percent (%) of Population Taking Vitamin D Supplement

As stated in the ‘Subjects and Methods’ chapter, only participants 20 years and older were explored when making comparisons regarding education level and vitamin D intake. Consequently, this alteration changed the total number of participants who were looked at when
comparing education. Within the sample of 9,716 participants who were over the age of 20 years old, of those 3,239 participants took vitamin D. Of these, 31.8% (n=1,383) of males took a vitamin D supplement and 42.58% (n=1,856) of the females took a vitamin D supplement.

Figure 7: Gender and Education Differences: Percent (%) of Population Taking Vitamin D Supplement

Among the five education groups, the results indicated a significantly different number of people who took a vitamin D supplement in each group [p=0.0000]. Within the educational groups: “less than a 9th grade education,” “less than a high school education,” “high school graduate or GED,” “some college education,” and “college graduates,” 21.4% (n=285), 20.7% (n=281), 33% (n=768), 38.9% (n=985), and 50% (n=920) took a vitamin D supplement, respectively. The smallest percent of vitamin D supplement takers, 20.7% (n=281) came from the group with less than a high school education. In contrast, the largest percentage of vitamin D
supplement takers, 50% (n=920) were from the group with a college education. This illustrates that people with more education took more vitamin D supplement.

In the groups with education level of “less than 9th grade,” “less than high school education,” “either graduated from high school or have a GED,” “some college education,” and the group with “college graduates,” significantly more females took vitamin D supplements than males: 15.3% (n=123) of males and 29.3% (n=162) of females [p= 0.0002], 25.6% (n=308) of males and 40.9% (n=460) of females [p=0.0000], 33% (n=398) of males and 44.3% (n=587) of females [p= 0.0000], and 46.8% (n=433) of males and 53.1% (n=487) of females [p=0.0140], respectfully. A significant difference existed between males and females at all education levels, except “less than high school education” where 17.8% (n=121) of males and 23.4% (n=160) of females took vitamin D [p= 0.0734].

Table 2 shows the amount of Vitamin D Supplement Taken by Americans. There was a significant difference in the mean amount of vitamin D supplements taken between men and women [p= 0.0002]. Women took on average 413.2 ± 9.7 IU of vitamin D supplements a day, which is significantly more than what men took, 359.9 ± 10.4 IU a day. There was a significant difference in the mean amount of vitamin D supplement taken in race/ethnicity groups [p=0.0000]. Whites took the most mean amount of vitamin D a day (397.9 ± 7.1 IU), followed by blacks (355.3 ± 13.7 IU), and Mexican-Americans (317.4 ± 9.7 IU). Each age group also took significantly different mean amounts of vitamin D supplements a day when compared to each other. The age group 2-5 years took the least mean amount of vitamin D a day, (307.4 ± 10.5 IU), and the age group 71-85 years took the most mean amount of vitamin D a day, (485.6 ± 16.1 IU). The results indicate the trend in the mean amount of vitamin D taken increased consistently with advancing age. The mean amount of vitamin D taken was not significantly different in
different income earning groups \[p=0.6230\]. Also, the mean amount of vitamin D taken was not significantly different in different education level groups \[p=0.5768\]. The level of significance of vitamin D intake did not change in the income or education groups when adjustments were made for age, gender, and ethnicity.

It was shown that the mean amount of vitamin D taken by the ethnic groups were significantly different for males and for females \[p= 0.0001 \text{ and } p=0.0003, \text{ respectively}\]. When adjusted for age and income, the significant difference disappeared in females \[p= 0.0669\] but not in males \[p= 0.0107\]. White men took significantly less vitamin D \((367.2 \pm 8.35 \text{ IU})\) than white women \((422.3 \pm 8.35 \text{ IU})\) \[p=0.0007\]. Mexican-American men take significantly less vitamin D \((296.4 \pm 13.0 \text{ IU})\) than Mexican-American women \((337.6 \pm 14.2 \text{ IU})\) \[p=0.0375\]. There was not a significant difference between black men \((336.2 \pm 11.4 \text{ IU})\) and black women \((370.5 \pm 20.7 \text{ IU})\) \[p=0.1105\].

There was a significant difference in the mean amount of vitamin D supplement taken among the different age groups for both by males and females \[p<0.05\]. However, men and women did not have significantly different intake amounts between the ages of 2 years to 17 years and 71 years to 85 years old. There was a significant difference found between men and women between the ages of 18 and 71 years old \[p < 0.05\]. Women took significantly more vitamin D \((341.7 \pm 11.8 \text{ IU})\) than men \((302.8 \pm 13.1 \text{ IU})\) in the age group 18-30 years \[p=0.0395\]. The group 18-30 years’ difference was no longer significant after adjusting for ethnicity and income \[p= 0.0949\]. Women took significantly more vitamin D \((412 \pm 17.4 \text{ IU})\) than men \((355 \pm 13.8 \text{ IU})\) in the age group 31-50 years \[p= 0.0366\]. Additionally, women in the age group 51-70 years took significantly more vitamin D \((498.6 \pm 18.8 \text{ IU})\) than men \((446.6 \pm 17.7 \text{ IU})\) \[p= 0.0187\].
The results showed that the mean amount of vitamin D supplement taken by the different income groups were never significantly different for both males and for females [p>0.05], except when males were adjusted for age, ethnicity and education. Men were not significantly different from women in vitamin D supplement intake in the annual income earning groups $35,000-$65,000. However, women took significantly more vitamin D (395.1 ± 17.23 IU) than men (342.3 ± 21 IU) in the income group <$20,000 [p= 0.0310]. As a result of adjusting for age and ethnicity, the income group <$20,000 no longer had a significant difference in the amount of vitamin D taken between men and women [p= 0.2958]. Women took significantly more vitamin D (434 ± 21.8 IU) than men (319 ± 12.1 IU) in the income group $20,000-34,999 [p= 0.0000], and also when adjusted for age, ethnicity, and education [p=0.0000].

It was shown that the mean amount of vitamin D taken by males were significantly different among educational levels [p=0.0075], but educational level did not significantly affect the amount of vitamin D taken by women [p= 0.4098]. The results of education level on vitamin D intake showed significant difference between men and women in the education levels <9th grade, high school graduate or GED, and college graduate [p <0.05]. There was no significant difference in the mean vitamin D intake between men and women in the education levels <11th grade and some college education [p >0.05]. Women took a significantly greater mean amount of vitamin D daily (479.9 ± 42.3 IU) than men (304.5 ± 15.4 IU) in the education level <9th grade [p= 0.0003]. Women took a significantly greater mean amount of vitamin D daily (454.6 ± 21.7 IU) than men (384.6 ± 20.1 IU) if they were high school graduates or had a GED, [p= 0.0412]. Once adjustments were made for age and ethnicity, there was no longer a significant difference in the amount of vitamin D taken between men and women who were high school graduates or
had a GED. Women took a significantly greater amount of vitamin D daily (441 ± 19.9 IU) than men (374 ± 12.1 IU) in the college graduates group [p=0.0038].
Table 2: Amount of Vitamin D Supplement Taken by Americans, in International Units (IU)

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<tr>
<th>Ethnicity</th>
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<td></td>
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<td>Crude</td>
<td>Adjusted</td>
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<td>365.4 ± 7.2</td>
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<td>0.0000</td>
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<td>2-5 years</td>
<td>313.9a ± 10.9</td>
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<td>440.8b ± 16.7</td>
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<td>355.7b ± 20.8</td>
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<td>318.4a ± 11.0</td>
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<td>378.8 ± 9.4</td>
<td>365.9b ± 14.1</td>
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<td>&gt; $65,000</td>
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<tr>
<td>College Grad</td>
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*Only respondents age 20 and older were used for Education.
**The different superscripts in rows show significant differences.
CHAPTER V: DISCUSSION

Vitamin D supplementation has been recommended for some time, especially for the elderly population (2,4-13,15, 20, 21). However, recent research showing deficient or insufficient levels of serum vitamin D among the American population in all ages prompted the recommendation of vitamin D supplements (2, 3-13, 15, 20, 21, 23, 25, 31). In the past 10-15 years, a significant decline in vitamin D status of roughly 5-20 nmol/L was observed between NHANES III (1988-1994) and NHANES 2000-2004 in persons ≥ 12 years old [p=0.0001]. Changes in BMI, milk intake, and sun protection appeared to have contributed to this decline (25). Vitamin D deficiency or insufficiency results from inadequate vitamin D intake from diet, insufficient sun exposure, low metabolism and/or high skin pigmentation (1-13, 25, 31). For most American adults, the primary source of vitamin D is diet (18,32). However, the data from NHANES 1999-2000 showed that the total vitamin D intake from food sources across all ages was only 3.8-6.9 µg or 152-276 IU per day. (3,14) This minimal amount is related to the fact that only a few foods contain vitamin D naturally, which include fortified milk, dairy products and some oily fish, and these foods were not eaten on a regular basis by the American population (3,14). In the United States, 40% - 60% of the food intake of vitamin D was supplied by fortified milk (3). Consequently, society’s decrease in milk consumption (25) has contributed to the decrease in vitamin D status as reported from NHANES III and NHANES 2003-2004 (15, 25).

Overall, this study showed that 33.7% of Americans took vitamin D supplement in the years 2001-2006. Even within this six years time, an upward trend was found in taking vitamin D supplements among Americans. In the three two- year cycles of NHANES, the percentage went up from 31.5% to 34.1% to 35.5% in 2001- 2002, 2003-2004 and 2005-2006 survey, respectively. These increases were not surprising, due to the facts that vitamin D research has
been much spotlighted. There has been a great deal of research and media reports on vitamin D deficiency among the American population, as well as the emerging reports on the possible benefits of vitamin D on many diseases, beyond bone health (25, 33). Serum vitamin D level is a part of routine physical check-ups for Americans recently identifying vitamin D deficiency and subsequent recommending vitamin D supplements. Higher usage of vitamin D supplements should be expected in up-coming years.

Research had found that both males and females have insufficient serum 25(OH)D (25) between 2000-2004, and furthermore, females have considerably lower serum 25(OH)D than males (25). Males serum 25(OH)D had significantly decreased from 1988-1994 to 2000-2004 as reported by NHANES (25). Research has shown that males of all age groups have higher vitamin D intake (food plus supplements) when compared to females (9). This study shows that significantly, more females took vitamin D supplements than males, and females took an amount that was significantly more than males. It was true that more females took vitamin D supplements and larger amounts of vitamin D in all race/ethnicity groups, in most age groups, in most education levels, and all income levels. Women appear to be the target population for media messages about the risks of osteoporosis, this heightened sense of awareness in women may relate to their higher vitamin D supplement intake than men. The message about the need for higher vitamin D intake has reached females, and their response to the knowledge of low serum vitamin D levels is more proactive than the response from males. Therefore, more education about higher vitamin D intake should be aimed at males.

In order to meet the needs of vitamin D recommendations, most population groups rely on diet during the winter, at temperate latitudes, and among people with restricted skin exposure to sunshine (32). A study done in Boston, Massachusetts found that “during the winter the
sunlight is incapable of producing vitamin D₃ in the skin at latitudes at or above 42 degrees north.” Additionally, increased skin pigmentation hinders the cutaneous production of 25-hydroxyvitamin D (31). Ultraviolet absorption is also reduced by melanin, so that short-term irradiation of dark skin produces a slower and smaller rise in plasma D₃ than comparable irradiation of light skin in the winter and summer months (9, 34). Melanin is extremely efficient in absorbing UVB radiation, and, thus increased skin pigmentation markedly reduces vitamin D₃ in skin by 99% (31).

In data found in NHANES 2000-2004, Non-Hispanic whites had the highest adjusted mean serum 25(OH)D concentrations (66.9 ± 0.9 nmol/L), followed by Mexican-Americans (53.9 ± 0.9 nmol/L), and then non-Hispanic blacks (40.1 ± 0.9 nmol/L) \( p=0.0001 \) (25). However, marked decreases in serum 25(OH)D in the race/ethnicity group non-Hispanic white from NHANES data in 1988-1994 to 2000-2004 has been linked to their increased BMI, decreased milk intake, and increased sun protection (25). On the other hand, the prevalence of vitamin D deficiency based on skin pigmentation is greater in darker skinned individuals than lighter skinned individuals. Specifically, NHANES III revealed the average circulating vitamin D, 25(OH)D in darker-skinned, African American women 60 years and older is about 40 nmol/L, compared to light skinned, Caucasian women 60 years and older have about 75 nmol/L (9).

In addition to decreased production of vitamin D₃ in individuals with darker pigmented skin, lactose intolerance primarily in African Americans, Asians and Mexican Americans lowers their dairy intake (30). Consequently, vitamin D ingestion may be reduced as well. Recent studies report low vitamin D intakes among different race and ethnicity groups (7). However, people of all skin tones who take multivitamins have been shown to have higher serum vitamin
D concentrations and those who do not take multivitamins have higher vitamin D insufficiency (31).

Vitamin D supplementation may be necessary to prevent vitamin D insufficiency in Americans with inadequate vitamin D intake from diet, especially those who do not get enough sun exposure or who have increased skin pigmentation (18, 31, 32). Despite recent efforts to increase vitamin D intake through appropriate fortification, dietary guidance and advice on vitamin D supplements would be beneficial for these population groups. Taking more vitamin D through supplements may be a viable option to prevent vitamin D insufficiency, particularly considering the biological and behavioral factors that may have contributed to lower serum 25(OH)D in these populations (25).

This analysis of NHANES data showed that only 19.4% of non-Hispanic blacks and 19.2% of Mexican-Americans took vitamin D supplements, compared to 38.5% of non-Hispanic whites. Black mean vitamin D supplement intake was 362.6 ± 14.5 IU and Mexican-Americans mean intake was 317.4 ± 9.7 IU per day. This NHANES data represented intakes of vitamin D supplements in non-Hispanic blacks and Mexican-American populations as less than necessary for a vitamin D deficient person to raise serum to protective levels in persons with darker skin pigments.

The current study revealed significantly more non-Hispanic whites took vitamin D supplements, and took a significantly larger mean amount of vitamin D supplement than non-Hispanic blacks or Mexican-Americans. This implies that the need for higher vitamin D intake has received a more positive response from non-Hispanic whites, than from the other race/ethnicity groups. Therefore, an approach to reach and educate non-Hispanic blacks and Mexican-Americans to increase their vitamin D intake is necessary.
Insufficient serum 25(OH)D were found in all ages between 2000-2004 (25). The highest serum 25(OH)D level, 75.43 ± 1.58 IU, is found in the youngest age group, 1-5 year olds (25). Serum vitamin D levels decrease with advancing age, the most insufficient serum vitamin D concentration, 57.45 nmol/L ± 0.76, was seen in the elderly aged 70 years and older (25).

Generally, the current study showed as age increased so did the percentage of people who took vitamin D supplements increased as well as the mean amount they were taking. The mere size of children may contribute to their observed lower mean intake of vitamin D supplements, because their needs may appear to some to be smaller as well.

Most healthy adults can meet minimum vitamin D requirements, 200 IU daily, by drinking three 8 ounce glasses of vitamin D-fortified milk a day (18). Therefore, young adults have vitamin D insufficiency mainly due to inadequate consumption of milk in addition to fear of skin cancer from sun exposure (31). The inability to meet daily requirements have been related to a variety of factors, including inadequate diet, non-compliance with dietary supplementation, lack of physician counseling on the importance of meeting Recommended Dietary Allowances (RDAs) (18).

This study showed that the percent of people who took a vitamin D supplement was highest in the elderly age group (71-85 years). On the other hand, the smallest group taking vitamin D supplements was the adolescent age group (13-17 years). The American Academy of Pediatrics has recommended that all infants and children including adolescents have a minimum daily intake of 400 IU of vitamin D a day (4). None of the participants in this study under the age of 18 years old met the new recommendation.
Parental influence contributes to the general intake of children, but parents have less control over the intake of their teens. Compared to children, adolescents have significantly lower serum 25(OH)D levels (4, 25). Research has demonstrated that 73.1% of adolescents have 25(OH)D levels to be considered insufficient (serum vitamin D <80 nmol/L), and up to 17% of adolescents have 25(OH)D levels considered deficient (<30 nmol/L) (4). Furthermore, Hispanics and African American adolescents have lower serum vitamin D than white adolescents (5). The low serum value may be due to current lifestyle choices, including the decline in outdoor activity and sunlight exposure in at these ages. This may be related to the American Academy of Pediatrics and the American Cancer Society recommendation that children and adolescents should have minimal sun exposure, without wearing protective clothing or sunscreen (4). In addition, the recent rise in BMI and obesity has been associated to more vitamin D deficiency in childhood (5). In following those guidelines, it became crucial that this age group get ample vitamin D supplementation (4).

Only 17.4% of females aged 13-17 years took a vitamin D supplement in this NHANES examination. Even less than adolescent females, only 15.9% of males in this age group took a vitamin D supplement. The small percentage of teens who did take a vitamin D supplement, did meet the AI for their age group (200 IU daily) for vitamin D. Nevertheless, the majority of American adolescents are not obtaining adequate vitamin D.

It has been recommended that adolescents who do not obtain 400 IU of vitamin D per day through vitamin D-fortified milk and vitamin D-fortified foods should receive a 400 IU vitamin D supplement daily (4). This study showed that the amount of vitamin D supplement taken on average was not meeting those recommendations, [males- 304.4 ± 20.7 IU, and females- 353.4 ± 31.9 IU].
Not meeting vitamin D intake recommendations in adolescent years is a major problem. Sufficient vitamin D intake is needed for good nutrition and rapid bone growth at these critical developmental ages (16). Vitamin D stimulates of synthesis of variety of proteins involved in modeling, remodeling, and mineralization of bone (35). As well as the vitamin is important in maintaining calcium homeostasis and skeletal metabolism throughout the lifecycle (16). Since this study revealed this age group has the lowest vitamin D supplement intake, educating this group about the need for higher vitamin D intake is critical. Unlike young children whose supplement intake is mainly based on the response of their parents, a greater effort is needed to target teens directly.

Elderly people have the lowest serum vitamin D concentration of all age groups (25). This examination showed that between the years 2000-2006, 53.3% of adults between the age of 71-85 years, averaged 477.6 ± 15.7 IU, per day. This age group had the greatest percentage of people taking vitamin D supplements. That proved elderly acknowledged the message of low vitamin D status and need for higher intake, and beneficial steps were made to correct it. However, the amount of vitamin D supplement taken by elderly was much less than the 600 IU recommend for that age group (≥71 years) (15).

There is a high prevalence of hypovitaminosis D in elderly adults (18). Less than 10% of older adults (51-70 years old) and no more than 2% of the elderly (older than 70 years old) met vitamin D requirements from food sources. The reduction in vitamin D intake paralleled the increased vitamin D requirements associated with aging (7). The elderly represent one population group that typically receives low sun light exposure (20), because of changes in lifestyle factors such as increased clothing and decreased outdoor activity (11). Although vitamin D-containing dietary supplements increased the percentage of populations meeting the AI by
10% to 25%, up to 90% of older individuals still did not consume adequate amounts of vitamin D (7). The best way for elderly to meet their AI, would be to increase their daily vitamin D supplement intake.

Some other organizations recommend even higher level of AI for vitamin D. The Dietary Guidelines by the Institute of Medicine recommend daily intake amount of vitamin D to be at least 200 IU for the age of older than 50 years and, 600 IU for the elderly over the age of 70 years (18, 36). The National Osteoporosis Foundation recommends that adults under 50 years old get 400-800 IU of vitamin D₃ daily, and that adults 50 and over get 800-1,000 IU of vitamin D₃ daily (28). Therefore, based on NHANES data, the adults under the age of 50 were meeting vitamin D recommendation of the Dietary Guidelines and National Osteoporosis Foundation, but adults over the age of 50 were falling short.

More Americans with higher education took a vitamin D supplement. Only 21.4% of people with less than a ninth grade education took a vitamin D supplement, but up to 50% of people who have graduated from college have taken a vitamin D supplement. Similarly, the mean amount of vitamin D taken increases with higher education completion. The results of this study showed that like education, with higher household income, more people take vitamin D supplements and take larger amounts. Therefore, it is more important to reach out and educate those of lower education, about the need to consume more vitamin D, than those of higher education. In addition, more education needs to be aimed at people of lower income levels about the need for higher vitamin D intake.

An important relationship exists between vitamin D supplement intake and serum 25-hydroxyvitamin D levels. An oral intake of 55 ug/day (2200 IU) of vitamin D has been shown to successfully raise 25(OH)D to necessary levels to be preventive against disease. For a vitamin D
deficient person, supplementing 150 IU of vitamin D will increase the 25(OH)D levels by
approximately 1 ng/mL. Some clinical recommendations for vitamin D deficient individuals are
1,000 IU daily, if their serum 25(OH)D is 25-32 ng/mL, 2,000 IU daily with a 15-25 ng/mL
serum 25(OH)D, and 3,000 IU daily for serum 25(OH)D below 15 ng/mL (26). One study
suggested that a baseline 25(OH)D concentration above 50 nmol/L (20 ng/mL), only 800 IU
vitamin D or more per day for 5 months was effective in raising the serum 25(OH)D level (30).
A randomized control trial on vitamin D in 65-85 years olds supplemented with 800 IU of
vitamin D a day increased serum 25(OH)D from 50 nmol/L to 80 nmol/L, and reduced fracture
risk by 33% (27, 36).

The major vitamin D supplement types are ergocalciferol (vitamin D$_2$) and
cholecalciferol (vitamin D$_3$). Research has claimed that the vitamin D$_3$ form raised vitamin D
levels in the serum higher than vitamin D$_2$ supplements (10-12). This study did not distinguish
between the vitamin D$_2$ consumption or vitamin D$_3$ consumption, either type were considered
equally as taking the supplement. Therefore, the physical 25(OH)D levels resulting from
supplementation at similar intake levels in like populations could vary greatly depending on the
type of vitamin D taken.

The Tolerable Upper Intake Level (UL) established by the Food and Nutrition Board for
vitamin D is 50 µg or 2000 IU (33). Serum 25(OH)D concentration is considered as the most
appropriate indicator of vitamin D status (32, 33, 37). Toxicity of vitamin D is show with serum
25(OH)D concentration ≥ 700 nmol/L, which may induce hypercalcemia in normal adults. Daily
doses of vitamin D at levels ≥ 250 µg increased serum 25(OH)D ≥ 700 nmol/L. Reviews of
clinical trials of vitamin D risk assessment found that there is little prospect of exposure of the
healthy population to toxic levels of vitamin D (≥250 µg/day) with current or likely levels of
fortified food and dietary supplements. The elevated serum calcium levels of hypercalcemia are the adverse effect of oral doses of vitamin D $\geq 95\mu g$ per day (33).

Conclusion

Supplements may be important for the nutrition of Americans people to supply sufficient vitamin D to meet physiological needs and health outcomes. This examination illustrated that a higher percent of vitamin D takers were females, non-Hispanic whites, the elderly, college graduates, and household incomes greater than $65,000$. The lowest percent of vitamin D takers were males, Mexican-Americans, adolescents, people with less than a high school education, and those with household incomes less than $20,000$. The groups that took the most mean vitamin D supplements (IU) were females, non-Hispanic whites, the elderly, high school graduates, and household incomes greater than $65,000$. The groups who took the least mean amount of vitamin D supplements were males, Mexican-Americans, ages 2-5 years, less than high school education, and household incomes less than $20,000$.

The results of this examination showed that some groups are more likely to take vitamin D supplements such as women, the elderly, people of higher education and higher income, and non-Hispanic whites. Yet, there are groups that remain with low vitamin D intake, particularly from supplements. The groups that are more likely to have low vitamin D supplement intake are males, non-Hispanic blacks and Mexican-Americans, adolescents, people with lower incomes and lower education. It is vital that those specific groups of Americans receive relevant and relatable education about their need to increase vitamin D intake, and why vitamin D supplements are an acceptable route for improvement.
REFERENCES


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\[ X = B, C \text{ or } D, \] files which are the various NHANES cycles. 'B' files are from the cycle 2001-2002, 'C' files are from the cycle 2003-2004, and 'D' files are from the cycle 2005-2006.