ESTIMATION OF VITAMIN D AND CALCIUM INTAKES IN THE UNITED STATES AND ASSOCIATIONS WITH CARDIOVASCULAR RISK FACTORS AND ADIPOSITY MEASURES BY AGE, SEX, PARENTAL POVERTY INCOME RATIO, AND RACE/ETHNICITY IN CHILDREN AND ADOLESCENTS 6-18 YEARS

A DISSERTATION

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DEDICATION

I would like to dedicate this dissertation to my family and friends who have supported me through my time as a "Professional Student." To my parents, Janice and Floyd Reeves, and Billy and Doris Parsons. Thank you for raising me to have faith in God, the infinite words of encouragement, and the drive to be successful in everything I do. To my brother, Bryan Parsons, thank you for being by your little sister's side throughout this process. To my husband and daughter, Jeromy and Samara Simmons, thank you also for the encouragement and love you both have given me.

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ABSTRACT

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ESTIMATION OF VITAMIN D AND CALCIUM INTAKE IN THE UNITED STATES AND ASSOCIATIONS WITH CARDIOVASCULAR RISK FACTORS AND ADIPOSITY MEASURES BY AGE, SEX, PARENTAL POVERTY INCOME RATIO, AND ETHNICITY IN CHILDREN AND ADOLESCENTS 6-18 YEARS

Estimates of vitamin D and calcium intake in the United States (US) were stratified by age, sex, parental poverty income ratio (PIR), and race/ethnicity in children (6 – 12 years) and adolescents (13 – 18 years) using the 2007-2008 National Health and Nutrition Examination Survey (NHANES) data set (STUDY I). Self-reported vitamin D and calcium intakes via dietary and supplemental sources were assessed by a 24-hour recalls. Information on 2347 participants, aged 6 – 18 years, including complete demographic and an in-person 24-hour recall, were obtained from the 2007-2008 NHANES data set. To evaluate differences in vitamin D and calcium intakes originating from diet and/or supplements, and by PIR, sex, and race/ethnicity categories, least-square means and standard errors were compared by univariate analysis of variance. Less than 10% of participants reported consuming a supplement that included either vitamin D or calcium. Non-Hispanic (NH) Blacks had significantly lower total vitamin D (4.22 $\pm$ 0.19 μg/d) and total calcium (754.5 $\pm$ 21.2 mg/d) intakes than Mexican Americans, Other Hispanics, and Non-Hispanic Whites (NH).

Female participants had significantly lower total vitamin D (4.84 ± 0.2 μg/d) and total calcium (801.7 ± 16.1 mg/d) intake than males. Total vitamin D intake was lower in the 13 – 18 years age group (4.96 ± 0.2 μg/d) than in the 6 – 12 years age group (5.55 ± 0.15 μg/d). Total calcium intake was lower in the 6 – 12 years age group (840.9 ± 15.4 mg/d) than in the 13- 18 years age group (914.8 + 23.9 mg/d). A subgroup analysis (n=1085; 12-18y) examined vitamin D and calcium intake associations with cardiovascular risk factors and adiposity by age, sex, parental PIR, and ethnicity (STUDY II). Male participants had significantly lower concentrations of total cholesterol (154.3 mg/dL), high-density lipoprotein cholesterol (HDL-C) (49.1 mg/dL), insulin (14.3uU/mL), C-reactive protein (CRP) (0.2 mg/dL), and diastolic blood pressure (59.0 mmHg). Systolic blood pressure was significantly lower in females (107.5 mmHg). Triglycerides (66.2 mg/dL) were significantly lower and HDL-C (55.1 mg/dL) was significantly higher in the NH Blacks. Diastolic blood pressure was significantly higher in NH Whites (61.4 mmHg) and NH Blacks (61.2 mmHg). Controlling for sex, race/ethnicity, and PIR (Model 3), linear regression analysis indicated a significant inverse association between vitamin D and calcium with triglycerides ($p = 0.05$) and hemoglobin A1c (HgbA1c) ($p = 0.01$). Controlling for sex and race/ethnicity (Model 2), linear regression analysis indicated a significant ($p = 0.02$) inverse association between vitamin D and calcium with waist circumference, triceps skinfold, and subscapular skinfold.

Parents and nutrition professionals should encourage children and adolescents to consume an overall healthy diet including foods high in vitamin D and calcium, and to potentially help reduce adiposity, blood triglycerides, and hemoglobin A1c levels. Furthermore, food manufacturers should increase the number of fortified foods available to aid in reducing vitamin D and calcium deficiencies.

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ABBREVIATIONS

$1,25(OH)_2D$	1,25- Dihydroxyvitamin D or Calcitriol
25(OH)D	25-hydroxyvitamin D
AF	Atrial Fibrillation
AI	Adequate Intake
ALSPC	Avon Longitudinal Study of Parents and Children
ANOVA	Univariate Analysis of Variance
Apo-A1	Apolipoprotein A1
Apo-B	Apolipoprotein B
BA	Buenos Aires
BMI	Body Mass Index
CAD	Coronary Artery Disease
CRP	C-Reactive Protein
CVD	Cardiovascular Disease
CYP2R1	Cytochrome P450, Family 2, Subfamily R, Polypeptide 1
DBP	Vitamin D Binding Protein
DHCR7	7-Dehydrocholesterol Reductase
DRI	Dietary Reference Intakes
EAR	Estimated Average Requirement
FDA	Food and Drug Administration
FFQ	Food Frequency Questionnaire
FGF-23	Fibroblast-Like Growth Factor 23
FMD	Flow-Mediated Dilation
FNDDS	Food and Nutrient Database for Dietary Studies
HDL-C	High-Density Lipoprotein Cholesterol
HgbA1c	Hemoglobin A1c
HOMA-IR	Homeostatic Model Assessment - Insulin Resistance Index
HPFS	Health Professionals' Follow-Up Study
IL-2	Interleukin - 2
IOM-FNB	Institute of Medicine Food and Nutrition Board

ABBREVIATIONS

IR	Insulin Resistance
IU	International Units
LDL-C	Low-Density Lipoprotein Cholesterol
Lp-PLA_2	Lipoprotein-Associated Phospholipase A_2
MetS	Metabolic Syndrome
MI	Myocardial Infarction
NCHS	National Center for Health Statistics
NH	Non-Hispanic
NHANES	National Health and Nutrition Examination Survey
NHS	Nurses' Health Study
PAD	Peripheral Artery Disease
PICU	Pediatric Intensive Care Unit
PIR	Poverty Income Ratio
PTH	Parathyroid Hormone
RAS	Renin-Angiotensin System
RDA	Recommended Dietary Allowance
RPP	(Heart) Rate-Systolic Pressure Product
SAC	San Antonio de los Cobres
SES	Socioeconomic Status
TNF-α	Tumor Necrosis Factor - Alpha
UL	Tolerable Upper Intake Level
U.S.	United States
UVB	Ultraviolet B
VDR	Vitamin D Receptor

CHAPTER I

INTRODUCTION

Vitamin D is essential in bone physiology and increases intestinal calcium and phosphorus absorption. Recently, evidence has emerged linking vitamin D deficiency and risk factors for cardiovascular disease.

The two major isoforms of vitamin D are vitamin D_3 and D_2. Vitamin D_3, is derived from photoactivated 7-dehydrocholesterol in the epidermis of the skin, and can be found naturally in fatty fish (salmon and fish liver oil) as well as egg yolk (Holick et al., 2008). Vitamin D_2 is found naturally in foods of plant origin and can be consumed as a supplement or in fortified foods (Lee, O'Keefe, Bell, Hensrud, & Holick, 2008). The major circulating form of vitamin D is 25-hydroxyvitamin D, [25(OH)D], a vitamin D metabolite used to assess vitamin D status (Holick et al., 2008). In 2010, the Institute of Medicine established Dietary Reference Intakes (DRIs) for vitamin D. For healthy children and adolescents 6 through 18 years of age, an Estimated Average Requirement (EAR) of 10 µg [400 International Units (IU)] (used to assess populations) and a Recommended Dietary Allowance (RDA) of 15 µg (600 IU) (used to assess individuals) were set to sufficiently maintain an average serum 25(OH) concentration of 16-20 ng/mL (40-50 nmol/L) ensuring normal, healthy bone growth (Food and Nutrition Board,

Institute of Medicine, 2010). There is lack of consensus regarding the optimal serum 25(OH)D concentration to minimize the negative metabolic effect associated with a vitamin D deficiency. Lee et al. (2008) defined vitamin D deficiency as a serum 25(OH)D concentration of $\leq$ 20 ng/mL (50 nmol/L), and vitamin D insufficiency as 21-29 ng/mL (52-72 nmol/L), with sufficiency being $\geq$ 30 ng/mL (75 nmol/L). Rippel et al. (2012) examined the relationship between hypovitaminosis D, which they defined as a serum 25(OH)D_3 concentrations of < 20 ng/mL (< 50 nmol/L), and outcomes in critically ill children admitted to a mixed cardiac and general tertiary pediatric intensive care unit. Hypovitaminosis was more prevalent in postoperative cardiac pediatric patients than in general medical Intensive Care Unit (ICU) patients. In another study, Garanty-Bogacka et al. (2011) studied vitamin D status in children with serum 25(OH)D_3 concentration classified as severe deficiency $\leq$ 10 ng/mL, insufficiency > 10 to < 20 ng/mL, and sufficiency 20-30 ng/mL, and the association with insulin resistance in obese adolescents, aged 10-18 years. Serum 25(OH)D concentration was negatively associated with age, gender, pubertal status, weight status, and insulin resistance index, and positively associated with high-density lipoprotein cholesterol (HDL-C). Williams et al. (2012) analyzed the relationship between 25(OH)D_2 and 25(OH)D_3 and cardiovascular disease (CVD) risk factors in childhood, and found a positive association between serum 25(OH)D_2 and C-reactive protein and interleukin-6, but an inverse relationship between serum 25(OH)D_2 and triglycerides and apolipoprotein-A1 (Apo-A1).

Furthermore, a positive association was found between increased serum 25(OH)D_3 concentrations and increased levels of HDL-C, Apo-A1, and adiponectin.

Adequate dietary calcium decreases the risk of developing hypertension, the metabolic syndrome and diabetes, and is associated with better lipid levels and glucose/insulin homeostasis (Lutsey & Michos, 2013). Calcium and vitamin D supplementation are linked to decreased abdominal visceral adipose tissue in adults (Rosenblum et al., 2012). Higher visceral adipose tissue volume is associated with the development of cardiovascular risk factors over time (Abraham, Pedley, Massaro, Hoffmann, & Fox, 2015).

It is estimated that 50% or more of the world's population has inadequate vitamin D levels, reflected by low serum 25(OH)D levels (Lutsey & Michos, 2013). With the recently established DRIs for intake levels of vitamin D and calcium, more research is needed to validate the recommended values for each age group, especially for children ($\leq$ 18 years) by comparing these recommended values to total vitamin D intake in a population.

Statement of the Problem

The purpose of this dissertation was to examine reported vitamin D and calcium intakes in children (6 -12 years) and adolescents (13 – 18 years) in the United States (US), and associations with cardiovascular disease (CVD) risk factors and adiposity measures by age, sex, parental poverty income ratio, and ethnicity in children and adolescents (12 – 18 years). Data on CVD risk factors were collected for participants 12 years and older in the 2007-2008 NHANES. As of December 2015, serum 25(OH)D

levels had not been released from the Centers of Disease Control and Prevention for this NHANES cycle. Therefore, vitamin D intake was used as a surrogate for 25(OH)D concentrations. Total dietary vitamin D intake has been shown to be positively associated with serum 25(OH)D levels.

Null Hypotheses

1. Dietary, supplemental, and total intakes of vitamin D will not differ by sex, parental poverty income ratio (PIR), and ethnicity in children (6 -12 years) and adolescents (13 – 18 years) (STUDY I).
2. Dietary, supplemental, and total intake of calcium will not differ by gender, PIR, and ethnicity in children (6 -12 years) and adolescents (13 – 18 years) (STUDY I).
3. US children (6 -12 years) and adolescents (13 – 18 years) do not meet the DRIs for vitamin D through diet and/or supplementation (STUDY I).
4. US children (6 -12 years) and adolescents (13 – 18 years) do not meet the DRIs for calcium through diet and/or supplementation (STUDY I).
5. Vitamin D intake is not inversely associated with known biomarkers of CVD in children and adolescents (12 - 18 years of age) (STUDY II).
6. Calcium intake is not inversely associated with known biomarkers of CVD in children and adolescents (12 -18 years of age) (STUDY II).

7. Vitamin D intake is not inversely associated with known measures of adiposity in children and adolescents (12 - 18 years of age) (STUDY II).
8. Calcium intake is not inversely associated with known measures of adiposity in children and adolescents (12 -18 years of age) (STUDY II).

CHAPTER II

REVIEW OF LITERATURE

Vitamin D, also referred to as "the sunshine vitamin", was discovered in the early twentieth century (1919-1924) as a dietary component found in cod liver oil that helped to cure the childhood bone disease known as rickets (Kidd, 2010).

Vitamins are components, essential to life, that are obtained strictly from the diet. Although essential to life, vitamin D is not considered a vitamin; it is defined as a prohormone because, in addition to being obtained in the diet, it can also be produced in the body through photoactivated synthesis in the skin from 7-dehydrocholesterol (Norman, 2008).

Forms and Sources of Vitamin D

The two major forms of vitamin D are vitamin D_3 (cholecalciferol) and vitamin D_2 (ergocalciferol). Most of the vitamin D in the body comes from photoactivated synthesis of 7-dehydrocholesterol in the epidermis of the skin. As 7-dehydrocholesterol is irradiated by ultraviolet B (UVB) rays, it is energized and structurally transformed, forming vitamin D_3 (Kidd, 2010). Not only is vitamin D_3 produced in the skin, it is also found naturally in fatty fish (salmon), fish liver oil, and egg yolk. Conversely,

vitamin D_2 is found in foods of plant origin and can be consumed as a supplement or in fortified foods (Lee et al., 2008). When the two forms are activated, they have been shown to have identical effects in the body. The only structural difference between the two forms is in their side chains, which some researchers believe does not affect metabolism (Food and Nutrition Board, Institute of Medicine, 2010).

In 2011, Van Horn and colleagues conducted the 10-year longitudinal National Heart, Lung, and Blood Institute Growth and Health Study examining food sources of vitamin D in 2379 white and African American girls aged 9-18 years. Participants were to keep a record of all food and drinks consumed for 3 consecutive days (2 weekdays and 1 weekend day) for visits 1 to 5, 7, 8, and 10. Food records were coded and analyzed for nutrients. Results indicated the majority of vitamin D intake was via milk and dairy products and fortified foods, especially through breakfast consumption, and in meat and bean products. Overall vitamin D intake was lower in African American girls than in the Caucasian girls [difference of 39.2 IU (0.98 µg)] per day at visit 3 but [26.8 IU (0.67 µg)/day at visit 10]. Consumption of milk and dairy products decreased with age, and consumption of soft drinks, fruit juices, and/or fruit drinks increased with age.

Activation of Vitamin D

As mentioned previously, the activation results in the conversion of 7-dehydrocholesterol in the skin on exposure of UVB spectrum from sunlight to a precursor of vitamin D_3 known as previtamin D_3. Seven-dehydrocholesterol reductase (DHCR7) (a key enzyme in the vitamin D pathway) converts 7-dehydrocholesterol to previtamin D_3, and then to vitamin D_3 through a heat-dependent process (Vimaleswaran et al., 2013).

Once vitamin D enters circulation, either as vitamin D_3 or D_2, two enzymatic hydroxylations are required for full activation. The first hydroxylation occurs in the liver, where vitamin D is converted to 25(OH)D by the action of CYP2R1, or vitamin D-25-hydroxylase (Kidd, 2010); (Vimaleswaran et al., 2013). In order for 25(OH)D to circulate, it must be bound to the specific plasma carrier protein, vitamin D binding protein (DBP) (Food and Nutrition Board, Institute of Medicine, 2010). The newly converted 25(OH)D molecule, bound to DBP, enters circulation where it is transported to the kidney and undergoes a second hydroxylation. The $25(OH)D_2$ and $25(OH)D_3$ molecules are hydroxylated to form $1,25(OH)_2D$, or calcitriol, through the action of CYP27B1, or 25-hydroxyvitamin D-α-hydroxylase (Vimaleswaran et al., 2013). Calcitriol ($1,25(OH)_2D$) is the biologically active form of vitamin D (Kidd, 2010). In addition to the expression in the proximal tubule of the kidney, the 1α-hydroxylase gene has been shown to be expressed in cells of at least ten extra-renal tissues. These tissues or cells include the colon, dendritic cells, endothelial cells, human brain, mammary, pancreatic islets, parathyroid glands, placenta, prostate, and keratinocytes. Although the kidney is the primary site for the production of $1,25(OH)_2D$, cells that express the 1α-hydroxylase gene can produce $1,25(OH)_2D$. However, the production of $1,25(OH)_2D$ by these extra-renal tissues does not increase the overall plasma concentration significantly (Norman, 2008). Once activated, $1,25(OH)_2D$ is bound to DBP and transported to vitamin D-receptor (VDR) target tissues for action (Food and Nutrition Board, Institute of Medicine, 2010) and enters the nuclei of the cells in these target tissues to regulate gene transcription and protein synthesis (Pourdjabbar, Swivedi, & Haddad, 2013). Some of

these target tissues include bone, intestine and parathyroid gland (Reichrath, Lehmann, Carlberg, Varani, & Zouboulis, 2007).

The major circulating form of vitamin D is 25(OH)D, used to assess vitamin D status, has a half-life of two to three weeks, and is a summation of all vitamin D, whether produced in the skin from sun exposure or obtained from dietary sources. Although $1,25(OH)_2D$ is the biologically active form of vitamin D, it is not used to assess nutritional status due to half-life of four-six hours, with circulating levels about a 1000 times less than that of 25(OH)D (Holick, 2009).

The hepatic hydroxylation of vitamin D is loosely regulated, whereas the renal hydroxylation is strongly regulated by two counter-acting hormones: parathyroid hormone (PTH) and fibroblast-like growth factor 23 (FGF23) (Food and Nutrition Board, Institute of Medicine, 2010). In vitamin D deficiency, the intestinal absorption of calcium is diminished, decreasing transient ionized calcium. This decrease triggers the calcium sensor in the parathyroid glands to increase the production and secretion of PTH. PTH's roles are to regulate calcium homeostasis by increasing calcium reabsorption in the kidney, increasing calcium mobilization from the skeleton to the blood stream, and increasing renal hydroxylation of 25(OH)D to form $1,25(OH)_2D$ (Holick, 2009). Serum vitamin D and calcium levels regulate PTH, and when there are insufficient levels of both, PTH is increased (Skaaby et al., 2013). If there is an adequate supply of circulating serum $1,25(OH)_2D$, FGF23 down-regulates the production of $1,25(OH)_2D$ and sends excess circulating 25(OH)D to adipose tissues for storage (Food and Nutrition Board, Institute of Medicine, 2010).

Vitamin D_2 vs. Vitamin D_3

As previously stated, the only structural difference between vitamin D_2 and D_3 is in the side chains which does not affect activation and metabolism. Previous studies have been conducted to determine if there is a difference in efficacy and findings have been inconsistent. Discrepancies may result from the varying doses and duration. Some studies indicate that the two forms are equally effective. For example, in 2008, Holick and colleagues conducted a study to determine if vitamin D_2 was just as effective as vitamin D_3 in maintaining circulating concentrations of 25(OH)D during the winter and early spring months. The study participants were randomly assigned to receive one of the four treatments: (I) placebo, (II) 1000 IU vitamin D_3, (III) 1000 IU vitamin D_2, and (IV) 500 IU vitamin D_2 plus 500 IU vitamin D_3. Subjects who received 1000 IU vitamin D_3, 1000 IU vitamin D_2, and 500 IU vitamin D_2 plus 500 IU vitamin D_3 gradually increased their 25(OH)D blood concentrations. However, none increased blood concentration levels of 25(OH)D above 30 ng/mL, a desirable vitamin D level. This finding suggests more than 1000 IU vitamin D_2 or D_3 is needed to maintain 25(OH)D concentrations at or above the vitamin D-sufficient range when the sun exposure is limited during the winter and early spring months.

Another study demonstrated vitamin D_2 is 33% less effective than D_3 in maintaining serum 25(OH)D concentrations (Armas, Hollis, & Heaney, 2004). Armas and colleagues conducted a randomized, controlled trial to determine the potency of the two calciferols. Participants were randomly assigned to receive one of the three treatments: (I) no supplement (the seasonal effect, control group), (II) one tablet

containing 50,000 IU (1.25 mg) vitamin D_2, and (III) 10 tablets containing 5,000 IU (125 µg)/tablet) vitamin D_3. The researchers found that 50,000 IU vitamin D_3 increases and maintains 25(OH)D levels substantially better (three times greater) than 50,000 IU vitamin D_2. For the first 3 days of the study, the serum 25(OH)D in each of the treatment groups increased similarly, which illustrated that both forms were absorbed comparably. After day 3, there was a greater, more rapid decline in serum 25(OH)D in the vitamin D_2 treated-group than in the vitamin D_3-treated group. This decline may have been due to the more rapid metabolism or clearance of the 25(OH)D_2 metabolite.

Vitamin D_3 was commercially produced in the 1950s as a supplement and has not been approved by the Food and Drug Administration (FDA) for use as a pharmaceutical agent in doses of 50,000 IU. However, a single dose of 50,000 IU vitamin D_2 has been approved because its use predated the FDA and was grandfathered in as a pharmaceutical drug (Holick et al., 2008).

The transport method of orally ingested vitamin D_2 requires constituents of lipid absorption, such as chylomicron carriers. Once absorbed, vitamin D_2 reaches the subclavian vein, where it is either sent to the liver via a chylomicron carrier or dispersed to other plasma carriers such as DBP, lipoproteins, and albumin (Haddad, Matsuoka, Hollis, Hu, & Wortsman, 1993). However, few studies have evaluated the transport of cutaneous-synthesized vitamin D_3. In 1993, Haddad and colleagues evaluated the difference in transport of orally ingested vitamin D_2 and the cutaneous synthesis of vitamin D_3 in ten healthy adults. Seven participants received whole body irradiation with a 27 mJ/cm^2 dose of UVB light, and the other three participants received and ingested

1.25 mg (50,000 IU) of vitamin D_2. After whole body irradiation, plasma vitamin D_3 increased by ten hours, peaked at 24 hours, and decreased by day three and day seven. Plasma vitamin D_2 peaked at four hours and began to decrease slightly by eight and 24 hours. Plasma vitamin D_2 declined rapidly to baseline levels by day two. Vitamin D_3 travels exclusively bound to DBP in plasma, which results in a slower vitamin D delivery to the liver and a more sustainable increase in plasma 25(OH)D concentrations. The relationship between vitamin D_2 and components of lipid absorption allows for a more, rapid vitamin D delivery to the liver and less-stable 25(OH)D concentrations in the blood.

Functions of Vitamin D

The primary function of vitamin D is to elevate and stabilize normal calcium and phosphorus levels in the blood. Plasma calcium levels are elevated by $1,25(OH)_2D$ by three actions. The first action is stimulating calcium and phosphorus absorption throughout the intestine, especially in the duodenal and jejunal regions (Food and Nutrition Board, Institute of Medicine, 2010; Jones, Strugnell, & DeLuca, 1998). Vitamin D is the only substrate that stimulates the enterocytes of the small intestine to mobilize calcium and phosphorus from the lumen to the plasma compartment (DeLuca, 1988). The second action of vitamin D, moving calcium from bone into the blood stream, requires PTH. Osteoclastic bone resorption is stimulated by $1,25(OH)_2D$ via a signal created through the interaction of PTH and vitamin D hormone with the osteoblast (Jones et al., 1998). In 2005, Abrams and colleagues evaluated the association among vitamin D, PTH, and calcium absorption in adolescent boys and girls. Participants were randomly assigned to receive either inulin-type fructans (prebiotics) or a maltodextrin control each day for

one year. Participants kept a food record of all food and beverages consumed for 2 days. During rapid pubertal growth and bone formation, decreased serum levels of 25(OH)D was associated with increased serum levels of PTH and $1,25(OH)_2D$ to meet calcium needs. The third action of vitamin D is to ensure the retention of calcium when needed by the stimulation of the renal distal tubule of the kidney with the help of PTH (Food and Nutrition Board, Institute of Medicine, 2010). Suppression of parathyroid secretions occurs through the action of $1,25(OH)_2D$, and the action of 25(OH)D suppresses secondary hyperparathyroidism in renal failure patients on dialysis (Jones et al., 1998).

Vitamin D regulates over 100 genes in the body and up to as much as 5% of the human genome (Food and Nutrition Board, Institute of Medicine, 2010). For example, osteocalcin and PTH, which are involved in the efficacy of calcium in the body and in bone formation, are regulated by vitamin D. Also, vitamin D receptor (VDR), a nuclear receptor for vitamin D, was found in the keratinocytes of the skin, T-lymphocytes, B-lymphocytes, monocytes, macrophages, and many other target organ cells. In addition, $1,25(OH)_2D$ is involved in the differentiation of keratinocytes of the skin and has been used in the treatment of psoriasis. Furthermore, $1,25(OH)_2D$ suppresses the production of cytokines, such as interleukin-2 (IL-2), tumor necrosis factor-α (TNF-α), and interferon-γ in T-lymphocytes (Jones et al., 1998). Through the conversion of 25(OH)D to $1,25(OH)_2D$, vitamin D may increase cellular immunity through the production of an anti-microbial peptide known as cathelicidin, which is capable of killing certain types of bacteria (Food and Nutrition Board, Institute of Medicine, 2010). Cathelicidin, regulated by vitamin D metabolites, is an endogenous antimicrobial peptide that protects against

Mycobacterium tuberculosis. In vitamin D insufficiency, there is an increased susceptibility to tuberculosis (Yamshchikov et al., 2010). One, twenty-five hydroxyvitamin D plays a role in B-lymphocyte proliferation and immunoglobulin production by inhibiting B-lymphocyte differentiation to plasma cells and class-switched memory B-cells. This inhibition leads to the proposed role of vitamin D in B-lymphocyte related disorders, such as systemic lupus erythematosus (Adams & Hewison, 2008). In addition, many VDR sites are found in a majority of cancer cell lines. Vitamin D can suppress the growth and differentiation in benign cancer cell lines (DeLuca, 1988).

Recommended Intake

Dietary reference intakes (DRIs) are nutrient reference values that are specified for normal, healthy persons. The four DRI components are: Estimated Average Requirement (EAR), the estimated average daily requirement of a nutrient; Recommended Dietary Allowance (RDA), based on the EAR and set to meet or exceed the nutrient requirement for 97.5% of each life stage group; Adequate Intake (AI), set if evidence is not sufficient enough for the EAR to be established, and an average intake based on observational studies; and Tolerable Upper Intake Level (UL), the estimated highest possible level of intake for an individual in the general population that does not pose a threat to the development of adverse effects due to toxicity. DRIs for vitamin D adequacy were established for each of the following life stage groups: infants 0 to 6 months, infants 6 to 12 months, children 1 through 3 years, children 4 through 8 years, children 9 through 13 years, adolescents 14 through 18 years, adults 19 through 30 years,

adults 31 through 50 years, adults 51 to 70 years, and adults 70 years of age and older (Food and Nutrition Board, Institute of Medicine, 2010).

For infants 1 to 12 months, an AI of 400 IU is adequate to maintain serum 25(OH)D concentrations between 30 nmol/L and 50 nmol/L to support normal, healthy bone growth. For children and adolescents 1 through 18 years, the reference values of 400 IU (EAR) and 600 IU (RDA) were set to sufficiently maintain an average serum 25(OH)D concentration of 40 nmol/L to ensure normal, healthy bone growth. For adults aged 19 through 50 years of age, an EAR of 400 IU and RDA of 600 IU vitamin D/day was established to maintain healthy bones. The established DRIs (EAR of 400 IU and RDA of 600 IU) for adults 51 to 70 years help to maintain bone mass and decrease the degree of bone loss. For older adults 71 years and older, the higher DRIs are not only recommended to reduce the incidence of fractures but to decrease the incidence of mortality and morbidity correlated with those fractures (Food and Nutrition Board, Institute of Medicine, 2010) (Table 1).

Table 1

Vitamin D Dietary Reference Intakes for Adequacy

Life Stage Group	AI/day	EAR/day	RDA/day
Infants: 0 to 6 months	400 IU (10 μg)	-	-
Infants: 6 to 12 months	400 IU (10 μg)	-	-
Children 1 through 3 years	-	400 IU (10 μg)	600 IU (15 μg)
Children 4 through 8 years	-	400 IU (10 μg)	600 IU (15 μg)
Children 9 through 13 years	-	400 IU (10 μg)	600 IU (15 μg)
Adolescents 14 through 18 years	-	400 IU (10 μg)	600 IU (15 μg)
Adults 19 through 30 years	-	400 IU (10 μg)	600 IU (15 μg)
Adults 31 through 50 years	-	400 IU (10 μg)	600 IU (15 μg)
Adults 51 to 70 years	-	400 IU (10 μg)	600 IU (15 μg)
Adults 70 years and older	-	400 IU (10 μg)	800 IU (20 μg)

Source: Food and Nutrition Board, Institute of Medicine (2010)

Table 2

Tolerable Upper Level Intakes for Vitamin D

Life Stage Group	**UL/day**
Infants: 0-6 months	1000 IU (25 µg)
Infants: 6-12 months	1500 IU (37.5 µg)
Children: 1-3 years	2500 IU (62.5 µg)
Children: 4-8 years	3000 IU (75 µg)
Children: 9-13 years	4000 IU (100 µg)
Adolescents: 14-18 years	4000 IU (100 µg)
Adults: 19-30 years	4000 IU (100 µg)
Adults: 31-50 years	4000 IU (100 µg)
Adults: 51-70 years	4000 IU (100 µg)
Adults: 70 years and older	4000 IU (100 µg)

Source: Food and Nutrition Board, Institute of Medicine (2010)

Vitamin D Toxicity

Oral intake of vitamin D above the UL (Table 2) can lead to severe, adverse effects, such as the development of vitamin D intoxication or hypervitaminosis D (Food and Nutrition Board, Institute of Medicine, 2010). Vitamin D intoxication is defined as serum 25(OH)D concentrations greater than 150 ng/mL (Holick, 2009), and hypervitaminosis D has been defined as serum 25(OH)D concentrations ranging from 700 to 1600 nmol/L (Aloia et al., 2008). These conditions can result in hypercalcemia, hypercalciuria, hyperphosphatemia, and in more severe instances, calcification of soft tissue, which can lead to renal and cardiovascular necrosis (Food and Nutrition Board, Institute of Medicine, 2010).

Excessive sun exposure does not lead to vitamin D toxicity. Cutaneous activation of previtamin D_3 from UVB rays can lead to the production of non-vitamin D forms, such as lumisterol and tachysterol, which limits the formation of vitamin D_3. Vitamin D_3 can also be converted to nonactive forms and stored (Food and Nutrition Board, Institute of Medicine, 2010). However, excess sun exposure can lead to other adverse effects, such as DNA-damage, sunburn, immune suppression, premature aging and skin cancer (Reichrath et al., 2007).

Vitamin D Deficiency

Vitamin D deficiency is a very common, preventable condition that affects over 1 billion people worldwide (Pourdjabbar, et al., 2013). Vitamin D deficiency or insufficiency can occur in all the life stage groups, from children to older adults. Vitamin D deficiency is defined as a serum 25(OH)D concentration of $\leq$ 20 ng/mL (50 nmol/L), and vitamin D insufficiency as 21- 29 ng/mL (52-72 nmol/L), with sufficiency being $\geq$ 30

ng/mL (75 nmol/l) (Lee et al., 2008). Previously, vitamin D deficiency has been identified primarily as bone health issues, such as rickets and osteomalacia. Rickets is a vitamin D deficiency disease in children which in the past, was a huge epidemic in Northern Europe, North America, and Northern Asia (DeLuca, 1988). Rickets is characterized by impaired mineralization of epiphyseal growth plate cartilage in children (Hajjar, Depta, & Mountis, 2010). Prolonged vitamin D deficiency in adults can result in a mineralization defect in the skeleton causing osteomalacia, secondary hyperparathyroidism, and increases in bone turnover and bone loss (Cashman et al., 2009). Presently, with evolving knowledge gained through significant research findings, vitamin D has been linked to the health of many tissues and organ systems throughout the body, particularly the cardiovascular system. Vitamin D deficiency has now been associated with a higher risk of developing hypertension, diabetes, metabolic syndrome, left ventricular hypertrophy, congestive heart failure, and chronic vascular inflammation (Lee et al., 2008).

Rippel et al. (2012) conducted a study to determine the relationship between hypovitaminosis D and the outcome in critically ill children admitted to a mixed cardiac and general tertiary pediatric intensive care unit (PICU) between July 2010 and March 2011 in Melbourne, Australia. Laboratory analyses were completed on serum 25(OH)D, serum calcium and phosphate, ionized calcium, pH, lactate, bicarbonate, and blood glucose. In this study, hypovitaminosis D was defined as a serum 25(OH)D_3 concentration of < 50 nmol/L (or < 20 ng/mL). Hypovitaminosis was present in 34.5% of the study population, and was more prevalent in postoperative cardiac patients than in the

general medical ICU patients. There was no association between vitamin D status and total calcium and phosphate levels; however, those participants with hypovitaminosis D were more likely to have received calcium supplementation within the first 24 hours of admission.

Although vitamin D deficiency can be caused from a variety of factors, the three most common factors are higher latitudes, obesity, and age. Vitamin D deficiency has been found to be more prevalent in locations that are furthest away from the equator. As distance from the equator increases, the risk for the development of vitamin D deficiency increases (Lee et al., 2008). In order for UVB radiation to begin vitamin D synthesis in the skin, it must first enter into the atmosphere. How UVB radiation enters into the atmosphere is mainly determined by the angle of the sun to the solar zenith, vertical angle. If the angle of the sun to the solar zenith is small, there is a smaller chance of absorption by the skin. For example, the solar zenith angle is smaller at higher latitudes and during the winter months (Diehl & Chiu, 2010).

In 2013, Hirschler et al. examined the prevalence of hypovitaminosis D and the relationship between serum 25(OH)D concentrations and age, gender, and risk factors for diabetes in two groups of Argentinean boys: San Antonio de los Cobres (SAC) boys and Buenos Aires (BA) boys. It was determined that the SAC boys had a higher prevalence of severe vitamin D deficiency, and a lower prevalence of overweight/obesity than the BA boys. This study suggests that the higher prevalence of 25(OH)D deficiency in SAC versus BA boys was possibly due to darker skin, higher altitudes, or even genetic backgrounds.

Vitamin D deficiency is also prevalent in the obese population. Some researchers believe this is due to the decreased bioavailability of vitamin D within the adipose tissue of obese individuals (Lee et al., 2008). In 2011, Garanty-Bogacka and colleagues conducted a study to examine the prevalence of vitamin D deficiency and the association between vitamin D and insulin resistance in 64 obese adolescents, aged 10-18 years. The results showed that serum 25(OH)D concentration was negatively associated with age, pubertal status, weight status and insulin resistance index, and positively associated with HDL-cholesterol level. Turer et al. (2013) studied the prevalence of vitamin D deficiency in overweight and obese US children and adolescents, aged 6 to 18 years of age who were enrolled in the 2003-2006 National Health and Nutrition Examination Survey (NHANES) study. The children and adolescents were classified according to their weight status using age- and gender-specific body mass index (BMI) percentiles: healthy-weight, overweight, obese, or severely obese. Turer and colleagues found the prevalence of vitamin D deficiency to be high in the overweight classification, higher in the obese classification, and highest in the severely obese classification.

Ethnicity has essentially been shown to be a determinant in vitamin D status. In 2012, Sulistyoningrum et al. conducted a study to determine ethnic-specific differences in serum 25(OH)D concentrations and body fat composition in European and South Asian participants from The Multicultural-Community Health Assessment Trial cohort. Subcutaneous and visceral adipose tissue, plasma 25(OH)D concentrations, and body fat composition were measured in all participants. Results indicated that South Asians had a

lower plasma 25(OH)D concentration and higher visceral adipose tissue than the European participants.

In 2013, Au et al. conducted a study to examine the association between not meeting the EAR and inadequate 25(OH)D concentrations. These associations were examined by weight status and race/ethnicity in a nationally representative population-based sample of US children and adolescents, aged 1 – 18 years who were surveyed in the NHANES 2005-2006. Children with inadequate 25(OH)D levels were older, weighed more, and had higher BMI percentiles and larger waist circumferences than those with adequate to optimal 25(OH)D levels. Total dietary intake of vitamin D was positively associated with 25(OH)D levels. There was a significant association between those not meeting the EAR and inadequate 25(OH)D status. There were significantly less non-Hispanic black, Mexican-American, and other/multiracial participants who met the EAR than non-Hispanic white participants.

Zhou et al. (2011) analyzed the association of serum 25(OH)D levels and multiple health outcome measures, including bone biomarkers and cardiovascular disease risk factors in a group of obese Hispanic and African-American children and adolescents. BMI, blood pressure, serum 25(OH)D, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides, hemoglobin A1c (HgbA1c), fasting insulin, fasting glucose, PTH, alkaline phosphatase, calcium, phosphorus, and magnesium were measured in each participant. A significant, negative correlation was found between systolic blood pressure and serum 25(OH)D

levels. Results also indicated severe 25(OH)D deficiency participants had significantly higher PTH than the reference group.

As individuals age, vitamin D status may be compromised due to a decreased availability of 7-dehydrocholesterol in the epidermis for the synthesis of vitamin D from sun exposure, lack of sun exposure, low dietary consumption of vitamin D, and malabsorption issues (Diehl & Chiu, 2010).

The Relationship Between Vitamin D and Cardiovascular Disease

Cardiovascular disease (CVD) is the number one cause of morbidity and mortality in the US, with an estimated death rate at 900,000 per year (Kendrick, Targher, Smits, & Chonchol, 2009). In the US, more than 40% of men and 50% of women have low vitamin D levels (< 30 ng/mL) (Hajjar et al., 2010). In addition, the prevalence of CVD and its complications are higher during the winter months and at latitudes further away from the equator, where the effects of sunlight and 25(OH)D are lower (Perez-Lopez, 2009). A possible correlation was been identified between serum vitamin D levels and many cardiovascular disorders, such as coronary artery disease, myocardial infarction, congestive heart failure, peripheral artery disease and hypertension (Vanga, Good, Howard, & Vacek, 2010; Kendrick et al., 2009). Cardiomyocytes and endothelial cells express the vitamin D receptor and the enzymes 1-alpha-hydroxylase and 24-hydroxylase. Over 170 genes in the coronary artery smooth muscle cells respond to $1,25(OH)_2D$. An insufficient circulating 25(OH)D level may decrease the normal function of these genes associated with vitamin D, possibly leading to an increased risk of CVD (Leu & Giovannucci, 2011). Low serum 25(OH)D concentrations are associated

with an increased risk of myocardial infarction, even after controlling for factors known to be associated with coronary artery disease (CAD). Circulating 25(OH)D levels of at least 30 ng/mL reduces the risk of myocardial infarction (MI) by half in adults (Giovannucci, Liu, Hollis, & Rimm, 2008).

Demir et al. (2014) examined the effects of vitamin D deficiency on atrial fibrillation (AF) by comparing 25(OH)D levels among nonvalvular AF, valvular AF, and control groups in sinus rhythm. The study included 102 participants with "nonvalvular chronic AF without any other cardiovascular disease, and 96 participants with AF, which is associated with rheumatic mitral valve disease who have moderate or severe mitral stenosis and/or regurgitation." One hundred, age-matched controls were also included. Serum PTH and 25(OH)D measurements and endocardiographic examinations were completed on all participants. During the endocardiographic evaluation, the left ventricular chamber, wall thickness, diameter of the left atrium, abnormal blood flows due to valve insufficiency, and the degree of valvular stenosis were measured. Results indicated a lower vitamin D and a higher PTH concentrations in the nonvalvular chronic AF group. The diameter of the left atrium was significantly larger in the AF groups than in the control groups. Through further examination of the AF groups, it was determined that increased diameter of the left atrium and decreased 25(OH)D levels were the predictors of the development of AF in the nonvalvular chronic AF study group.

In 2011, Mheid and colleagues examined the relationship of serum 25(OH)D levels with arterial stiffness and vascular dysfunction in healthy adults. The results indicated that lower serum 25(OH)D levels were positively correlated with abnormalities

in the indexes of arterial stiffness with higher augmentation index (augmented pressure/total arterial pressure) and pulse wave velocity, and lower subendocardial viability ratio (oxygen index under diastolic phase/systolic phase). In addition, lower levels of 25(OH)D were associated with abnormalities in the indexes of vascular function with lower flow-mediated dilation (FMD) and reactive hyperemia index. Insufficient levels of 25(OH)D were associated with increased arterial stiffness and endothelial dysfunction in healthy adults.

In 2007, Martins and colleagues examined the relationship between serum 25(OH)D concentrations and CVD risk factors in US adults using data from the Third National Health and Nutrition Examination Survey (NHANES III). The researchers found low serum 25(OH)D levels to be more prevalent in women, elderly persons, racial/ethnic minorities, and participants with obesity, hypertension, and diabetes mellitus.

Kendrick et al. (2009) conducted a cross-sectional analysis of data from NHANES III to determine if there was an association between serum 25(OH)D concentrations and the prevalence of CVD, defined as self-reported angina, myocardial infarction, and stroke. Health and nutritional status data from 16,603 non-institutionalized, adult men and women were analyzed. Of the 16,603 adult participants analyzed, 1308 (8%) self-reported having CVD, 681 (4.1%) a history of angina, 537 (3.2%) a history of myocardial infarction, and 309 (1.9%) a history of stroke. Twenty-five hydroxyvitamin D deficiency was seen in 22% of the participants. Those participants self-reported having CVD had a higher incidence of 25(OH)D deficiency. This

prevalence suggests the need to achieve optimal 25(OH)D levels in individuals at risk for developing CVD to decrease the prevalence of CVD-related complications, such as angina, myocardial infarction, and stroke.

In 2014, Kelishadi et al. investigated the association of serum 25(OH)D levels with cardiometabolic risk factors and metabolic syndrome in a nationally representative sample of the pediatric population, ages 10 – 18 years, in Iran. There was a high prevalence of hypovitaminosis D in this pediatric population. However, there was no significant difference in 25(OH)D levels by gender. Mean levels of total cholesterol and LDL-C were significantly higher in boys than girls. Total HDL-C had a significant positive correlation with 25(OH)D, independent of age, gender, and anthropometic measures.

Tarcin et al. (2009) conducted a study to examine the effects of vitamin D deficiency and vitamin D replacement on insulin sensitivity, endothelial function, inflammation, oxidative stress markers, and leptin in vitamin D-deficient participants. Results revealed a negative association between vitamin D levels and endothelial function, which helps to confirm the idea that hypovitaminosis D is correlated with atherosclerosis. Vitamin D deficiency was also more prevalent in participants with acute coronary syndrome when compared with healthy controls. Furthermore, there was a significant improvement in endothelial function after vitamin D replacement therapy.

Williams et al. (2013) examined the association of racial differences in vitamin D levels (as reflected by serum 25(OH)D) with racial disparities in the prevalence of insulin resistance between blacks and whites in the United States using data from the NHANES

2001- 2006. The prevalence of insulin resistance was higher in non-Hispanic blacks than in non-Hispanic whites. Insulin was also higher in men than in women. Participants in the lowest quintiles of serum 25(OH)D levels were significantly more likely to have insulin resistance than those in the highest quintile of 25(OH)D.

Common risk factors in the development of CVD disease and diabetes in overweight children and adolescents include low HDL-C, increased LDL-C and triglycerides, high blood pressure, and impaired glucose tolerance. Furthermore, elevated C-reactive protein (CRP) and interleukin-6 (IL-6), which is a proinflammatory cytokine, are also common in obese children and adolescents (Sacheck et al., 2011). In 2011, Sacheck and colleagues examined the association between serum vitamin D levels and cardiometabolic risk factors independent of adiposity in adolescents aged 9-14 years. The researchers found no significant relationship between BMI and serum 25(OH)D levels. In addition, children in this study who presented with increased cardiometabolic risk factors were no more likely to be vitamin D deficient than those with normal levels.

In 2012, Williams et al. analyzed the relationships between 25(OH)D_2 and D_3 and cardiovascular risk factors in childhood in a cross-sectional cohort study of 4274 children from the Avon Longitudinal Study of Parents and Children (ALSPC). The ALSPC recruited pregnant women who resided in Avon, England. Laboratory measurements included serum concentrations of 25(OH)D_2, 25(OH)D_3, apolipoproteins AI and B, triglycerides, CRP, IL-6, leptin, adiponectin, HDL-C, LDL-C, triglycerides, and blood pressure. Researchers found an inverse relationship between 25(OH)D_2 and apolipoprotein B (Apo-B) and triglycerides, and a positive relationship between

25(OH)D_2 and CRP. A relationship was observed between 25(OH)D_3 and HDL-C, apolipoprotein A1 (Apo-A1), and adiponectin, which is associated with cardioprotective levels in these children.

Metabolic syndrome (MetS) has been defined as a cluster of metabolic abnormalities characterized by abdominal adiposity, dyslipidemia, elevated glucose, hypertension, and insulin resistance (IR) (Magnussen et al., 2012). Makariou et al. (2012) investigated the relationship between vitamin D and non-traditional risk factors for CVD in participants with MetS. There were 110 participants included in the study: 52 participants were diagnosed with MetS and 58 participants served as controls. Serum levels of total cholesterol, HDL-C, triglycerides, Apo-A1 and Apo-B, insulin, CRP, lipoprotein-associated phospholipase A_2 (Lp-PLA_2), and 25 (OH)D were determined, and LDL-C was calculated. Results indicated increased levels of triglycerides, Apo-B, fasting plasma glucose, insulin, but decreased HDL-C and Apo-AI in participants with MetS compared with the control group. There was a significant, inverse association between 25(OH)D concentrations and triglycerides, LDL-C and PTH.

Few epidemiological studies have been conducted in children and adolescents associating the risk of MetS with low serum 25(OH)D levels. In 2011, Ganji and colleagues analyzed the association between serum 25(OH)D levels and the prevalence of MetS in US children using data from NHANES 2001-2006 that included: waist circumference $\geq$ 90th percentile; triglycerides $\geq$ 110 mg/dL; HDL-C $\leq$ 40 mg/dl; either systolic blood pressure or diastolic blood pressure > 90th percentile; and fasting glucose $\geq$ 100 mg/dL], CRP, and homeostatic model assessment-insulin resistance index

(HOMA-IR) in US children using data from NHANES 2001-2006. The study sample of 5867 consisted of 50.6% boys and 49.4% girls, and the mean age was 15.4 years. The frequency of MetS in this study sample was 5.4%, and was significantly higher in boys than in girls. Serum 25(OH)D was seen significantly higher in girls than in boys. Serum 25(OH)D was inversely correlated with MetS. Waist circumference, systolic blood pressure, and HOMA-IR were significantly higher and HDL-C was significantly lower in participants with low serum 25(OH)D levels. Due to the significant findings in this study on the association between vitamin D status and MetS, further examination of vitamin D supplementation in possibly reversing the cardiometabolic risk factors in children and adolescents is warranted.

Peripheral Arterial Disease

Peripheral arterial disease (PAD) is associated with a high risk of morbidity and mortality from CVD and is estimated to affect approximately 5 million adults in the US. Atherosclerosis, dyslipidemia, diabetes mellitus, hypertension, smoking, reduced kidney function, and elevated CRP and fibrinogen levels are all risk factors for the development of PAD (Melamed et al., 2008). In 2008, Melamed and colleagues examined the relationship between serum 25(OH)D levels and the occurrence of PAD in the general US population using data from NHANES 2001-2004. Participants with PAD were less physically active and had lower serum 25(OH)D levels than those without PAD.

In 2012, Striker et al. studied the effect of a single, oral, high-dose vitamin D supplementation on endothelial function in patients with PAD in a double-blind, placebo-controlled, intervention pilot study. Sixty-two participants with PAD were included in the

study who were randomized to receive either a single, oral supplementation of 100,000 IU of vitamin D_3 or a placebo. Laboratory analysis at baseline and at the end of the 1-month study were drawn to measure plasma homocysteine, total cholesterol, HDL-C, LDL-C, triglycerides, ionized calcium, phosphorus, creatinine, 25(OH)D, and plasma intact PTH levels. Results indicated an association of 25(OH)D levels and serum intact PTH. A significant increase in serum 25(OH)D levels and a trend in microcirculatory improvement were observed in those participants receiving the single, oral dose of 100,000 IU vitamin D compared to the placebo group. There was no other significant correlations seen with 25(OH)D and the other laboratory measurements.

Serum 25(OH)D is associated with the calcification of the iliac and femoral arteries. Atherosclerotic artery calcification, an increase in arterial stiffness, and vitamin D deficiency may influence the course of PAD (Zagura et al., 2011). In 2011, Zagura and colleagues examined the relationship between arterial stiffness, aortic calcification and vitamin D levels in participants with symptomatic PAD and in healthy participants. The results indicated that increased aortic stiffness and abnormal 25(OH)D levels are independently associated with the degree of aortic calcification in participants with symptomatic PAD and in healthy participants. In addition, serum 25(OH)D and aortic pulse wave velocity were related to the severity grade of atherosclerosis.

Hypertension

The renin-angiotensin system (RAS) is a regulatory cascade that plays an important part in the regulation of blood pressure, and electrolyte and volume homeostasis (Figure 1). Renin, an aspartyl protease, is predominately synthesized and

secreted by the juxtaglomerular apparatus in the nephron of the kidney (Liet al., 2004; Li, 2003; Pilz et al., 2009). The release of renin from the juxtaglomerular cells is tightly regulated by certain physiological stimuli such as volume or salt depletion, reduction in renal vascular perfusion pressure, and renal sympathetic nerve activity (Li et al., 2002). The primary function of renin is to cleave angiotensin I from angiotensinogen. Angiotensin I, a decapeptide, cleaves two amino acids to form the octapeptide, angiotensin II, by the action of the angiotensin-converting enzyme (ACE). Angiotensin II is the main component that affects the RAS by interacting with the angiotensin II receptors in various tissues, including the brain, heart, kidney, adrenal glands, and peripheral vasculature. Increased activation of the RAS has been linked to the development of hypertension, heart attack and stroke (Li et al., 2004; Li, 2003; Pilz et al., 2009).

Hypertension is defined as having a blood pressure measurement of $\geq$ 140 systolic and/or $\geq$ 90 diastolic. It has been estimated to affect 67% of the adults aged 60 years and older, and is projected to affect 1.6 billion people worldwide by the year 2025 (Martini & Wood, 2008). Hypertension is often associated with other risk factors related to CVD, such as metabolic syndrome, diabetes mellitus, obesity, and dyslipidemia.

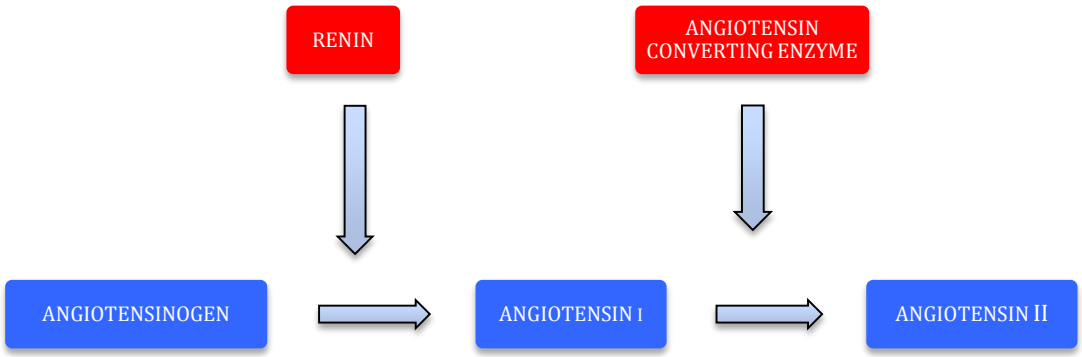

Figure 1. The Renin-Angiotensin System

Adequate serum vitamin D levels (> 30 ng/ml) have been shown to assist in preventing the development of hypertension and protecting the kidney through the suppression of the RAS (Hajjar et al., 2010; Lee et al., 2008). Vitamin D not only acts as an inhibitor of renin expression in the juxtaglomerular apparatus, but also as an inhibitor of vascular smooth muscle cell proliferation (Forman, Bischoff-Ferrari, Willett, Stampfer, & Curhan, 2005). Vitamin D has been shown to function as a negative endocrine regulator of the RAS in mice. The RAS and serum vitamin D levels are important for the homeostasis of electrolytes, volume, and blood pressure, not only in animals, but also in humans (Li et al., 2002).

Forman et al. (2007) studied the relationship between serum 25(OH)D levels and the risk of developing hypertension among a sample of 613 men from the Health Professionals' Follow-Up Study (HPFS) and a sample of 1198 women from the Nurses' Health Study (NHS) without hypertension at baseline. When data from the two cohort studies were combined, participants with a serum 25(OH)D level < 15 ng/mL had higher risk of developing hypertension than those participants with a serum 25(OH)D level of $\geq$ 30 ng/mL, independent of age, BMI, physical activity, race, menopausal status, and other covariates.

In 2010, Scragg and colleagues conducted a study to examine the association of vitamin D, heart rate, and heart rate-systolic pressure product (RPP) using data from NHANES III and NHANES 2001-2006. RPP is a measure of cardiac work oxygen demand, which is related to heart muscle blood flow in healthy participants. Results of the study indicated a negative correlation with pulse rate, systolic blood pressure, and

RPP with vitamin D level. The association suggests a direct effect of vitamin D on the heart, possibly through vitamin D signaling in heart muscle cells and the regulation of heart rate.

In 2015, Tomaino et al. examined the relationship between 25(OH)D levels and blood pressure in adolescents (aged 13-15 years) at risk for vitamin D deficiency in two Peruvian regions, both located at sea level. Adolescents in Lima were more likely to be overweight than adolescents in Tumbes. There was a negative correlation found between weight status and 25(OH)D levels. Overweight adolescents had significantly lower 25(OH)D levels than those of normal weight. Systolic blood pressure, diastolic blood pressure, and mean arterial pressure were all elevated in the vitamin D deficient adolescents.

American and European blacks tend to have a higher prevalence of hypertension. One of the reasons for a higher prevalence of hypertension is thought to be caused by a low vitamin D status due to decreased cutaneous synthesis and increased skin pigmentation (Scragg, Sowers, & Bell, 2007). To explore this possible relationship, Scragg and colleagues in 2007 conducted a cross-sectional analysis using data from NHANES III to determine if vitamin D status is inversely associated with systolic and diastolic blood pressure, and to determine if ethnic differences in vitamin D status are associated with ethnic differences in blood pressure. Scragg et al. found that systolic blood pressure and pulse pressure are both inversely correlated with serum 25(OH)D concentrations. In addition, the ethnic differences in serum 25(OH)D concentrations explained about half of the differences in ethnic blood pressure. Even though American

and British blacks who have low serum 25(OH)D levels have a high risk of developing hypertension, low vitamin D status and hypertension have also been found to be negatively correlated in other ethnic groups. In 2011, Griffin and colleagues found that a single-time baseline measurement of serum vitamin D levels among young, adult, Caucasian women was significantly correlated with a greater incidence of systolic hypertension 14 years later. Furthermore, systolic blood pressure has been shown to be inversely associated with serum vitamin D concentrations in non-hypertensive white persons in the United States (Judd, Nanes, Ziegler, Wilson, & Tangpricha, 2008)

Impaired vitamin D status plays a role in the development of hypertension. Vitamin D deficiency in young adults may lead to impaired brachial artery flow-mediated dilation (FMD). Also, middle-aged and older adults have decreased brachial artery FMD, resulting in vascular endothelial dysfunction. A combination of age plus vitamin D deficiency leads to a much higher risk of developing hypertension (Jablonski, Chonchol, Pierce, Walker, & Seals, 2011). Jablonski et al. (2011) conducted a study to determine if brachial artery FMD is associated with serum vitamin D status, and if vitamin D deficiency and impaired brachial artery FMD are associated with vascular inflammation in otherwise healthy, middle-aged and older adults. The results of this study indicated a relationship between vitamin D deficiency and brachial artery FMD. Also, these results indicated an association between inadequate serum 25(OH)D status and vascular endothelial inflammation. However, FMD was not related to $1,25(OH)_2D$ concentrations in the middle-aged and older adult population. In vitamin D-deficient participants, there was a decreased expression of 1α-hydroxylase enzyme and vitamin D receptors, resulting

in a limited conversion of 25(OH)D to 1,25$(OH)_2$D, reduced vitamin D signaling in the vascular endothelium, thus resulting in reductions in brachial artery FMD.

Calcium

Adequate serum 25(OH)D levels are associated with decreased cardiometabolic risk. Adequate dietary calcium has also been shown to be cardioprotective. The Institute of Medicine Food and Nutrition Board (IOM-FNB) established the 2010 DRIs for calcium adequacy for each of the following life stage groups: infants 0 to 6 months, infants 6 to 12 months, children 1 through 3 years, children 4 through 8 years, males and females 9 through 18 years, males 19 to 70 years and females 19-50, females 50+ years and males 70+ years (Food and Nutrition Board, Institute of Medicine, 2010) (Table 3).

For infants 0 to 6 months, an AI of 200 mg was established to reflect the calcium content of exclusively breast-fed infants. The established AI for infants 6 – 12 months is also 200 mg, which takes into account the intake of calcium from food sources. The established AIs for the above life-stage groups are to promote bone accretion and positive calcium balance, and to meet growth needs. For children 1-18 years, the daily recommendation was established to promote bone accretion and positive calcium balance. For children 1 through 3 years of age, the reference values of 500 mg (EAR) and 700 mg (RDA) are set to achieve the calcium retention level of 142 mg/day for bone accretion.

Table 3

Calcium Dietary Reference Intakes for Adequacy

Life Stage Group	**AI/day**	**EAR/day**	**RDA/day**
Infants: 0 to 6 months	200 mg	-	-
Infants: 6 to 12 months	200 mg	-	-
Children 1 through 3 years	-	500 mg	700 mg
Children 4 through 8 years	-	800 mg	1000 mg
Males: 9 to 18 years	-	1100 mg	1300 mg
Males: 19-70 years	-	800 mg	1000 mg
Males: < 70 years	-	1000 mg	1200 mg
Females: 9-18 years	-	1100 mg	1300 mg
Females: 19-50 years	-	800 mg	1000 mg
Females: 50+ years	-	1000 mg	1200 mg

Source: Food and Nutrition Board, Institute of Medicine (2010)

An EAR of 800 mg and a RDA of 1000 mg has been established for children 4 to 8 years. During this prepubertal life stage, the EAR was set to achieve a calcium retention between 140 and 160 mg/day. For males and females aged 9 to 18 years, the reference values of 1100 mg (EAR) and 1300 mg (RDA) helps to achieve bone accretion levels 92-210mg/day. For males and females 19-50 years, the reference values of 800 mg (EAR) and 1000 mg (RDA) were set to promote bone maintenance and neutral calcium balance. In the latter stages of adulthood, the natural process of bone loss is evident because calcium absorption decreases with age. Therefore, the reference values for males and females 51-70 years of age were set at 1000 mg (EAR) and 1200 mg (RDA), respectively (Food and Nutrition Board, Institute of Medicine, 2010).

Calcium intake of children and adolescents in the United States is generally lower than the daily recommendations. As noted above, adequate calcium intake is important for the development of peak bone mass in children. Milk and milk products provide at least 50% of calcium intake of children in the United States. However, by adulthood, the consumption of milk decreases significantly. In 2015, Cluskey et al. conducted a study to identify major dietary calcium sources and note the differences among Asian, Hispanic, and non-Hispanic White parents and children, and to evaluate differences in dietary sources of calcium within race/ethnic group by dietary acculturation. Milk was the primary dietary source of calcium among all groups, and for both parents and children. Significantly, non-Hispanic White parents consumed more of their calcium from milk than Asian parents. Cheese was ranked as the second highest dietary source of calcium

for both Hispanic and non-Hispanic White parents, while yogurt was the second highest for Asian parents. Milk, cheese, and yogurt were the three highest dietary sources of calcium among children. Milk with cereal was a better dietary source of calcium for Hispanic and non-Hispanic White children than for Asian children. In a within race/ethnicity comparison, tofu and dark green leafy vegetable consumption was significantly higher in foreign-born Asian parents while cheese was significantly lower than US-born Asian parents (Cluskey et al., 2015).

In 2014, de Oliveira and colleagues conducted a study to assess calcium intake by eighth-grade adolescents, to compare intake to the DRIs, and to investigate variables associated with daily calcium intake. Students completed two questionnaires: (1) a questionnaire about socioeconomic status (SES), dietary habits, and physical activity practices; and (2) a food frequency questionnaire (FFQ) covering foods rich in calcium (milk, yogurt, ricotta, cheeses, processed cheese spread, cheese sourdough, oats, beans, dark green vegetables, cauliflower, fish, cake, ice cream, and sweet containing milk). Mean calcium intake per student was 540 mg per day, which is below the daily recommendation for calcium intake. In addition, an association was observed between drinking soft drinks three or more times per week and less adequate calcium intake (de Oliviera et al., 2014).

Vitamin D, Calcium, and Overweight/Obesity

Overweight in children and adolescents can lead to a variety of health problems, including type 2 diabetes mellitus, obstructive sleep apnea, hypertension, dyslipidemia, and metabolic syndrome (Daniels et al., 2005). Vitamin D and calcium intake have been

shown to be associated with lower rates of obesity and, therefore, decreased atherosclerotic risk associated with obesity (Lutsey & Michos, 2013).

In 2012, Rosenblum et al. conducted two double-blind, placebo-controlled studies to examine the effects of calcium and vitamin D supplemented orange juice (regular or lite) on weight loss and changes of visceral adipose tissue in overweight and obese adults. Participants were randomly assigned to either the treatment or control group via a computer-generated randomization code. Treatment group participants received 240 mL of regular/lite orange juice fortified with 350 mg calcium and 100 IU vitamin D_3 three times per day, and control group participants received 240 mL regular/lite orange juice three times per day for 16 weeks. No significant differences in BMI, body weight, and waist circumference were seen after 16 weeks. However, in both study trials, the reduction in visceral adipose tissue was significantly greater in the treatment groups receiving vitamin D and calcium than in the control groups.

In 2014, Gopinath et al. conducted a study to determine whether dairy food consumption and dietary calcium intake were correlated to blood pressure in adolescents based on gender. Results indicated that boys had higher intakes of energy, saturated and monounsaturated fatty acids, carbohydrates, total sugars, calcium, protein, and total dairy and milk. Boys had significantly lower diastolic blood pressure than girls. Systolic blood pressure, however, was higher in boys than girls. Total dairy food consumption and specifically, milk and cheese consumption, were inversely associated with blood pressure among girls (Gopinath et al., 2014).

NHANES

The NHANES is an ongoing survey designed to assess the health and nutritional status of adults and children in the US. It examines a nationally representative sample of about 5000 persons each year. (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008a). NHANES is a major program of the National Center for Health Statistics (NCHS), which is a part of the Centers for Disease Control and Prevention (CDC). The data sets are publically available and released by the National Center for Health Statistics (NCHS) in two-year intervals. NHANES is designed to collect health and nutrition information through household interviews and physical examinations for participants representing the civilian, non-institutionalized population of US adults and children (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008a). The NHANES household interview consists of questions regarding demographic, socioeconomic, dietary, and health status. Participants use touch-sensitive computer screens to enter their own responses to certain sensitive questions in complete privacy. The physical examination includes medical, dental, and physiological measurements, as well as laboratory tests administered by highly-trained medical personnel. Although the household interviews are conducted in the participants' homes, the physical examinations are conducted in specifically-designed and equipped mobile centers, which travel to locations throughout the country. The study sample receives compensation and a report of medical findings for participating in the survey.

The 2007-2008 survey used for this study was a multistage, stratified sampling design, with over-sampling of certain race/ethnic groups (mainly the entire Hispanic populations and not just the Mexican American population) and age groups to ensure their adequate representation (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008b).The 2007-2008 NHANES was the latest version of the survey expected to release the serum 25(OH)D concentrations of the sample participants during the analyses of the study data for this dissertation. However, as of December 2015, serum 25(OH)D levels had not been released from the CDC. Therefore, vitamin D intake was used as a surrogate for serum 25(OH)D concentrations.

CHAPTER III

ESTIMATION OF VITAMIN D AND CALCIUM INTAKES IN THE UNITED STATES BY AGE, SEX, PARENTAL PIR, AND RACE/ETHNICITY IN CHILDREN (6 - 12 YEARS) AND ADOLESCENTS (13 - 18 YEARS)

(STUDY I)

Study Design and Population

The sample participants used for this study were US children (6 - 12 years) and adolescents (13 - 18 years) who participated in the 2007-2008 NHANES cross-sectional study. The 2007-2008 NHANES data represented a subset of the 53,113,128 children age 6 – 18 years in the US. All participants 12 years and older signed the consent form with their parents, and participants aged 6-11 years signed an assent form and their parent signed the consent form.

Data Collection Procedures

The 2007 – 2008 NHANES database was accessed online to retrieve body measurement and nutrient data for the study. BMI was calculated as weight (kilogram)/height (m^2). Children and adolescents were categorized into one of three groups based on their BMI: underweight/normal ($\leq 85^{th}$ percentile); overweight ($> 85^{th}$ percentile and $< 95^{th}$ percentile); obese ($\geq 95^{th}$ percentile) (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008e). Nutrient data included intakes (total, dietary, and supplemental) of vitamin D and

calcium, and were accessed using the Food and Nutrient Database for Dietary Studies (FNDDS). Nutrient data obtained from the NHANES database were collected from in-person 24-hour dietary recall information and a Dietary Supplement Questionnaire administered during the household interviews. For children and adolescents 12 years and older, data on food intake were obtained by an interviewer in English and Spanish recording a 24-hour dietary recall (Day 1); and for children 6-11 years, parents/caregivers assisted with the dietary recalls (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008d).

Key study demographic variables retrieved from the NHANES data file included self-reported race/ethnicity, parental PIR, age, and sex for children 6 - 18 years. Race/ethnicity groups were derived from self-reported information collected during the screener and household interviews. Participants were categorized into the following groups: Mexican American, Other Hispanic, Non-Hispanic (NH) White, NH Black, and Other Race-including Multiracial (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008b). Participants were classified by income into parental PIR groups: low = PIR $\leq$ 131% income; median = PIR 131.01 to 185% income; and high = PIR > 185% income. Participants were divided into one of two age groups: 6 – 12 years and 13 – 18 years. Any participant who did not have completed demographic information was eliminated from the study. A total of 2347 participants, aged 6 – 18 years, from NHANES 2007-2008 provided complete demographic and in-person 24-hour recalls and were used in this study.

Hypotheses

The purpose of the study was to estimate vitamin D and calcium intakes in the US based on age, sex, parental PIR, and race/ethnicity in children 6 - 12 years and adolescents 13 - 18 years using 2007 – 2008 NHANES data.

This study was designed to test the following null hypotheses:

1. Dietary, supplemental, and total intakes of vitamin D will not differ by sex, parental PIR, and ethnicity in children (6 - 12 years) and adolescents (13 - 18 years).
2. Dietary, supplemental, and total intakes of calcium will not differ by sex, parental PIR, and ethnicity in children (6 - 12 years) and adolescents (13 - 18 years).
3. US children (6 - 12 years) and adolescents (13 - 18 years) do not meet the DRIs for vitamin D through diet and/or supplementation.
4. US children (6 - 12 years) and adolescents (13 - 18 years) do not meet the DRIs for calcium through diet and/or supplementation.

Data Analysis

Statistical analyses were performed using SPSS (IBM SPSS Statistics 22.0). Descriptive statistics were used to estimate frequencies for all categorical/demographic variables. Means and Crosstabs procedures in SPSS were used to determine mean $\pm$ standard error.

To evaluate the differences of vitamin D and calcium intakes (from diet and/or supplements) and the PIR, sex, and race/ethnicity categories, least-square means and standard error were compared by univariate analysis of variance. The Bonferroni test was

used to find significant differences for multiple comparisons. A P-value of ≤ 0.05 was used to determine statistical significance.

Results

Demographic Characteristics

Demographic characteristics of all participants are summarized in Table 4. Overall, approximately 60% of the participants were 6 - 12 years, and 39.5% were 13 - 18 years. The distribution of sex was 61.2% female and 38.8% male. There was a lower percentage of obese children and adolescents (15.4%) than overweight (16.5%) or under/normal weight (68.1%) children and adolescents. The study population was comprised of 31.0% NH White, 26.3% NH Black, 25.1% Mexican American, 13.0% Other Hispanic, and 4.5% Other Race-including Multiracial. Income distribution by parental PIR was 48.8% low income, 42.0% high income, and 9.2% median income. Less than 10% of the participants reported consuming a supplement with either vitamin D or calcium.

Table 4a presents the demographic characteristics of the participants aged 6 - 12 years. The percentage of males and females included was similar (50.2% and 49.8%, respectively). The majority of children aged 6 - 12 years were under/normal weight (56.2%) versus the overweight (15.8%) or obese (23.8%). Distribution by self-reported race/ethnic groups was Mexican American (27.3%), Other Hispanic (12.1%), NH White (29.4%), NH Black (26.0%), and Other Race-including Multiracial (5.1%). Income distribution by parental PIR was low (40.7%), medium (11.8%), and high (40.1%). The

majority of participants aged 6 - 12 years did not take a vitamin D (87.4%) or a calcium (92.4%) supplement.

Demographic characteristics of participants aged 13 - 18 years are provided in Table 4b. There were slightly more male participants (51.6%) than female participants (48.4%). The distribution of BMI indicated that 57.2% of adolescents age 13 - 18 years were under/normal weight, 16.3% were overweight, and 22.4% were obese. Ethnic distribution of adolescents aged 13 - 18 years was 33.4% NH White, 26.9% NH Black, 21.8% Mexican American, 14.3% Other Hispanic, and 3.6% Other Race-including Multiracial. The majority of the adolescents were in the high parental PIR group (44.1%), although a substantial number fell into the low income group (35.2%). Approximately, one-tenth of adolescents age 13 - 18 years reported taking a vitamin D (9.1%) or a calcium (8.1%) supplement.

Estimates of Vitamin D Intake by Parental PIR

Mean intakes of vitamin D from food and supplements for children and adolescents 6 - 18 years during 2007-2008 were categorized by parental PIR (Table 5). Total intake of vitamin D was highest in the high versus the low and median parental PIR categories, and dietary vitamin D intake was lowest in the medium versus low and high parental PIR categories. Although a difference was noted, these differences were not significant. Supplemental vitamin D intake was significantly higher ($p = 0.001$) in the high parental PIR group than the low.

Table 4

Demographic Characteristics of Children and Adolescents Aged 6 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008

Characteristic	n*	%
Age Group		
6 - 12 years	1420	60.5
13 - 18 years	927	39.5
Sex		
Male	911	38.8
Female	1436	61.2
BMI		
Under/Normal Weight	1496	68.1
Overweight	364	16.5
Obese	338	15.4
Race/Ethnicity		
Mexican American	590	25.1
Other Hispanic	305	13
Non-Hispanic White	728	31
Non-Hispanic Black	618	26.3
Other Race-including Multiracial	106	4.5
Parental Poverty Income Ratio		
Low	932	48.8
Median	177	9.2
High	802	42
Vitamin D Supplement?		
Yes	218	9.3
No	2129	90.7
Calcium Supplement?		
Yes	183	7.8
No	2164	92.2

*Totals may not equal grand total due to missing data.

Table 4a

Demographic Characteristics of Children Aged 6 – 12 Years, National Health and Nutrition Examination Survey, 2007-2008

Characteristic	n*	%
Sex		
Male	713	50.2
Female	707	49.8
BMI		
Under/Normal Weight	798	56.2
Overweight	225	15.8
Obese	338	23.8
Race/Ethnicity		
Mexican American	388	27.3
Other Hispanic	172	12.1
Non-Hispanic White	418	29.4
Non-Hispanic Black	369	26
Other Race-including Multiracial	73	5.1
Parental Poverty Income Ratio		
Low	578	40.7
Median	167	11.8
High	569	40.1
Vitamin D Supplement?		
Yes	179	12.6
No	1241	87.4
Calcium Supplement?		
Yes	108	7.6
No	1312	92.4

* Totals may not equal due to missing data

Table 4b

Demographic Characteristics of Adolescents Aged 13 – 18 Years, National Health and Nutrition Examination Survey, 2007-2008

Characteristic	n*	%
Sex		
Male	478	51.6
Female	449	48.4
BMI		
Under/Normal Weight	530	57.2
Overweight	151	16.3
Obese	208	22.4
Race/Ethnicity		
Mexican American	202	21.8
Other Hispanic	133	14.3
Non-Hispanic White	310	33.4
Non-Hispanic Black	249	26.9
Other Race-including Multiracial	33	3.6
Parental Poverty Income Ratio		
Low	326	35.2
Median	100	10.8
High	409	44.1
Vitamin D Supplement?		
Yes	84	9.1
No	843	90.9
Calcium Supplement?		
Yes	75	8.1
No	852	91.9

* Totals may not equal due to missing data

For children aged 6 – 12 years (Table 5a), total and dietary vitamin D intakes were lowest in the medium parental PIR category. Supplemental vitamin D intake was significantly higher ($p = 0.003$) in the high parental PIR category than the low.

For adolescents aged 13 – 18 years (Table 5b), although not significant, total and dietary intakes were highest in the high parental PIR category compared to the low and medium parental PIR categories. Supplemental vitamin D intake was higher in the medium parental PIR income category than low or high categories.

Estimates of Vitamin D Intake by Race/Ethnicity

Mean intakes of vitamin D from food and supplements for children and adolescents aged 6 - 18 years during 2007-2008 were categorized by race/ethnicity (Table 5). When total vitamin D intake was compared for all groups, NH Blacks had a significantly lower total vitamin D intake than Mexican Americans ($p = 0.003$), Other Hispanics ($p < 0.001$), and NH Whites ($p < 0.001$), and had a significantly lower dietary vitamin D intake than Mexican Americans ($p < 0.001$), Other Hispanics ($p < 0.001$), and NH Whites ($p < 0.001$). NH Whites had a significantly higher supplemental vitamin D intake than NH Blacks ($p < 0.001$) and Mexican Americans ($p < 0.001$).

For children 6 - 12 years (Table 5a), NH Blacks had a significantly lower total vitamin D intake than Other Hispanics ($p = 0.007$) and NH Whites ($p = 0.001$), and a significantly lower dietary vitamin D intake than Mexican Americans ($p = 0.012$), Other Hispanics ($p < 0.001$), and NH Whites ($p = 0.003$). Also, participants in the Other Race-including category had a significantly lower dietary intake than Other Hispanics

($p = 0.005$). For supplemental vitamin D, Mexican Americans had a significantly lower intake than NH Whites ($p = 0.013$).

For adolescents 13 - 18 years (Table 5b), NH Blacks had a significantly lower total vitamin D intake than Mexican Americans ($p = 0.003$), Other Hispanics ($p = 0.045$), and NH Whites ($p < 0.001$), and a significantly lower dietary vitamin D intake than Mexican Americans ($p< 0.001$) and NH whites ($p < 0.001$). NH Whites had a significantly higher supplemental vitamin D intake than Mexican Americans ($p = 0.027$) and NH Blacks ($p < 0.001$).

Estimates of Vitamin D Intake by Sex

Mean intakes of total vitamin D (dietary and supplemental), dietary vitamin D, and supplemental vitamin D were also tabulated for children and adolescents 6 - 18 years based on sex (Table 5). For the population as a whole, male participants had a significantly higher total vitamin D ($p < 0.001$) and dietary vitamin D ($p < 0.001$) than female participants. Supplemental intake did not differ by sex.

For children 6 - 12 years, male participants had a significantly ($p = 0.001$) higher intake of dietary vitamin D intake than females (Table 5a). Total vitamin D intake did not differ. Females had a higher intake of supplemental vitamin D intake than males. For adolescents 13 to 18 years, males had a significantly higher total ($p < 0.001$) and dietary vitamin D ($p < 0.001$) intake than females (Table 5b). Although not significant, males had a higher supplemental intake of vitamin D than females.

Estimates of Vitamin D Intake by Age Group

Mean intakes of total (dietary and supplemental), dietary, and supplemental vitamin D for children and adolescents aged 6 - 18 years during 2007-2008 were categorized by age group and compared by parental PIR, race/ethnicity, and sex (Table 6). Children (6 - 12 years) in the low parental PIR had significantly higher total ($p = 0.003$) and dietary ($p = 0.002$) vitamin D intakes than adolescents (13 - 18 years). Dietary vitamin D intake was significantly higher in children in the low and medium parental PIR category than adolescents. Supplemental vitamin D intake was significantly higher ($p = 0.001$) in adolescents in the medium parental PIR group than children.

When comparing total vitamin D intake by age group and race/ethnicity, vitamin D intake was significantly higher in Other Hispanic ($p = 0.005$) and NH Black ($p = 0.005$) children (6 - 12 years), dietary vitamin D intake was significantly higher in Other Hispanic ($p = 0.005$) and NH Black ($p = 0.05$) children, and supplemental vitamin D was significantly higher in Other Hispanic and NH Black children when compared to adolescents (13 - 18 years). NH White children had higher total, dietary, and supplemental vitamin D intakes than adolescents, although differences were not significant.

Females, aged 6 - 12 years, had significantly higher total ($p = 0.003$) and dietary ($p = 0.004$) vitamin D intakes than females, aged 13 - 18 years. Although not significant, females (6 - 12 years) had a higher supplemental vitamin D intake than 13 - 18 year old females.

Table 5

Vitamin D Intake (Total, Dietary, and Supplemental) of US Children and Adolescents Aged 6 – 18 Years by Parental PIR and Sex by Race/Ethnicity, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
Parental PIR [2-4]	µg/d	n	µg/d (v)	n	µg/d (w)	n	µg/d (x)	n	µg/d (y)	n	µg/d (z)	n	
Total Vitamin D													
All	5.32 ± 0.12	2149	5.30 ± 0.25	527	5.90 ± 0.32	278	6.11 ± 0.23	684	4.22 ± 0.19	565	4.57 ± 0.47	95	vy,wy,xy
Low (a)	5.15 ± 0.16	904	5.09 ± 0.29	257	5.91 ± 0.45	142	5.75 ± 0.35	240	4.29 ± 0.29	233	4.00 ± 0.72	32	
Medium (b)	5.12 ± 0.33	267	4.84 ± 0.59	89	6.83 ± 1.00	39	6.12 ± 0.69	63	3.81 ± 0.46	74	1.70 ± 0.60	2	
High (c)	5.54 ± 0.19	978	5.84 ± 0.52	181	5.51 ± 0.51	97	6.35 ± 0.33	381	4.28 ± 0.30	258	4.97 ± 0.63	61	
Difference by column													
Dietary Vitamin D													
All	4.69 ± 0.09	1964	5.04 ± 0.22	474	5.17 ± 0.23	257	5.06 ± 0.17	627	3.81 ± 0.15	516	3.99 ± 0.33	90	vy,wv,xy
Low (a)	4.74 ± 0.13	842	4.99 ± 0.26	236	5.37 ± 0.33	133	4.98 ± 0.28	226	3.96 ± 0.24	216	3.69 ± 0.61	31	
Medium (b)	4.36 ± 0.24	247	4.32 ± 0.40	82	4.90 ± 0.62	38	5.19 ± 0.54	58	3.46 ± 0.39	67	1.70 ± 0.60	2	
High (c)	4.74 ± 0.15	875	5.48 ± 0.49	156	4.97 ± 0.39	86	5.10 ± 0.24	343	3.78 ± 0.23	343	4.23 ± 0.41	57	
Difference by column													
Supplemental Vitamin D													
All	1.03 ± 0.07	2149	0.77 ± 0.11	527	1.12 ± 0.20	278	1.48 ± 0.15	684	0.74 ± 0.12	565	0.79 ± 0.32	95	vx,xy
Low (a)	0.74 ± 0.09	904	0.50 ± 0.13	257	0.88 ± 0.25	142	1.05 ± 0.21	240	0.62 ± 0.16	233	0.42 ± 0.42	32	
Medium (b)	1.09 ± 0.20	267	0.85 ± 0.29	89	2.05 ± 0.84	39	1.34 ± 0.40	63	0.68 ± 0.29	74	0.00 ± 0.00	2	
High (c)	1.30 ± 0.12	978	1.11 ± 0.24	181	1.10 ± 0.31	97	1.76 ± 0.22	381	0.87 ± 0.19	258	1.01 ± 0.44	61	
Difference by column	ac												

Table 5 continued.

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	µg/d	n	µg/d (v)	n	µg/d (w)	n	µg/d (x)	n	µg/d (y)	n	µg/d (z)	n	
Sex [2,4]													
Total Vitamin D													
All	5.30 ± 0.11	2347	5.31 ± 0.23	590	5.84 ± 0.31	305	6.12 ± 0.23	728	4.19 ± 0.18	618	4.53 ± 0.45	106	vy,wy,xy
Male (a)	5.75 ± 0.17	1191	5.54 ± 0.35	299	6.64 ± 0.45	154	6.98 ± 0.34	379	4.27 ± 0.24	305	4.16 ± 0.61	54	
Female (b)	4.84 ± 0.15	1156	5.08 ± 0.31	291	5.02 ± 0.40	151	5.18 ± 0.29	349	4.12 ± 0.26	313	4.92 ± 0.66	52	
Difference by column	ab				ab		ab						
Dietary Vitamin D													
All	4.71 ± 0.09	2134	5.11 ± 0.21	528	5.13 ± 0.22	281	5.08 ± 0.17	661	3.78 ± 0.14	567	4.17 ± 0.34	97	vx,xy
Male (a)	5.27 ± 0.14	1076	5.42 ± 0.32	265	5.83 ± 0.32	143	5.91 ± 0.27	342	4.28 ± 0.23	276	4.02 ± 0.53	50	
Female (b)	4.13 ± 0.11	1058	4.79 ± 0.26	263	4.41 ± 0.31	138	4.20 ± 0.20	319	3.31 ± 0.17	291	4.33 ± 0.42	47	
Difference by column	ab				ab		ab						
Supplemental Vitamin D													
All	1.02 ± 0.07	2347	0.74 ± 0.11	590	1.11 ± 0.19	305	1.51 ± 0.15	728	0.73 ± 0.11	618	0.71 ± 0.28	106	vy,wy,xy
Male (a)	0.99 ± 0.09	1191	0.73 ± 0.15	299	1.23 ± 0.28	154	1.65 ± 0.21	379	0.40 ± 0.10	305	0.43 ± 0.31	54	
Female (b)	1.05 ± 0.10	1156	0.75 ± 0.16	291	0.98 ± 0.25	151	1.35 ± 0.20	349	1.04 ± 0.19	313	1.00 ± 0.48	52	
Difference by column													

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean ± SE
3 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 Significant differences by row or column groups are indicated by letter. P ≤ 0.05

Table 5a

Vitamin D Intake (Total, Dietary, and Supplemental) of US Children Aged 6 – 12 Years by Parental PIR and Sex by Race/Ethnicity, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
Parental PIR [2-4]	µg/d	n	µg/d (v)	n	µg/d (w)	n	µg/d (x)	n	µg/d (y)	n	µg/d (z)	n	
Total Vitamin D													
All	5.55 ± 0.15	1314	5.36 ± 0.29	349	6.52 ± 0.41	159	6.22 ± 0.28	394	4.76 ± 0.26	347	4.46 ± 0.57	65	wy,xy
Low (a)	5.56 ± 0.21	578	5.32 ± 0.34	192	6.73 ± 0.63	80	6.36 ± 0.44	141	4.82 ± 0.40	143	2.94 ± 0.41	22	
Medium (b)	5.21 ± 0.38	167	4.91 ± 0.77	55	5.91 ± 0.75	23	7.14 ± 0.87	38	3.80 ± 0.51	50	2.30 ± 0.00	1	
High (c)	5.65 ± 0.24	569	5.67 ± 0.62	102	6.46 ± 0.69	56	5.96 ± 0.88	215	5.02 ± 0.43	154	5.31 ± 0.84	42	
Difference by column											ac,bc		
Dietary Vitamin D													
All	4.93 ± 0.11	1184	5.11 ± 0.23	307	5.82 ± 0.30	149	5.18 ± 0.19	357	4.24 ± 0.20	311	3.90 ± 0.34	60	vy,wy,xy, wz
Low (a)	5.12 ± 0.16	534	5.19 ± 0.29	174	6.00 ± 0.45	76	5.40 ± 0.30	135	4.53 ± 0.33	128	3.08 ± 0.40	21	
Medium (b)	4.65 ± 0.28	154	4.17 ± 0.49	49	5.04 ± 0.74	23	6.20 ± 0.61	36	3.78 ± 0.45	45	2.30 + 0.00	1	
High (c)	4.82 ± 0.17	496	5.50 ± 0.53	84	5.90 ± 0.47	50	4.82 ± 0.27	186	4.13 ± 0.30	138	4.40 ± 0.46	38	
Difference by column											bc		
Supplemental Vitamin D													
All	1.10 ± 0.09	1314	0.86 ± 0.15	349	1.06 ± 0.25	159	1.52 ± 0.18	394	0.96 ± 0.17	347	0.86 ± 0.41	65	vx
Low (a)	0.83 ± 0.12	578	0.62 ± 0.17	192	1.03 ± 0.36	80	1.19 ± 0.28	141	0.77 ± 0.22	143	0.00 ± 0.00	22	
Medium (b)	0.92 ± 0.22	167	1.20 ± 0.43	55	0.87 ± 0.60	23	1.26 ± 0.50	38	0.40 ± 0.28	50	0.00 ± 0.00	1	
High (c)	1.45 ± 0.15	569	1.14 ± 0.31	102	1.20 ± 0.41	56	1.78 ± 0.26	215	1.32 ± 0.30	154	1.33 ± 0.62	42	
Difference by column	ac								bc		ac,bc		

Table 5a continued.

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	µg/d	n	µg/d (v)	n	µg/d (w)	n	µg/d (x)	n	µg/d (y)	n	µg/d (z)	n	
Sex [2,4]													
Total Vitamin D													
All	5.52 ± 0.14	1420	5.31 ± 0.27	388	6.43 ± 0.40	172	6.21 ± 0.28	418	4.77 ± 0.25	369	4.28 ± 0.53	73	wy,wz,xy,xz
Male (a)	5.71 ± 0.20	713	5.15 ± 0.36	197	7.22 ± 0.57	83	6.69 ± 0.40	222	4.86 ± 0.35	176	3.29 ± 0.59	35	wy,wz,xy,xz
Female (b)	5.33 ± 0.20	707	5.48 ± 0.40	191	5.69 ± 0.55	89	5.66 ± 0.39	196	4.70 ± 0.36	193	5.20 ± 0.85	38	
Difference by column					ab		ab				ab		
Dietary Vitamin D													
All	4.95 ± 0.11	1267	5.15 ± 0.22	338	5.86 ± 0.30	159	5.22 ± 0.20	373	4.21 ± 0.19	332	3.95 ± 0.33	65	vz,wz,xz
Male (a)	5.32 ± 0.16	628	5.18 ± 0.29	168	6.51 ± 0.43	79	5.76 ± 0.30	194	4.70 ± 0.31	156	3.39 ± 0.47	31	vz,wy,wz,xz
Female (b)	4.60 ± 0.14	639	5.12 ± 0.33	170	5.22 ± 0.39	80	4.64 ± 0.25	179	3.78 ± 0.23	176	4.46 ± 0.46	34	vy,wy
Difference by column	ab				ab				ab		ab		
Supplement Vitamin D													
All	1.10 ± 0.09	1420	0.83 ± 0.40	388	1.01 ± 0.23	172	1.54 ± 0.18	418	0.99 ± 0.16	369	0.77 ± 0.36	73	xz
Male (a)	1.02 ± 0.11	713	0.73 ± 0.17	197	1.02 ± 0.32	83	1.65 ± 0.24	222	0.69 ± 0.18	176	0.29 ± 0.29	35	xz
Female (b)	1.18 ± 0.13	707	0.92 ± 0.22	191	1.00 ± 0.34	89	1.42 ± 0.27	196	1.25 ± 0.27	193	1.21 ± 0.64	38	
Difference by column													

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean ± SE
3 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 Significant differences by row or column groups are indicated by letter. P ≤ 0.05

Table 5b

Vitamin D Intake (Total, Dietary, and Supplemental) of US Children Aged 13 - 18 Years by Parental PIR and Sex by Race/Ethnicity, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
Parental PIR [2-4]	µg/d	n	µg/d (v)	n	µg/d (w)	n	µg/d (x)	n	µg/d (y)	n	µg/d (z)	n	
Total Vitamin D													
All	4.96 ± 0.20	835	5.19 ± 0.47	178	5.07 ± 0.50	119	5.98 ± 0.39	290	3.36 ± 0.26	218	4.81 ± 0.85	30	vy,wy,xy
Low (a)	4.42 ± 0.27	326	4.40 ± 0.55	65	4.85 ± 0.60	62	4.87 ± 0.56	99	3.44 ± 0.41	90	6.32 ± 2.01	10	vw,yz
Medium (b)	4.98 ± 0.59	100	4.71 ± 0.91	34	8.14 ± 2.22	16	4.57 ± 1.08	25	3.83 ± 0.94	24	1.10 ± 0.00	1	vw,vy,vz,wx,xy,xz
High (c)	5.38 ± 0.32	409	6.05 ± 0.88	79	4.20 ± 0.71	41	6.86 ± 0.56	166	3.18 ± 0.35	104	4.22 ± 0.81	19	
Difference by column													
Dietary Viamin D													
All	4.33 ± 0.17	780	4.90 ± 0.45	167	4.27 ± 0.36	108	4.91 ± 0.31	270	3.16 ± 0.22	205	4.17 ± 0.75	30	vy,xy
Low (a)	4.08 ± 0.24	308	4.44 ± 0.56	62	4.53 ± 0.49	57	4.36 ± 0.54	91	3.13 ± 0.32	88	4.98 ± 1.69	10	
Medium (b)	3.89 ± 0.42	93	4.55 ± 0.70	33	4.69 ± 1.11	15	3.54 ± 0.92	22	2.82 ± 0.73	22	1.10 ± 0.00	1	
High (c)	4.64 ± 0.26	379	5.44 ± 0.87	72	3.68 ± 0.59	36	5.41 ± 0.41	157	3.28 ± 0.35	95	3.90 ± 0.80	19	
Difference by column													
Supplemental Vitamin D													
All	0.91 ± 0.11	835	0.60 ± 0.19	178	1.20 ± 0.34	119	1.41 ± 0.24	290	0.39 ± 0.13	218	0.65 ± 0.48	30	vx,xy
Low (a)	0.57 ± 0.13	326	0.15 ± 0.11	65	0.69 ± 0.32	62	0.86 ± 0.31	99	0.39 ± 0.20	90	1.34 ± 1.34	10	
Medium (b)	1.36 ± 0.40	100	0.29 ± 0.29	34	3.75 ± 1.80	16	1.46 ± 0.69	25	1.25 ± 0.69	24	0.00 ± 0.00	1	
High (c)	1.08 ± 0.18	409	1.09 ± 0.38	79	0.98 ± 0.47	41	1.74 ± 0.37	166	0.19 ± 0.14	104	0.32 ± 0.32	19	
Difference by column													

Table 5b continued.

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	µg/d	n	µg/d (v)	n	µg/d (w)	n	µg/d (x)	n	µg/d (y)	n	µg/d (z)	n	
Sex [2,4]													
Total Vitamin D													
All	4.97 ± 0.19	927	5.31 ± 0.45	202	5.07 ± 0.47	133	6.01 ± 0.38	310	3.33 ± 0.23	249	5.08 ± 0.84	33	xy
Male (a)	5.82 ± 0.30	478	6.28 ± 0.75	102	5.97 ± 0.71	71	7.40 ± 0.59	157	3.46 ± 0.31	129	5.77 ± 1.29	19	vy,xy
Female (b)	4.06 ± 0.22	449	4.32 ± 0.46	100	4.04 ± 0.56	62	4.57 ± 0.44	153	3.19 ± 0.35	120	4.15 ± 0.92	14	
Difference by column	ab		ab		ab		ab				ab		
Dietary Vitamin D													
All	4.35 ± 0.16	867	5.03 ± 0.42	190	4.18 ± 0.33	122	4.90 ± 0.30	288	3.17 ± 0.20	235	4.63 ± 0.78	32	vy,xy
Male (a)	5.20 ± 0.25	448	5.84 ± 0.72	97	4.98 ± 0.45	64	6.11 ± 0.48	148	3.72 ± 0.32	120	5.06 ± 1.15	19	vy,xy
Female (b)	3.43 ± 0.17	419	4.19 ± 0.42	93	3.30 ± 0.46	58	3.62 ± 0.30	140	2.59 ± 0.24	115	4.01 ± 0.93	13	
Difference by column	ab		ab		ab		ab		ab				
Supplemental Vitamin D													
All	0.90 ± 0.11	927	0.57 ± 0.17	202	1.23 ± 0.32	133	1.45 ± 0.24	310	0.34 ± 0.11	249	0.59 ± 0.44	33	xy
Male (a)	0.94 ± 0.16	478	0.73 ± 0.29	102	1.48 ± 0.51	71	1.65 ± 0.38	157	0.00 ± 0.00	129	0.71 ± 0.71	19	
Female (b)	0.86 ± 0.14	449	0.42 ± 0.18	100	0.95 ± 0.36	62	1.26 ± 0.31	153	0.71 ± 0.23	120	0.43 ± 0.43	14	
Difference by column													

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean ± SE
3 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 Significant differences by row or column groups are indicated by letter. P ≤ 0.05

Table 6

Vitamin D Intake (Total, Dietary, and Supplemental) of US Children (6 – 12 Years) versus Adolescents (13 – 18 Years) by Parental PIR, Sex, and Race/Ethnicity by Age Group, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

	Total Population (6-18 Years) **µg/d M ± SE**	**Children (6 - 12 Years)** **µg/d M ± SE**	**Adolescents (13-18 Years)** **µg/d M ± SE**	**Difference by Column**
Total Vitamin D Intake				
All	5.32 ± 0.12	5.55 ± 0.15	4.96 ± 0.20	
Income				
Low	5.15 ± 0.16	5.56 ± 0.21	4.42 ± 0.27	*
Medium	5.12 ± 0.33	5.21 ± 0.38	4.98 ± 0.59	
High	5.54 ± 0.19	5.65 ± 0.24	5.38 ± 0.32	
Race/Ethnicity				
Mexican American	5.30 ± 0.25	5.36 ± 0.29	5.19 ± 0.47	
Other Hispanic	5.90 ± 0.32	6.52 ± 0.41	5.07 ± 0.50	*
Non-Hispanic White	6.11 ± 0.23	6.22 ± 0.28	5.98 ± 0.39	
Non-Hispanic Black	4.22 ± 0.19	4.76 ± 0.26	3.36 ± 0.26	*
Other Race/Multiracial	4.57 ± 0.47	4.46 ± 0.57	4.81 ± 0.85	
Sex				
Male	5.75 ± 0.17	5.71 ± 0.20	5.82 ± 0.30	
Female	4.84 ± 0.15	5.33 ± 0.20	4.06 ± 0.22	*
Dietary Vitamin D Intake				
All	4.69 ± 0.09	4.93 ± 0.11	4.33 ± 0.17	
Income				
Low	4.74 ± 0.13	5.12 ± 0.16	4.08 ± 0.24	*
Medium	4.36 ± 0.24	4.65 ± 0.28	3.89 ± 0.42	*
High	4.74 ± 0.15	4.82 ± 0.17	4.64 ± 0.26	
Race/Ethnicity				
Mexican American	5.04 ± 0.22	5.11 ± 0.23	4.90 ± 0.17	
Other Hispanic	5.17 ± 0.23	5.82 ± 0.30	4.27 ± 0.36	*
Non-Hispanic White	5.06 ± 0.17	5.18 ± 0.19	4.91 ± 0.31	
Non-Hispanic Black	3.81 ± 0.15	4.24 ± 0.20	3.16 ± 0.22	*
Other Race/Multiracial	3.99 ± 0.33	3.90 ± 0.34	4.17 ± 0.75	

Table 6 continued.

	Total Population (6-18 Years) µg/d M ± SE	Children (6 - 12 Years) µg/d M ± SE	Adolescents (13-18 Years) µg/d M ± SE	Difference by Column
Dietary Vitamin D Intake				
Sex				
Male	5.27 ± 0.14	5.32 ± 0.16	5.20 ± 0.25	
Female	4.13 ± 0.11	4.60 ± 0.14	3.43 ± 0.17	*
Supplemental Vitamin D Intake				
All	1.03 ± 0.07	5.55 ± 0.15	4.96 ± 0.20	
Income				
Low	0.74 ± 0.09	0.83 ± 0.12	0.57 ± 0.13	
Medium	1.09 ± 0.20	0.92 ± 0.22	1.36 ± 0.40	*
High	1.30 ± 0.12	1.45 ± 0.15	1.08 ± 0.18	
Race/Ethnicity				
Mexican American	5.30 ± 0.25	5.36 ± 0.29	5.19 ± 0.47	
Other Hispanic	5.90 ± 0.32	6.52 ± 0.41	5.07 ± 0.50	*
Non-Hispanic White	6.11 ± 0.23	6.22 ± 0.28	5.98 ± 0.39	
Non-Hispanic Black	4.22 ± 0.19	4.76 ± 0.26	3.36 ± 0.26	*
Other Race/Multiracial	4.57 ± 0.47	4.46 ± 0.57	4.81 ± 0.85	
Sex				
Male	0.99 ± 0.09	1.02 ± 0.11	0.94 ± 0.16	
Female	1.05 ± 0.10	1.18 ± 0.13	0.86 ± 0.14	

1 Values are expressed as mean (M) ± standard error (SE)
2 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
3 Significant differences of children versus adolescents are indicated by P ≤ 0.05

Estimates of Calcium Intake by Parental PIR

Mean intakes of calcium (total, dietary, and supplemental) were categorized by parental PIR in children and adolescents 6 - 18 years (Table 6). Although there were no significant differences by parental PIR, total and dietary calcium intakes were lower in the medium than the high and low parental PIR groups. Supplemental calcium intake was significantly higher in the high parental PIR group ($p < 0.001$) than the low parental PIR group. Supplemental intake was highest in the high parental PIR, although the difference was not significant.

For children 6 - 12 years (Table 6a), even though there were no significant differences in total and dietary calcium intakes by parental PIR, differences were noted. Total calcium intake was lowest in the high parental PIR group, and dietary calcium intake was highest in the high parental PIR group. Supplemental calcium intake was significantly higher in the high parental PIR group ($p = 0.003$) than in the low parental PIR group.

For adolescents 13 - 18 years (Table 6b), total and dietary calcium intakes were highest in the high income group, although the differences were not significant. The high parental PIR group had a significantly higher supplemental calcium intake ($p = 0.001$) than the low parental PIR group.

Estimates of Calcium Intake by Race/Ethnicity

Mean intakes of calcium (total, dietary, and supplemental) were categorized by race/ethnicity in children and adolescents 6 to 18 years (Table 7). When total calcium intake was compared for all groups, NH Blacks had a significantly lower total calcium

intake than Mexican Americans ($p = 0.023$), Other Hispanics ($p < 0.001$), and NH Whites ($p < 0.001$). NH Blacks also had a significantly lower dietary calcium intake than Mexican Americans ($p < 0.001$), Other Hispanics ($p < 0.001$), and NH Whites ($p < 0.001$). NH Whites had a significantly higher supplemental calcium intake than Mexican Americans ($p = 0.008$) and NH Blacks ($p = 0.016$).

For children 6 - 12 years (Table 7a), NH Blacks had a significantly lower total calcium intake than Other Hispanics ($p < 0.001$) and NH Whites ($p = 0.023$). Other Race-including Multiracial also had a significantly lower total calcium intake than Other Hispanics ($p = 0.002$) and NH Whites ($p = 0.047$). Other Hispanics had a significantly higher dietary calcium intake than Mexican Americans ($p = 0.021$), NH Blacks ($p < 0.001$), and Other Race-including Multiracial ($p = 0.001$). NH Whites had a significantly higher dietary calcium intake than NH Blacks ($p = 0.002$) and Other Race-including Multiracial ($p = 0.012$).

For adolescents 13 - 18 years (Table 7b), total calcium intake was significantly lower in NH Blacks than in Mexican Americans ($p = 0.001$) and NH Whites ($p < 0.001$). Also, NH Blacks had a significantly lower dietary calcium intake than Mexican Americans ($p < 0.001$) and NH Whites ($p < 0.001$). NH Blacks had a significantly lower ($p = 0.012$) supplemental calcium intake than NH Whites. Although not significant, supplemental calcium was higher in NH Whites than in Mexican Americans and Other Hispanics. No supplemental calcium intake was reported in the Other Race-including Multiracial group.

Estimates of Calcium Intake by Parental PIR and Race/Ethnicity

When calcium intake was compared for all participants 6 - 18 years by parental PIR category across race/ethnicity (Table 7), NH Blacks had the lowest total calcium intake compared to Mexican Americans, Other Hispanics, NH Whites and Other Race-including Multiracial based on parental PIR. NH Whites reported the highest intake of total calcium intake for the high income category, and Other Hispanics reported the greatest total intake in the low and medium income categories. Other Race-including Multiracial had the lowest total calcium intake for low parental PIR, and NH Blacks reported the lowest total calcium intake for medium and high parental PIR categories. A majority of the reported calcium intake came from dietary intake and not supplemental intake. NH Blacks had the lowest dietary intake for all parental PIR categories. For dietary calcium intake in the low parental PIR category, Other Hispanics consumed the highest intake, and NH Whites had the highest dietary calcium intakes in the medium and high parental PIR categories. Supplemental calcium intake was low in all participants 6 - 18 years. For low and medium parental PIR categories, no supplemental calcium intake was reported for the Other Race-including Multiracial group. Mexican Americans had the lowest supplemental calcium intake in the low and medium parental PIR categories, and Other Race-including Multiracial had the lowest supplemental calcium intake in the high parental PIR category. NH Whites supplemental calcium intake was greatest in the low and high parental PIR categories, and Other Hispanics reported the greatest supplemental calcium intake in the medium parental PIR group.

For 6 - 12 years (Table 7a), Other Race-including Multiracial had the lowest total calcium intake compared to Mexican Americans, Other Hispanics, NH Whites, and NH Blacks. NH Whites had the highest total and dietary calcium intake in the medium parental PIR category, and Other Hispanics had the highest total and dietary calcium intakes in the low and high parental PIR categories. Other Race-including Multiracial had the lowest total and dietary calcium intakes in the low and high parental PIR categories. NH Blacks had the lowest total and dietary intakes in the medium parental PIR category. Overall, reported supplemental calcium intake was low, so the majority of the calcium intake came from dietary sources. There was no reported supplemental intake by the Other Race-including Multiracial group for low and medium parental PIR. Mexican Americans had the lowest reported supplemental intake in the low and high parental PIR categories, and NH Blacks had the lowest supplemental intake in the medium parental PIR category. For supplemental calcium intake, NH Blacks had the highest intake in the low parental PIR category, NH Whites had the highest intake in the medium parental PIR category, and Other Hispanics had the highest intake in the high parental PIR category.

For adolescents 13 - 18 years (Table 7b), NH Blacks had the lowest total calcium intake compared to Mexican Americans, Other Hispanics, NH Whites, and Other Race-including Multiracial. Other Race-including Multiracial had the highest total calcium intake in the low parental PIR category. Mexican Americans had the highest dietary calcium intake in the low parental PIR category. Other Hispanics had the highest total and dietary calcium intakes in the medium parental PIR category, and NH Whites had the highest total and dietary calcium intakes in the high parental PIR category. NH Blacks

had the lowest total calcium intake in the low and high parental PIR categories, whereas Other Race-including Multiracial had the lowest total calcium intake in the medium parental PIR category. NH Blacks had the lowest dietary calcium intake in all parental PIR categories. Supplemental calcium intake for all parental PIR categories was low. There was no report of supplemental intake for Other Race-including Multiracial for all parental PIR groups. The majority of the reported supplemental intake was in the high parental PIR group. Mexican Americans had the lowest reported supplemental calcium intake in the low and medium parental PIR categories, and NH Blacks had the lowest intake in the high parental PIR category. NH Whites had the highest supplemental intake for low and high parental PIR, and Other Hispanics reported the highest intake in the medium parental PIR category.

Estimates of Calcium Intake by Sex

Mean intakes of calcium (total, dietary, and supplemental) were categorized by gender in children and adolescents 6 - 18 years (Table 7). Males had a significantly higher intake of total ($p < 0.001$) and dietary ($p < 0.001$) calcium than females. Although differences were seen in supplemental calcium intake, no significant differences were noted.

For children 6 - 12 years (Table 7a), although not significant, total and dietary calcium intakes were higher in males than females. No significant differences in supplemental calcium intake were seen between males and females.

For children 13 - 18 years (Table 7b), males had significantly higher total ($p < 0.001$) and dietary ($p < 0.001$) calcium intakes than females. No significant differences in supplemental calcium intake were seen between males and females.

Estimates of Calcium Intake by Sex and Race/Ethnicity

When calcium intake was compared for all participants 6 - 18 years by gender category across race/ethnicity (Table 7), males had a greater total and dietary calcium intakes than females in all race/ethnic groups with the exception of the Other Race - Multiracial group where females reported a higher intake. Males had a greater supplemental calcium intake in Mexican Americans, Other Hispanics, and NH Whites; whereas, females had a greater supplemental intake in NH Blacks and Other Race - including Multiracial.

For children 6 - 12 years (Table 7a), males had a higher total calcium intake in Other Hispanics, NH Whites, and NH Black, and females reported higher total calcium intake in the Mexican American and Other Race - including Multiracial groups. For dietary intake, males reported a higher intake in all race/ethnic groups except in the Other Race - including Multiracial in which females had the greater dietary intake than males. Males had a higher supplemental intake than females in the Mexican American, Other Hispanic, and NH White groups, whereas females had a greater intake in NH Blacks and Other Race - including Multiracial.

For adolescents 13 - 18 years (Table 7b), males had a greater total and dietary calcium intake than females in all of the race/ethnic groups; whereas, Other Race - including Multiracial females had the greater intake. No supplemental calcium intake was

reported for both males and females in the Other Race - including Multiracial group. For the other groups, males had a higher supplemental intake in the Mexican American, Other Hispanic, and NH White groups. NH Black females reported a higher supplemental calcium intake than NH Black males.

Estimates of Calcium Intake by Age Group

Mean intakes of total (dietary and supplemental), dietary, and supplemental calcium for children (6 - 12 years) and adolescents (13 - 18 years) during 2007-2008 were categorized by age group and compared by parental PIR, race/ethnicity, and sex (Table 8). Overall, adolescents (13 - 18 years) had higher intakes of calcium than children (6 - 12 years), although not significant. Adolescents (13 - 18 years) had significantly higher total ($p = 0.005$) and dietary ($p = 0.004$) calcium intakes than children (6 - 12 years) in the high parental PIR category.

For total calcium intake, Other Race-including Multiracial ($p = 0.009$) and Mexican American ($p = 0.009$) adolescents had a significantly higher intake than children. For dietary intake, Mexican American ($p = 0.008$) and Other Race - including Multiracial ($p = 0.008$) adolescents also had significantly higher dietary calcium intakes than children. NH Black children had a significantly ($p = 0.008$) higher dietary intake than adolescents.

Adolescent (13 - 18 years) males had significantly higher total ($p = 0.005$), dietary ($p = 0.004$), and supplemental ($p < 0.001$) calcium intake than children (6 - 12 years). Adolescent females had a significantly ($p < 0.001$) higher supplemental calcium intake than children.

Table 7

Calcium Intake (Total, Dietary, and Supplemental) of US Children and Adolescents Aged 6 – 18 Years by Parental PIR and Sex by Race/Ethnicity, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	mg/d	n	mg/d (v)	n	mg/d (w)	n	mg/d (x)	n	mg/d (y)	n	mg/d (z)	n	
Parental PIR [2-4]													
Total Calcium													
All	869.6 ± 13.2	2149	871.4 + 27.1	527	937.6 ± 39.9	278	948.4 ± 26.4	684	754.5 ± 21.2	565	778.5 ± 53.7	95	vy,wy,xy
Low (a)	860.8 ± 18.7	904	891.4 ± 34.7	257	927.5 ± 46.5	142	922.5 ± 39.9	240	745.2 ± 33.0	233	699.3 ± 82.1	32	vy,wy,xy,vz,wz,yz
Medium (b)	839.1 ± 37.2	267	816.7 ± 62.5	89	1001.6 ± 87.0	39	960.0 ± 93.6	63	678.1 ± 57.7	74	817.0 ± 34.7	2	vy,wy,xy,yz
High (c)	886.1 ± 21.1	978	869.8 ± 53.7	181	926.6 ± 65.9	97	962.7 ± 37.1	381	784.9 ± 31.6	258	818.7 ± 71.2	61	wy,xy
Difference by column									ab,bc		ab,ac		
Dietary Calcium													
All	933.8 ± 12.8	1964	956.9 ± 26.2	474	993.8 ± 33.4	257	1008.2 ± 25.6	627	813.1 ± 20.2	516	815.1 ± 53.1	90	vy,wy,xy
Low (a)	916.4 ± 18.2	842	966.9 ± 33.2	236	981.9 ± 44.5	133	969.1 ± 39.4	226	793.7 ± 31.8	216	721.9 ± 81.5	31	vy,wy,xy,vz, wz,xz
Medium (b)	892.0 ± 36.5	247	875.7 ± 60.6	82	1003.5 ± 85.2	38	1024.1 ± 93.2	58	736.7 ± 56.9	67	817.0 ± 34.7	2	wy,xy,wz,xz
High (c)	962.4 ± 20.3	875	984.5 ± 52.9	156	1008.1 ± 62.4	86	1031.2 ± 35.8	343	853.0 ± 29.3	233	865.7 ± 70.3	57	wy,xy,wz,xz
Difference by column			bc						bc		ac		
Supplemental Calcium													
All	16.2 ± 1.7	2149	10.70 ± 2.3	527	18.8 ± 5.1	278	24.2 ± 3.9	684	12.0 ± 2.5	565	6.3 ± 4.4	95	vx,xy,wz,xz
Low (a)	7.3 ± 1.2	904	3.51 ± 1.50	257	7.8 ± 2.9	142	9.9 ± 2.6	240	9.3 ± 3.2	233	0.00 ± 0.00	32	vw,vx,vy
Medium (b)	13.9 ± 3.1	267	9.9 ± 3.8	89	23.8 ± 12.0	39	17.2 ± 7.7	63	11.2 ± 4.6	74	0.00 ± 0.00	2	vw,wy
High (c)	25.1 ± 3.4	978	21.3 ± 6.0	181	32.8 ± 13.1	97	34.4 ± 6.7	381	14.6 ± 4.5	258	9.8 ± 6.9	61	wy,xy,wz,xz
Difference by column	ac		ac,bc		ab,ac		ac,bc						

Table 7 continued.

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	mg/d	n	mg/d (v)	n	mg/d (w)	n	mg/d (x)	n	mg/d (y)	n	mg/d (z)	n	
Sex [2,4]													
Total Calcium													
All	866.4 ± 12.7	2347	953.3 ± 24.5	528	941.3 ± 35.5	305	944.2 ± 25.7	728	755.6 ± 20.3	618	778.5 ± 52.5	106	vy,wy,xy
Male (a)	929.1 ± 19.5	1191	1012.8 ± 39.5	265	1032.5 ± 46.3	154	1056.4 ± 40.5	379	773.2 ± 29.2	305	730.6 ± 64.6	54	
Female (b)	801.7 ± 16.1	1156	893.3 ± 28.6	263	848.3 ± 53.1	151	822.3 ± 29.5	349	738.5 ± 28.2	313	828.3 ± 83.3	52	
Difference by column	ab		ab		ab,ac		ab						
Dietary Calcium													
All	935.4 ± 12.3	2134	953.3 ± 24.5	528	1001.2 ± 34.3	281	1013.0 ± 25.1	661	811.3 ± 19.4	567	844.6 ± 51.5	97	vy,wy,xy,xz
Male (a)	1011.0 ± 18.9	1076	1012.8 ± 39.5	265	1087.1 ± 42.6	143	1139.9 ± 39.6	342	850.6 ± 28.0	276	787.0 ± 62.4	50	
Female (b)	858.6 ± 15.4	1058	893.3 ± 28.6	263	912.2 ± 53.4	138	876.9 ± 27.9	319	774.1 ± 26.6	291	905.8 ± 82.8	47	
Difference by column	ab		ab		Ab		ab				ab		
Supplemental Calcium													
All	15.8 ± 1.6	2347	10.2 ± 2.1	590	18.8 ± 4.9	305	24.4 ± 3.8	728	11.3 ± 2.3	618	5.7 ± 4.0	106	vx,xy
Male (a)	15.7 ± 2.3	1191	11.6 ± 3.1	299	23.0 ± 8.3	154	27.7 ± 5.9	379	3.5 ± 1.1	305	1.9 ± 1.9	54	
Female (b)	15.9 ± 2.1	1156	8.8 ± 2.8	291	14.6 ± 5.0	151	20.8 ± 4.6	349	18.8 ± 4.4	313	9.6 ± 7.9	52	
Difference by column									ab		ab		

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean ± SE
3 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 Significant differences by row or column groups are indicated by letter. P ≤ 0.05

Table 7a

Calcium Intake (Total, Dietary, and Supplemental) of US Children Aged 6 – 12 Years by Parental PIR and Sex by Race/Ethnicity, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
Parental PIR [2-4]	mg/d	n	mg/d (v)	n	mg/d (w)	n	mg/d (x)	n	mg/d (y)	n	mg/d (z)	n	
Total Calcium													
All	840.9 ± 15.4	1314	805.5 ± 29.3	349	984.3 + 45.0	159	902.7 ± 30.4	394	768.9 ± 27.2	347	689.2 ± 51.3	65	xy,xz,wy.wz
Low (a)	856.5 ± 22.3	578	855.1 ± 38.9	192	969.4 + 60.1	80	942.5 ± 47.3	141	757.3 ± 41.8	143	551.0 ± 62.6	22	wy,xy,wz,xz
Medium (b)	854.1 ± 49.9	167	729.3 ± 84.4	55	1024.7 + 85.4	23	1151.8 ± 136.4	38	680.5 ± 68.7	50	1164.0 ± 0.0	1	wy,xy,vx,vz
High (c)	821.2 ± 23.1	569	753.4 ± 50.8	102	989.0 + 88.9	56	832.6 ± 38.8	215	808.4 ± 42.0	154	750.2 ± 69.7	42	vw,wz
Difference by column							bc		bc				
Dietary Calcium													
All	921.6 ± 14.6	1184	907.8 ± 27.7	307	1037.7 ± 42.9	149	982.5 ± 29.2	357	845.6 ± 25.6	311	736.6 ± 48.5	60	wy,wz,xz,xy
Low (a)	920.8 ± 21.3	534	938.8 ± 36.8	174	1013.1 ± 57.4	76	977.4 ± 46.2	135	838.1 ± 39.6	128	577.3 ± 59.6	21	vz,wz,xz,yz
Medium (b)	915.0 ± 49.1	154	805.3 ± 83.3	49	1014.7 ± 86.0	23	1198.3 ± 34.4	36	751.3 ± 67.2	45	1164.0 ± 0.00	1	wy,xy
High (c)	924.6 ± 21.5	496	903.1 ± 27.7	84	1085.7 ± 85.6	50	944.3 ± 36.2	186	883.2 ± 38.7	138	813.4 ± 64.7	38	wz
Difference by column							ab,bc				ac		
Supplement Calcium													
All	10.4 ± 1.3	1314	7.0 ± 1.6	349	11.9 ± 4.6	159	12.5 ± 2.5	394	11.1 ± 2.7	347	9.2 ± 6.5	65	
Low (a)	5.8 ± 1.1	578	4.3 ± 2.0	192	7.0 ± 3.8	80	6.7 ± 2.2	141	7.1 ± 2.2	143	0.00 + 0.0	22	vw vy
Medium (b)	10.3 ± 3.2	167	11.87 ± 4.6	55	10.0 ± 6.9	23	16.6 ± 11.2	38	4.3 ± 3.0	50	0.00 + 0.0	1	vy.wy.xy
High (c)	15.2 ± 2.6	569	9.7 ± 3.4	102	19.6 ± 11.5	56	15.7 ± 3.8	215	17.0 ± 5.7	154	14.3 ± 10.0	42	vw
Difference by column	ac		ab,ac		ac		ab,ac		ac,bc				

Table 7a continued.

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	mg/d	n	mg/d (v)	n	mg/d (w)	n	mg/d (x)	n	mg/d (y)	n	mg/d (z)	n	
Sex [2,4]													
Total Calcium													
All	832.8 ± 15.0	1420	794.1 ± 27.6	388	984.1 ± 45.6	172	889.4 ± 30.1	418	767.4 ± 26.3	369	688.8 ± 51.5	73	vw,wy,wz,xz
Male (a)	862.5 ± 22.3	713	790.6 ± 41.3	197	1105.0 ± 58.3	83	938.6 ± 45.0	222	777.3 ± 39.5	176	638.5 ± 72.1	35	vw,wy,wz,xy,xz
Female (b)	802.9 ± 19.8	707	797.8 ± 36.7	191	871.4 ± 67.5	89	833.7 ± 38.8	196	758.5 ± 35.2	193	735.2 ± 73.4	38	
Difference by column					ab								
Dietary Calcium													
All	922.2 ± 14.3	1267	903.8 ± 26.0	338	1052.7 ± 43.2	159	983.2 ± 37.6	373	840.8 ± 24.8	332	764.4 ± 48.1	65	wz,xz
Male (a)	967.7 ± 21.3	628	918.9 ± 39.5	168	1145.6 ± 54.6	79	1055.2 ± 43.2	194	870.9 ± 37.6	156	717.7 ± 67.5	31	wy,wz,xy,xz
Female (b)	877.5 ± 18.9	639	888.8 ± 34.0	170	960.9 ± 66.4	80	905.2 ± 37.2	179	814.1 ± 32.8	176	807.0 ± 68.5	34	
Difference by column					ab								
Supplemental Calcium													
All	10.0 ± 1.2	1420	6.8 ± 1.5	388	11.0 + 4.3	172	12.1 ± 2.3	418	11.0 ± 2.6	369	8.2 ± 5.8	73	vw.vx.vy
Male (a)	10.2 ± 1.7	713	7.0 ± 2.0	197	14.6 ± 7.9	83	16.5 ± 4.0	222	5.3 ± 1.7	176	2.9 ± 2.9	35	vw,vx,vz,wy,wz,xy,xz
Female (b)	9.8 ± 1.7	707	6.7 ± 2.3	191	7.7 ± 3.7	89	7.1 ± 2.0	196	16.1 ± 4.6	193	13.2 ± 10.8	38	vy,wy,xy
Difference by column					ab		ab		ab		ab		

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean ± SE
3 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 Significant differences by row or column groups are indicated by letter. P ≤ 0.05

Table 7b

Calcium Intake (Total, Dietary, and Supplemental) of US Adolescents Aged 13 – 18 Years by Parental PIR and Sex by Race/Ethnicity, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	mg/d	n	mg/d (v)	n	mg/d (w)	n	mg/d (x)	n	mg/d (y)	n	mg/d (z)	n	
Parental PIR [2-4]													
Total Calcium													
All	914.8 ± 23.9	835	1000.4 ± 0.55	178	875.1 ± 55.5	119	1010.4 ± 46.3	290	731.7 ± 33.9	218	971.9 ± 123.1	30	vy,xy
Low (a)	868.5 ± 33.6	326	998.6 ± 73.8	65	873.3 ± 72.8	62	894.0 ± 69.6	99	725.9 ± 54.1	90	1025.6 ± 192.3	10	vy,yz
Medium (b)	814.1 ± 54.1	100	958.0 ± 86.1	34	968.4 ± 176.8	16	668.5 ± 87.1	25	673.3 ± 107.9	24	470.0 ± 0.00	1	vx,vy,wx,wy
High (c)	976.3 ± 38.4	409	1020.1 ± 102.1	79	841.3 ± 97.5	41	1131.3 ± 66.6	166	750.1 ± 47.6	104	970.1 ± 167.3	19	vy,wx,xy
Difference by column							ab,bc						
Dietary Calcium													
All	952.3 ± 23.3	780	1047.2 ± 53.6	167	933.3 ± 52.7	108	1042.2 ± 45.3	270	763.8 ± 32.5	205	971.9 ± 123.1	30	vy,xy
Low (a)	908.8 ± 33.2	308	1045.5 ± 72.0	62	940.3 ± 70.2	57	956.8 ± 70.1	91	729.2 ± 52.1	88	1025.6 ± 192.3	10	vy,yz
Medium (b)	854.0 ± 53.0	93	980.2 ± 84.1	33	986.3 ± 175.3	15	739.0 ± 81.8	22	706.7 ± 107.3	22	470.0 ± 0.00	1	
High (c)	1011.8 ± 37.2	379	1079.4 ± 101.2	72	900.3 ± 88.4	36	1134.1 ± 64.5	157	809.1 ± 44.6	95	970.1 ± 167.3	19	xy
Difference by column	bc						bc						
Supplemental Calcium													
All	25.2 ± 3.8	835	17.9 ± 6.0	178	28.0 ± 10.2	119	40.1 ± 8.5	290	13.4 ± 4.8	218	0.00 ± 0.00	30	xy
Low (a)	9.9 ± 2.8	326	1.3 ± 1.3	65	8.9 ± 4.2	62	14.5 ± 5.4	99	12.9 ± 7.5	90	0.00 ± 0.00	10	vx,vz
Medium (b)	19.9 ± 6.2	100	6.6 ± 6.6	34	43.8 ± 27.3	16	18.2 ± 9.5	25	25.5 ± 12.2	24	0.00 ± 0.00	1	vw,vx,vy, wx,wy
High (c)	38.7 ± 7.2	409	36.4 ± 13.0	79	50.8 ± 26.6	41	58.7 ± 14.3	166	11.1 ± 7.2	104	0.00 ± 0.00	19	vw,vx,wy,xy
Difference by column	ac		ac		ac		ac						

Table 7b continued.

	Total Population [1]		Mexican American		Other Hispanic		Non-Hispanic White		Non-Hispanic Black		Other Race/Multiracial		Difference by row
	mg/d	n	mg/d (v)	n	mg/d (w)	n	mg/d (x)	n	mg/d (y)	n	mg/d (z)	n	
Sex [2,4]													
Total Calcium													
All	917.7 ± 22.6	927	996.2 ± 50.7	202	885.8 ± 56.1	133	1018.1 ± 44.5	310	738.2 ± 31.9	249	977.0 ± 118.4	33	xy
Male (a)	1028.3 ± 35.0	478	1138.3 ± 83.6	102	947.6 ± 72.9	71	1223.0 ± 72.4	157	767.8 ± 43.3	129	900.3 ± 120.0	19	vy,vz,wx, xy,xz
Female (b)	799.9 ± 27.2	449	851.3 ± 53.6	100	815.1 ± 86.3	62	807.8 ± 45.6	153	706.4 ± 47.0	120	1081.2 ± 229.7	14	yz
Difference by column	ab		ab				ab						
Dietary Calcium													
All	954.8 ± 22.1	867	1041.3 ± 49.5	190	934.1 ± 54.7	122	1051.6 ± 43.6	288	769.7 ± 30.8	235	1007.6 ± 118.0	32	vy,xy,yz
Male (a)	1071.7 ± 34.2	448	1175.4 ± 81.2	97	1014.8 ± 66.5	64	1251.0 ± 71.2	148	824.1 ± 42.1	120	900.3 ± 120.0	19	vy,xy,xz
Female (b)	829.8 ± 26.3	419	901.5 ± 51.8	93	845.1 ± 87.8	58	840.8 ± 42.3	140	713.0 ± 44.5	115	1164.4 ± 231.3	13	wz,xz,yz
Difference by column	ab		ab				ab				ab		
Supplemental Calcium													
All	24.7 ± 3.5	927	16.7 ± 5.4	202	28.9 ± 9.7	133	41.1 ± 8.2	310	11.7 ± 4.2	249	0.00 ± 0.00	33	vx
Male (a)	23.9 ± 5.2	478	20.6 ± 8.3	102	32.9 ± 15.5	71	43.7 ± 13.0	157	1.2 ± 1.2	129	0.00 ± 0.00	19	vy,wy,xy
Female (b)	25.5 ± 4.7	449	12.9 ± 6.9	100	24.5 ± 10.8	62	38.4 ± 10.0	153	23.1 ± 8.6	120	0.00 ± 0.00	14	vx
Difference by column			ab						ab				

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean ± SE
3 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 Significant differences by row or column groups are indicated by letter. P ≤ 0.05

Table 8

Calcium Intake (Total, Dietary, and Supplemental) of US Children (6 – 12 Years) versus Adolescents (13 - 18 Years) by Parental PIR, Sex, and Race/Ethnicity by Age Group, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

	Total Population (6-18 Years) **µg/d M ± SE**	**Children (6 - 12 Years)** **µg/d M ± SE**	**Adolescents (13-18 Years)** **µg/d M ± SE**	**Difference by Column**
Total Calcium Intake				
All	869.6 + 13.2	840.9 ± 15.4	914.8 ± 23.9	
Income				
Low	860.8 ± 18.7	856.5 ± 22.3	868.5 ± 33.6	
Medium	839.1 ± 37.2	854.1 ± 49.9	814.1 ± 54.1	
High	886.1 ± 21.1	821.2 ± 23.1	976.3 ± 38.4	*
Race/Ethnicity				
Mexican American	871.4 + 27.1	805.5 ± 29.3	1000.4 ± 0.55	*
Other Hispanic	937.6 ± 39.9	984.3 ± 45.0	875.1 ± 55.5	
Non-Hispanic White	948.4 ± 26.4	902.7 ± 30.4	1010.4 ± 46.3	
Non-Hispanic Black	754.5 ± 21.2	768.9 ± 27.2	731.7 ± 33.9	
Other Race/Multiracial	778.5 ± 53.7	689.2 ± 51.3	971.9 ± 123.1	*
Sex				
Male	929.1 ± 19.5	862.5 ± 22.3	1028.3 ± 35.0	*
Female	801.7 ± 16.1	802.9 ± 19.8	799.9 ± 27.2	
Dietary Calcium Intake				
All	933.8 ± 12.8	921.6 ± 14.6	952.3 ± 23.3	
Income				
Low	916.4 ± 18.2	920.8 ± 21.3	908.8 ± 33.2	
Medium	892.0 ± 36.5	915.0 ± 49.1	854.0 ± 53.0	
High	962.4 ± 20.3	924.6 ± 21.5	1011.8 ± 37.2	*
Race/Ethnicity				
Mexican American	956.9 ± 26.2	907.8 ± 27.7	1047.2 ± 53.6	*
Other Hispanic	993.8 ± 33.4	1037.7 ± 42.9	933.3 ± 52.7	
Non-Hispanic White	1008.2 ± 25.6	982.5 ± 29.2	1042.2 ± 45.3	
Non-Hispanic Black	812.1 ± 20.2	845.6 ± 25.6	763.8 ± 32.5	*
Other Race/Multiracial	815.0 ± 53.1	736.6 ± 48.5	971.9 ± 123.1	*

Table 8 continued

	Total Population (6-18 Years) µg/d M ± SE	Children (6 - 12 Years) µg/d M ± SE	Adolescents (13-18 Years) µg/d M ± SE	Difference by Column
Dietary Calcium Intake				
Sex				
Male	1011.0 ± 18.9	967.7 ± 21.3	1071.7 ± 34.2	*
Female	858.6 ± 15.4	877.5 ± 18.9	829.8 ± 26.3	
Supplemental Calcium Intake				
All	16.2 ± 1.7	10.4 ± 1.3	25.2 ± 3.8	*
Income				
Low	7.3 ± 1.2	5.8 ± 1.1	9.9 ± 2.8	*
Medium	13.9 ± 3.1	10.3 ± 3.2	19.9 ± 6.2	*
High	25.1 ± 3.4	15.2 ± 2.6	38.7 ± 7.2	*
Race/Ethnicity				
Mexican American	10.7 ± 2.3	7.0 ± 1.6	17.9 ± 6.0	*
Other Hispanic	18.8 ± 5.1	11.9 ± 4.6	28.0 ± 10.2	*
Non-Hispanic White	24.2 ± 3.9	12.5 ± 2.5	40.1 ± 8.5	*
Non-Hispanic Black	12.0 ± 2.5	11.1 ± 2.7	13.4 ± 4.8	
Other Race/Multiracial	6.3 ± 4.4	9.2 ± 6.5	0	
Sex				
Male	15.7 ± 2.3	10.2 ± 1.7	23.9 ± 5.2	*
Female	15.9 ± 21.1	9.8 ± 1.7	25.5 ± 4.7	*

1 Values are expressed as mean (M) ± standard error (SE)
2 Income categorized by child's family PIR: PIR ≤ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
3 Significant differences of children versus adolescents are indicated by P ≤ 0.05

Percentage Not Meeting the EAR/RDA by Race/Ethnicity, Age, Parental PIR or Sex

A substantial percentage (83.3%) of the US population of children and adolescents in 2007-2008 did not meet the EAR for vitamin D, as well as the RDA (93.7%) (Table 9). The percentage for NH Whites (78.8%) not meeting the EAR for total vitamin D intake was less than Mexican Americans (84.4%), Other Hispanics (80.6%), NH Blacks (88.1%), and Other Race - including Multiracial (87.7%) categories. NH Whites had the lowest percentage for not meeting the RDA (90.9%) for total vitamin D intake compared to Mexican Americans (94.5%), Other Hispanics (92.7%), NH Blacks (96.4%), and Other Race - including Multiracial (95.2%). Mexican Americans had the lowest percentage of children and adolescents (6 -18 years) for not meeting the EAR (79.5%) and RDA (86.9%) for dietary vitamin D intake. NH Blacks had the highest percentage of the participants not meeting the EAR (86.2%) for dietary vitamin D, and Other Hispanics had the highest percentage of the participants for not meeting the RDA (91.1%) for dietary vitamin D. For PIR, the high income group had the lowest percentage of not meeting the EAR (81.0%) and RDA (92.7%) for total vitamin D intake, and the low income group reported the highest percentage of participants not meeting the EAR (85.0%) and RDA (94.5%) for total vitamin D intake. High income category had the lowest percentage of not meeting the EAR (80.8%) and RDA (87.4%) for dietary vitamin D intake. The medium income group had the highest percentage of not meeting the EAR (84.6%), and the low income group had the highest percentage of not meeting the RDA (91.5%) for dietary vitamin D intake in children and adolescents aged 6 - 18 years. Female participants had a greater percentage not meeting the EAR (85.7%) and RDA

(94.6%) for total vitamin D intake and the greatest percentage of not meeting the EAR (93.3%) and RDA (98.7%) for dietary vitamin D intake. (Table 9).

For children 6 - 12 years (Table 9a), NH Whites had the lowest percentage of children not meeting the EAR (79.7%), and Other Hispanics had the lowest percentage of children not meeting the RDA (90.7%) for total vitamin D intake. Other Race - including Multiracial had the highest percentage of children not meeting the EAR (90.4%) and RDA (95.9%) for total vitamin D intake. Other Hispanics had the lowest percentage not meeting the EAR (85.5%) and Mexican Americans had the lowest percentage of children not meeting the RDA (97.9%) for dietary vitamin D intake. Also, females had the highest percentage of children not meeting the EAR (84.4%) and RDA (93.6%) for total vitamin D intake and the highest percentage not meeting the EAR (92.5%) and RDA (98.7%) for dietary vitamin D.

In adolescents 13 - 18 years (Table 9b), NH Blacks had the highest percentage of adolescents not meeting the EAR (92.0%) and RDA (98.8%) for total vitamin D intake, and the highest percentage of adolescents not meeting the EAR (95.3%) and RDA (100%) for dietary vitamin D intake. For PIR, the high income group had the lowest percentage of adolescents not meeting the EAR (81.4%) and RDA (92.9%) for total vitamin D intake, and the lowest percentage for not meeting the EAR (88.7%) for dietary vitamin D intake. Males had the lowest percentage of adolescents not meeting the EAR (79.9%) and RDA (92.3%) for total vitamin D, and the EAR (85.7%) and RDA (96.4%) for dietary vitamin D intake.

The majority of the participants (aged 6 - 18 years) did not meet the EAR (65.1%) and RDA (76.3%) for total calcium intake (Table 10). Other Hispanics had the lowest percentage for not meeting the EAR (59.1%) and RDA (69.5%) for total calcium intake, and the lowest percentage for not meeting the EAR (61.3%) and RDA (70.5%) for dietary calcium intake. Other Race - including Muliracial had the highest percentage for not meeting the EAR (73.6%) and RDA (82.1%) for total calcium intake, and the highest percentage for not meeting the EAR (73.6%) and RDA (82.1%) for dietary calcium intake. The younger age group (6-12 years) had a lower percentage of not meeting the EAR (63.5%) and RDA (74.9%) for total calcium intake and a lower percentage of not meeting the EAR (64.2%) and RDA (75.8%) for dietary calcium intake as well. Medium income had the highest percentage of not meeting the EAR for total (70.1%) and dietary (70.8%) calcium intake. Although the medium income group had the lowest percentage of not meeting the RDA for total (74.9%) and dietary (75.7%) calcium intake, the differences in the percentages between the medium income group and those for the low and high income categories were small. Females had a higher percentage of not meeting the EAR (70.8%) for dietary intake and RDA for total (80.2%) and dietary (81.4%) calcium intake (Table 10).

Table 9

Percentage of US Children and Adolescents Aged 6 – 18 Years Not Meeting the EAR and the RDA for Vitamin D by Race/Ethnicity, Age, Parental PIR, and Sex, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

		% not meeting the EAR	% not meeting the EAR	% not meeting the RDA	% not meeting the RDA
	n [1]	By total intake	By dietary intake	By total intake	By dietary intake
Race/Ethnicity					
All	2347	83.3	90.1	93.7	93.3
Mexican American (a)	590	84.4	79.5	94.5	86.9
Other Hispanic (b)	305	80.6	81.3	92.7	91.1
Non-Hispanic White (c)	728	78.8	80.2	90.9	88.3
Non-Hispanic Black (d)	618	88.1	86.2	96.4	90.7
Other/Multiracial (e)	106	87.7	84.9	95.2	90.5
Difference by column [2]		bd, cd	ad,cd	cd	
Age					
All	2347	83.3	81.9	93.7	89.1
6-12 years (a)	1420	83.1	80.5	93.3	87.7
13-18 years (b)	927	83.7	84.1	94.4	91.1
Difference by column					
Parental PIR					
All	2149	83.2	82.4	93.7	89.5
Low (a)	904	85.0	83.5	94.5	91.5
Medium (b)	267	84.6	84.6	94.3	90.6
High (c)	978	81.0	80.8	92.7	87.4
Difference by column					
Sex					
All	2347	83.3	90.2	93.7	98.0
Male (a)	911	81.0	87.1	92.9	97.3
Female (b)	1436	85.7	93.3	94.6	98.7
Difference by column [2]		ab	ab		

1 Totals may not equal grand total due to missing data
2 Significant difference by column as indicated by letter. $P < 0.05$
3 EAR for Vitamin D = 10 µg/d; RDA for Vitamin D = 15 µg/d

Table 9a

Percentage of US Children Aged 6 – 12 Years Not Meeting the Ear and the RDA for Vitamin D by Race/Ethnicity, Parental PIR, and Sex, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

		% not meeting the EAR	% not meeting the EAR	% not meeting the RDA	% not meeting the RDA
	n [1]	By total intake	By dietary intake	By total intake	By dietary intake
Race/Ethnicity					
All	1420	83.1	90.3	93.3	98.3
Mexican American (a)	388	84.3	89.4	94.8	97.9
Other Hispanic (b)	172	80.2	85.5	90.7	98.7
Non-Hispanic White (c)	418	79.7	89.5	91.1	98.4
Non-Hispanic Black (d)	369	85.6	93.1	94.9	98.2
Other/Multiracial (e)	73	90.4	96.9	95.9	100.0
Difference by column [2]		bd,be,cd,ce	ae,bd,be,ce		
Parental PIR					
All	1314	83.0	90.4	93.3	98.4
Low	578	84.3	89.0	93.6	98.3
Medium	167	86.2	91.6	94.6	98.7
High	569	80.8	91.7	92.6	98.4
Difference by column					
Sex					
All	1420	83.1	90.3	93.3	98.3
Male (a)	713	81.8	88.1	93.0	97.9
Female (b)	707	84.4	92.5	93.6	98.7
Difference by column [2]			ab		

1 Totals may not equal grand total due to missing data
2 Significant difference by column as indicated by letter. $P < 0.05$
3 EAR for Vitamin D = 10 µg/d; RDA for vitamin D = 15 µg/d

Table 9b

Percentage of US Adolescents 13 – 18 Years Not Meeting the EAR and the RDA for Vitamin D by Race/Ethnicity, Parental PIR, and Sex, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

		% not meeting the EAR	% not meeting the EAR	% not meeting the RDA	% not meeting the RDA
	n [1]	By total intake	By dietary intake	By total intake	By dietary intake
Race/Ethnicity					
All	927	83.7	90.0	94.4	97.5
Mexican American (a)	202	84.7	87.9	94.1	95.8
Other Hispanic (b)	133	81.2	91.8	95.5	99.2
Non-Hispanic White (c)	310	77.7	86.8	90.7	95.8
Non-Hispanic Black (d)	249	92.0	95.3	98.8	100.0
Other/Multiacial (e)	33	81.8	84.4	93.9	96.9
Difference by column [2]		ad,bd,cd,de	cd,de	cd	ad,cd
Parental PIR					
All	835	83.5	90.0	94.3	97.4
Low	326	86.5	90.1	96.3	98.4
Medium	100	82.0	91.4	94.0	96.8
High	409	81.4	88.7	92.9	96.8
Difference by column					
Sex					
All	927	83.7	90.0	94.4	97.5
Male (a)	478	79.9	85.7	92.3	96.4
Female (b)	449	87.8	94.5	96.0	98.6
Difference by column [2]		ab	ab	ab	

1 Totals may not equal grand total due to missing data
2 Significant difference by column as indicated by letter. $P < 0.05$
3 EAR for Vitamin D = 10 μg/d; RDA for Vitamin D = 15 μg/d

Table 10

Percentage of US Children and Adolescents Aged 6 – 18 Years Not Meeting the EAR and the RDA for Calcium by Race/Ethnicity, Age, Parental PIR, and Sex, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

		% not meeting the EAR	% not meeting the EAR	% not meeting the RDA	% not meeting the RDA
	n [1]	By total intake	By dietary intake	By total intake	By dietary intake
Race/Ethnicity					
All	2347	65.1	66.4	76.3	77.4
Mexican American (a)	590	64.6	65.6	78.1	78.5
Other Hispanic (b)	305	59.1	61.3	69.5	70.5
Non-Hispanic White (c)	728	60.3	62.1	72.7	74.2
Non-Hispanic Black (d)	618	72.7	73.5	81.2	82.7
Other/Multiracial (e)	106	73.6	73.6	82.1	82.1
Difference by column [2]		ad,bd,cd,ae,be,ce	ad,bd,cd,ae,be,ce	ad,bd,cd,ae,be,ce	bd,cd,be,ce
Age					
All	2347	65.1	66.4	76.3	77.4
6-12 years (a)	1420	63.5	64.2	74.9	75.8
13-18 years (b)	927	67.5	69.7	78.4	79.8
Difference by column					
Parental PIR					
All	2149	65.1	66.3	76.2	77.2
Low (a)	904	64.1	64.6	76.1	76.7
Medium (b)	267	70.1	70.8	74.9	75.7
High (c)	978	64.5	66.7	76.6	78.2
Difference by column					
Sex					
All	2347	65.1	66.4	76.3	77.4
Male (a)	1191	69.3	62.1	72.5	73.5
Female (b)	1156	60.9	70.8	80.2	81.4
Difference by column [2]		ab	ab	ab	ab

1 Totals may not equal grand total due to missing data.
2 Significant difference by column as indicated by letter. $P < 0.05$
3 4-8 years: EAR for Calcium = 800 mg/day; RDA for Calcium = 1000 mg/day; 9-12 years: EAR for Calcium = 1000 mg/day; RDA for Calcium = 1300 mg/day

Table 10a

Percentage of US Children Aged 6 – 12 Years Not Meeting the EAR and the RDA for Calcium by Race/Ethnicity, Parental PIR, and Sex, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

		% not meeting the EAR	% not meeting the EAR	% not meeting the RDA	% not meeting the RDA
	n [1]	By total intake	By dietary intake	By total intake	By dietary intake
Race/Ethnicity					
All	1420	63.5	64.2	74.9	75.8
Mexican American (a)	388	65.7	66.2	78.6	79.1
Other Hispanic (b)	172	53.3	54.1	62.2	62.8
Non-Hispanic White (c)	418	58.4	59.3	72.5	73.2
Non-Hispanic Black (d)	369	68.8	69.4	77.5	79.1
Other/Multiracial (e)	73	79.5	79.5	86.3	86.3
Difference by column [2]		ae,bd,be,cd,ce	ae,bd,be,cd,ce	ab,bc,bd,be,ce	ab,bc,bd,be,ce
Parental PIR					
All	1314	63.0	63.9	74.7	75.4
Low (a)	578	60.0	60.4	73.9	74.6
Medium (b)	167	67.7	67.7	71.3	71.9
High (c)	569	64.7	66.3	76.4	77.3
Difference by column					
Sex					
All	1420	63.4	64.2	74.9	75.8
Male (a)	713	61.4	62.4	72.5	73.5
Female (b)	707	65.5	66.0	77.4	78.1
Difference by column [2]				ab	ab

1 Totals may not equal grand total due to missing data.

2 Significant difference by column as indicated by letter. $P < 0.05$

3 4-8 years: EAR for Calcium = 800 mg/day; RDA for Calcium = 1000 mg/day; 9-12 years: EAR for Calcium = 1000 mg/day; RDA for Calcium = 1300 mg/day

Table 10b

Percentage of US Adolescents Aged 13 - 18 Years Not Meeting the EAR and the RDA for Calcium by Race/Ethnicity, Parental PIR, and Sex, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

		% not meeting the EAR	% not meeting the EAR	% not meeting the RDA	% not meeting the RDA
	n [1]	By total intake	By dietary intake	By total intake	By dietary intake
Race/Ethnicity					
All	927	67.5	69.7	78.4	79.8
Mexican American (a)	202	62.4	64.4	77.2	77.2
Other Hispanic (b)	133	67.7	70.7	78.9	80.5
Non-Hispanic White (c)	310	62.9	65.8	72.9	75.5
Non-Hispanic Black (d)	249	78.3	79.5	86.7	88.0
Other/Multiracial (e)	33	60.6	60.6	72.7	72.7
Difference by column [2]		ad,bd,cd,de	ad,bd,cd,de	ad,bd,cd,de	ad,bd,cd,de
Parental PIR					
All	835	68.1	70.2	78.6	80.1
Low (a)	326	71.2	72.1	80.1	80.4
Medium (b)	100	74.0	76	81.0	82.0
High (c)	409	64.3	67.2	76.8	79.5
Difference by column					
Sex					
All	927	67.5	69.7	78.4	79.8
Male (a)	478	60.3	61.7	72.6	73.4
Female (b)	449	75.3	78.2	84.6	86.6
Difference by column [2]		ab	ab	ab	ab

1 Totals may not equal grand total due to missing data.
2 Significant difference by column as indicated by letter. $P < 0.05$
3 EAR for Calcium = 1000 mg/day; RDA for Calcium = 1300 mg/day

For children 6 - 12 years (Table 10a), Other Hispanics had the lowest percentage of children not meeting the EAR (53.5%) and RDA (62.2%) for total calcium intake, and EAR (54.1%) and RDA (62.8%) for dietary calcium intake. Other Race including - Multiracial had the highest percentage of not meeting the EAR for total (79.5%) and dietary (79.5%) calcium and RDA for total (86.3%) and dietary (86.3%) calcium intake. The low income group had the lowest percentage of children not meeting the EAR for total (60.0%) and dietary (60.4%) calcium intake; whereas the medium income group had the lowest percentage for not meeting the RDA for total (71.3%) and dietary (71.9%) calcium intake. Male participants had the lowest percentage for not meeting the EAR for total (61.4%) and dietary (62.4%) calcium intake, and the lowest percentage for not meeting the RDA for total (72.5%) and dietary (73.5%) calcium intake.

For adolescents 13 - 18 years (Table 10b), Other Race - including Multiracial had the lowest percentage of adolescents not meeting the EAR for total (60.6%) and dietary (60.6%) calcium intake, and the lowest percentage for not meeting the RDA for total (72.7%) and dietary (72.7%) calcium intake. NH Blacks had the highest percentage for adolescents not meeting the EAR for total (78.3%) and dietary (79.5%) calcium and RDA for total (86.7%) and dietary (88.0%) calcium intake. The high income group had the lowest percentage of not meeting the EAR for total (64.3%) and dietary (67.2%) calcium intake, and RDA for total (76.8%) and dietary (79.5%) calcium intake. The medium income group had the highest percentage of not meeting the EAR for total (74.0%) and dietary (76.0%) calcium and RDA for total (81.0%) and dietary (82.0%) calcium intake.

Females had the highest percentage of not meeting the EAR for total (75.3%) and dietary (78.2%) calcium and RDA for total (84.6%) and dietary (86.6%) calcium intake.

CHAPTER IV

THE ASSOCIATIONS OF VITAMIN D AND CALCIUM INTAKES IN THE UNITED STATES WITH CARDIOVASCULAR RISK FACTORS AND MEASURES OF ADIPOSITY BY SEX, PARENTAL PIR, AND RACE/ETHNICITY IN CHILDREN AND ADOLESCENTS 12 - 18 YEARS

(STUDY II)

Study Design and Population

The sample participants used for this study were US children and adolescents, aged 12 - 18 years who participated in the 2007-2008 NHANES cross-sectional study. The 2007-2008 NHANES data represented a subset of the 29,308,746 children age 12 - 18 years in the US. In order to participate in the study, all participants signed a consent form with their parents.

Data Collection Procedures

The 2007 - 2008 NHANES database was accessed online to retrieve body measurement data, nutrient data, and laboratory data for the study, Body measurement data obtained included BMI category, waist circumference, triceps skinfold, subscapular skinfold, and blood pressure. BMI was calculated as weight (kilogram)/height (m^2) (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008e). Nutrient data included total, dietary, and

supplemental intake of vitamin D and calcium, accessed using the Food and Nutrient Database for Dietary Studies (FNDDS). Nutrient data were obtained from in-person 24-hour dietary recall information and a Dietary Supplement Questionnaire administered during the household interviews. Data on food intake were obtained by an interviewer in English and Spanish recording a 24-hour dietary recall (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008d).

Key study demographic variables retrieved from the NHANES data file included self-reported race/ethnicity, parental PIR, age, and gender for children and adolescents 12 - 18 years. Data on the CVD risk factor data analyzed in this study were collected on adolescents 12 years and older in the 2007-2008 NHANES because several CVD variables were not obtained from younger children during the survey. Race/ethnicity groups were derived from self-reported information collected during the screener and household interviews. Participants were categorized into the following groups: Mexican American, Other Hispanic, NH White, NH Black, and Other Race - including Multiracial (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008b). Participants were classified by income into PIR groups: low = PIR $\leq$ 131% income; median = PIR 131.01 to 185% income; and high = PIR > 185% income. Any participant who did not have completed demographic information was eliminated from the study. A total of 1085 participants, aged 12 - 18 years, from the 2007-2008 NHANES data set, provided complete demographic and in-person 24-hour recalls and were used in this study.

Laboratory data for children 12 - 18 years were obtained and included total cholesterol, HDL-C, LDL-C, triglycerides, fasting glucose, insulin, HgbA1c, CRP, HOMA-IR, and QUICKI (Centers for Disease Control and Prevention's National Health and Nutrition Examination Survey, 2007-2008c). HOMA-IR is a method for assessing β-cell function and insulin resistance (Wallace, Levy, & Matthews, 2004). Fasting plasma glucose and fasting plasma insulin are used to calculate HOMA-IR (Abbasi, Okeke, & Reaven, 2014). QUICKI is a simple insulin sensitivity check index for insulin resistance, which is calculated by 1/log insulin + log glycemia in mg/dL (Hrebicek et al., 2002).

Hypotheses

The purpose of the study was to examine the associations of vitamin D and calcium intake in the United States with cardiovascular risk factors and adiposity measures by, gender, parental PIR, and race/ethnicity in children 12 - 18 years using data from the 2007 – 2008 National Health and Nutrition Examination Survey.

This study was designed to test the following null hypotheses:

1. Vitamin D intake is not inversely associated with known biomarkers of CVD in children and adolescents (12 -18 years of age).
2. Calcium intake is not inversely associated with known biomarkers of CVD in children and adolescents (12 – 18 years of age).
3. Vitamin D intake is not inversely associated with known measures of adiposity in children and adolescents (12 – 18 years of age).

4. Calcium intake is not inversely associated with known measures of adiposity in children and adolescents (12 - 18 years of age).

Data Analysis

Statistical analyses were performed using SPSS (IBM SPSS Statistics 22.0). A value of $P \leq 0.05$ was considered significant. Least-square means and standard error, compared by univariate analysis of variance (ANOVA), were used to evaluate (1) the differences of total vitamin D and calcium intake and PIR, sex, and race/ethnicity categories; (2) ethnicity, gender, and PIR differences in the occurrence of cardiovascular risk factors (total cholesterol, triglycerides, LDL-C, HDL-C, fasting glucose, HgbA1c, insulin, HOMA-IR, QUICKI, CRP, systolic blood pressure, and diastolic blood pressure); and (3) ethnicity, gender, PIR differences in measures of adiposity (BMI, waist circumference, triceps skinfold, and subscapular skinfold). The Bonferroni *post-hoc* test was used find significant differences with multiple comparisons. Multiple linear regression was used to assess the association of vitamin D and calcium intake with cardiovascular risk factors and measures of adiposity.

Results

Biomarkers of Cardiovascular Disease by Sex

Male participants had a significantly higher intake of vitamin D (5.7 µg/d) and calcium (994.6 mg/dL) than females (4.1 µg/day, 782.6 mg/dL, respectively) (Table 11). Males had a significantly lower total cholesterol (154.3 mg/dL) than females (160.8 mg/dL). Females had a significantly higher HDL-C (53.2 mg/dL) than males (49.1

mg/dL). Insulin levels were significantly lower in males (14.3 uU/mL) than in females (17.2 uU/mL). CRP was significantly higher in females (0.2 mg/dL) than in males (0.1 mg/dL). Systolic blood pressure was significantly lower in females (107.5 mmHg) than in males (112.0 mmHg), whereas diastolic blood pressure was significantly lower in males (59.0 mmHg) than in females (61.4mmHg).

Biomarkers of Cardiovascular Disease by Parental PIR

There were no significant differences in total cholesterol, LDL-C, and HDL-C found by income (Table 12). Triglycerides were significantly lower in the high income group (79.4 mg/dL) than in the medium (84.5 mg/dL) and low (92.2 mg/dL) income groups. There were no significant differences in fasting glucose, HgbA1c, insulin, HOMA-IF, QUICKI, CRP, systolic blood pressure, and diastolic blood pressure among the three income categories.

Biomarkers of Cardiovascular Disease by Race/Ethnicity

NH Blacks had a significantly lower intake (3.4 µg/d) of vitamin D than the Mexican American (5.1 µg/d), Other Hispanic (5.1 µg/d), and NH White (6.1 µg/d) groups (Table 13). Furthermore, NH Blacks had a significantly lower intake (728.9 mg/dL) of calcium than the Mexican American (928.8 mg/dL) and NH White (1009.5 mg/dL) groups.

Table 11

Vitamin D Intake, Calcium Intake, and Biomarkers of Cardiovascular Disease by Sex in Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

Variable (Sex)	n [1]	Total	n	Males	n	Females	Difference By Row [3]
		M (SE)		M (SE)		M (SE)	
Intake							
Vitamin D Intake	1085	5.0 (0.2)	563	5.7 (0.3)	522	4.1 (3.7)	*
Calcium Intake	1085	892.6 (20.4)	563	994.6 (31.5)	522	782.6 (24.5)	*
Lipids							
Total Cholesterol (mg/dL)	937	157.4 (1.0)	494	154.3 (1.3)	443	160.8 (1.5)	*
Triglycerides (mg/dL)	414	85.0 (2.4)	235	86.5 (3.3)	179	83.0 (3.5)	
LDL-Cholesterol (mg/dL)	414	87.9 (1.2)	235	86.7 (1.6)	178	89.5 (1.9)	
HDL-Cholesterol (mg/dL)	937	51.0 (0.4)	494	49.1 (0.5)	443	53.2 (0.6)	*
Glucose Homeostasis							
Fasting Glucose (mg/dL)	416	97.9 (1.3)	236	98.4 (1.0)	180	97.1 (2.6)	
Hemoglobin A1c (%)	941	5.2 (0.2)	496	5.3 (0)	445	5.2 (0.5)	
Insulin (uU/mL)	407	15.5 (0.7)	231	14.3 (0.9)	176	17.2 (0.1)	*
HOMA-IR	407	3.8 (0.2)	231	3.5 (0.2)	176	4.1 (0.3)	
QUICKI	407	0.1 (0)	231	0.1 (0)	176	0.1 (0)	
Inflammatory Marker							
C-Reactive Protein (mg/dL)	931	0.2 (0)	486	0.1 (0.1)	445	0.2 (0.3)	*
Blood Pressure							
Systolic	999	109.8 (0.3)	521	112.0 (0.5)	478	107.5 (0.4)	*
Diastolic	999	60.2 (0.4)	521	59.0 (0.5)	478	61.4 (0.5)	*

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean (M) $\pm$ standard error (SE)
3 Significant differences by row groups are indicated by *. $P \leq 0.05$

Table 12

Vitamin D Intake, Calcium Intake, and Biomarkers of Cardiovascular Disease by Parental PIR in Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

Variable (Parental PIR)	n [1]	Total	n	Low (x)	n	Medium (y)	n	High (z)	Difference By Row [3]
		M (SE)		M (SE)		M (SE)		M (SE)	
Intake									
Vitamin D Intake	981	4.9 (0.2)	393	4.5 (0.2)	122	4.7 (0.5)	466	5.3 (0.3)	
Calcium Intake	981	887.5 (21.3)	393	844.9 (29.0)	122	794.41 (50.6)	466	947.8 (35.0)	
Lipids									
Total Cholesterol (mg/dL)	859	157.8 (1.0)	352	157.2 (1.7)	103	156.5 (2.6)	404	158.6 (1.4)	
Triglycerides (mg/dL)	378	85.5 (2.6)	161	92.2 (4.6)	45	84.5 (6.2)	172	79.4 (3.1)	xz, yz
LDL-Cholesterol (mg/dL)	378	87.9 (1.3)	161	85.6 (2.0)	45	89.0 (3.1)	172	89.9 (1.9)	
HDL-Cholesterol (mg/dL)	859	50.9 (0.4)	352	50.4 (0.7)	103	50.4 (1.2)	404	51.5 (0.6)	
Glucose Homeostasis									
Fasting Glucose (mg/dL)	380	98.1 (1.4)	162	101.0 (3.2)	46	98.2 (1.2)	172	95.4 (0.6)	
Hemoglobin A1c (%)	863	5.2 (0)	354	5.3 (0)	104	5.3 (0.1)	405	5.2 (0)	
Insulin (uU/mL)	372	15.0 (0.1)	159	15.6 (1.0)	43	15.2 (1.5)	170	14.3 (0.8)	
HOMA-IR	372	3.6 (0.2)	159	3.8 (0.2)	43	3.8 (0.4)	170	3.4 (0.2)	
QUICKI	372	3.6 (0.2)	159	3.8 (0.2)	43	3.8 (0.4)	170	3.4 (0.2)	

Table 12 continued

Variable	n	Total	n	Low (x)	n	Medium (y)	n	High (z)	Difference By Row
		M (SE)		M (SE)		M (SE)		M (SE)	
Inflammatory Marker									
C-Reactive Protein (mg/dL)	854	0.2 (0)	353	0.2 (0)	100	0.2 (0)	401	0.2 (0)	
Blood Pressure									
Systolic	909	109.8 (0.3)	368	109.4 (0.5)	111	110.8 (0.9)	430	109.9 (0.5)	
Diastolic	909	60.1 (0.4)	368	59.6 (0.6)	111	60.0 (1.1)	430	60.6 (0.5)	

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean (M) $\pm$ standard error (SE)
3 Significant differences by row groups are indicated by a letter. $P \leq 0.05$

Table 13

Vitamin D Intake, Calcium Intake, and Biomarkers of Cardiovascular Disease by Race/Ethnicity in Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

Variable (Race)	n [1]	Total	n	Mexican American (a)	n	Other Hispanic (b)	n	Non-Hispanic White (c)	n	Non-Hispanic Black (d)	n	Other Race/ Multiracial (e)	Difference By Row [3]
		M (SE)		M (SE)		M (SE)		M (SE)		M (SE)		M (SE)	
Intake													
Vitamin D Intake	1085	5.0 (0.2)	253	5.1 (0.4)	146	5.1 (0.4)	350	6.1 (0.4)	291	3.4 (0.2)	45	4.7 (0.7)	ad, bd, cd
Calcium Intake	1085	892.6 (20.4)	253	928.8 (42.8)	146	877.8 (52.1)	350	1009.5 (41.5)	291	728.9 (29.5)	45	886.2 (94.5)	ad,bc,bd,cd
Lipids													
Total Cholesterol (mg/dL)	937	157.4 (4.1)	226	156.2 (1.9)	133	153.6 (2.6)	303	159.0 (1.8)	236	159.0 (2.1)	39	154.7 (4.1)	
Triglycerides (mg/dL)	414	88.0 (2.4)	94	93.1 (5.5)	63	94.9 (7.7)	136	91.0 (3.6)	105	66.2 (4.1)	16	69.7 (6.5)	ad, bd, cd, ae, be, ce
LDL-Cholesterol (mg/dL)	414	87.9 (1.2)	94	88.9 (2.5)	63	83.4 (3.2)	136	90.1 (2.2)	105	88.1 (2.5)	16	80.4 (5.3)	
HDL-Cholesterol (mg/dL)	937	51.0 (0.4)	226	49.4 (0.8)	133	50.3 (1.1)	303	49.5 (0.7)	236	55.1 (0.9)	39	49.5 (1.6)	ad, bd, cd, de
Glucose Homeostasis													
Fasting Glucose (mg/dL)	416	97.9 (1.3)	94	99.4 (1.9)	64	104.2 (6.8)	137	97.5 (1.7)	105	93.1 (0.8)	16	97.6 (1.9)	

Table 13 continued

Variable	n[a]	Total	n	Mexican American (a)	n	Other Hispanic (b)	n	Non-Hispanic White (c)	n	Non-Hispanic Black (d)	n	Other Race/ Multiracial (e)	Difference By Row [3]
		M (SE)		M (SE)		M (SE)		M (SE)		M (SE)		M (SE)	
Glucose Homeostasis													
Hemoglobin A1c (%)	941	5.2 (0)	227	5.2 (0)	135	5.3 (0.1)	303	5.2 (0)	236	5.4 (0.1)	40	5.2 (0)	ad, cd
Insulin (uU/mL)	407	15.5 (0.7)	93	17.6 (1.4)	62	14.7 (1.3)	134	12.9 (0.1)	103	17.6 (1.7)	15	15.6 (3.3)	bc,cd
HOMA-IR	407	3.8 (0.2)	93	4.3 (0.3)	62	3.7 (0.3)	134	3.1 (0.2)	103	4.2 (0.5)	15	3.9 (0.1)	
QUICKI	407	0.1 (0)	93	0.1 (0)	62	0.1 (0)	134	0.2 (0)	103	0.1 (0)	15	0.1 (0)	
Inflammatory Marker													
C-Reactive Protein (mg/dL)	931	0.2 (0)	222	0.2 (0)	133	0.2 (0)	302	0.2 (0)	234	0.2 (0)	40	0.1 (0)	
Blood Pressure													
Systolic	999	109.8 (0.3)	240	109.1 (0.6)	136	109.5 (0.9)	320	110.1 (0.5)	266	110.8 (0.6)	37	106.4 (1.8)	
Diastolic	999	60.2 (0.4)	240	58.9 (0.6)	136	57.9 (1.0)	320	61.4 (0.6)	266	61.2 (0.8)	37	58.9 (1.5)	ac,ad,bc,bd,ce,de

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean (M) $\pm$ standard error (SE)
3 Significant differences by row groups are indicated by a letter. $P \leq 0.05$

Triglycerides were significantly lower in the NH Black (66.2 mg/dL) and Other Race - including Multiracial (69.7 mg/dL) groups than in the Mexican American (93.1 mg/dL), Other Hispanic (94.9 mg/dL), and NH White (91.0 mg/dL) groups. HDL-C was significantly higher in the NH Blacks (55.1 mg/dL) than in the Mexican American (49.4mg/dL), Other Hispanic (50.3 mg/dL), NH White (49.5 mg/dL), and Other Race - including Multiracial (49.5 mg/dL) groups. HbgA1c was significantly higher in the NH Blacks (5.4%) than in NH Whites (5.2%) and Mexican Americans (5.2%). Insulin was significantly lower in NH Whites (12.9 uU/mL) than in NH Blacks (17.6 uU/mL) and Mexican Americans (17.6 uU/mL). Diastolic blood pressure was significantly highest in the NH Whites (61.4 mmHg) and NH Blacks (61.2 mmHg) compared to Mexican Americans (58.9 mmHg), Other Hispanics (57.9 mmHg), and Other Race - including Multiracial (58.9 mmHg).

Measures of Adiposity by Sex

No significant differences in BMI and waist circumference between males and females were found (Table 14). Females had significantly greater triceps skinfold (19.1 mm) and subscapular skinfold (16.5 mm) than males.

Measures of Adiposity by Parental PIR

No significant differences in BMI, waist circumference, triceps skinfold, and subscapular skinfold among the three income groups were found (Table 15). Although not significant, triceps skinfold was lower in the high income group than in the low and medium groups, and subscapular skinfold was highest in the low income group.

Measures of Adiposity by Race/Ethnicity

No significant differences in BMI, waist circumference, and triceps skinfold and race/ethnicity (Table 16). Other Race - including Multiracial had the lowest BMI, lowest waist circumference, and lowest triceps skinfold when compared to the other race/ethnic groups. Mexican Americans had a significantly higher subscapular skinfold than participants in the NH White and Other Race - including Multiracial groups.

Association Between Vitamin D Intake and Cardiovascular Risk Factors

No significant differences were found between vitamin D intake and CVD risk factors in the simple linear model using vitamin D intake as the predictor (Table 17). When adjusted for sex in Model 1, a significant inverse association was found between vitamin D intake and systolic blood pressure ($p < 0.01$), diastolic blood pressure ($p < 0.01$), total cholesterol ($p < 0.01$), HDL-C ($p < 0.01$), insulin ($p = 0.02$), CRP ($p = 0.02$), and QUICKI ($p < 0.01$). In Model 2, which was adjusted for sex + race/ethnicity, a significant inverse relationship was found between vitamin D intake and triglycerides ($p < 0.01$), HDL-C ($p < 0.01$), fasting glucose ($p = 0.03$), insulin ($p = 0.05$), HOMA-IR ($p = 0.02$), and QUICKI ($p < 0.01$). In Model 3, triglycerides ($p = 0.05$) and HgbA1c ($p = 0.01$) were significantly and inversely associated with vitamin D intake.

Association Between Calcium Intake and Cardiovascular Risk Factors

In the simple linear regression model, there was a significant inverse association between calcium intake and triglycerides ($p = 0.01$) and a significant positive association with HDL-C ($p = 0.03$) using calcium intake as the predictor (Table 18). When controlling for gender (Model 1), calcium intake was negatively associated with systolic

blood pressure ($p < 0.01$), and QUICKI ($p < 0.01$), and positively associated with diastolic blood pressure ($p < 0.01$), total cholesterol ($p < 0.01$), HDL-C ($p < 0.01$), CRP ($p = 0.03$), and insulin ($p = 0.02$). Model 2, which was adjusted for gender and race/ethnicity, a negative association ($p < 0.01$) was found between calcium intake and triglycerides, fasting glucose, insulin, and HOMA-IR, and a positive association ($p < 0.01$) between HDL-C and QUICKI. Model 3 controlled for gender, race/ethnicity, and PIR, and showed calcium intake was negatively associated with triglyerides ($p = 0.04$) and HgbA1c ($p < 0.01$).

Association Between Vitamin D and Measures of Adiposity

In simple linear regression and in Model 1 (adjusted for gender), a significant inverse association was found between vitamin D intake and triceps skinfold and subscapular skinfold (Table 19). Model 2 was controlled for gender and race/ethnicity and an association between vitamin D intake and waist circumference ($p = 0.02$), triceps skinfold ($p = 0.04$), and subscapular skinfold ($p = 0.03$) was found. No significant associations were found in Model 3, which was controlled for gender, race/ethnicity, and PIR.

Association Between Calcium and Measures of Adiposity

A significant association was found between calcium intake and BMI ($p = 0.03$), triceps skinfold ($p < 0.01$) and subscapular skinfold ($p < 0.01$) in the simple linear regression model (Table 20). In Model 1 (controlled for gender), a significant association ($p <0.01$) was found between calcium intake triceps skinfold and subscapular skinfold. Model 2 controlled for gender and race/ethnicity and a significant inverse relationship (p

= 0.02) was found between calcium intake and waist circumference, triceps skinfold, and subscapular skinfold. No significant associations were found in Model 3, which was controlled for gender, race/ethnicity, and PIR.

Table 14

Vitamin D Intake, Calcium Intake, and Measures of Adiposity by Sex in Children and Adolescents Aged 12 to 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

	n [1]	Total	n	Males	n	Females	Difference By Row [3]
		M (SE)		M (SE)		M (SE)	
Intake							
Vitamin D Intake	1085	5.0 (0.2)	563	5.7 (0.3)	522	4.1 (3.7)	*
Calcium Intake	1085	892.6 (20.4)	563	994.6 (31.5)	522	782.6 (24.5)	*
Adiposity							
BMI (kg/m^2)	1040	24.0 (0.2)	547	23.9 (0.3)	493	24.0 (0.3)	
Waist Circumference (cm)	1008	81.5 (0.5)	535	81.7 (0.7)	473	81.3 (0.7)	
Triceps Skinfold (mm)	995	16.2 (0.3)	529	13.7 (0.4)	466	19.1 (0.3)	*
Subscapular Skinfold (mm)	954	14.6 (0.3)	512	13.0 (0.3)	442	16.5 (0.3)	*

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean (M) $\pm$ standard error (SE)
3 Significant differences by row groups are indicated by *. $P \leq 0.05$

Table 15

Vitamin D Intake, Calcium Intake, and Measures of Adiposity of Children and Adolescents 12 – 18 Years by Parental PIR, National Health and Nutrition Examination Survey, 2007 – 2008 [1-4]

	n [1]	Total	n	Low (x)	n	Medium (y)	n	High (z)	Difference By Row [4]
		M (SE)		M (SE)		M (SE)		M (SE)	
Intake									
Vitamin D Intake	981	4.9 (0.2)	393	4.5 (0.2)	122	4.7 (0.5)	466	5.3 (0.3)	
Calcium Intake	981	887.5 (21.3)	393	844.9 (29.0)	122	794.41 (50.6)	466	947.8 (35.0)	
Adiposity									
BMI (kg/m2)	940	24.0 (0.2)	377	24.3 (0.3)	113	24.0 (0.1)	450	23.8 (0.3)	
Waist Circumference (cm)	915	81.6 (0.5)	374	82.5 (0.8)	103	82.3 (1.6)	438	80.7 (0.7)	
Triceps Skinfold (mm)	903	16.3 (0.3)	368	16.6 (0.4)	100	16.8 (0.8)	435	15.9 (0.4)	
Subscapular Skinfold (mm)	864	14.6 (0.3)	350	15.1 (0.4)	96	14.7 (0.8)	418	14.2 (0.4)	

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean (M) $\pm$ standard error (SE)
3 Income categorized by child's family PIR: PIR $\leq$ 131% = low income, 131.01 to 185% = median income, > 185% PIR = high income.
4 No significant differences were found.

Table 16

Vitamin D Intake, Calcium Intake, and Measures of Adiposity by Race/Ethnicity in Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-3]

Variable	n [1]	Total	n	Mexican American (a)	n	Other Hispanic (b)	n	Non-Hispanic White (c)	n	Non-Hispanic Black (d)	n	Other Race/ Multiracial (e)	Difference By Row [3]
		M (SE)		M (SE)		M (SE)		M (SE)		M (SE)		M (SE)	
Intake													
Vitamin D Intake	1085	5.0 (0.2)	253	5.1 (0.4)	146	5.1 (0.4)	350	6.1 (0.4)	291	3.4 (0.2)	45	4.7 (0.7)	ad, bd, cd
Calcium Intake	1085	892.6 (20.4)	253	928.8 (42.8)	146	877.8 (52.1)	350	1009.5 (41.5)	291	728.9 (29.5)	45	886.2 (94.5)	
Adiposity													
BMI (kg/m2)	1040	24.0 (0.2)	243	24.5 (0.4)	139	23.8 (0.5)	336	23.3 (0.3)	278	24.6 (0.4)	44	22.0 (0.9)	
Waist Circumference (cm)	1008	81.5 (0.5)	239	83.1 (1.0)	136	81.9 (1.3)	319	81.7 (0.8)	273	80.3 (0.9)	41	77.8 (2.5)	
Triceps Skinfold (mm)	995	16.2 (0.3)	235	17.3 (0.5)	134	16.0 (0.7)	318	16.1 (0.4)	268	15.6 (0.5)	40	15.1 (1.1)	
Subscapular Skinfold (mm)	954	14.6 (0.3)	227	15.9 (0.5)	130	14.6 (0.8)	307	13.8 (0.4)	253	14.8 (0.5)	37	12.1 (1.1)	ac,ae

1 Totals may not equal grand total due to missing data.
2 Values are expressed as mean (M) $\pm$ standard error (SE)
3 Significant differences by row groups are indicated by letter. $P \leq 0.05$

Table 17

Linear Association Between Vitamin D Intake and Cardiovascular Risk Factors for US Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-5]

	Simple linear	Model 1 [3]	Model 2 [4]	Model 3 [5]
Risk Factors	β (p-Value)	β (p-Value)	β (p-Value)	β (p-Value)
Systolic Blood Pressure (mm Hg)	-0.03 (0.42)	-0.25 (< 0.01)*	0.03 (0.32)	0.03 (0.44)
Diastolic Blood Pressure (mm Hg)	-0.04 (0.27)	0.10 (< 0.01)*	0.04 (0.23)	0.04 (0.21)
Total Cholesterol (mg/dL)	0.01 (0.77)	0.10 (< 0.01)*	0.03 (0.40)	0.02 (0.67)
LDL-Cholesterol (mg/dL)	-0.01 (0.78)	0.04 (0.50)	-0.01 (0.92)	0.09 (0.10)
Triglyceride (mg/dL)	0.08 (0.13)	-0.04 (0.49)	-0.19 (<0.01)*	-0.10 (0.05)*
Direct HDL-cholesterol (mg/dL)	-0.02 (0.59)	0.16 (< 0.01)*	0.12 (<0.01)*	0.03 (0.42)
Fasting Glucose (mg/dL)	-0.01 (0.79)	-0.03 (0.61)	-0.11 (0.03)*	-0.08 (0.13)
Hemoglobin A1c (%)	-0.03 (0.34)	-0.03 (0.39)	0.06 (0.1)	-0.09 (0.01)*
Insulin (uU/mL)	-0.02 (0.67)	0.12 (0.02)*	-0.10 (0.05)*	-0.05 (0.37)
C-Reactive Protein (mg/dL)	0.01 (0.68)	0.08 (0.02)*	-0.02 (0.56)	0.02 (0.59)
HOMA-IR	-0.03 (0.61)	0.10 (0.06)	-0.13 (0.02)*	-0.06 (0.28)
QUICKI	0.02 (0.64)	-0.15 (<0.01)*	0.14 (<0.01)*	0.05 (0.30)

1. In the regression model, vitamin D intake was treated as the predictor.
2. $P \leq 0.05$ indicates significance (*)
3. Model 1: adjusted for sex
4. Model 2: adjusted for sex and race/ethnicity
5. Model 3: adjusted for sex, race/ethnicity, and PIR

Table 18

Linear Association Between Calcium Intake and Cardiovascular Risk Factors in Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-5]

	Simple linear	Model 1 [3]	Model 2 [4]	Model 3 [5]
Risk Factors	β (p-Value)	β (p-Value)	β (p-Value)	β (p-Value)
Systolic Blood Pressure (mm Hg)	-0.02 (0.50)	-0.25 (<0.01)*	-0.03 (0.31)	0.03 (0.43)
Diastolic Blood Pressure (mm Hg)	0.01 (0.85)	0.10 (<0.01)*	0.04 (0.19)	0.04 (0.27)
Total Cholesterol (mg/dL)	-0.01 (0.98)	0.10 (<0.01)*	0.03 (0.40)	0.02 (0.66)
LDL-Cholesterol (mg/dL)	-0.04 (0.45)	0.03 (0.57)	-0.01 (0.88)	0.09 (0.09)
Triglycerides (mg/dL)	0.13 (0.01)*	-0.02 (0.65)	-0.19 (<0.01)*	-0.11 (0.04)*
Direct HDL-Cholesterol (mg/dL)	-0.07 (0.03)*	0.15 (<0.01)*	0.11 (<0.01)*	0.03 (0.38)
Fasting Glucose (mg/dL)	0.01 (0.89)	-0.02 (0.67)	-0.11 (0.03)*	-0.08 (0.12)
Hemoglobin A1c	-0.01 (0.80)	-0.03 (0.45)	0.06 (0.09)	-0.09 (<0.01)*
Insulin (uU/mL)	-0.03 (0.54)	0.12 (0.02)*	-0.10 (0.05)*	-0.05 (0.38)
C-Reactive Protein (mg/dL)	-0.02 (0.48)	0.07 (0.03)*	-0.02 (0.51)	-0.02 (0.66)
HOMA-IR	-0.04 (0.47)	0.10 (0.06)	-0.14 (<0.01)*	-0.06 (0.28)
QUICKI	-0.02 (0.76)	-0.15 (<0.01)*	0.14 (<0.01)*	0.06 (0.29)

1. In the regression model, calcium intake was treated as the predictor.
2. $P \leq 0.05$ indicates significance (*)
3. Model 1: adjusted for sex
4. Model 2: adjusted for sex and race/ethnicity
5. Model 3: adjusted for sex, race/ethnicity, and PIR

Table 19

Linear Association Between Vitamin D Intake and Measures of Adiposity in Children and Adolescents Aged 12 – 18 years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-5]

	Simple linear	Model 1 [3]	Model 2 [4]	Model 3 [5]
Risk Factors	β (p-Value)	β (p-Value)	β (p-Value)	β (p-Value)
Body Mass Index (kg/m**2)	-0.05 (0.11)	0.01 (0.89)	-0.04 (0.19)	-0.03 (0.31)
Waist Circumference (cm)	-0.02 (0.59)	-0.01 (0.74)	-0.08 (0.02)*	-0.05 (0.16)
Triceps Skinfold (mm)	-0.08 (0.02)*	0.34 (<0.01)*	-0.07 (0.04)*	-0.04 (0.22)
Subscapular Skinfold (mm)	-0.09 (0.01)*	0.21 (<0.01)*	-0.08 (0.03)*	-0.04 (0.20)

1. In the regression model, vitamin D intake was treated as the predictor.
2. P ≤ 0.05 indicates significance (*)
3. Model 1: adjusted for sex
4. Model 2: adjusted for sex and race/ethnicity
5. Model 3: adjusted for sex, race/ethnicity, and PIR

Table 20

Linear Association Between Calcium Intake and Measures of Adiposity in Children and Adolescents Aged 12 – 18 Years, National Health and Nutrition Examination Survey, 2007 – 2008 [1-5]

	Simple linear	Model 1 [3]	Model 2 [4]	Model 3 [5]
Risk Factors	β (p-Value)	β (p-Value)	β (p-Value)	β (p-Value)
Body Mass Index (kg/m**2)	-0.07 (0.03)*	0.001 (0.98)	-0.05 (0.17)	-0.03 (0.34)
Waist Circumference (cm)	-0.03 (0.35)	-0.01 (0.68)	-0.08 (0.02)*	-0.05 (0.18)
Triceps Skinfold (mm)	-0.15 (<0.01)*	0.32 (<0.01)*	-0.07 (0.02)*	-0.03 (0.34)
Subscapular Skinfold (mm)	-0.14 (<0.01)*	0.20 (<0.01)*	-0.08 (0.02)*	-0.04 (0.29)

1. In the regression model, vitamin D intake was treated as the predictor.
2. $P \leq 0.05$ indicates significance (*)
3. Model 1: adjusted for sex
4. Model 2: adjusted for sex and race/ethnicity
5. Model 3: adjusted for sex, race/ethnicity, and PIR

CHAPTER V

DISCUSSION

To our knowledge, this is the first study (Study I) examining vitamin D and calcium intake in children (6 - 12 years) and adolescents (13 - 18 years) by age, sex, race/ethnicity, and parental PIR using the 2007-2008 NHANES survey data set. As of December 2015, serum 25(OH)D levels had not been released from the CDC. Therefore, vitamin D intake was used as a surrogate for serum 25(OH)D concentrations. The study hypotheses stating that total, dietary, and supplemental vitamin D and calcium intake by children and adolescents in the United States differed by race/ethnicity, sex, age, and parental PIR were accepted. NH Blacks had the lowest intakes of vitamin D and calcium compared to Mexican Americans, Other Hispanics, NH Whites, and Other Race - including Multiracial. NH Blacks were also found to have the highest percentage of children and adolescents not meeting the EAR/RDA for vitamin D, whereas the highest percentage of not meeting the EAR/RDA for calcium intake was found in the Other Hispanics group. In a previous study, it was found that mean intakes of vitamin D by children (6-18 years) and ethnic group was lower than the EAR for vitamin D (Moore, Radcliffe, & Liu, 2014). Calcium-rich food choices differ among race/ethnic groups (Cluskey et al., 2015). Kirkpatrick et al. (2012) found that fewer NH Blacks met the recommendations for fruit, vegetables, grains, and milk, when compared to NH Whites and Mexican Americans, and more NH Whites met the recommendations

for milk consumption when compared to NH Blacks and Mexican Americans (Kirkpatrick, Dodd, Reedy, & Krebs-Smith, 2012). Males had a higher intake of vitamin D and calcium than females in the study. Similar to our findings, Al-Musharaf and colleagues found that female participants had significantly lower serum 25(OH)D levels in both pre-adolescents and adolescents compared to male participants. This is possibly due to the fact that females have more body fat percentage than males, resulting in the sequestration of vitamin D in body fat resulting in lower serum 25(OH)D (Al-Musharaf et al., 2012). Younger participants (6 - 12 years) had a lower percentage of not meeting the EAR/RDA for calcium intake. This could be a result of younger children consuming more dairy products (milk, cheese, yogurt, etc.) than older adolescents. De Oliveira et al. (2014) found that students (mean age 14.3 $\pm$ 1.0 years) who consumed soft drinks $\geq$ 3 times/week had a lower intake of calcium (de Oliveira et al., 2014). Although no significant differences in total and dietary intakes of vitamin D and calcium were found, medium PIR had the lowest reported intake, which could have been due to the low sample size of the medium PIR group. Supplemental vitamin D and calcium intake were, however, significantly higher in the high PIR group than the low PIR group. Bailey et al. (2010) found that dietary supplement use was associated with a higher prevalence of participants meeting the RDA for calcium and vitamin D than those not taking a supplement (Bailey et al., 2010).

A recent report by Moore et al. (2014) compared total, dietary, and supplemental vitamin D intake of children during 2007-2010 by race/ethnicity, sex, age, and family PIR. The results indicated NH Whites had a significantly higher total intake of vitamin D

than NH Blacks and Hispanics, and total vitamin D intake was higher in the Hispanic children group than in the NH Blacks. Total vitamin D intake was higher in boys than girls, and it decreased with age (Moore et al., 2014). Total, dietary, and supplemental calcium intake was not examined.

In a study conducted by Moore et al. (2005), intakes of vitamin D in the United States from food and food plus supplements by age, sex, and race/ethnicity group were analyzed. Results of the study showed the younger participants had the highest vitamin D intakes, and intake decreased as age increased. Vitamin D intake was also highest in NH Whites and in males (Moore, Murphy, & Holick, 2005).

The present study (Study II) analyzed the association of vitamin D and calcium intake with cardiovascular risk factors and measures of adiposity in children and adolescents (12 - 18 years) using the 2007-2008 NHANES. The study hypotheses stating that vitamin D and calcium intakes were associated with cardiovascular risk factors and measures of adiposity were accepted. NH Blacks had a significantly lower intake of vitamin D and calcium compared to Mexican Americans, Other Hispanics, and NH Whites. Triglycerides were significantly lower and HDL-C was significantly higher in the NH Blacks than any other race/ethnicity group. This may have been due to a decrease in the amount of dairy products consumed. Although dairy products contain vitamin D and calcium, they are also high in saturated fat, which can raise cholesterol levels. Triceps skinfold and subscapular skinfold were significantly higher in females than males. Females generally have a higher percentage of body fat than males. No significant differences were found between parental PIR groups and measures of adiposity. Body

mass index is the measure of adiposity most commonly employed in children and adults because skinfold thickness is not always available. Waist circumference, and waist circumference-to-height ratio are more accurate measures of adiposity-related mortality (Brambilla, Bedogni, Heo, & Pietrobelli, 2013).

In 2016, Moore and Liu conducted a study to evaluate the association of serum 25(OH)D concentrations and multiple measures of adiposity in children using the 2005-2006 NHANES data. Results revealed a positive correlation between dietary vitamin D intake and serum 25(OH)D concentrations, and a negative correlation between 25(OH)D concentrations and markers of adiposity (waist circumference, waist circumference-to-height ratio, body mass index, and triceps skinfold thickness) (Moore & Liu, 2016). Another study examined the association between 25(OH)D concentrations and adiposity measures. Cediel and collegues (2016) found serum 25(OH)D concentrations were inversely associated with total and central adiposity and insulin resistance (Cediel et al., 2016).

In 2010, Torres and colleagues evaluated the effects of a high-calcium diet with energy restriction on measures of abdominal measures of obesity and cardiometabolic risk factors in Brazilian obese subjects. Participants were randomly assigned to one of two dietary regimens: low-calcium diet (<500 mg/day) or a high-calcium diet (1200-1300 mg/day with non-fat powdered milk (60g/day). After 16 weeks, metabolic variables (total cholesterol, triglycerides, LDL-cholesterol, insulin, and PTH) and blood pressure decreased significantly in both groups. In the high-calcium group only, participants had a greater reduction in waist circumference, waist-to-hip ratio, diastolic blood pressure,

mean blood pressure, and serum insulin levels (Torres, Francisschetti, Genelhu, & Sanjuliani, 2010).

In the present study, a significant association was noted between vitamin D and calcium and cardiovascular risk factors. When adjusted for sex, race/ethnicity and PIR, a significant inverse association between vitamin D and calcium intake and triglycerides and HgbA1c was found. A significant difference also was found between vitamin D intake and systolic blood pressure when adjusted for sex. Previous research has found vitamin D to be negatively associated with the development of hypertension. Adequate serum vitamin D levels decrease the renin-angiotensin-aldosterone system. Although serum 25(OH)D levels were not available for analyses in the present study, it has been shown to be related to vitamin D intake in previous studies, as stated previously. Serum 25(OH)D levels have been shown to be inversely associated with cardiovascular risk factors. In 2009, Kendrick and colleagues examined the association between serum 25(OH)D and the prevalence of cardiovascular disease in adults using NHANES III (1988-1994). The results showed a strong, significant relationship between serum 25(OH)D and certain cardiovascular disease markers such as self-reported angina, myocardial infarction, and stroke (Kendrick et al., 2009). Zittermann et al. (2012) suggested a serum 25(OH)D level of 30-35ng/L was the best choice for reducing the risk of cardiovascular mortality (Zittermann et al., 2012). In 2015, Tomaino et al. evaluated the association between serum 25(OH)D levels and blood pressure among adolescents in Peru, and found an association between serum 25(OH)D deficiency and elevated diastolic blood pressure (Tomaino et al., 2015). Zhang et al. (2014) found that serum 25(OH)D

levels were negatively associated with LDL-cholesterol and positively associated with HDL-cholesterol and apolipoprotein A1 (Zhang et al., 2014). In addition, calcium supplementation has been shown to have beneficial effects on blood pressure and cardiovascular event rates in men (Reid et al., 2010).

In the present study, a significant association was noted between vitamin D and calcium and measures of adiposity. When adjusted for gender and race/ethnicity, a significant inverse association between vitamin D and calcium intake and waist circumference, triceps skinfold, and subscapular skinfold was found. In 2015, Keast et al. studied the associations between yogurt, dairy, calcium, and vitamin D intake and obesity among U.S. children aged 8 - 18 years using the 2005-2008 NHANES database. The results of this study indicated that yogurt and dairy consumption were associated with higher calcium and vitamin D intakes, and that the higher consumption of yogurt, dairy, calcium, and vitamin D intake were associated with lower measures of adiposity in U.S. children (Keast et al., 2015).

In 2011, Torres and colleagues examined the association between dietary calcium intake and measures of adiposity and metabolic profile in hypertensive patients. Participants were divided into one of two groups, based on their usual dietary calcium intake: low calcium group (<800 mg/day) and high calcium group (>800 mg/day). Participants in the low calcium group had a significantly higher BMI and % body fat than those participants in the high calcium group (Torres et al., 2011).

Strengths and Limitations

Several strengths of this study should be noted. First, the 2007-2008 NHANES was a large, nationally representative population-based sample, and data were collected over a two-year period. Second, several cardiovascular risk factors (total cholesterol, HDL-cholesterol, LDL-cholesterol, triglycerides, fasting glucose, insulin, hemoglobin A1c, C-reactive protein, HOMA-IR, QUICKI, and blood pressure) were examined to determine their associations with vitamin D and calcium intakes. Third, several measures of adiposity (BMI, waist circumference, triceps skinfold, and subscapular skinfold) were examined to determine their associations with vitamin D and calcium intakes. Fourth, the current study examined differences in children and adolescents. Few studies have been conducted assessing vitamin D and calcium intakes in children and adolescents, aged 6-18 years. Most studies have been performed with older populations. Finally, associations of vitamin D and calcium intakes with cardiovascular risk factors and measures of adiposity were controlled by demographic variables, such as sex, parental PIR, and race/ethnicity.

Limitations of this study should also be noted. First, the 2007-2008 NHANES study design was cross-sectional, and therefore, causal inference cannot be made. Second, vitamin D intake was used as a surrogate for serum 25(OH)D concentrations. As of December 2015, serum 25(OH)D concentrations for 2007-2008 NHANES were not available to the public. Serum 25(OH)D concentrations would have provided a more accurate assessment of vitamin D. Third, the use of more accurate body composition measures were not used, such as dual energy X-ray absorptiometry (DEXA), BodPod,

and bioelectric impedence to assess body fat. Fourth, to determine vitamin D and calcium intake of the children and adolescents in the study, a 24-hour recall was used which relies on memory and may not reflect usual intake (Willett, 1998). Ollberding et al. (2014) found that a greater number of 24-hour recalls better reflected usual nutrient intake versus a fewer number (Ollberding, Couch, Woo, & Kalkwarf, 2014). The present study analyzed vitamin D and calcium intakes based on self-reported intake. Participants may not have accurately reported their intake, and possibly could have changed their eating habits as a result of the questionnaire. Fifth, physical activity, smoking intake, and alcohol consumption and the association of vitamin D and calcium intake were not analyzed. There may have been a significant inverse relationship between vitamin D and calcium intake and these variables.

CHAPTER VII

CONCLUSION

Since its discovery in cod liver oil, vitamin D has been found to play essential roles in the prevention of certain diseases such as rickets, osteomalacia, CVD, and hypertension. The two major isoforms of vitamin D, vitamin D_2 and vitamin D_3, have both demonstrated protective effects in the prevention of these diseases. Vitamin D deficiency, or hypovitaminosis, can lead to CVD complications, such as left ventricular hypertrophy, myocardial infarction, and hypertension.

In 2015, the Dietary Guidelines for Americans Advisory Committee stated one-third of all children and youth are either overweight or obese, and about three-fourths of the total population consumes a diet low in vegetables, fruits, dairy, and oils (Scientific Advisory Report of the Dietary Guidelines for Americans, 2015). This puts the population, children and adolescents included, at risk for vitamin and mineral deficiencies such as vitamin D and calcium. Children and adolescents should consume nutrient-dense foods that contain vitamin D and calcium to help prevent these deficiencies. However, if dietary recommendations cannot be met through diet alone, food fortification and dietary supplements may be useful. Also, healthy eating patterns that include eating more fruits, vegetables, whole grains, dairy, and lean proteins and less saturated fats, added sugars, and sodium can help with maintaining a healthy weight and reduce the risk of developing chronic diseases, such as cardiovascular disease.

Future Directions and Implications

More research is needed to further determine the positive and protective effects of vitamin D and calcium intakes in not only reducing and improving the complications related to cardiovascular disease and obesity, but also maintaining overall health in otherwise healthy individuals, especially in children and adolescents. Very few studies on children and adolescents are available that focus on vitamin D and calcium intakes and their relationship with cardiovascular risk factors and measures of adiposity.

Recommendations for future studies include examining serum 25(OH)D concentrations in children (6 - 12 years) and adolescents (13 - 18 years) by age, sex, race/ethnicity, and parental PIR and associations with cardiovascular risk factors and measures of adiposity using the 2007-2008 NHANES data. The present study evaluated vitamin D and calcium intakes instead of serum 25(OH)D concentrations. By using serum 25(OH)D levels, more definitive associations may be found. Furthermore, examining the male and female differences by looking at intakes of vitamin D and calcium per 1000 calories, which could eliminate the sex differences seen. Additionally, further research is needed examining vitamin D and calcium intakes with reported smoking status, alcohol consumption, and physical activity and associations with cardiovascular risk factors and measures of adiposity in adolescents (12 - 18 years). Finally, more research is also needed to evaluate optimal serum 25(OH)D levels and vitamin D and calcium intakes to reduce the risk of chronic diseases.

In conclusion, parents and nutrition professionals should encourage children and adolescents to consume an overall healthy diet including foods high in vitamin D and

calcium, fresh fruits, vegetables, whole grains, and dairy products to reduce the risk of developing cardiovascular disease and obesity. Nutrition professionals should also educate individuals with chronic diseases on how to decrease adverse effects through a healthy lifestyle. Also, allowing food manufacturers to increase the number of available fortified foods will aid in reducing the risks of vitamin D and calcium deficiencies. Because the current study found NH Blacks had low intakes of vitamin D and calcium, more health messaging to these parents and children and encouraging intake of dietary supplements would be beneficial.

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Appendix A

Institutional Review Board Exemption

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Office of Research
6700 Fannin Street
Houston, TX 77030-2343
713-794-2480 Fax 713-794-2488

January 07, 2014

Ms. Jennifer Parsons
Nutrition & Food Sciences
6700 Fannin Street
Houston, TX 77030

Dear Ms. Parsons:

Re: Estimation of Vitamin D and Calcium Intake in the United States and Associations with Cardiovascular Risk Factors and Adiposity Measures by Age, Gender, Parental Poverty Income Ration and Ethnicity of Children<18 Years (Protocol #: 17556)

The above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and was determined to be exempt from further review.

Any modifications to this study must be submitted for review to the IRB using the Modification Request Form. Additionally, the IRB must be notified immediately of any unanticipated incidents. If you have any questions, please contact the TWU IRB.

Sincerely,

Jan Foster

Jan Foster, PhD, APRN, CNS
Institutional Review Board - Houston

cc. Dr. Rose Bush, Department of Nutrition & Food Sciences - Houston
Carolyn Moore , PhD, RD, Department of Nutrition & Food Sciences - Houston
Graduate School