THE ASSOCIATION BETWEEN CIRCULATING VITAMIN D LEVELS AND BODY COMPOSITION IN COLLEGIATE FEMALE ATHLETES

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BY

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ABSTRACT

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THE ASSOCIATION BETWEEN CIRCULATING VITAMIN D LEVELS AND BODY COMPOSITION IN COLLEGIATE FEMALE ATHLETES

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The current study looked at the relationship between serum vitamin D concentrations, vitamin D intake, sunlight exposure, BMI, and body fat percentage in both indoor and outdoor female collegiate athletes during fall and spring seasons. Healthy collegiate female athletes, between the ages of 18-22, had BMI calculated from anthropometric measurements, body fat percentage assessments via dual energy X-ray absorptiometry (DXA) scans, serum vitamin D levels determined via fingerstick and dried blood spots, followed by liquid chromatography/tandem mass spectrometry (LC-MS/MS). In addition, sunlight badges worn during a 24-hour period assessed sunlight exposure in fall and spring seasons. Estimated dietary vitamin D intake assessed via Vitamin D Food Frequency Questionnaire (VDFFQ), and sunlight habits were assessed via TWU Sunlight Habits Questionnaire (TSHQ). **Results:** No association between BMI, body fat composition, and vitamin D concentration was observed. Decreased serum D levels were seen in outdoor athletes from fall to spring, and increased levels from fall to spring in indoor athletes. Decreased UV exposure was seen from fall to spring in both groups.

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CHAPTER I

INTRODUCTION

Vitamin D is an important secosteroid hormone that regulates bone metabolism, immune, skeletal muscle, and adipocyte function (Alemzadeh, Kichler, Babar, & Calhoun, 2008; DeLuca, 2004; Wacker & Holick, 2013). Vitamin D_3, cholecalciferol, is synthesized from 7-dehydrocholesterol in the skin through ultraviolet (UV) exposure to sunlight. Vitamin D_3 is then hydroxylated in the liver to 25-hydroxyvitamin D $(25(OH)D)_3$ and hydroxylated again in the kidney to 1,25-dihydroxyvitamin D ($1,25(OH)_2D_3$), the active form of vitamin D in the body (Holick, 2013). Vitamin D can be obtained in the diet from salmon, mackerel, sardines, egg yolk, cod liver oil, and fortified foods like milk, orange and other juices, and some breads and cereals (Holick, 2004). Sufficient vitamin D levels have been found to range from 21-100 ng/ml using guidelines from various organizations (Vitamin D Council, 2014). Vitamin D levels vary by ethnicity and season and are reduced in darker pigmented individuals as well as in the winter (Alemzadeh et al., 2008; Halliday et al., 2011). There is a high incidence of vitamin D insufficiency, or hypovitaminosis D, in the United States (Forrest & Stuhldreher, 2011).

More recently, vitamin D has been studied to determine its relationship with body mass index (BMI), considering the large number of people in the United States who are overweight or obese as well as vitamin D deficient, to see if there is an overlap between the two populations (Alemzadeh et al., 2008; Kamycheva, Joakimsen, & Jorde, 2002; McGill, Stewart, Lithander, 2008; Wortsman, Matsuoka, Chen, Lu, & Holick, 2000; Vanlint 2013). A high BMI is associated with decreased circulating vitamin D and availability in both children and adults (Alemzadeh et al., 2008; Wortsman et al., 2000). Alemzadeh et al., 2008, have also found a significant inverse relationship with vitamin D_3 and waist circumference in children and adolescents. Beyond BMI, low circulating levels of vitamin D in obese subjects are related to increased systemic inflammation (Bellia, et al.,, 2011).

A relationship between BMI and vitamin D status in athletes has not been observed (Halliday et al., 2011). However, Halliday et al., did see a negative relationship between vitamin D status and illness occurrence in athletes.

The proposed study uses athletes as the target population because there have not been many studies done on athletes and vitamin D. The purpose of the current study is to determine the relationship of vitamin D status, through UV exposure and dietary intake, and body composition in collegiate female athletes who participate in either an indoor or outdoor sport.

Null Hypotheses

These hypotheses have been developed to determine if vitamin D concentration is associated with body composition in an athletic population. The independent variables are vitamin D intake, UV exposure, and specificity of sport (indoor versus outdoor). Vitamin D concentration has been used as an independent variable when comparing BMI and body fat percentage. The dependent variables in the current study include BMI, body fat composition, and serum vitamin D concentration. The null hypotheses of the study include:

1. There are no significant differences between indoor and outdoor athletes regarding age, BMI, and body fat percentage.
2. There is no significant difference in vitamin D concentration in indoor versus outdoor athletes.
3. There is no significant relationship between vitamin D concentration and BMI.
4. There is no significant relationship between vitamin D concentration and body fat percentage.
5. There is no significant interaction of sport type and season on serum 25(OH)D concentration.
6. There is no significant interaction of sport type and season on vitamin D intake.
7. There is no significant interaction of sport type and season on UV exposure.

Assumptions

1. All participants are healthy individuals.
2. The Vitamin D Food Frequency Questionnaire (VDFFQ) is a reliable and a valid measure of the participants' dietary vitamin D consumption.

3. The TWU Sunlight Habits Questionnaire is a reliable and valid measure of the participants' sunlight habits.
4. The participants wear the sunlight badges as instructed
5. The limitations imposed in the current study will not destroy the external validity of the results.
6. All participants provide accurate information for the current study.
7. All testing performed for the current study is reliable and accurate.

Limitations

1. Small population size of the study.
2. Tanning bed use of some of the participants
3. Vitamin D supplementation of some of the participants

Significance of the Study

Vitamin D is important for growth and metabolism. It is essential for bone metabolism and calcium homeostasis. Evaluation of vitamin D consumption, UV exposure, and serum vitamin D concentration will determine whether intake and exposure levels are sufficient to maintain adequate vitamin D concentrations. In persons with elevated BMIs, vitamin D concentrations are decreased when compared with those within a normal BMI range. The current study may confirm that relationship in an athletic population.

CHAPTER II

REVIEW OF THE LITERATURE

History of Vitamin D

Vitamin D was discovered in the early twentieth century by Professor Elmer V. McCollum at Johns Hopkins University following the discovery of vitamin A. In an experiment, McCollum bubbled oxygen into cod liver oil and found that, while it destroyed vitamin A and became unable to prevent vitamin A deficiency, the oil was able to cure rickets, a childhood bone disease characterized by brittle bones leading to skeletal malformation (McCollum et al., 1922; DeLuca, 2014). During that time another scientist, Professor Harry Steenbock, found that he could prevent rickets in rats using UV irradiation (DeLuca, 2014). The actual structure of vitamin D_2 was isolated in 1931 and vitamin D_3 in 1937 (Askew et al., 1931; DeLuca, 2014). In 1978, it was discovered that vitamin D is synthesized in the skin (Esvelt et al., 1978).

Synthesis and Metabolism

The complete synthesis and metabolism of vitamin D is shown below in Figure 1 (Holick, 2010). Vitamin D is synthesized from 7-dehydrocholesterol in the skin by ultraviolet (UV) irradiation yielding previtamin D_3 which is rapidly converted by a heat dependent process into Vitamin D_3, or cholecalciferol (Holick, 2007). Excessive UV exposure degrades previtamin D_3 and vitamin D_3 into inactive compounds, thus preventing toxic buildup of vitamin D in the body (Wacker & Holick, 2013).

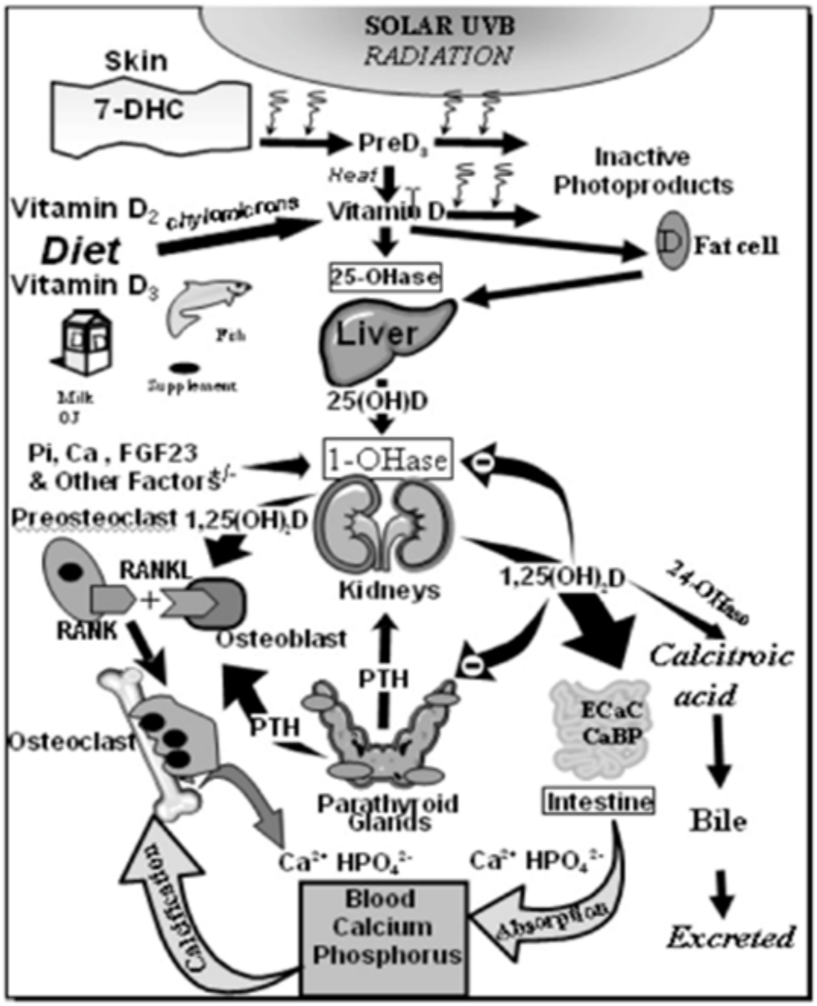

Figure 1. Synthesis and Metabolism of Vitamin D (Holick, 2010)

Vitamin D_3, as well as vitamin D_2 ingested from dietary sources, are transported by the lymphatic system and can be stored in fat cells for later release. Vitamin D_3 is then bound to a vitamin D binding protein and shuttled to the liver where it is hydroxylated via D-25-hydroxylase forming 25-hydroxyvitamin D_3,

$25(OH)D_3$, the circulating form of vitamin D, and the form used to assess vitamin D status (Wacker & Holick, 2013). $25(OH)D_3$ is biologically inactive and must then be hydroxylated again in the kidney to form 1,25-dihydroxyvitamin D_3 ($1,25(OH)_2 D_3$), the active form of vitamin D in the body and also known as calcitriol (Christakos et al., 2010; DeLuca, 2014).

Functions of Vitamin D

Vitamin D is fat-soluble secosteroid compound that functions as a hormone in the human body and is synthesized in the skin. Vitamin D is involved in bone metabolism, immune, skeletal muscle, and adipocyte function (Alemzadeh, Kichler, Babar, 2008; DeLuca, 2004; Wacker & Holick, 2013). Its main function is to maintain calcium homeostasis in the body as shown in Figure 2 below (DeLuca, 2004).

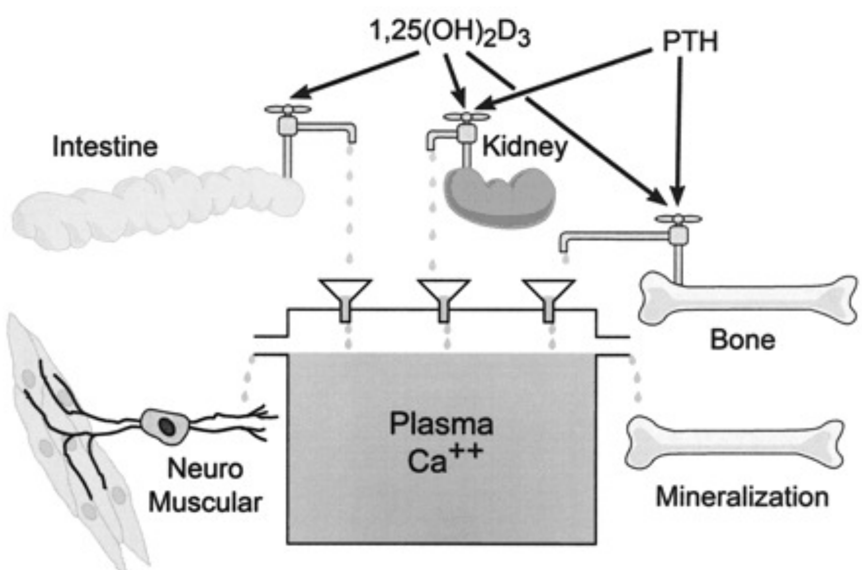

Figure 2. Role of Vitamin D in Increasing Plasma Calcium Concentration (DeLuca 2011)

The active form of vitamin D, 1,25-dihydroxyvitamin D_3, causes an increase in intestinal calcium absorption via protein induction, allows for mobilization of calcium from the bone when absent from the diet, and is required for the distal renal tubule in the kidney to resorb filtered calcium. The parathyroid hormone (PTH) is involved in the latter two processes. When hypocalcemia is sensed, the parathyroid gland releases PTH that stimulates the production of $1,25(OH)_2$ D_3. Vitamin D functions through a single receptor known as the vitamin D receptor (VDR). VDRs have been located on parathyroid gland cells, osteoblasts, enterocytes, and distal renal tubule cells. The receptor has also been found on ovarian cells, keratinocytes, promyelocytes, lymphocytes, colon cells, and pituitary gland cells. There are also some reports that the VDR has been found on skeletal muscle, cardiac muscle and liver muscle, however this has not been widely confirmed (DeLuca, 2004). Low levels of vitamin D have been associated with osteoporosis, rickets in children and osteomalacia in adults, obesity, certain cancers, multiple sclerosis, type I diabetes mellitus, rheumatoid arthritis, autoimmune thyroid disease, inflammatory bowel disease, lupus, and asthma (Holick, 2007).

Dietary Sources of Vitamin D

Another form of vitamin D known as vitamin D_2, or ergocalciferol, is formed from irradiation of yeast, and is used for supplementation in the diet (DeLuca, 2004; Holick, 2007). Natural food sources of vitamin D_3 include oily fish (like salmon, mackerel and sardines), cod liver oil, egg yolk, and shitake mushrooms (Wacker &

Holick, 2013). Fortified foods include milk (both dairy and non-dairy), butter, margarine, cheese, yogurt, breakfast cereals, and infant formula (Wacker & Holick, 2013). The table below from the National Institute of Health (NIH) shows a list of foods containing vitamin D naturally or via fortification (NIH, 2010).

Table 1

Selected Food Sources of Vitamin D (NIH, 2010)

Food	IUs per serving*	Percent DV**
Cod liver oil, 1 tablespoon	1,360	340
Swordfish, cooked, 3 ounces	566	142
Salmon (sockeye), cooked, 3 ounces	447	112
Tuna fish, canned in water, drained, 3 ounces	154	39
Orange juice fortified with vitamin D, 1 cup (check product labels, as amount of added vitamin D varies)	137	34
Milk, nonfat, reduced fat, and whole, vitamin D-fortified, 1 cup	115-124	29-31
Yogurt, fortified with 20% of the DV for vitamin D, 6 ounces (more heavily fortified yogurts provide more of the DV)	80	20
Margarine, fortified, 1 tablespoon	60	15
Sardines, canned in oil, drained, 2 sardines	46	12
Liver, beef, cooked, 3 ounces	42	11
Egg, 1 large (vitamin D is found in yolk)	41	10
Ready-to-eat cereal, fortified with 10% of the DV for vitamin D, 0.75-1 cup (more heavily fortified cereals might provide more of the DV)	40	10
Cheese, Swiss, 1 ounce	6	2

*IUs = International Units. ** DV = Daily Value.

Vitamin D can also be supplemented through consumption of multivitamins, vitamin D_2 and vitamin D_3 supplements in pill or liquid form, and through prescription injections of vitamin D_3 from a medical doctor (Wacker & Holick, 2013).

Estimated Vitamin D Requirements

Both the Food and Nutrition Board of the Institute of Medicine (IOM) and the Endocrine Society have put forth the following Recommended Dietary Allowances (RDA) for vitamin D on the basis of minimum UV exposure shown in Table 2 below.

Table 2

Recommended Dietary Allowances (RDAs) for Vitamin D (IOM, 2010; Holick et al., 2011)

Age	*Male*	*Female*	*Pregnancy*	*Lactation*
0–12 months*	400 IU (10 mcg)	400 IU (10 mcg)		
1–13 years	600 IU (15 mcg)	600 IU (15 mcg)		
14–18 years	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)
19–50 years	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)	600 IU (15 mcg)
51–70 years	600 IU (15 mcg)	600 IU (15 mcg)		
>70 years	800 IU (20 mcg)	800 IU (20 mcg)		

*Adequate Intake (AI)

The Tolerable Upper Intake Levels (UL), or the maximum daily intake without harmful effects, for vitamin D as stated by the IOM and the Endocrine Society are shown in Table 3 below.

Table 3

Tolerable Upper Intake Levels (ULs) for Vitamin D (IOM, 2010; Holick et al., 2011)

Age	Male	Female	Pregnancy	Lactation
0–6 months	1,000 IU (25 mcg)	1,000 IU (25 mcg)		
7–12 months	1,500 IU (38 mcg)	1,500 IU (38 mcg)		
1–3 years	2,500 IU (63 mcg)	2,500 IU (63 mcg)		
4–8 years	3,000 IU (75 mcg)	3,000 IU (75 mcg)		
≥9 years	4,000 IU (100 mcg)	4,000 IU (100 mcg)	4,000 IU (100 mcg)	4,000 IU (100 mcg)

The Endocrine Society recommends 1,500-2,000 IU/day with an UL intake of 10,000 IU/day for adults at risk for vitamin D deficiency (Holick et al., 2011).

The amount of UV exposure necessary to synthesize an adequate amount of vitamin D depends on the UV index, season, latitude, and skin pigmentation (Freedman et al., 2013; Holick, 2005). The UV index determines the risk of overexposure to UV radiation and is determined by measuring the strength of ground-level UV radiation and comparing it with ozone concentration, altitude, cloud coverage, time of day, and wavelength (EPA, 2013). Seasonality also affects vitamin D status as highest 25(OH)D levels are measured in the spring/summer and lowest levels in the fall/winter (Kasahara, Singh, Noymer, 2013). Regarding latitude, little to no synthesis of vitamin D occurs at latitudes of 35 degrees and greater during the winter (Holick, 2005). Skin pigmentation is another factor in determining the amount of UV exposure necessary to synthesize adequate vitamin D. Those with lighter complexions require less UV exposure than those with more pigmented skin as melanin, the component responsible for skin pigmentation, protects against UV radiation thus inhibiting the synthesis of cholecalciferol. Lower levels of vitamin D in white versus black participants receiving the same amount of UV exposure regardless of age and gender have been observed (Harris & Dawson-Hughes, 1998; Dawson-Hughes, 2004; Freedman, 2013).

Vitamin D Deficiency

Vitamin D deficiency is defined by serum vitamin D concentrations at ≤20 ng/ml 25(OH)D, insufficiency at 21-29 ng/ml 25(OH)D, and sufficiency at ≥30 ng/ml with 40-60 ng/ml 25(OH)D as the preferred concentration range (Holick et al., 2011). Vitamin D toxicity is rare and occurs at 25(OH)D levels of >150 ng/ml (Holick et al., 2011). There is still some debate surrounding optimal vitamin D status. Table 4 below shows the current concentration levels for vitamin D status from various organizations.

Table 4

Vitamin D [25(OH)D] Range Guidelines from Various Organizations (Vitamin D Council, 2014)

Status	Vitamin D Council	Endocrine Society	Food and Nutrition Board	Testing Laboratories
Deficient	0-30 ng/ml	0-20 ng/ml	0-11 ng/ml	0-31 ng/ml
Insufficient	31-39 ng/ml	21-29 ng/ml	12-20 ng/ml	
Sufficient	40-80 ng/ml	30-100 ng/ml	>20 ng/ml	32-100 ng/ml
Toxic	>150 ng/ml			

Using the NHANES 2006 data, the prevalence of vitamin D deficiency (≤20 ng/ml) in U.S. adults was 41.6%, with the highest rates for African Americans (82.1%) and Hispanics (69.2%), with Caucasians (30.9%) having the lowest incidence of deficiency (Forrest & Stuhldreher, 2011). Deficiency was significantly more common among those without college education, with obesity, with poor health status, hypertension, low high-density lipoprotein (HDL) cholesterol levels, or not consuming milk daily (Forrest & Stuhldreher, 2011). Supplementation guidelines to treat vitamin D deficiency are also debated with amounts ranging from 1000-5000 IU/day or weekly injections of up to 20,000 IU 25(OH)D (NIH, 2010; Vanlint 2013; Vitamin D Council, 2014). The incidence of vitamin D deficiency in elite athletes is up to 83% of gymnasts (Lovell, 2008). In a study of elite female soccer players, the average daily intake of vitamin D was 163 IU while the average

25(OH)D concentration was 30 ng/ml (Gibson et al., 2011). Recommendations for supplementation in vitamin D deficient athletes are 50,000 IU vitamin D_3 per week for 8 weeks with a steady level achieved after 90 days and retesting at 3 months (Shuler et al., 2012).

Vitamin D and BMI/Body Fat Percentage

Several studies have shown a relationship between BMI and vitamin D concentration. Vitamin D status has been shown to be significantly negatively associated with obesity, or those with a BMI ≥30 kg/m^2, (Kang et al., 2013, Vanlint, 2013). There are several theories for explaining this relationship. One explanation for this relationship may be decreased intake of dietary vitamin D and calcium in obese adults versus non-obese adults (Vanlint, 2013). Another explanation may be decreased sunlight exposure in obese versus non-obese populations (Vanlint, 2013). An alternate reason may be increased sequestration of vitamin D. In individuals with obesity, the skin's ability to synthesize vitamin D is not affected, however, larger amounts of subcutaneous fat sequester more vitamin D and reduce its release into the circulation (NIH, 2010, Vanlint, 2013). A high BMI is associated with decreased vitamin D circulation and availability in both children and adults (Alemzadeh et al., 2008; Wortsman et al., 2000). A significant inverse relationship with vitamin D_3 and waist circumference in children and adolescents has been observed (Alemzadeh et al., 2008). A decrease in BMI and increase fat loss in overweight and obese adults when supplemented with both calcium and vitamin D also has been observed (Zhou et al., 2010; Zhu et al., 2013; Rosenblum et al., 2012). In one study of vitamin D deficient obese female adults, daily supplementation with 25 μg vitamin D_3 significantly decreased body fat mass (Salepour et al., 2012). Beyond BMI, low circulating levels of vitamin D in obese subjects are related to increased systemic inflammation (Bellia, Garcovich, D'Adamo, 2011). A relationship between BMI and vitamin D status in athletes has not been shown (Halliday et al., 2011).

Vitamin D and Athletic Performance

Several recent studies have shown a relationship between vitamin D and athletic performance. Optimal neuromuscular performance has been associated with 25(OH)D levels of 50 ng/ml (Shuler et al., 2012). Fast twitch type II muscle fibers, in particular, are sensitive to vitamin D deficiency and supplementation helps reverse type II muscle fiber atrophy (Shuler et al., 2012). Benefits of increasing vitamin D to optimal levels include increased muscle protein synthesis, ATP concentration, jump height and velocity, jump power, strength, and physical performance (Shuler et al., 2012).

Beyond muscular benefits, vitamin D supplementation reduces stress fractures and inflammation (Lappe et al., 2008; Willis, Peterson, Larson-Meyer, 2008; Shuler et al, 2012). Furthermore, low levels of 25(OH)D have been associated with increased pro-inflammatory cytokines, TNF-α and interleukin-6 (Shuler et al., 2012). Lower levels of vitamin D in athletes are associated with anemia, resulting in reduced oxygen-carrying capacity of blood, which can adversely affect athletic performance (Cannell et al, 2009; Constantini et al, 2010; Sim et al, 2010). Additional studies on vitamin D status and vitamin D supplementation in athletic populations are needed to support these recent findings.

CHAPTER III

MATERIALS AND METHODS

This correlation and longitudinal study received partial funding from TWU Research Enhancement Program and Human Nutrition Research Funds. The anthropometric information was obtained with permission through Texas Woman's University's Institute for Women's Health Exercise and Sports Nutrition Clinic. The study was approved by Texas Woman's University Institutional Review Board and all participants signed an informed consent.

Participants

Sixteen participants signed consent forms agreeing to participate in data collection, however only 15 participants completed both the fall and spring assessments. Participants consisted of Caucasian and Hispanic female collegiate athletes at Texas Woman's University actively participating in soccer (n = 9) and gymnastics (n = 6). Ages of participants ranged from 18 to 22 years. Participants were categorized as either indoor (gymnastics) or outdoor (soccer) athletes. Each participant was assessed in the fall of 2013 and again in the spring of 2014.

Exclusion criteria included:

1. Any athlete not actively participating in a TWU sport
2. Any actively participating athlete who had not undergone a routine preseason physical and been cleared by the physician.

Study Design

This correlation study collected data in September and October of 2013 for the fall assessment and February and March of 2014 for the spring assessment. The data collected was used to determine the association between BMI, body composition, and vitamin D concentration. Data used in the study included, BMI, body composition, information regarding sunlight habits, vitamin D consumption, serum concentrations of vitamin D_3, and UV exposure. Data regarding sunlight habits were taken from the TWU Sunlight Habits Questionnaire. Dietary vitamin D consumption levels were determined using the Vitamin D Food Frequency Questionnaire (VDFFQ). Serum vitamin D concentrations were measured from participant blood samples. Ultraviolet (UV) exposure was measured using modified polysulphone badges.

BMI and Body Composition

BMI and body composition of participants were obtained with permission from the Institute for Women's Health at Texas Woman's University from the ongoing Sports and Wellness Evaluation Program study. Each participant's height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured using a stadiometer (Perspective Enterprises, Portage, MI) and a Tanita digital scale. BMI was calculated from anthropometric measurements. Body composition was measured using the Dual-energy X-ray Absorptiometer (DXA, Lunar Prodigy, Madison, WI) at Texas Woman's University, Institute for Women's Health, Exercise and Sports Nutrition Clinic. Total body scans were completed with the participant lying in the supine position in the middle of the table with the center line on the table pad running lengthwise down the center of the participant's body, head directly below the horizontal line at the top of the table pad with approximately 1.3 cm between the top of the head and the line. Arms were snug against the side of the body with palms facing the scanning table, entire body within the scan lines of the table pad (if necessary the participant's hands tucked slightly under the hips, but not under pelvic bones), feet and knees strapped together with two straps provided by the system with legs relaxed into straps prior to scan. Entire body remained motionless until scan was complete. The total body scan took approximately 6 min to complete for each participant and provided percentage body fat and lean body mass.

Age

Age was determined according to the individual's date of birth and represents the individual's age at the time of baseline and final data collection.

Questionnaires

At the beginning of the study each participant also completed a TWU Sunlight Habits Questionnaire inquiring about natural skin pigmentation, reaction to sunlight, tanning bed use, and seasonal sun exposure habits (see Appendix A). During both fall and spring assessments each athlete completed a two-day Vitamin D Food Frequency Questionnaire to assess the average intake of vitamin D from foods and/or supplements (see Appendix B). Average vitamin D intake was calculated using Nutritionist Pro™ Diet Analysis software (Axxya Systems, Stafford, TX).

Serum Vitamin D Collection

Serum vitamin D_3 concentrations were determined via fingerstick and dried blood spots, followed by liquid chromatography/tandem mass spectrometry (LC-MS/MS] from ZRT Laboratory (Newman et al., 2009; van den Ouweland et al., 2010). Each participant completed the blood spot test in both the fall and spring. Each test required 8-12 drops of blood delivered onto the test strip via lancet. Blood spot tests were analyzed by ZRT Laboratory with reference concentration for adequate vitamin D_3 set at 32-100 ng/ml.

UV Exposure

Sunlight badges were obtained from the University of Queensland, Australia Health and Engineering Sciences Department. Badges were made of modified polysulphone and have been tested and confirmed to be a valid and reliable way to measure UV exposure (Parisi & Kimlin, 2004). Standard curves for UVB radiation were calculated in the fall and the spring using integrated measurements from an ILT1700 Research Radiometer from International Light Technologies. The response sensitivity factor for monochromatic irradiance at 310 nm was set at $1.622 \times 10^{-4}(A)(cm^2)(W^{-1})$. Sunlight badges were measured in duplicate every 15 min for the first hour and then measurements were taken at 1 hr intervals over the next 7 hr.

Once the designated time limit was met, each badge was covered with aluminum foil to prevent further UV exposure and placed into an opaque envelope and sent to Dr. Alfio Parisi, at the University of Southern Queensland, Queensland, Australia. The sunlight badges described above were used to set a standard curve for the current study. Two sunlight badges were given to each participant for both the fall and spring assessments. Participants were instructed to wear one badge per day for two consecutive days pinned at chest level on the outermost layer of clothing from the time they woke up until they went to bed. Participants were instructed to repin the badges to the outermost layer of clothing each time clothing was changed. Participants who used tanning beds were also instructed to wear the badges in the tanning beds for accuracy of UV exposure. Aluminum foil and an opaque envelope were provided for each badge as well as an instruction sheet with directions on usage and proper storage of the badges when not in use. Once the badges were returned to the principal investigator they were also sent to Dr. Alfio Parisi in Queensland, Australia to determine the UV irradiation against the standard curves already developed (See Appendix C).

Null Hypotheses

These hypotheses determined if vitamin D concentration was associated with body composition in an athletic population. The independent variables were vitamin D intake, UV exposure, and specificity of sport (indoor versus outdoor). Vitamin D concentration was used as an independent variable when comparing BMI and body fat percentage. The dependent variables in the current study included BMI, body fat composition, and serum vitamin D concentration. The null hypotheses of the study include:

1. There are no significant differences between indoor and outdoor athletes regarding age, BMI, and body fat percentage.
2. There is no significant difference in vitamin D concentration in indoor versus outdoor athletes.
3. There is no significant relationship between vitamin D concentration and BMI.
4. There is no significant relationship between vitamin D concentration and body fat percentage.
5. There is no significant interaction of sport type and season on serum 25(OH)D concentration.
6. There is no significant interaction of sport type and season on vitamin D intake.
7. There is no significant interaction of sport type and season on UV exposure.

Statistical Analyses

The software used for statistical analysis in the current study is the IBM Statistical Packages for the Social Sciences (SPSS) version 19.0 (SPSS Inc., Chicago, IL). The tests given below were used:

1. T-tests were used for the comparison of indoor versus outdoor athletes in the categories of BMI and body fat percentage.
2. The Spearman correlation test was used to look at the relationships of BMI, body fat percentage, and UV exposure in relation to vitamin D concentration.
3. Factorial ANOVA was used to assess the significance of the effects of season, sport type and the interaction of these two variables with serum 25(OH)D concentration, vitamin D intake, and UV exposure respectively.

CHAPTER IV

RESULTS

The purpose of the current study was to determine if there was an association between BMI, body fat percentage, and vitamin D status in collegiate female indoor and outdoor athletes. Independent t-tests were used to compare age, BMI, and body fat percentage between the indoor and outdoor athletes. Correlations were used to assess the association between BMI, body fat percentage, and circulating vitamin D levels. Data were tested for normality and not found to be normally distributed; therefore, Spearman rank order correlation was used to test association between variables. The correlations assessed included 1) BMI and circulating 25(OH)D levels and 2) body fat percentage and circulating 25(OH)D levels at baseline in the fall. Factorial ANOVA was used to assess any significant effects of season and/or sport type on circulating 25(OH)D concentration, vitamin D intake, and UV exposure between the indoor and outdoor athletes in both the fall and spring seasons. Significance was set at a p value of .05 for all tests.

Description of the Participants

Participants consisted of indoor (n = 6) and outdoor (n = 9) collegiate female athletes ranging in age from 18.4 to 22.2 years, actively participating in a sport, gymnastics or soccer, respectively, at Texas Woman's University at the Denton campus.

Results of the TWU Sunlight Habits Questionnaire for indoor athletes were as follows (see Appendix D). Five of the six indoor athletes used tanning facilities, with four of these five athletes who used those tanning facilities, going 1-5 times per week. The average time per session was 10-20 min without use of sunscreen. Five of the six participants wore makeup with an SPF ranging from 10-20. Only one of the six indoor athletes supplemented (600 IU via multivitamin). As part of the questionnaire, the athletes took an eight-question vitamin D knowledge quiz. The average score of this test was 62.5%. Sunscreen, with an SPF ranging from 8 to 70, was seldom or sometimes used in 83% of participants. Participants were more likely to wear sunscreen in the summer and less likely in the fall, winter, and spring. Most participants were likely to increase time outdoors in spring and summer and during the hours of 10 a.m. to 6 p.m.; however, most participants spent their recreational time indoors.

Results of the TWU Sunlight Habits Questionnaire for outdoor athletes were as follows. One of the nine participants did not return the TSHQ therefore data results consist of the eight who did complete the questionnaire. Participants never or seldom wore a hat or covered legs in the sun. Only one participant of the eight used tanning facilities and they were used at a rate of less than once per month for a span of 12 min without the use of sunscreen. Four of the eight participants used makeup with SPF, with an average SPF of 15. Two of the eight participants took a vitamin D supplement regularly (2000 IU/day; 400 IU via daily multivitamin). The average score of an eight-question test over vitamin D knowledge was 78.1%. Participants seldom to sometimes wore sunscreen; SPF ranged from 10-90. There was a varied range of how often sunscreen was worn during time spent outdoors. All participants were more likely to wear sunscreen in summer than in the fall, winter, and spring seasons. The typical hours spent outdoors were 7 am to 6 pm with 50-70% skin exposure. Participants were more likely to decrease time outdoors only in winter.

Results of the descriptive statistics are shown in Table 5 below. The average age of indoor participants was 20.2 ± 1.5 years; average age of outdoor participants was 19.4 ± 0.7 years. BMI ranged from 19.4 kg/m^2 to 31.0 kg/m^2 and body fat percentages ranged from 14.3% to 43.3% for both groups. BMI and body fat percentage of the indoor athletes averaged 24.5 ± 2.8 kg/m^2 and 27.0 ± 6.5%, respectively. BMI and body fat percentage of the outdoor athletes averaged 23.5 ± 4.0 kg/m^2 and 32.1 ± 8.2%, respectively. There were no significant differences between indoor and outdoor athletes regarding age (p = .27), BMI (p = .60), or body fat percentage (p = .23).

Table 5

Descriptive Statistics

	Indoor Athletes n=9	Outdoor Athletes n=6	*p*
Age (years)	20.2 ± 1.5	19.4 ± 0.7	.27
BMI (kg/m^2)	24.5 ± 2.8	23.5 ± 4.0	.60
Body fat %	27.0 ± 6.5	32.1 ± 8.2	.23

Mean ± Standard Deviation

Serum 25(OH)D concentrations of indoor athletes ranged from 26 to 47 ng/ml in the fall and 19 to 57 ng/ml in the spring. Of the six participants one had deficient 25(OH)D levels in the fall, and two were deficient in the spring using Endocrine Society guidelines of <30 ng/ml (see Appendix E). Vitamin D intake ranged from 6 to 844 IU in the fall and 27 to 523 IU in the spring. Four of the six did not meet the RDA for vitamin D intake in the fall and five of the six did not meet the RDA in the spring (see Appendix F). UV exposure ranged from 0 to 2.24 J/cm^2 in the fall and 0 to 0.19 J/cm^2 in the spring (see Appendix G).

Serum 25(OH)D concentrations of outdoor athletes ranged from 28 to 38 ng/ml in the fall and 21 to 37 ng/ml in the spring. Of the nine participants two were vitamin D deficient in the fall and six were deficient in the spring (see Appendix E). Vitamin D intake ranged from 66 to 2067 IU in the fall and 31 to 2425 IU in the spring. Six of the nine participants did not meet the RDA for vitamin D in the fall and seven of the 9 participants did not meet the RDA in the spring (see Appendix F). UV exposure ranged from 0 to 2.52 J/cm^2 in the fall and 0 to 0.25 J/cm^2 in the spring (see Appendix G).

Testing the Hypotheses

Spearman's rank order correlation was used to assess relationships between BMI, body fat percentage, and serum 25(OH)D concentration. Results are shown in Table 6 below. No correlation was found between BMI and fall serum 25(OH)D concentration (r_s = .043; p = .879). No correlation was found between body fat percentage and fall serum 25(OH)D concentration (r_s = -.202; p = .47). After analyzing the data, the null hypothesis was accepted (all p values were > .05) which indicated that there were no significant associations between BMI, body fat percentage, and fall serum 25(OH)D concentration.

Table 6

Spearman's Rank Order Correlation Results

Fall Serum 25(OH)D (ng/ml) vs. Variable Below	r_s	*p*
BMI	.043	.879
Body fat %	-.202	.47

Serum 25(OH)D concentrations were subjected to a factorial ANOVA having two levels of season (spring, fall) and two levels of sport (indoor, outdoor). The significance level for all effects was set at .05. Results are shown in Table 7, Table 8, and Figure 3 below. The main effect of season yielded an *F* ratio of *F* = .537, *p* = .477, indicating that the mean score was not significantly different in the fall (*M* = 34.20, *SD* = 6.383) than in the spring (*M* = 34.53, *SD* = 12.983). However, the main effect of sport type yielded an F ratio of *F* = 5.794, *p* = .032, indicating that the mean 25(OH)D concentration was significantly greater for the indoor participants than for the outdoor participants. The interaction effect was significant, *F* = 7.557, *p* = .032, as 25(OH)D decreased from fall to spring in the outdoor group but increased from fall to spring in the indoor group.

Table 7

*Serum 25(OH)D Concentrations**

	Fall	Spring
Outdoor	32.11 ± 3.59	28.44 ± 5.46
Indoor	37.33 ± 8.60	43.67 ± 16.05
All Athletes	34.20 ± 6.38	34.53 ± 12.98

** Mean ± Standard Deviation*

Table 8

Effect of Season or Sport on Serum 25(OH)D Concentration

	F	*p*
Effect of season	0.537	.477
Effect of sport	5.794	.032*
Interaction effect	7.557	.017*

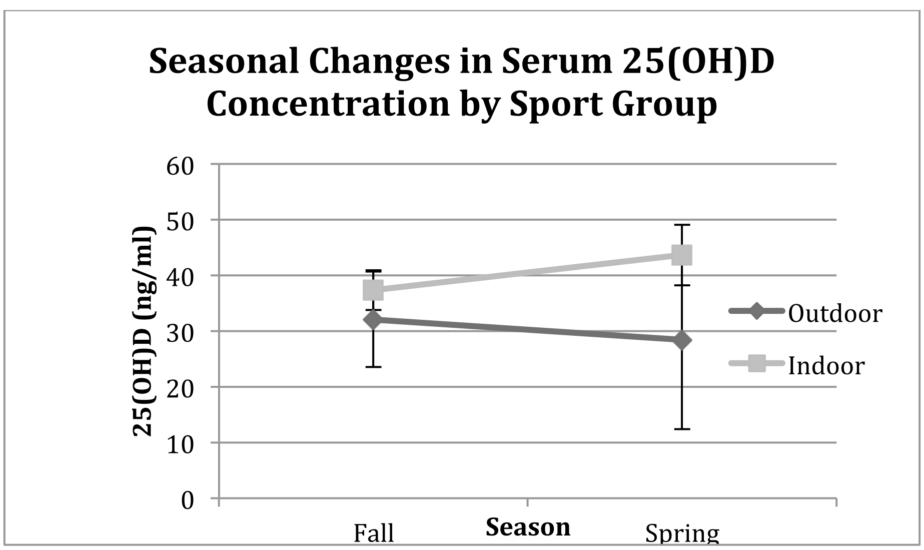

Figure 3. Seasonal Changes in Serum 25(OH)D Concentration by Sport Group

Vitamin D intake (IU) was also subjected to a factorial ANOVA with same effects of season and sport type. Results are shown in Table 9, Table 10, and Figure 4 below. The main effect of season yielded an *F* ratio of *F* = 1.011, *p* = .333, indicating that the mean score was not significantly different in the fall (*M* = 409.68, *SD* = 546.64) than in the spring (*M* = 332.61, *SD* = 613.35). The main effect of sport type yielded an F ratio of *F* = 0.629, *p* = .442, indicating that the mean vitamin D intake was not significantly different between the indoor and outdoor athletes. The interaction effect was not significant, *F* = 0.172, *p* =.685 as vitamin D intake was unchanged from fall to spring in both indoor and outdoor athletes.

Table 9

*Vitamin D Intake via Diet and Supplementation (IU)**

	Fall	Spring
Outdoor	490.73 ± 653.57	441.38 ± 776.89
Indoor	288.09 ± 351.66	169.47 ± 185.58
All Athletes	409.68 ± 546.64	332.61 ± 613.35

* Mean ± Standard Deviation

Table 10

*Effect of Season or Sport on Vitamin D Intake (IU)**

	F	*P*
Effect of season	1.011	.333
Effect of sport	0.629	.442
Interaction effect	0.172	.685

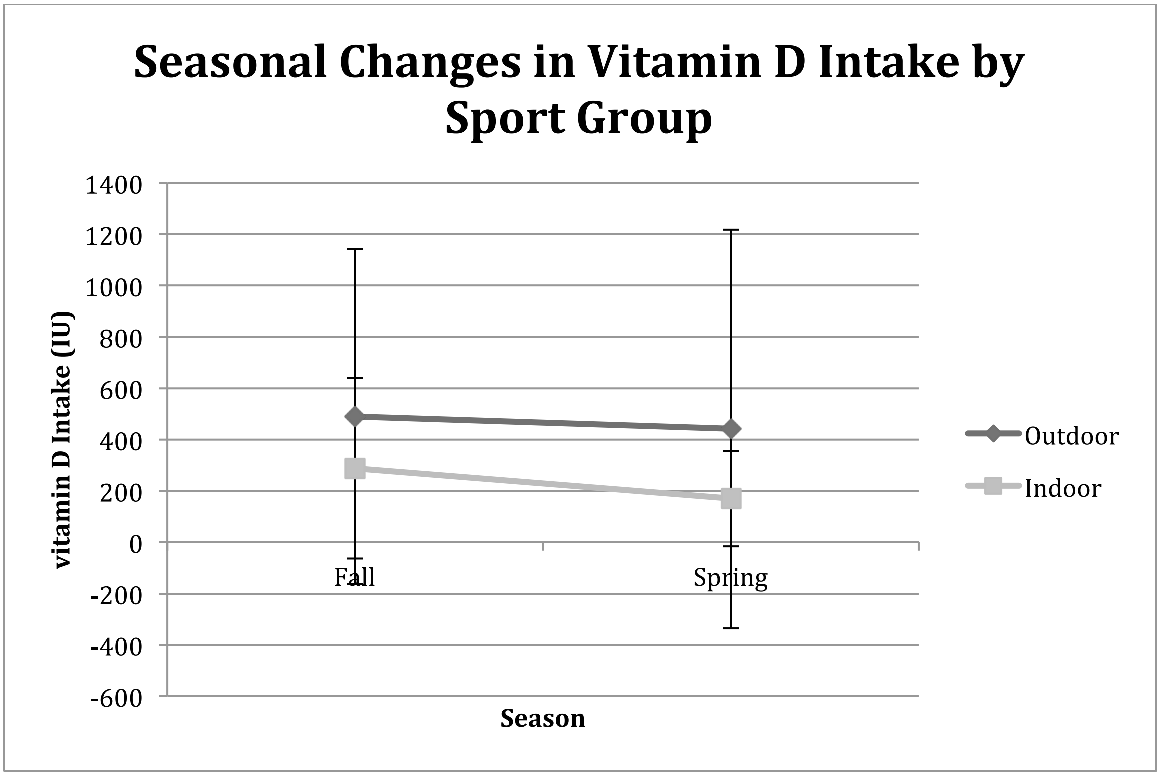

Figure 4. Seasonal Changes in Vitamin D by Sport Group

Finally, UV exposure was subjected to a factorial ANOVA with same effects of season and sport type. Results are shown in Table 11, Table 12, and Figure 5 below. The main effect of season yielded an F ratio of F = 7.396, p = .018, indicating that the mean score for UV exposure was significantly higher in the fall (M = 0.813, SD = 0.932) than in the spring (M = 0.092, SD = 0.932). The main effect of sport type yielded an F ratio of F = 0.390, p = .543, indicating that the mean UV exposure was not significantly different between the indoor and outdoor athletes. The interaction effect was not significant, F = 0.298, p = .594 as UV exposure decreased similarly from fall to spring in both indoor and outdoor athletes.

Table 11

*UV Exposure (J/cm²)**

	Fall	Spring
Outdoor	0.931 ± 0.987	0.099 ± 0.105
Indoor	0.635 ± 0.898	0.082 ± 0.102
All Athletes	0.813 ± 0.932	0.092 ± 0.100

*Mean ± Standard Deviation

Table 12

Effect of Season or Sport on UV Exposure (J/cm²)

	F	*P*
Effect of season	7.396	.018*
Effect of sport	0.390	.543
Interaction effect	0.298	.594

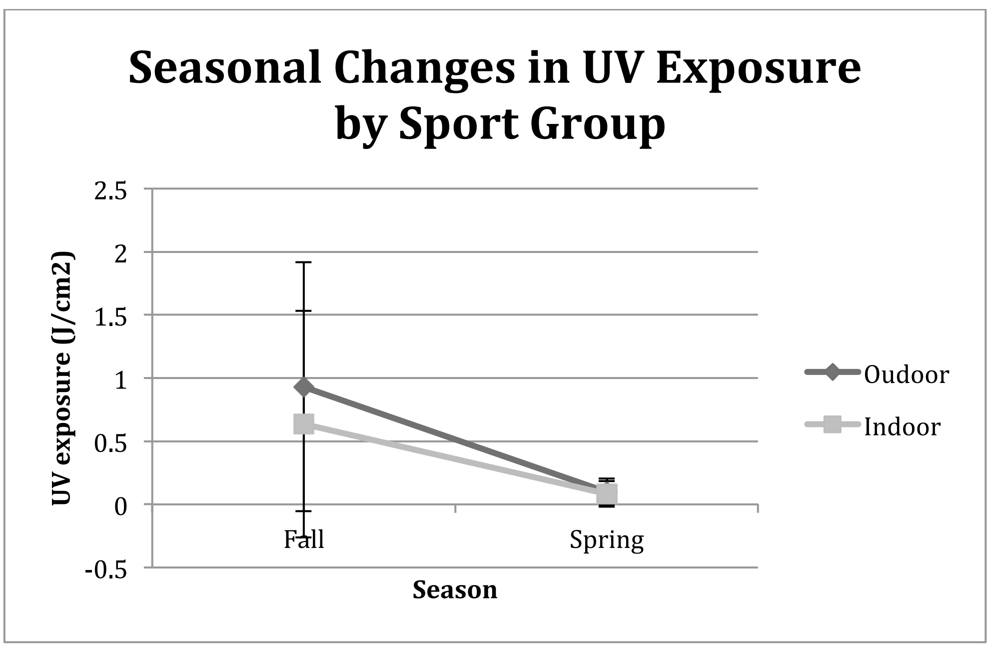

Figure 5. Seasonal Changes in UV Exposure by Sport Group

CHAPTER V

SUMMARY, DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDIES

The purpose of the current study was to determine if there was an association between BMI, body fat percentage, and serum 25(OH)D concentration in indoor and outdoor collegiate female athletes .The anthropometric information was obtained with permission through Texas Woman's University's Institute for Women's Health, Exercise and Sports Nutrition Clinic.

Summary

There were a total of 15 athletes who provided data including serum 25(OH)D concentration, UV exposure via sunlight badges, and Vitamin D Food Frequency Questionnaires, in both the fall and spring seasons. The TWU Sunlight Habits Questionnaire was completed at baseline in the fall. Anthropometric data, including body fat percentage via DXA scan, and BMI, were obtained at baseline in the fall. Athletes were grouped into either indoor or outdoor sport type. Adequate serum 25(OH)D concentration was set by ZRT lab testing facility at 32 ng/ml.

Descriptive statistics, independent t-tests specifically, were used to assess any significant differences between sport type groups in age, BMI, and body fat percentage. There were no significant differences in age, BMI, and body fat percentage between the two groups.

Spearman rank order correlations were used to assess relationship between BMI, body fat percentage, and serum 25(OH)D concentration at baseline in the fall. After analyzing the data the null hypothesis was retained as there was not a significant relationship between BMI, body fat percentage, and serum 25(OH)D concentration.

Factorial ANOVA was used to assess significant effects of season, sport type, or the interaction between the two concerning serum 25(OH)D concentration, vitamin D intake, and UV exposure. Regarding serum 25(OH)D concentrations, the null hypothesis was rejected as the mean 25(OH)D was significantly greater for the indoor participants than for the outdoor participants; 25(OH)D concentration also decreased from fall to spring in the outdoor group, but increased from fall to spring in the indoor group. Regarding vitamin D intake, the null hypotheses were retained as there were no significant effects of sport type, season, or their interaction with vitamin D intake. Finally, regarding UV exposure, the null hypothesis was rejected as there was a significant effect of season on UV exposure as exposure significantly decreased from the fall to the spring season in athletes of both sport types.

Discussion

In summary, the study did not find any significant relationship with BMI, body fat percentage, and serum 25(OH)D concentration. These results are not analogous to the findings that body composition and vitamin D status are correlated in adult and adolescent populations (Kang et al., 2013; Vanlint, 2013). The average

BMIs for both sport types were 23.5 and 24.5 kg/m^2, within a normal BMI range, and body fat percentages were 27.1 and 32.1%, also within a normal range for females. Because the participants were not obese or over-fat this may have affected the ability to find a relationship between serum vitamin D levels and BMI or body fat percentage. Halliday et al., also found no correlation between 25(OH)D concentration and BMI or body composition in a study consisting of 41 indoor and outdoor male and female athletes (Halliday et al., 2011). These results show the need for further research on body composition and vitamin D status in an athletic population. Because body fat percentage is not taken into account when determining BMI and because BMI is not an accurate indicator of body composition in an athletic population, further studies should focus on body fat percentage rather than BMI (Ode et al., 2007; Wallner-Leibmann et al., 2013). The current study did find that there were significant decreases in UV exposure from fall to spring in athletes for both indoor and outdoor sport types which is consistent with current research in a general population (Kasahara, Singh, & Noymer, 2013). These results were analogous to the results of the TWU Sunlight Habits Questionnaire. The current study also saw a decrease in serum 25(OH)D in the outdoor sport group from fall to spring while there was an increase in serum 25(OH)D from fall to spring in the indoor sport group, although both athlete groups showed no significant differences in vitamin D intake and UV exposure from fall to spring. One possible explanation that could account for the unseasonable increase in 25(OH)D concentration from fall to spring in the indoor athletes is the use of tanning beds 1-5 times per week in 5 of the 6 indoor participants. Only one of the outdoor athletes admitted to the use of tanning beds once a month. Tanning bed use has also been significantly correlated with vitamin D concentrations (Cicarma et al., 2009; Halliday et al., 2011; Thieden et al., 2008). The percentage of vitamin D deficient athletes (47% in the fall and 53% in the spring) agrees with other studies showing the deficiency of vitamin D in athletes ranging from 24.4% to 83% depending upon season (Constantini et al., 2010; Gibson et al., 2011; Halliday et al., 2011; Lovell, 2008; Villacis et al., 2014).

Strengths of the current study are listed below. Strengths include availability of accurate anthropometric measurements via DXA scan, accuracy of 25(OH)D concentrations via ZRT testing kits, and accuracy of UV calibration and exposure. Each of these measurements and tests were reliable and valid.

Limitations of the study are reported below. The small sample size used in the current study may have limited the ability to find significant relationships in the statistical analyses performed, as larger sample sizes are generally needed for an accurate representation of the group tested. Because BMI and body fat were only taken at baseline in the fall, only the fall 25(OH)D concentrations were used for the Spearman rank order correlation tests. Had BMI and body composition been measured again in the spring the correlation test could have been run again. While the Vitamin D Food Frequency Questionnaire can be a practical method for obtaining data, it is not without limitations. Participants were asked to specifically record all foods consumed on the list containing vitamin D in specific amounts (i.e. cups, teaspoons, ounces, etc.) and brands to ensure accuracy; however, some amounts were estimations and not specific. For example, "a handful" was recorded as a measurement in one questionnaire, and brand names were not given for some food items. Also, the VDFFQ was only an intake record for the 2 days the participants wore the sunlight badges in the fall and in the spring. Therefore, intake may not have been representative of usual vitamin D intake. Finally sunlight badges were worn for only 2 days in the fall and spring and may not have been representative of usual exposure. A few of the badges were damaged before they were analyzed and could have altered the data had they been analyzed. Because none of the badges were damaged in duplicate, the sample size was not affected. There was also no way of ensuring that participants wore the badges for the entire day in the appropriate area on the body. Also, only Caucasian and Hispanic females were used in the current study. It is unclear if males or other ethnicities would have different outcomes from what was shown in the current study as neither population was assessed.

Conclusions

In conclusion, there was no significant relationship found between BMI, body fat composition, and serum 25(OH)D concentration in the current study.

Recommendations for Further Studies

Additional studies could include a larger population size for a more representative sample of the collegiate, athletic population. Also, different ethnicities and both the male and female sexes could be studied to further investigate the relationship between BMI, body fat percentage, and 25(OH)D concentration. With a larger population size available, exclusion criteria could include tanning bed use. UV exposure and dietary intake could be recorded for a longer period of time to better represent usual habits.

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APPENDIX A

TWU Sunlight Habits Questionnaire

TWU Sunlight Questionnaire

This questionnaire is designed to assess your general knowledge of Vitamin D, it's production in the skin, and its availability in your diet.

There is a general variety of questions, from your weekly habits to your general knowledge of Vitamin D and the sun. The questions will have a variety of general answer formats. Some of them may ask your general frequency of an activity, and others may ask you to agree or disagree on a scale with the statement presented. In all cases answer the question by checking or bubbling the matching bubble.

For example:

	Light Blue, Grey, or Green	Blue, Grey, or Green	Blue	Dark Brown	Brownish Black
What is the color of your eyes?	●	○	○	○	○

Or

	Light Blue, Grey, or Green	Blue, Grey, or Green	Blue	Dark Brown	Brownish Black
What is the color of your eyes?	○	○	✓	○	○

Your honesty with the questions will help to validate the questionnaire, and give us an easy and effective way to determine attitudes towards sunlight. For the questions please choose the closet match, and only choose one answer.

For the questions that include specific time frames use these guidelines. Check if you spend at least 75% of that time engaged in the activity, and check all that are appropriate, for these questions only you may have more than one answer.

For Example: If you spend the hours of 8am through 4pm outdoors you would check the boxes for 7am-10am, 10am-3pm. Since 3pm-4pm is not a significant portion of the 4pm-6pm time frame, you would not check that box. It would look like this:

	Midnight - 7am	7am-10am	10am-3pm	3pm-6pm	6pm-midnight
In a typical workday, what hours would you work outdoors?	○	●	●	○	○

As general guidelines, remember that most windows are treated to prevent UV exposure, and are considered to be indoors, even with very large windows. Many make up brands also include UV protection.

Thank you for your participation.

1 Page Total:

TWU Sunlight Questionnaire

Please provide some general information about yourself

Age	________________	
Sex	◯ Male	◯ Female
Height	________________ Ft	________________ In
Weight	________________ Lb	
Job Title		
Where do you live or work? (State and Country)	________________ State	________________ Country

These questions will help us to determine your skin tone, Please answer these questions with the natural characteristics of your skin, eyes, and hair in mind.

What is the color of your eyes?	Light Blue, Grey, or Green ◯	Blue, Grey, or Green ◯	Blue Only ◯	Dark Brown ◯	Brownish Black ◯
What is the natural color of your hair?	Sandy Red ◯	Blonde ◯	Chestnut/Dark Blonde ◯	Dark Brown ◯	Black ◯
What is the color of your skin in non exposed areas?	Reddish ◯	Very Pale ◯	Pale with a Beige Tint ◯	Light Brown ◯	Dark Brown ◯
Do you have freckles in the non exposed areas of your skin?	Many ◯	Several ◯	Few ◯	Incidental ◯	None ◯
What happens if you stay in the sun too long?	Painful Redness, Blistering ◯	Blistering, then Peeling ◯	Burns sometimes then peeling ◯	Rarely Burns ◯	Never Burns ◯
To what degree do you tan?	Not at all ◯	Light Color Tan ◯	Reasonable Tan ◯	Tan very easily ◯	Turn Dark Brown Quickly ◯
Do you tan within several hours of sun exposure?	Never ◯	Seldom ◯	Sometimes ◯	Often ◯	Always ◯
How does your face react to the sun?	Very Sensitive ◯	Sensitive ◯	Normal ◯	Very Resistant ◯	Never had a Problem ◯

Fitzpatrick TB. Soleil et Peau. *J Med Esthet* 1975;2:33034.

2 Page Total:

TWU Sunlight Questionnaire

These questions will tell us about your habits in relation to sunlight. Please indicate how often you engage in the following activities. Please choose only one answer per question.

Question					
How often do you seek sunshine?	Never ○	Seldom ○	Sometimes ○	Often ○	Always ○
How often do you avoid the sun?	Never ○	Seldom ○	Sometimes ○	Often ○	Always ○
How often do you wear a hat when it is sunny?	Never ○	Seldom ○	Sometimes ○	Often ○	Always ○
How often do you cover your arms and legs when it is sunny?	Never ○	Seldom ○	Sometimes ○	Often ○	Always ○
How often do you use tanning facilities?	Never ○	Less than once per Month ○	3-5 Times per Month ○	1-2 Times per Week ○	3-5 Times per Week ○
How long do you tan per session?		Minutes ____________			
Does your tanning facility provide the correct UV to produce Vitamin D?		Yes ○	No ○	Unknown ○	
Do you purposefully use tanning facilities to make Vitamin D?		Yes ○	No ○		
How often do you wear makeup that contains UV protection/?		Yes ○	No ○	Not Applicable ○	
What SPF is it?		SPF ____________			
I regularly take a Vitamin D Supplement.		Yes ○	No ○		
Do you wear anything while tanning?		Tanning Accelerators ○	UV Protection ○	None ○	

3 Page Total:

TWU Sunlight Questionnaire

These questions are related to your general knowledge of sunlight and vitamin D, please state whether you agree or disagree with the statement based on the scale below.

	Agree	Disagree
Sun Exposure is the Best source of Vitamin D.	◯	◯
Even while wearing sunscreen you can produce Vitamin D.	◯	◯
There is no need to get Vitamin D from the sun because food is fortified.	◯	◯
Vitamin D can be easily obtained from a supplement.	◯	◯
Dietary sources of Vitamin D are better than Vitamin D from sunlight.	◯	◯
Fatty fish are the best food source of Vitamin D.	◯	◯
I avoid fish because they may contain mercury.	◯	◯
Lots of foods contain Vitamin D.	◯	◯

4 Page Total:

TWU Sunlight Questionnaire

This series of questions is designed to assess your use of sunscreen in various situations. Consider how you would act in a normal situation, i.e. a normal planned weekend outing or day at work.

How often do you use sunscreen in general?	Never ◯	Seldom ◯	Sometimes ◯	Often ◯	Always ◯
What SPF did you generally use?		SPF	____________		
How often do you use sunscreen while working, including makeup?	Never ◯	Seldom ◯	Sometimes ◯	Often ◯	Always ◯
What SPF do you use?		SPF	____________	Same as above	◯
How often do you use sunscreen during recreational activities?	Never ◯	Seldom ◯	Sometimes ◯	Often ◯	Always ◯
What SPF do you use?		SPF	____________	Same as above	◯
Are you more likely to wear sunscreen during **Winter**?		Yes ◯	No ◯		
Are you more likely to wear sunscreen during **Spring**?		Yes ◯	No ◯		
Are you more likely to wear sunscreen during **Summer**?		Yes ◯	No ◯		
Are you more likely to wear sunscreen during **Autumn**?		Yes ◯	No ◯		

5 Page Total:

TWU Sunlight Questionnaire

These questions are related to your work habits. These questions will help us to estimate your time spent outdoors. If you are a student, you may consider your time studying or in class as work. Please consider as a workday those days in which a majority of your time is spent working. Please consider as a recreational day those days in which a majority of time is spent engaged in recreational activities or running errands.

Work Days:

How many days per week do you work?	Days				
How long is a typical work week for you?	Hours				
In a typical workday, what hours would you work outdoors?	Midnight - 7am ◯	7am-10am ◯	10am-3pm ◯	3pm-6pm ◯	6pm-midnight ◯
What percentage of your skin is exposed to sunlight while you work?	(30% or Less) Hands and Face, or Less ◯	(30%-50%) Short Sleeves ◯	(50%-70%) Shorts and a T-Shirt ◯	(70%-90%) Shirtless or Bikini and Shorts ◯	(90% or more) Small Swimsuit or Nothing ◯

Recreational Habits:

How many hours per week do you spend in recreational activities?	____________________ Hours				
When do you engage in recreational activities?	Early Morning ◯	Morning ◯	Midday ◯	Late Afternoon ◯	Late Night ◯
How much of this recreational activity is spent outdoors?	Midnight - 7am ◯	7am-10am ◯	10am-3pm ◯	3pm-6pm ◯	6pm-midnight ◯
What percentage of your skin is exposed to sunlight during recreational activities?	(30% or Less) Hands and Face, or Less ◯	(30%-50%) Short Sleeves ◯	(50%-70%) Shorts and a T-Shirt ◯	(70%-90%) Shirtless or Bikini and Shorts ◯	(90% or more) Small Swimsuit or Nothing ◯
Do you engage in active team or individual sports outdoors?	Yes ◯	No ◯			

6 Page Total:

TWU Sunlight Questionnaire

These next set of questions are related to your seasonal habits, concerning time outdoors and sun exposure.

Do you tend to Increase or Decrease your time spent **outdoors** during the **Winter**?		Increase	Decrease		
		◯	◯		
When do you spend most of your time **outdoors** during **Winter**?	Midnight - 7am	7am-10am	10am-3pm	3pm-6pm	6pm-midnight
	◯	◯	◯	◯	◯
Do you tend to Increase or Decrease your time spent **outdoors** during the **Spring**?		Increase	Decrease		
		◯	◯		
When do you spend most of your time **outdoors** during **Spring**?	Midnight - 7am	7am-10am	10am-3pm	3pm-6pm	6pm-midnight
	◯	◯	◯	◯	◯
Do you tend to Increase or Decrease your time spent **outdoors** during the **Summer**?		Increase	Decrease		
		◯	◯		
When do you spend most of your time **outdoors** during **Summer**?	Midnight - 7am	7am-10am	10am-3pm	3pm-6pm	6pm-midnight
	◯	◯	◯	◯	◯
Do you tend to Increase or Decrease your time spent **outdoors** during the **Autumn**?		Increase	Decrease		
		◯	◯		
When do you spend most of your time **outdoors** during **Autumn**?	Midnight - 7am	7am-10am	10am-3pm	3pm-6pm	6pm-midnight
	◯	◯	◯	◯	◯

7 Page Total:

TWU Sunlight Questionnaire

This last set of questions is related to taking vacation. Even if you did not take a vacation, please answer the questions related to your general vacation habits.

Did you take a Vacation this year?		Yes	No		
		◯	◯		
Where did you go? (City and State, or Country)		City, St (Country) ______________________________			
How much time did you spend outdoors on your vacation?	Less than 1 hour per day	1-4 hours per day	4-8 hours per day	8-12 hours per day	More than 12 hours per day
	◯	◯	◯	◯	◯
What percentage of you skin was exposed to the sun?	(30% or Less) Hands and Face, or Less	(30%-50%) Short Sleeves	(50%-70%) Shorts and a T-Shirt	(70%-90%) Shirtless or Bikini and Shorts	(90% or more) Small Swimsuit or Nothing
	◯	◯	◯	◯	◯
How often did you use sunscreen on vacation?	Never	Seldom	Sometimes	Often	Always
	◯	◯	◯	◯	◯
What SPF did you use?	SPF _____________				
Describe the typical weather conditions during your vacation.					

8 Page Total:

APPENDIX B

Vitamin D Food Frequency Questionnaire

Vitamin D Food Frequency Questionnaire

How often did you eat the following foods each day? Please list number of times each day if applicable.

Please give specific serving sizes when possible (ounces, cups, tablespoons, etc.)

List the type of food (Chex cereal, 2% milk, cheddar cheese, salmon, oysters, cashews, romaine lettuce, etc.)

Food	Day 1	Day 2
Fortified cereal		
Fortified milk		
Fortified orange juice		
Eggs		
Cream		
Cheese		
Fortified soy/almond milk		
Butter or margarine		

Fish or shellfish		
Liver		
Cod-liver oil		
Nuts or seeds		
Leafy green vegetables		
Salad dressing		
Other Please indicate here any other possible sources of vitamin D		
Multi-vitamin/Multimineral Supplement		

APPENDIX C

Calibration Curves for UV Exposure

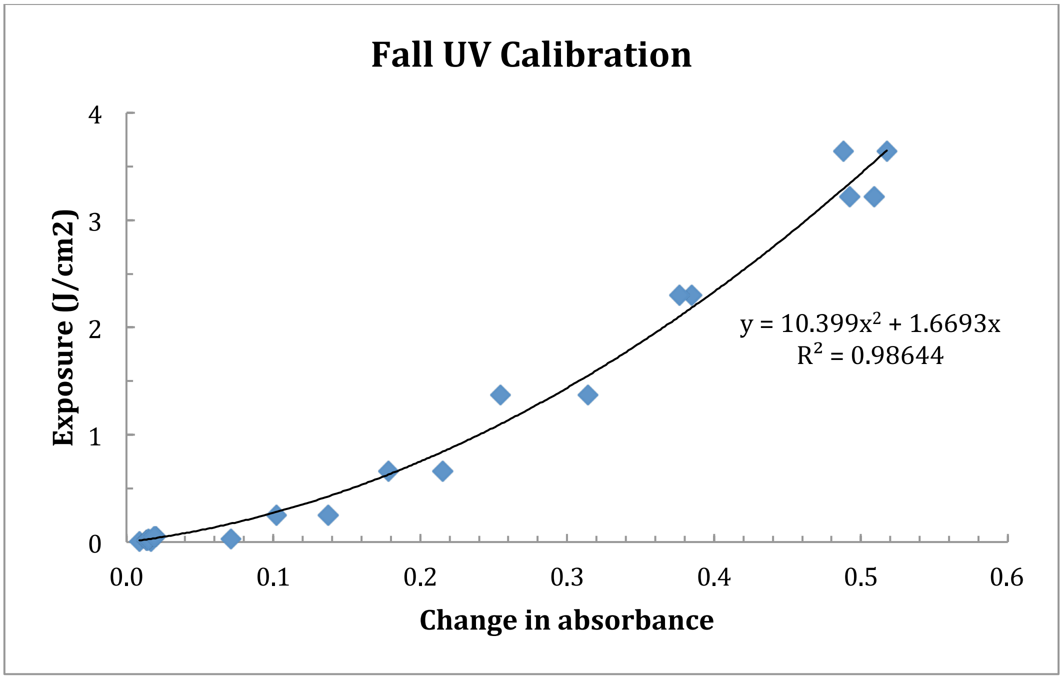

Figure A1. Fall UV Calibration Curve

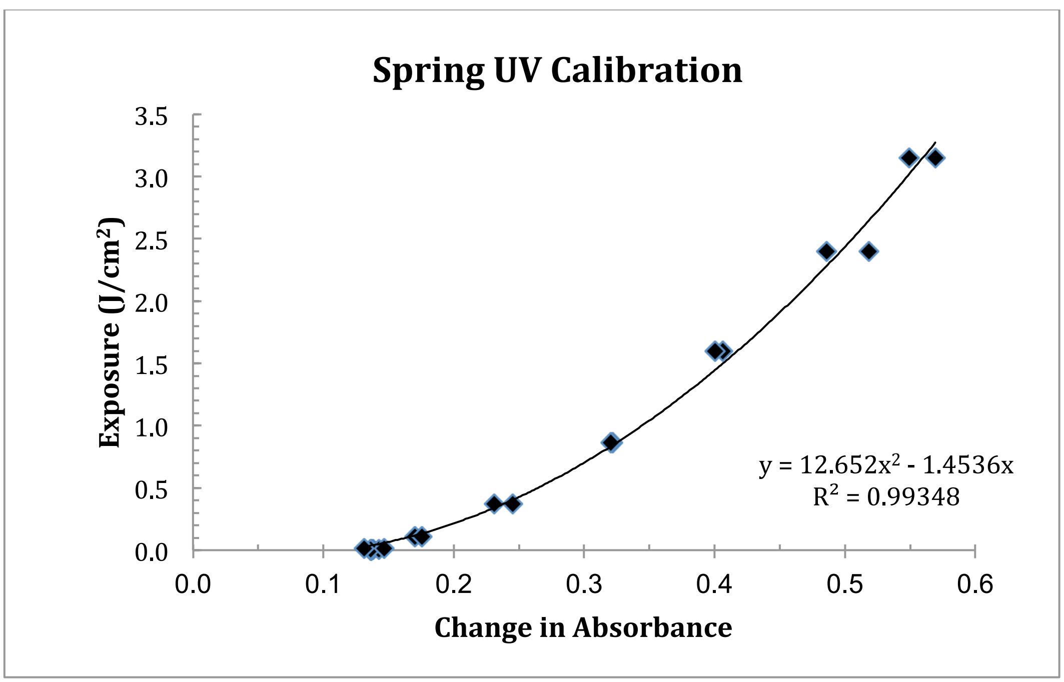

Figure A2. Spring UV Calibration Curve

APPENDIX D

TWU Sunlight Habits Questionnaire Data

Sunlight Questionnaire - Indoor Athletes

eye color	Light bl/gry/grn	bl/gry/grn	Blue only	dark brown	brn-black
	1	2	2	1	
nat hair color	red	blonde	chestnut/ dark blonde	dark brown	Black
		1	3	2	
skintone non-exp	reddish	very pale	pale w/ beige	lt brown	dark brown
		2	3	1	
freckles	many	several	few	incidental	None
	1	1	2	2	
sun too long	painful red & blister	blis & peel	burn some & peel	rarely burn	never burn
	1		3	2	
tan degree	not at all	light color	reasonable	very easily	dark brown quickly
	1		1	4	
tan w/in hrs exp	never	seldom	sometimes	often	Always
	1		2	1	1
facial sun rxn	very sensitive	sensitive	normal	very resistant	never a prob
	1	1	4		
seek sunshine	never	seldom	sometimes	often	Always
		2	3	1	
avoid sunshine	never	seldom	sometimes	often	Always
	2	3		1	
wear a hat in sun	never	seldom	sometimes	often	Always
	3	2	1		
cover arms/legs in sun	never	seldom	sometimes	often	Always
	2	3	1		
tanning facilities	never	< 1 /month	3-5 /month	1-2 /wk	3-5 /wk
	1	1		2	2
how long per session	minutes				
	15	12	10 to 20	12	20

does facility provide correct UV to produce vit D?	yes	no	unknown		
	1		4		
use tanning facilities purposefully to make D	yes	no			
		5			
wear makeup w/ spf?	yes	no			
	5	1			
what SPF?	#				
	12, 10, 15, 20 , 17				
take D supp regularly	yes	no			
	1	5			
wear anything while tanning?	tan accel	UV prot	none		
	1	2	3		
sun exp best D source	agree	disagree			
	3	3			
can produce D w/ spf	agree	disagree			
	6				
no need D from sun 2/2 food sources	agree	disagree			
		6			
vit D easily obtained from supplement	agree	disagree			
	5	1			
diet D > sun D	agree	disagree			
	2	4			
fatty fish best food D	agree	disagree			
	2	4			
avoid fish 2/2 mercury	agree	disagree			
		6			
lots of foods w/ D	agree	disagree			
	6				
how often sunscreen in general	never	seldom	sometimes	often	Always
		2	3		1
what SPF?	spf				

	30-50, 30, 8, 15-30, 70, 30-50				
how often sunscreen while working	never	seldom	sometimes	often	Always
	1	3	1	1	
what SPF?	spf				
	30-50, 30, 10, 15, 15, 30-50				
how often sunscreen during rec activities	never	seldom	sometimes	often	Always
		2	3		1
more likely to wear sunscreen in winter	yes	no			
	1	5			
more likely to wear sunscreen in spring	yes	no			
	2	4			
more likely to wear sunscreen in summer	yes	no			
	6				
more likely to wear sunscreen in autumn	yes	no			
	2	4			
days you work/school	days				
	4, 4, 4, 5, 4, 5				
typical work week	hrs				
	40, 15, 15, 19, 19, 16				
typical hrs outdoors	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
		2	1		
% of skin exposure	30 % or <	30-50%	50-70%	70-90%	90+%
	2	1	2		
# of hrs of rec activities	hours				
	20	20	20	20	20
when rec activities	early morning	morning	midday	late afternoon	late night
	5		6	6	
when outdoors	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
			1	1	
% of skin exposure	30 % or <	30-50%	50-70%	70-90%	90+%
	1	1	2	1	

team/individ sports?	yes	no			
	1	5			
time outdoors in winter	increase	decrease			
		6			
when out in winter	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm- midnight
		2	3	2	
time outdoors in spring	increase	decrease			
	5	1			
when out in spring	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm- midnight
		1	3	4	1
time out in summer	increase	decrease			
	6				
when out in summer	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm- midnight
			5	4	2
time out in autumn	increase	decrease			
	2	4			
when out in autumn	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm- midnight
		3	4	3	1
vacation this year	yes	No			
	6				
where	city, st, country				
	CA, TX, AK, Paris, MI, Puerto Rico				
how much outdoors	<1 hr/d	1-4 hr/d	4-8 hr/d	8-12 hr/d	>12 hr/d
		1	3	1	1
% of skin exposure	30 % or <	30-50%	50-70%	70-90%	90+%
			2	3	1
how often use sunscrn	never	seldom	sometimes	often	always
		1		4	1
what SPF?	spf				
	30, 50, 30, 15, 70, 50				
typical weather	describe				
	partly sunny, hot, sunny, hot & sunny, Hot & sunny, mostly sunny, very sunny				

Sunlight Questionnaire - Outdoor Athletes

eye color	Light bl/gry/grn	bl/gry/grn	Blue only	dark brown	brn-black
		5	1	2	
nat hair color	red	blonde	chestnut/ dark blonde	dark brown	Black
	1	1	2	4	
skintone non-exp	reddish	very pale	pale w/ beige	lt brown	dark brown
		1	4	3	
freckles	many	several	few	incidental	None
			3	1	4
sun too long	painful red & blister	blis & peel	burn some & peel	rarely burn	never burn
			4	3	1
tan degree	not at all	light color	reasonable	very easily	dark brown quickly
		1	2	4	1
tan w/in hrs exp	never	seldom	sometimes	often	Always
		1	3	2	2
facial sun rxn	very sensitive	sensitive	normal	very resistant	never a prob
		2	5		1
seek sunshine	never	seldom	sometimes	often	Always
			6		2
avoid sunshine	never	seldom	sometimes	often	Always
	3	2	3		
wear a hat in sun	never	seldom	sometimes	often	Always
	5	3			
cover arms/legs in sun	never	seldom	sometimes	often	Always
	6	2			
tanning facilities	never	< 1 /month	3-5 /month	1-2 /wk	3-5 /wk
	7	1			
how long per session	minutes				
	12				
does facility provide correct UV to produce vit D?	yes	no	unknown		
			1		
use tanning facilities purposefully to make D	yes	no			

		1			
wear makeup w/ spf?	yes	no			
	4	3			
what SPF?	#				
	15	15	15		
take D supp regularly	yes	no			
	2	2			
wear anything while tanning?	tan accel	UV prot	none		
			1		
sun exp best D source	agree	disagree			
	8				
can produce D w/ spf	agree	disagree			
	7	1			
no need D from sun 2/2 food sources	agree	disagree			
		8			
vit D easily obtained from supplement	agree	disagree			
	2	6			
diet D > sun D	agree	disagree			
		8			
fatty fish best food D	agree	disagree			
	6	2			
avoid fish 2/2 mercury	agree	disagree			
		8			
lots of foods w/ D	agree	disagree			
	5	3			
how often sunscreen in general	never	seldom	sometimes	often	always
		4	3		1
what SPF?	spf				
	70-90, 15, 70, 70, 10, 50, 30 ,50				
how often sunscreen while working	never	seldom	sometimes	often	always
	2	5	1		
what SPF?	spf				
	70-90, 15, 70, 70, 10, 15, 15				
how often sunscreen during rec activities	never	seldom	sometimes	often	always
	1	2	2	2	1

more likely to wear sunscreen in winter	yes	no			
		8			
more likely to wear sunscreen in spring	yes	no			
		8			
more likely to wear sunscreen in summer	yes	no			
	8				
more likely to wear sunscreen in autumn	yes	no			
	2	6			
days you work/school	days				
	5, 2, 4, 4, 5, 4				
typical work week	hrs				
	20-25, 8, 20, 40, 15, 27				
typical hrs outdoors	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
		3	2		
% of skin exposure	30 % or <	30-50%	50-70%	70-90%	90+%
	1		5		
# of hrs of rec activities	hours				
	20, 10, 10, 10-12, 13, 20, 15				
when rec activities	early morning	morning	midday	late afternoon	late night
	6	2	3	2	1
when outdoors	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
	1	5	5	1	1
% of skin exposure	30 % or <	30-50%	50-70%	70-90%	90+%
			8		
team/individ sports?	yes	no			
	8				
time outdoors in winter	increase	decrease			
	1	7			
when out in winter	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
		1	3	3	1
time outdoors in spring	increase	decrease			
	8				
when out in spring	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
		1	6	5	1

time out in summer	increase	decrease			
	7	1			
when out in summer	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
		4	5	3	2
time out in autumn	increase	decrease			
	7	1			
when out in autumn	midnight - 7	7-10am	10am-3pm	3pm-6pm	6pm-midnight
		2	5	1	1
vacation this year	yes	no			
	6	2			
where	city, st, country				
	TX, CA, FL, CO, AL TX				
how much outdoors	<1 hr/d	1-4 hr/d	4-8 hr/d	8-12 hr/d	>12 hr/d
		1	5		1
% of skin exposure	30 % or <	30-50%	50-70%	70-90%	90+%
			4	1	2
how often use sunscrn	never	seldom	sometimes	often	always
		3	1	1	2
what SPF?	spf				
	80, 70, 70, 15, 50, 30-50, 15-50				
typical weather	describe				
	very sunny, hot, sunny, warm, humid, very sunny, seldom cloudy, sunny, warm				

APPENDIX E

Serum 25(OH)D Concentrations

Table A1

Serum 25(OH)D Concentrations (ng/ml)

ID #	Fall 2013	Spring 2014
Outdoor		
0385	30	21
0709	37	27
0707	30	25
0710	34	32
0717	38	37
0651	33	24
0652	30	28
0647	28	26
0653	29	36
Indoor		
0739	47	55
0332	33	46
0737	31	29
0599	26	19
0598	41	56
0185	46	57

APPENDIX F

Vitamin D Intake

Table A2

Average Vitamin D Intake (IU)

Season	Fall 2013	Spring 2014
ID	Outdoor	
0385	89	117
0709	2067	2425
0707	209	412
0710	705	700
0717	151	58
0651	829	31
0652	113	60
0647	188	139
0653	66	31
ID	Indoor	
0739	6	27
0332	210	58
0737	30	73
0599	844	118
0598	598	523
0185	41	219

APPENDIX G

UV Exposure

Table A3

UV Exposure (J/cm²)

		Fall 2013 B							Spring 2014C				
dos no	pre abs	post exp abs	delta A	av delta A	Exposure		dos no	pre abs	post exp abs	delta A	av delta A	Exposure	
24w	0.1022	0.2443	0.127	0.128	0.021		41g	0.1165	0.2063	0.11287	0.102	nil	
24	0.1245	0.2509	0.1193				41	0.1371	0.2045	0.0872			
24	0.119	0.2653	0.1465			0.127	41	0.1367	0.2092	0.1046			0
24	0.1101	0.2395	0.1188				41	0.13	0.2078	0.1035			
25w	0.1154	0.2963	0.1958	0.205	0.233		42g	0.1179	0.1931	0.09345	0.094	nil	
25	0.1137	0.3091	0.1914				42	0.1364	0.1935	0.09653			
25	0.1228	0.3441	0.2298				42	0.1384	0.2054	0.1014			
25	0.1277	0.313	0.2024				42	0.1206	0.1897	0.085			
26w	0.1121	0.2295	0.1123	0.088	nil		43g	0.1191	0.199	0.067	0.060	nil	
26	0.1127	0.2062	0.0748				43	0.1331	0.1962	0.0612			
26	0.1201	0.2052	0.0685				43	0.1281	0.2018	0.0567			0
26	0.1	0.219	0.0				43	0.1	0.189	0.0			

	216	5	96					244	8	542			
40 w	0.1106	0.8029	0.6851	0.687	4.976		44 g	0.1163	0.2068	0.0773	0.074	nil	
40	0.1279	0.8201	0.6951				44	0.1235	0.2037	0.0691			
40	0.1223	0.816	0.6798				44	0.132	0.2141	0.0771			
40	0.1135	0.8101	0.6888				44	0.125	0.195	0.0717			
45 g	0.1172	0.6261	0.5232	0.524	2.713		47 g	0.132	0.2162	0.0964	0.085	nil	
45	0.1314	0.6332	0.5123				47	0.135	0.2106	0.0797			
45	0.1367	0.6534	0.5478			2.240	47	0.1451	0.2151	0.0813			0
45	0.1235	0.6235	0.5128				47	0.1356	0.2057	0.0822			
46 g	0.1178	0.5598	0.4477	0.436	1.768		48 g	0.1295	0.2151	0.096	0.087	nil	
46	0.125	0.554	0.4413				48	0.1346	0.213	0.0799			
46	0.1362	0.5514	0.4313				48	0.137	0.2242	0.0961			
46	0.1213	0.544	0.4224				48	0.1233	0.2008	0.0764			
53 g	0.1211	0.2206	0.1018	0.084	nil		49 g	0.1256	0.2336	0.1165	0.112	nil	
53	0.1351	0.2148	0.082				49	0.1244	0.2424	0.1248			
53	0.1367	0.2101	0.075			2.199	49	0.1321	0.2555	0.1182			0

			6										
53	0.1284	0.2006	0.0779				49	0.1315	0.2192	0.0899			
54g	0.1122	0.7634	0.6496	0.650	4.399		50g	0.1373	0.2014	0.0741	0.080	nil	
54	0.1185	0.7673	0.6471				50	0.1378	0.1992	0.0815			
54	0.1306	0.7911	0.6602				50	0.1399	0.212	0.0864			
54	0.1244	0.7621	0.6426				50	0.127	0.1936	0.078			
81w	0.1173	0.266	0.1591	0.136	0.036		83w	0.09343	0.1683	0.0474	0.049	nil	
81	0.1316	0.2462	0.1161				83	0.1173	0.1826	0.0677			
81	0.1188	0.266	0.1469				83	0.1046	0.1946	0.0521			0
81	0.1207	0.247	0.1214				83	0.1043	0.1699	0.0272			
82w	0.1005	0.2914	0.1879	0.167	0.110		84w	0.09965	0.2267	0.113	0.082	nil	
82	0.1177	0.2656	0.1499				84	0.09697	0.1862	0.0553			
82	0.1143	0.2745	0.1588				84	0.104	0.1921	0.0628			
82	0.1106	0.2808	0.1712				84	0.1047	0.2188	0.0968			
84g	0.1266	0.2102	0.09	0.095	nil	0.000	86w	0.08903	0.1724	0.0481	0.040	nil	
84	0.1	0.227	0.1				86	0.1	0.163	0.0			

	316	5	02					126		321			
			3										
			0.1										
	0.1	0.229	04					0.1	0.172	0.0			
84	365	3	4				86	021	2	397			0
			0.0					0.0					
	0.1	0.212	82					985	0.164	0.0			
84	278	8	1				86	6	4	381			
			0.0					0.0					
90	0.1	0.207	89	0.08			87	968	0.167	0.0	0.04		
g	199	8	3	5	nil		w	5	2	511	6	nil	
			0.0										
	0.1	0.211	83					0.1	0.165	0.0			
90	339	3	9				87	09	8	445			
			0.0										
	0.1	0.229	97					0.1	0.176	0.0			
90	335	4	3				87	034	6	478			
			0.0										
	0.1	0.203	68					0.1	0.160	0.0			
90	242	7	4				87	028	9	422			
			0.0										
96	0.1	0.194	92	0.08			91	0.1	0.217	0.1	0.09		
w	029	6	4	4	nil		w	198	2	007	6	nil	
			0.0										
	0.1		69					0.1	0.222	0.0			
96	209	0.194	5			0	91	309	4	853			
			0.0										
	0.1	0.209	90					0.1	0.249	0.1			
96	056	1	1				91	338	5	128			0
			0.0										
	0.1	0.194	84					0.1	0.214	0.0			
96	107	6	5				91	235	1	841			
16			0.1										
4	0.1	0.252	37	0.15	0.06		92	0.1	0.212	0.0	0.07		
w	075	9	5	0	7		w	206	3	944	5	nil	
			0.1										
16	0.1	0.266	52					0.1	0.191	0.0			
4	202	4	7			2.521	92	315	2	548			
			0.1										
16	0.1		70					0.1	0.201	0.0			
4	262	0.293	2				92	307	2	628			
			0.1										
16	0.1	0.267	39					0.1	0.207	0.0			
4	148	5	8				92	24	3	867			

85 g	0.1188	0.1965	0.0747	0.076	nil	spring 2014 D	17 g	0.1171	0.173	0.0648	0.063	nil	
85	0.1328	0.1931	0.0675				17	0.1176	0.1816	0.0631			
85	0.1345	0.208	0.0775			0.105	17	0.1373	0.2037	0.0715			
85	0.1227	0.2069	0.0847				17	0.1293	0.1653	0.0525			
86 g	0.1138	0.2188	0.2188	0.198	0.210		19 g	0.1273	0.1885	0.1885	0.182	0.154	
86	0.1202	0.195	0.195				19	0.1177	0.1787	0.1787			
86	0.1309	0.1915	0.1915				19	0.1256	0.1879	0.1879			0.183712909
86	0.1195	0.1884	0.1884				19	0.1156	0.1716	0.1716			
90 w	0.1298	0.2444	0.2444	0.233	0.349		20 g	0.1248	0.2181	0.2181	0.200	0.214	
90	0.1063	0.2396	0.2396				20	0.1373	0.1935	0.1935			
90	0.09978	0.2275	0.2275			0.460	20	0.1342	0.1975	0.1975			
90	0.1273	0.2213	0.2213				20	0.1283	0.1893	0.1893			
92 w	0.1221	0.2725	0.2725	0.278	0.572		55 g	0.1178	0.1963	0.1963	0.192	0.187	
92	0.1389	0.2826	0.2826				55	0.1194	0.192	0.192			
92	0.1283	0.285	0.285				55	0.1315	0.194	0.194			0.193
92	0.1	0.270	0.2				55	0.1	0.185	0.1			

	255	6	706					185	7	857				
93g	0.1162	0.2109	0.2109	0.211	0.256		56g	0.131	0.1919	0.1919	0.195	0.198		
93	0.1199	0.2127	0.2127				56	0.1251	0.192	0.192				
93	0.1329	0.2188	0.2188			0.128	56	0.1328	0.2034	0.2034				
93	0.1206	0.2007	0.2007				56	0.1256	0.1935	0.1935				
94g	0.1138	0.2059	0.0937	0.088	nil		57g	0.1284	0.3584	0.2211	0.220	0.294		
94	0.1351	0.214	0.0955				57	0.1143	0.3518	0.214				
94	0.1306	0.2177	0.0871				57	0.141	0.3611	0.2212				0.247381882
94	0.1179	0.1992	0.0748				57	0.1394	0.3525	0.2255				
94w	0.1144	0.6538	0.5519	0.542	2.933		58g	0.1279	0.3206	0.2073	0.196	0.200		
94	0.1342	0.6606	0.5449				58	0.1262	0.3209	0.19				
94	0.1266	0.6666	0.5509			1.724	58	0.1367	0.3247	0.1981				
94	0.1244	0.6417	0.5216				58	0.1356	0.3117	0.1877				
95w	0.0938	0.2649	0.2649	0.267	0.516		59g	0.1051	0.1852	0.1852	0.184	0.161		
95	0.1063	0.2666	0.2666				59	0.1274	0.1888	0.1888				

95	0.1019	0.2791	0.2791				59	0.1285	0.1859	0.1859			0.167546151
95	0.0999	0.2587	0.2587				59	0.1212	0.1768	0.1768			
95g	0.1218	0.2072	0.2072	0.210	0.251		60g	0.1082	0.1869	0.1869	0.188	0.174	
95	0.1256	0.2135	0.2135				60	0.1185	0.1892	0.1892			
95	0.1305	0.2188	0.2188			0.273	60	0.1322	0.1942	0.1942			
95	0.1222	0.1986	0.1986				60	0.1128	0.1814	0.1814			
96g	0.1244	0.215	0.215	0.221	0.295		81g	0.1206	0.1958	0.1958	0.194	0.196	
96	0.1323	0.2231	0.2231				81	0.1277	0.1956	0.1956			
96	0.1316	0.2295	0.2295				81	0.1389	0.1958	0.1958			0.217071982
96	0.1242	0.2145	0.2145				81	0.1331	0.1904	0.1904			
101w	0.1202	0.4869	0.4869	0.492	2.348		82g	0.1243	0.2122	0.2122	0.206	0.239	
101	0.1252	0.491	0.491				82	0.1309	0.2097	0.2097			
101	0.1249	0.5066	0.5066			1.174	82	0.1325	0.2091	0.2091			
101	0.1307	0.4836	0.4836				82	0.1263	0.1942	0.1942			
102w	0.1185	0.2372	0.1297	0.106	nil		87g	0.1161	0.2251	0.1045	0.100	nil	
10	0.1	0.217	0.0				87	0.1	0.228	0.0			

2	274	2	97					213	8	973			
			0.0										
10	0.1	0.215	89					0.1	0.231	0.1			0.076
2	321	5	3				87	288	1	004			83194
			0.1										
10	0.1	0.224	09					0.1	0.222	0.0			
2	353	4	6				87	187	9	989			
16			0.1										
5	0.1	0.198	98	0.19	0.20		88	0.1	0.164	0.1	0.18	0.15	
w	069	6	6	6	1		g	209	1	641	2	4	
16	0.1		0.1					0.1		0.1			
5	301	0.196	96				88	149	0.173	73			
			0.2										
16	0.1	0.204	04					0.1	0.197	0.1			
5	191	5	5			0.165	88	425	3	973			
			0.1										
16	0.1	0.185	85					0.1	0.192	0.1			
5	256	3	3				88	427	5	925			
16			0.1										
6	0.1	0.173	73	0.17	0.12		97	0.1	0.217	0.2	0.20	0.24	
w	035	7	7	3	8		g	137	3	173	7	2	
			0.1										
16	0.1	0.171	71					0.1	0.202	0.2			
6	157	9	9				97	309	5	025			
			0.1										
16	0.1	0.184	84					0.1		0.2			
6	157	8	8				97	293	0.204	04			0.220
			0.1										
16	0.1	0.162	62					0.1	0.204	0.2			
6	096	2	2				97	22	5	045			
16			0.4										
7	0.1	0.450	50	0.45	1.93		98	0.1	0.195	0.1	0.19	0.19	
w	019	6	6	2	1		g	133	4	954	5	9	
16	0.1		0.4					0.1	0.195	0.1			
7	157	0.452	52				98	309	8	958			
			0.4										
16	0.1	0.465	65					0.1	0.201	0.2			
7	157	8	8			1.076	98	266	3	013			
16	0.1		0.4					0.1	0.189	0.1			
7	201	0.441	41				98	24	1	891			
16			0.2										
9	0.1	0.202	02	0.20	0.22		10	0.1	0.189	0.1	0.18	0.15	
w	036	9	9	2	1		0g	206	1	891	1	2	
16	0.1	0.197	0.1				10	0.1	0.180	0.1			

9	178	8	97		0	243	5	805		
			8							
			0.2							0.076
16	0.1	0.205	05		10	0.1	0.183	0.1		16481
9	355	4	4		0	287	1	831		9
			0.2							
16	0.1	0.200	00		10	0.1	0.172	0.1		
9	273	4	4		0	212	5	725		

APPENDIX H

Institutional Review Board (IRB) Approval

TWU
TEXAS WOMAN'S UNIVERSITY
DENTON DALLAS HOUSTON

Institutional Review Board
Office of Research and Sponsored Programs
P.O. Box 425619, Denton, TX 76204-5619
940-898-3378 FAX 940-898-4416
e-mail: IRB@twu.edu

May 8, 2012

[redacted]

Dear Ms. Hudson:

Re: *Association Between Circulating Vitamin D Levels and Body Composition in Collegiate Female Athletes (Protocol #: 17014)*

The above referenced study has been reviewed by the TWU Institutional Review Board (IRB) and appears to meet our requirements for the protection of individuals' rights.

If applicable, agency approval letters must be submitted to the IRB upon receipt PRIOR to any data collection at that agency. A copy of the approved consent form with the IRB approval stamp and a copy of the annual/final report are enclosed. Please use the consent form with the most recent approval date stamp when obtaining consent from your participants. The signed consent forms and final report must be filed with the Institutional Review Board at the completion of the study.

This approval is valid one year from April 6, 2012. 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,

Rhonda R. Buckley

Dr. Rhonda Buckley, Co-Chair
Institutional Review Board - Denton

enc.

cc. Dr. Chandan Prasad, Department of Nutrition & Food Sciences
Dr. Nancy DiMarco, Department of Nutrition & Food Sciences
Graduate School