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Vitamin D status, adiposity, and athletic performance measures in college-aged students

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VITAMIN D STATUS, ADIPOSITY, AND ATHLETIC PERFORMANCE MEASURES IN
COLLEGE-AGED STUDENTS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Kinesiology

by
Laura Forney
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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	ii
ABSTRACT.....	v
CHAPTER	
1 INTRODUCTION	1
2 REVIEW OF LITERATURE	4
Sources of Vitamin D in the Diet.....	4
Vitamin D Synthesis	5
Vitamin D, Muscle in Elderly/Diseased vs. Athletic Populations	5
Known Molecular Mechanisms of Vitamin D.....	9
Vitamin D Status and Fat Mass	9
Summary and Specific Aim	11
3 METHODS	13
Study Subjects.....	13
Study Design	13
Blood Collection and Analysis	13
Sun Exposure and Dietary Intake	14
Resting Metabolic Rate	14
Body Composition – Dual-energy X-ray Absorptiometry (DXA)	14
Cardiorespiratory Fitness Testing	15
Anaerobic Power Measurements	15
Strength, Power and Flexibility Testing	15
Statistical Analysis.....	16
4 RESULTS	17
Vitamin D Status: Measures of Intake and Serum Content	17
Sun Exposure	17
Body Composition and Resting Metabolic Rate.....	18
Performance Measurements.....	18
Correlational Analysis	19
5 DISCUSSION	20
6 CONCLUSION.....	25
Future Directions	26
REFERENCES	28
APPENDIX 1	37
Table 1	37
Table 2	38

Table 3	40
Figure 1	42
Figure 2	43
APPENDIX 2.....	44
International Physical Activity Questionnaire	44
Physical Activity Readiness Questionnaire	46
Sun Exposure Survey.....	47
APPENDIX 3.....	48
LSU IRB Approval	48
PBRC IRB Approval.....	53
VITA.....	60

ABSTRACT

Research suggests that elevated serum concentrations of 25-hydroxyvitamin D (25OHD) are associated with slowing the development of many age-related chronic diseases. Recent reports also show a positive relationship between 25OHD and muscle synthesis, strength, power and decreased body fat in elderly individuals. However, these findings have not been consistently reported in younger, healthy populations. **PURPOSE:** To investigate the relationship between 25OHD levels, body composition, measures of aerobic fitness and muscular strength and power in a young, physically active population. **METHODS:** Thirty-nine active subjects (20 males, 19 females; 23 ± 0.7 years old) reported to the lab six times for testing. Blood was drawn and 25OHD concentrations were determined using an enzyme-linked immunosorbent assay (ELISA). Primary outcomes included: body composition (dual-energy x-ray absorptiometry, DXA); resting metabolic rate; maximal oxygen uptake (VO_{2max}); power output (Wingate); and strength (eight repetition maximum of bench press, upright row and leg extension and flexion). Primary analysis included all participants, and sub-group analyses on those individuals considered to have sub-optimal serum 25OHD (< 35 ng/mL); LOW ($n = 20$, 25.97 ± 1.97 ng/mL) and adequate levels of 25OHD (< 35 ng/mL) HIGH ($n = 19$, 44.15 ± 2.17 ng/mL). **RESULTS:** Half of the subjects ($n = 20$) exhibited less than optimal 25OHD status, due in part to lack of dietary intake. HIGH males had significantly higher VO_{2max} values when compared to LOW males ($p < 0.01$). **CONCLUSION:** A high percentage of college-aged male and female individuals may not be consuming enough vitamin D and aerobic fitness may also be linked to vitamin D status.

CHAPTER 1 – INTRODUCTION

Vitamin D has garnered a significant amount of attention for its potential to improve overall health and quality of life in humans. Low vitamin D status has been linked to obesity, cardiovascular disease, type 2 diabetes, cancer and other diseases common in our society today. However, more research is needed in order to fully understand the benefits of improving vitamin D status and its cellular mechanisms of action.

One of the most applicable newly discovered benefits of vitamin D supplementation is its role in muscle protein synthesis (1). Type I muscle fibers, known also as slow-twitch fibers, have increased oxidative capacity and low glycolytic activity and are resistant to fatigue (2). Type IIa fibers have both high oxidative and glycolytic activity, while type IIb fibers have high glycolytic and low oxidative capacity and wear out quickly (2). Different muscles have varying quantities of fiber types based on the type of training and genetics. For example, those who run marathons have more type I fiber content overall, while weight-lifters have more type II fibers (2). Originally, studies involving vitamin D and muscle growth and composition were conducted in elderly populations (3, 4). Muscle biopsies of elderly patients with vitamin D deficiency indicated atrophy of type II muscle fibers, which are those recruited first to help prevent falls (5). Current research found that supplementation with vitamin D increased functional muscle tissue in elderly patients (4). Specifically, improved lower extremity function, as assessed by 8 foot walk tests and sit-to-stand tests, has been associated with higher 25-hydroxyvitamin D (25OHD) levels in both active and inactive subjects over the age of 60 (4). Supplementation studies examining the changes in muscle fiber morphology are few in number, but several have shown an improvement in overall muscle composition. Sorensen, et al. showed that 3-6 months of supplementation with calcium and vitamin D (in the form of 25OHD), led to an increase in cross-sectional area of type IIa fibers (6). However, this study provided 25OHD

supplementation combined with calcium, and did not primarily focus on muscle morphology. More recently, a significant increase in the number and diameter of type II fibers, along with a concurrent increase in strength were observed after several years of supplementation in elderly subjects (7). The most important finding in these studies was that the improvement in muscle composition translated into an increase in functional capabilities such as strength, fall prevention and ability to perform activities of daily living (8).

Not only does vitamin D supplementation have the potential to increase muscle protein synthesis, but there may be concomitant reductions in adiposity as well (9). A cell culture project determined that incubation of 3T₃-L1 preadipocytes with 1,25(OH)₂D prevented differentiation into adipocytes in a dose-dependent manner (10). A complete understanding of the role of vitamin D in adipocyte regulation has no defined direction even though multiple possible routes show a potential understanding of the decrease in adiposity. While the mechanisms have yet to be completely elucidated, it is apparent that improved vitamin D status is correlated with a more favorable body composition (11).

With the increased interest in non-osseous functions of vitamin D, many researchers have become concerned with the vitamin D status of athletes (12). Since the discovery of the physiological changes that take place in the elderly after increasing circulating levels of 25OHD, research has been done investigating the benefits of increasing the status in these physically active individuals. While no conclusive results have been reported concerning the changes in body composition or muscle physiology in a younger, physically active population, one major determination has become apparent: a significant number of athletes – regardless of sport or season – have insufficient or deficient vitamin D levels (12). Therefore, it is important to investigate both the incidence of insufficiency of vitamin D in a healthy, physically active

population, as well as the potential relationships between serum 25OHD and measures of fitness and athletic performance.

In summary, longitudinal studies indicate that an increase in muscle tissue is accompanied by a decrease in fat mass, and vitamin D status is one of the most robust predictors of muscle mass decrease with aging (13). These findings lead us to ask whether similar results will be observed in the general population. Additionally it is also important to address whether improvements in vitamin D status result in an increase in muscle tissue and if these improvements translate to improvement in cardiovascular and muscular performance (14).

CHAPTER 2 – REVIEW OF LITERATURE

Sources of Vitamin D in the Diet

The majority of the world's population has low levels of vitamin D, with estimates reaching as high as 59 percent worldwide. Additionally, it has been estimated that over 60 percent of Americans may also be deficient in vitamin D (16, 17). This phenomenon may be due to misinformation about the sources and conversion of vitamin D into a physiologically relevant form. For example, some nutritionists and educators believe that sufficient amounts are ingested in a normal healthy diet (1), while others disagree (15).

Vitamin D is readily available in the American diet, albeit not in large quantities. It is unlikely that the prevalence of vitamin D deficiency and insufficiency would be seen at the astronomical rates observed today if it were a standard part of a normal diet. Vitamin D is even less likely to be found in diets in developing countries due to the reduced access to foods naturally containing vitamin D, as well as lack of regulation regarding the fortification of foods with vitamin D that are present in developed countries (16). Vitamin D content is highest in fatty fish and liver, particularly cod liver (16). In the United States, most cereals, grains, orange juice and dairy products are fortified with vitamin D, in amounts required by the Food and Drug Administration (16). Even with adequate intake through the diet, most individuals have insufficient vitamin D levels in the body (17). Up until late 2010, the Institute of Medicine (IOM) Dietary Reference Intakes indicated that the Recommended Dietary Allowance (RDA) of vitamin D should be 400 IU per day for healthy adults, with higher values for elderly and youth. These values were regarded by nutritionists, researchers, and physicians as severely insufficient (16). The IOM recommendation release in 2010 increased the RDA to 600 IU per day for individuals between the ages of one and 71 years old, although this value is still widely debated in the research community as inadequate. As a result, there is an increased likelihood for

individuals on a fortified diet to have low levels of vitamin D and recommendations can be made as to increasing status applicable to everyone (18).

Vitamin D Synthesis

Vitamin D synthesis takes place in several different steps. A precursor compound known as 7-dehydrocholesterol (7DHC), stored in the skin, is converted to previtamin D₃ when photons from UVB light come in contact with a particle of 7DHC (17). Optimal wavelengths for this conversion are less than 315 nm (17). However, these wavelengths typically do not make it through the ozone layer to come in contact with the surface of the earth (17). Different wavelengths of light cause different isomers from 7DHC and limits how much previtamin D₃ is formed (17). Current estimates range from 12-15% of 7DHC is actually converted to previtamin D₃, which ultimately determines the amount of vitamin D that is synthesized (17).

Once previtamin D₃ is made, it is further converted to vitamin D₃ with heat (17). The first two conversion steps happen together, since heat accompanies UV radiation. Vitamin D₃ is mobilized by binding to the D binding protein (DBP) and enters circulation. Upon reaching the liver, vitamin D₃ is converted to its active form of 25-hydroxyvitamin D (25OHD)(17). 25-hydroxyvitamin D enters circulation and is converted to 1,25-dihydroxyvitamin D (1,25(OH)₂D) in the kidneys (19). It is 1,25(OH)₂D that is the metabolically active form of vitamin D (17). Because of the time course in vitamin D synthesis and metabolism, serum concentration of 25OHD is widely preferred as the standard for determining vitamin D status, when compared to serum 1,25(OH)₂D levels (19).

Vitamin D, Muscle In Elderly/Diseased vs. Athletic Populations

Even though the benefits of increased strength with vitamin D supplementation were not a direct measure in initial studies, more recent research in elderly populations confirms that vitamin D supplementation may lead to increased muscle strength (1), or an increase in the force

produced by the muscle (20). Other results have shown that increased levels of 25OHD are positively correlated fat free mass (9), including muscle, bone, tissue, and cellular contents (21). While results show that there is an increase in muscle tissue, as determined by DXA and biopsies and enzymatic activity of tissue samples, it is important to note that this increase is not of clinical significance if it is not accompanied by an improvement in strength. In fact, current studies indicate that supplementation with vitamin D, along with strength training activities, in elderly subjects not only leads to an increase in muscle tissue but an increase in strength as well (22).

It is well established that vitamin D plays an integral role in improving bone density and calcium absorption (23). Research began by investigating the role of vitamin D and calcium supplementation in elderly subjects to prevent osteomalacia, the softening of bone tissue due to lack of vitamin D and subsequent absorption of calcium (24). Because of the increased calcium absorption in bones, and with the aid of vitamin D, bone density increased in these patients and osteomalacia was reduced (25). Further investigation indicated that myopathy was significantly correlated to the prevalence of osteomalacia and decreased bone density; furthermore, supplementation with vitamin D seemed to benefit those suffering from osteomalacia not only by increasing bone density but by increasing muscle strength as well (6).

Vitamin D research focusing on changes in muscle mass first began when low levels of serum 25OHD were correlated with myopathy (26). The onset of sarcopenia and loss of muscle mass and strength is inevitable for every person, regardless of training state or physical ability. Sarcopenia is characterized by the loss of type II muscle fibers, those that are predominately active in strength generation (27). While many exercise rehabilitation programs focus on resistance training for elderly individuals, the new muscle fibers that develop from this type of training are type I fibers, which are more oxidative in nature (27). Many studies investigating increased muscle synthesis, both as an increase in fiber number or an increase in size of existing

fibers, and strength in those suffering from sarcopenia note that building muscle strength is important in elderly populations to decrease falls risks and maintain functional ability (28). Resistance training is the preferred method of training for these individuals for two reasons: first, the exercise directly stimulates the target of interest in skeletal muscle instead of a systemic effect that would be characteristic of aerobic activities; secondly, because elderly individuals in this situation are already prone to falling because of decreased strength, resistance training types of activities can be carried out in a more controlled environment in order to decrease this risk (22). The problem with resistance training activities is that while the muscle is being resynthesized, it is not being replaced by a metabolic or functional equivalent in terms of fiber types. For example, one intervention study saw increases in both type I and type II fiber cross-sectional area after 15 and 30 weeks of training, but the increases in type I fibers were significant at both time points. There was no increase in type II fiber cross-sectional area at 15 weeks, and the increase seen at 30 weeks was vastly lower than the increase seen in type I fibers even though it was considered statistically significant (29). Vitamin D supplementation is believed to bring a potential solution to this problem. Several studies have indicated that vitamin D supplementation, in conjunction with resistance training activities, increases muscle strength by increasing the number of type II fibers (30).

The advantages of vitamin D supplementation should not be limited to the clinical setting. While studies dating back to the 1940s have correlated vitamin D levels with increases in strength performance in athletes (1), this interest has not been maintained until recently. Currently, only a few studies have investigated the role of vitamin D in athletes and the implications on performance. Research involving vitamin D supplementation has revealed the importance of maintaining bone density, increased muscle synthesis, and its role in increasing

immune function in athletes (31), but most have only speculated that increasing vitamin D status in these individuals could increase performance and never explicitly explored this hypothesis.

While all of these benefits stand to increase athletic performance in trained individuals, no specific correlations between these phenomena have been drawn to the physiological responses that occur during exercise. A review of the literature indicates a two-fold importance of sufficient levels of vitamin D in athletes: first, that deficiency can impede and limit performance, and second, that increasing vitamin D levels in non-deficient athletes may improve athletic performance (32). Some of the first studies investigating the effects of vitamin D and athletic performance were carried out in Germany in the 1950s, when it was determined that athletes with increased UV exposure time routinely had increased performance results. It has also been determined recently that athletes who train indoors and during the winter are at increased risk for deficient levels and decreased performance (32). One such study showed that German gymnasts had significantly lower serum 25OHD levels, and 37% of participants' levels were in the range for osteomalacia and 45% presenting with symptoms of hypocalcemia. While these levels were not correlated directly with a decrease in performance, the risk associated with low levels of calcium, such as softened bone tissue and grand mal seizures (as observed in the study) certainly leads to unsafe conditions for athletic performance (32). Although there are very few recent, published studies that have investigated the role of vitamin D status and athletic performance, an investigation revealed a direct positive correlation, in females ages 12 to 14 years, between serum 25OHD levels and muscle power and force using a series of leg strength and jumping tests (33). In conclusion, athletes engaging in both aerobic and resistance types of activities may be at risk for vitamin D deficiency-related performance implications, which are magnified if they train or perform during winter months when natural UV levels are decreased.

The benefits of vitamin D are well established for elderly populations (4). To date, there has been much speculation about the performance-enhancing potential of vitamin D supplementation in athletes (12); however, no consistent link has been made between these two very polar populations. As a result, it is possible for clinically healthy individuals engaging in recreational activities to benefit from an improvement in vitamin D status.

Known Molecular Mechanisms of Vitamin D

Because calcium absorption in bone is so tightly regulated by the amount of vitamin D in the body, athletes should be careful to take in the appropriate amount of vitamin D to lower the risk of fractures, which could impede on performance and training (31). The molecular mechanism between 25OHD and increased cell synthesis, especially in the muscles, seems to indicate that the active form 1,25(OH)₂D binds to the vitamin D nuclear receptor. This complex interacts with the retinoic x-receptor (RXR), which binds to vitamin D response elements (VDRE), which activate gene sequences that regulate cell growth. This process is hypothesized to regulated protein synthesis in muscle cells, but is not completely understood at this point (31). Aside from its role in cell proliferation in the immune system, vitamin D has also been tied to the secretion of antimicrobial peptides from cells of the immune system such as monocytes and macrophages, which act by degrading the membrane of pathogenic substances (31). Vitamin D is also hypothesized to help regulate the release of both proinflammatory and anti-inflammatory cytokines, which are released during exercise, although this mechanism is not known at this point (31).

Vitamin D Status and Fat Mass

Multiple studies have linked vitamin D status, quantified by both 25OHD and 1,25(OH)₂D levels, to body mass. Most studies have indicated that higher 25OHD status is correlated with lower body mass, although this relationship is not robust and some researchers

debate on whether 25OHD or 1,25(OH)₂D is the best marker of vitamin D status (19). The consensus in the current literature seems to indicate that 25OHD is the best predictor of overall vitamin D status, with a majority of the articles noting a stronger negative relationship between body fat and 25OHD than with 1,25(OH)₂D because of its regulation of PTH. However, it is important to note that Lagunova, et al, indicated that both 25OHD and 1,25(OH)₂D were predictors of body mass index (BMI), fat mass, and percent adiposity (34).

Exploring the relationship between vitamin D status and body composition also has other challenges. Because vitamin D is a fat-soluble vitamin, it is possible that those with increased adiposity would have increased stores of vitamin D. However, this does not appear to be true. In fact, obese individuals are one of the most at-risk populations for hypovitaminosis D, or deficiency of vitamin D, and the associated symptoms and health risks (35). This observation is due to the bioavailability of circulating 25OHD and the nature of vitamin D metabolism. One study proved this phenomenon quite well, by supplementing both obese and non-obese subjects with identical oral doses of vitamin D₃ and exposing them to identical amounts of UVB light 24 hours after ingestion. The study hypothesis assumed that the obese subjects would have increased serum levels of 25OHD due to the increased fat stores for vitamin D, as well as larger body surface area able to absorb the UV light. The results showed the opposite. The obese subjects had significantly lower vitamin D levels despite equal levels of 7DHC, UV exposure time, and ingested vitamin D when compared to non-obese counterparts (36). The article summarized, “obesity did not affect the capacity of the skin to produce vitamin D₃, but may have altered the release of vitamin D₃ from the skin into the circulation” (36). A review of the literature concurs with this notion, noting that the increased adiposity between the subcutaneous stores of vitamin D and the circulatory system limit the available amount of 25OHD for use by

the body, and increased in storage sites for vitamin D leading to a preference for storage rather than circulation (34).

Although increased obesity is correlated with decreased serum 25OHD levels, there is also significant speculation that supplementation with vitamin D could lead to an increased rate of lipolysis (37). While the mechanism has not been completely identified at this point, one popular belief involves the role of $1,25(\text{OH})_2\text{D}$ and the control of the calcium adipocyte signaling pathway. It was previously believed that $1,25(\text{OH})_2\text{D}$ was responsible for increasing calcium levels in adipocytes, causing an increase in lipogenesis and a decrease in lipolysis (38). This tends to support the notion that increased vitamin D levels would increase adiposity, which is not the current belief as 25OHD has been correlated with an increase in lean body mass (39).

Summary and Specific Aims

Though the relationships between vitamin D, body composition and athletic performance have been established independently in populations of various ages (9, 21, 40), a comprehensive study examining all of these factors together has yet to be completed in a young population. Vitamin D also provides gains in two significant areas – clinical importance and health benefits (41), as well as performance gains (12, 31) – that serve two very contrasting populations of individuals. Accordingly, it the specific aim of this study to investigate the relationship between 25OHD levels, body composition and resting metabolic rate, measures of aerobic fitness, and muscular power and strength in a young, physically active population. It is hypothesized that many of the subjects will have low levels of 25OHD, and that there will be a positive relationship between 25OHD and measures of aerobic fitness and strength, as well as an inverse relationship between 25OHD and overall adiposity.

In conclusion, vitamin D is already known to be one of the most necessary supplements for optimal health in all individuals (42). It is exciting to investigate new benefits of a

supplement that is already known to support necessary physiological processes, especially knowing that most people are clinically deficient, including a large number of physically active individuals. A positive relationship among muscle strength, mass and serum 25OHD is somewhat substantiated by the literature (39), indicating potential benefits for athletes by improving vitamin D levels.

CHAPTER 3 – METHODS

Study Subjects

Forty subjects (n = 20 males, n = 20 females; ages 18-40 years) were recruited to participate in the study. To be eligible for the study, participants were required to be physically active in moderate to vigorous intensity activities for at least 3 days per week and have had maintained a consistent body weight for three months prior to the study. Subjects had no history of supplementing with vitamin D outside of what is included in a daily multivitamin (400 IU). This project was approved by the Louisiana State University Institutional Review Board.

Study Design

Subjects reported to the lab six times. On the first day, all subjects signed an informed consent document, completed physical activity and health assessment questionnaires and height and weight were recorded. Subjects then completed tests to determine resting metabolic rate, plasma vitamin D status, body composition, maximal cardiorespiratory fitness (VO_{2max}) and anaerobic power, strength and flexibility over the course of five additional visits that took place over a 14-day period. At least 72 hours of rest were included between the anaerobic power, VO_{2max} and strength tests to allow for adequate recovery. Resting metabolic rate and blood collection took place on days 5 to 7 of the menstrual cycle for females, as these measurements can be influenced by hormone cycles.

Blood Collection and Analysis

During the assessment period, subjects reported to the lab for a single blood draw. They were asked to refrain from strenuous exercise for 24 hours and fasted for 12 hours prior to collection. A registered nurse collected 20 mL blood samples in vacutainers containing no additive in the exercise biochemistry lab at Louisiana State University. Samples were allowed to chill for at least one hour at 8-10°C, after which they were centrifuged at 10°C (10 minutes, 1000

ref) and plasma aspirated, aliquoted and stored at -80°C until analysis. Vitamin D (25OHD) status was determined using ELISA (Alpco Diagnostics, Salem, NH) with a BioTek microplate reader (BioTek Instruments, Model MQX200, Winooski, Vt., USA).

Sun Exposure and Dietary Intake

A week before blood collection, subjects were issued two surveys that accounted for their overall endogenous vitamin D production and exogenous dietary intake, which were returned at the time of the blood collection. The first questionnaire was a sun exposure survey to quantify the amount of time spent outdoors and in sunlight, since endogenous vitamin D is produced by exposure to ultraviolet light. This method, set forth by Hanwell et al., combines the time spent outdoors or in exposure to ultraviolet light into a numerical scale (43). The second questionnaire was a seven day dietary log that was analyzed for dietary 25OHD content using the USDA database (44).

Resting Metabolic Rate

Resting metabolic rate (RMR, kcal/day) was assessed via analysis of oxygen consumption using a metabolic cart (Moxus Metabolic Systems, Pittsburgh, PA). Subjects arrived at the lab after a 12-hour fast and having refrained from strenuous exercise for 24 hours. Subjects were asked to lie in a supine position in a thermoneutral environment while data were collected. The procedure continued until 10 minutes of steady state data was collected, defined as $\pm 5\%$ of the respiratory exchange ratio (45). RMR was calculated via the modified Weir equation (46).

Body Composition – Dual-energy X-ray Absorptiometry (DXA)

Whole-body DXA scans were performed by a trained technician using a General Electric Lunar iDXA (General Electric; Milwaukee, WI) and analyzed using enCORE software version 13.40. The subject first changed into a hospital gown and removed all metal objects from his or

her body. The subject was centered on the surface of the machine and secured. The subject was instructed to lie completely motionless for the duration of the scan, which lasted approximately 10 minutes.

Cardiorespiratory Fitness Testing

$\text{VO}_{2\text{max}}$ was analyzed using a modified Bruce Protocol (47). Participants were asked to refrain from alcohol consumption and vigorous exercise for 24 hours prior to testing. This protocol required participants to walk or run on a treadmill while the speed and incline was progressively increased until the subject reached fatigue. Exhaled gases were analyzed during the testing period using a metabolic cart (Moxus Metabolic Systems, Pittsburgh, PA).

Anaerobic Power Measurements

Anaerobic power was measured on a cycle ergometer (Monark Ergonomic, Vansbro, Sweden) using the Wingate testing protocol (48). The protocol included a self-selected warm-up period during which the participants pedaled at a relaxed frequency against little or no resistance. The testing period required the subjects to pedal against a given resistance, calculated based on the body weight of the subject, for 30 seconds. This period was followed by a cool-down period that lasted as long as was deemed necessary. Revolutions per 5 second intervals were counted and applied to the Wingate equations (48).

Strength, Power and Flexibility Testing

Strength measurements were assessed by eight repetition maximums (8RM) for several lifts, including upright bench press, bicep curl, tricep pushdown, leg curl, leg extension and upright row. For assessment of power, subjects were asked to perform vertical and horizontal jumps, with allowed countermovement before each jump. The best of three jumps was recorded and used for data analysis. Vertical jump height was determined as the difference between the height of outstretched hand at rest and the highest point the subject reached during the jump;

horizontal jump distance was determined by initial landing spot of the subjects' heel on a marked tape measure (49). Subjects' flexibility was assessed by a sit-and-reach test (47).

Statistical Analysis

Data were analyzed using SPSS (Version 19, IBM, Armonk, NY). Descriptive statistics, including mean and standard error (SE), were calculated for all outcome variables. A one-way, four-level ANOVA was used to compare the subjects by gender and vitamin D status, either above HIGH (>35 ng/mL) or below LOW (<35 ng/mL) the normal value for physically active individuals (50). Student's t-tests with a Bonferroni multiple comparison correction were used *post hoc*. Pearson stepwise correlation analysis was used to determine relationships between all measurements. Significance was set at $p < 0.05$. All values presented are mean \pm SE.

CHAPTER 4 – RESULTS

Subjects were between the ages of 20 and 38 years old and mean anthropometric measurements are shown in Table 1. Forty subjects were recruited into the study. One female was excluded from all analyses due to failure to complete testing. One male subject was excluded from 25OHD serum analysis, as his value was considered a statistical outlier. Overall, males had significantly higher dietary intake of vitamin D; however, there were no other significant differences in descriptive measures aside from those expected based on variation of body size and composition between genders (Table 1).

Vitamin D Status: Measures of Intake and Serum Content

Twenty subjects (9 females, 11 males) presented with serum 25OHD levels lower than 35 ng/mL, which is considered to be below normal in young, physically active individuals (50) (Table 2). While the recommended daily intake of vitamin D is 600 IU (51), or 4200 IU per week, only one subject in the study met this criterion. However, this subject's serum 25OHD still fell below the normal 25OHD level. The mean dietary vitamin D intake for participants was just above 1000 IU per week, and these values did not correlate with serum levels (Figure 1). Intake was significantly higher in males than in females ($p = 0.002$); however, there was no significant difference in intake between the HIGH and LOW vitamin D groups ($p = 0.93$) nor was there a relationship between vitamin D intake and serum 25OHD content ($r = 0.003$).

Sun Exposure

Using the charting procedure for sun exposure, scores ranged from 11 to 52. In the study in which the survey measurement was proposed, the scores ranged from 0 to 41 (43). In addition, there were no significant differences in sun exposure between men and women, or the HIGH and LOW vitamin D groups ($p = 0.66$ and $p = 0.81$, respectively) (Table 2). There were

no significant correlations in the complete data set, nor were there any correlations when divided by gender or between the high and low 25OHD groups.

Body Composition and Resting Metabolic Rate

Aside from the expected differences in percent body fat between genders ($P \leq 0.001$), there were no other significant differences in percent body fat between groups (Table 1)(52). There was a non-significant negative trend between vitamin D status and BMI ($r = -0.31$, $p = 0.19$). This relationship was also observed in body composition in males, showing decreased adiposity with increased serum 25OHD ($r = -0.38$, $p = 0.20$). As expected, there was a significant difference between RMR in men and women ($P \leq 0.001$) (Table 2) but no significant difference in resting metabolic rate between the high vitamin D group and the low vitamin D group ($p = 0.94$) was observed (Table 2)(53). Of the subjects with normal serum 25OHD levels, there was a positive but non-significant correlation between resting metabolic rate and vitamin D status (males $n = 9$, $r = 0.26$ and females, $r = 0.41$).

Performance Measurements

There was a statistically significant difference in VO_{2max} between males in the low and high groups ($p \leq 0.01$), where males with serum vitamin D above the recommended levels for physically active adults had roughly a 20% higher VO_{2max} compared to those who fell below the normal standard (Figure 1). This relationship was not observed in females, and there were no other statistically significant differences in VO_{2max} among any other groups (data not shown).

Anaerobic power ($P \leq 0.001$) was significantly higher in males than females; however, there were no significant differences in anaerobic power based on 25OHD status ($p = 0.76$ for females and $p = 0.34$ for males) (Table 2). The lack of significance was maintained when comparing absolute measurements or watts per body weight (kg) between LOW and HIGH 25OHD groups. As expected, males had significantly higher 8RMs in all lifts compared to

females ($P \leq 0.001$), as would be predicted (Table 2). However, there were no significant differences between LOW and HIGH groups in any of the 8RM or flexibility measurements (Table 2).

Correlational Analysis

Correlations were performed between 25OHD concentrations and all outcome variables for the entire group of subjects, by gender, and by LOW and HIGH groups. No statistically significant relationships were discovered.

CHAPTER 5 – DISCUSSION

Based on the known and purported benefits of vitamin D, it is recommended that physically active individuals maintain a higher vitamin D status to achieve optimal health and performance benefits (12, 31). In this study, we also show that males who had serum 25OHD levels above the recommended limit of 35 ng/mL had significantly higher cardiorespiratory fitness levels when compared to males below this value. These findings are in agreement with the results of several studies investigating the relationships among serum 25OHD, cardiorespiratory fitness and several markers of mortality in middle-aged men and women (54, 55). These markers included several indices of obesity, changes in insulin resistance and glucose metabolism, as well as decreases in inflammation and triglyceride content (56, 57). While the evidence is conclusive that physical activity can induce all of these changes alone (58), it is possible that increasing 25OHD may also induce these beneficial effects may help clinical populations as well (57).

In this study, there were no significant relationships between strength or power output and serum 25OHD, nor were there observed relationships between 25OHD and flexibility measures. It has been shown that increasing serum 25OHD status in elderly populations results in improvements in muscle mass and strength, and that low levels of 25OHD accurately predict the acceleration in age-related loss of muscle mass (59, 60), which was not observed in the current study. This finding may be a function of regular exercise modality. For example, males were more inclined to engage in a structured routine with strict running distances and weight lifting protocols while females were more likely to engage in a variety of running distances and events or other aerobic group physical activity classes. This gender-based variation in training regimen could potentially influence the development of muscle strength and power differently in each group, which would cause the observed differences between males and females in strength

and power. There were no significant differences in flexibility when associated with 25OHD content. There are no studies in young, healthy populations investigating this relationship. Only a few results in elderly populations show improvements in flexibility, which is due to the changes in muscle tissue that occur with increases in 25OHD content (61).

Low levels of 25OHD are associated with high levels of body fat (9, 13). In this study, there was a trend ($p = 0.20$) for a negative correlation between 25OHD and body fat percentage in males. Additionally, there was no relationship between 25OHD and RMR and a consensus on this relationship has not yet emerged in the literature.

Half of the healthy, physically active participants in this study presented with insufficient or deficient levels of serum 25OHD. Clinical studies have defined deficiency as serum levels below 10 ng/mL and insufficiency as levels between 10 and 30 ng/mL (62); however, depending on the research environment, these reference values may fall between 15 and 35 ng/mL. Because vitamin D studies have been conducted in a wide variety of populations, it cannot be assumed that the same reference values apply to all individuals (63). We considered 35 ng/mL as the normal reference value for subjects in this study because this cutoff has been used as the reference value in a previous study with physically active individuals (32).

Studies have shown that it is difficult to achieve adequate vitamin D status using dietary measures alone, especially when considered independent of supplementation with multivitamins (42). In the United States, many foods are required by the Food and Drug Administration to be fortified with vitamin D, including but not limited to: orange juice, dairy products and cereals (63). While the fortification of these foods helps to increase vitamin D intake, they cannot be considered a means for obtaining sufficient vitamin D (42). As a result, it is not surprising that the dietary intake of vitamin D was extremely low in the young adults enrolled in this study. The Institute of Medicine's recommendation for vitamin D is 600 IU per day, and only one of the 39

subjects in the current study met this requirement with an average daily intake of 700 IU (4,644 IU per week). This is a common trend and several recently published studies have reported similar results in young, physically active individuals (50, 64).

Vitamin D levels (25OHD) are not only associated with dietary intake, but are also related to UV exposure (16). Data were collected during the summer and early fall in the southeastern United States where the number of days with adequate UV exposure from sunlight is estimated at 218 per year. Current recommendations suggest that ten to fifteen minutes in sunlight will produce a large amount of vitamin D, but this conversion is affected by a number of different factors, including ethnicity, adiposity, age, geographical location, as well as behaviors such as sunscreen use or wearing protective clothing (17, 65). In this study, sun exposure was evaluated by a survey that allowed for direct combination of time spent in the sun as well as overall exposure (43). We used this particular survey because many individuals in the current study enjoy recreational activities outdoors, but did so under different conditions including time of day or wearing various different types of clothing, making analysis of time under UV exposure difficult. The scores obtained in the present study varied significantly as both a function of time spent outdoors and the amount of skin exposed to sun. We found no correlation between sun exposure or dietary intake and serum 25OHD levels. Surprisingly, we also found no significant relationship between length of sun exposure and serum 25OHD, despite that fact that most subjects reported infrequent sunscreen use, which maximized the potential for endogenous vitamin D production. These results are confirmed in studies investigating the vitamin D status of different populations in the United States (66, 67). Previous reports and the present results indicate that individuals with significant sun exposure may still be at risk for vitamin D deficiency.

One of the biggest challenges in vitamin D research is the understanding of optimal levels for different populations. Because the benefits of increasing serum 25OHD in athletes are not completely elucidated to date, current research is beginning to determine the concentration at which optimal health and athletic performance occurs in physically active individuals. Studies in adolescent dancers note that non-specific musculoskeletal pain occurred with serum concentrations as low as 20 ng/mL (68), with a decrease in athletic performance observed in a population where mean serum 25OHD concentration was 12 ng/mL (33). It is also important to note that optimal concentrations for populations with chronic illness are thought to be 25 ng/mL. Accordingly, the estimate of “normal” serum 25OHD concentration (> 35 ng/mL) used in the current study is a conservative for young, healthy, and physically individuals.

Our current study includes several limitations. First, subjects were mostly Caucasian (n = 36) with several Hispanics (n = 3) but included no African Americans. The observed levels of insufficiency would have potentially been greater if more minorities had been recruited, as they are at a higher risk for insufficiency or deficiency because increased melanin plays a role in blocking the production and circulation of 25OHD (18). It is crucial to point out that our data were analyzed using the USDA Nutrient Database for vitamin D content (44). While the amounts listed in the USDA nutrient database include amounts of both D2 and D3, D3 is regarded to be much more biologically active in humans (19). Therefore, the dietary analysis included the highest possible value because it considers both forms. It should be noted that dietary intake was significantly higher in males than in females (n = 20 males, n = 19 females). This difference in dietary intake may be due to the fact that males tend to eat more on a daily basis (69).

In conclusion, this study showed a positive relationship between aerobic fitness and 25OHD status in physically active males. A secondary finding was that vitamin D intake was

lower than that which is currently recommended, and a large percentage of young, healthy and physically active individuals had low serum levels of 25OHD. Finally, sun exposure and dietary intake did not appear to influence 25OHD status.

CHAPTER 6 – CONCLUSION

Results of this study are promising. A significant percent of a young, active population presented with low levels of an important nutrient, therefore it is important to increase awareness of the importance of including vitamin D in an overall healthy diet.. It is documented in studies using subjects between ages ranging from adolescence to the community-dwelling elderly that insufficient levels of 25OHD are associated with symptoms such as muscle soreness and myopathy, even significant muscle weakness (5, 33). In children and the elderly, the benefits of vitamin D are even more important, as bone growth and maintenance are tightly correlated with levels of 25OHD (70). Since vitamin D is essential for bone health, as well as potentially increasing athletic performance and altering body composition, it is important for young individuals and athletes to appreciate its nutritive value (31).

Because there was a significant difference between males above and below the normal serum 25OHD levels and the resulting levels of aerobic fitness, further research in the area of supplementation and resulting athletic performance is warranted. There is very little understanding about the direction of this relationship at this time. Some of the most recent studies showed a positive relationship between cardiorespiratory fitness, as measured by VO_{2max} treadmill testing, and serum 25OHD levels (54, 55). These results are noteworthy, as the relationship was observed in both healthy adult men and women, and was conducted using several thousand subjects. The major disadvantage to these studies were the confounding factors of adiposity, as there was a negative relationship observed between both 25OHD and body fat, as well as cardiorespiratory fitness and obesity. While the former would suggest that vitamin D status could positively influence body composition, the latter clouds the understanding of this relationship. Many factors influence this relationship. Individuals who are more aerobically fit tend to spend more time outdoors and consistently have diets higher in nutritious foods, most

definitely those that have increased vitamin D content (54). The converse relationship is also true: those who are less fit tend to spend more time indoors and or have a diet high in processed foods, lacking basic nutrients. Therefore, the directionality of the results observed in the mentioned studies cannot be determined. Further work in understanding this relationship should be conducted using a longitudinal training study, in which subjects are supplementing and participating in a concurrent athletic training program. Resulting changes in fitness and body composition could be compared to subjects who are given a placebo but still participating in physical activity. In fact, this is the next step in the research plan, which began with the present study.

Future Directions

Improvements in body composition and fitness levels are understood on many physiological levels, but the resulting reduction in chronic levels of inflammation is perhaps the most positive systemic change. It is understood that an increase in adiposity results in an increase in low-grade inflammation (71). The effects of this rise in inflammation include impaired glucose and lipid metabolism, increased insulin resistance, or vascular destruction, which can lead to a cardiovascular event (71). However, all of these adverse effects can be overcome in part with exercise training (72). While the concentration of inflammatory cytokines increases acutely with exercise, chronic training leads to an increased ability to attenuate overall inflammation by both a decrease in proinflammatory cytokines and increase in anti-inflammatory cytokines (72). One of the secondary investigations concerning 25OHD is its role in improving immune function (31, 64). New studies using cell culture models have indicated that 25OHD directly inhibits the production of inflammatory cytokines IL-6 and TNF- α (73). Further analysis indicated that this inhibition was due to binding of 25OHD to DNA, causing activation of a gene that produces MKP-1 (73). MKP-1 interferes directly with the cellular pathway

leading to the production of IL-6 and TNF- α (73). These results are novel and directly applicable to clinical populations, indicating the importance of maintaining high 25OHD levels in those suffering from obesity, type 2 diabetes, or other chronic conditions. A major topic of interest would be the changes in inflammation that occur in the presence of increased 25OHD concentrations in those who are physically active. This topic is of considerable interest to those who conducted the present study and is a potential future step in their line of research.

In summary, increasing vitamin D levels has the potential to increase muscle mass and decrease adiposity, which can potentially regulate systemic inflammation. Future research should focus on understanding these and other physiological changes that are caused by vitamin D. Additionally, because of the large percentage of individuals with insufficient levels of 25OHD, other investigations should focus on ways to effectively measure vitamin D status and methods to increase functional levels in the body.

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APPENDIX 1

Table 1. Demographic and Anthropometric Measures

		Gender		25OHD Status	
	Overall	Male	Female	Low	High
Number of Participants	39	20	19	20	19
Males (n)	20			11	9
Females (n)	19			9	10
Age	23.26 ± 0.7	23.75 ± 1.1	22.74 ± 0.7	22.75 ± 0.5	23.79 ± 1.2
Height (cm)	167.77 ± 1.9	174.37 ± 2.1	160.82 ± 2.3	169.29 ± 2.5	166.17 ± 2.9
Weight (kg)	68.85 ± 2.1	77.29 ± 2.4	59.79 ± 1.8	71.96 ± 3.1	65.40 ± 2.6
% Body Fat	24.19 ± 1.3	18.65 ± 1.5	30.02 ± 1.0	24.66 ± 1.7	23.69 ± 2.0
BMI	24.34 ± 0.6	25.45 ± 0.8	23.17 ± 0.7	24.99 ± 0.9	23.65 ± 0.7

Data are presented as means ± SE. BMI, body mass index; RMR, resting metabolic rate; 25OHD, 25-hydroxyvitamin D.

Table 2. Performance Measures Outcomes

		Gender		25OHD Status	
	Overall	Male	Female	Low	High
Number of Participants	40	20	19	20	19
Males (n)				11	9
Females (n)				9	10
RMR (kcal/day)	1435.38 \pm 44.8	1593.78 \pm 53.7	1268.64 \pm 49.6	1438.32 \pm 71.7	1432.28 \pm 54.4
25OHD (ng/mL)	34.83 \pm 1.9	33.02 \pm 2.1	36.73 \pm 3.2	25.97 \pm 1.2	44.15 \pm 2.2*
Dietary Intake (IU/week)	1117.16 \pm 169.2	1601.90 \pm 273.6 [†]	606.90 \pm 112.4	1131.55 \pm 254.1	1102.00 \pm 228.6
Sun Exposure (score)	28.82 \pm 1.8	29.60 \pm 2.9	30.02 \pm 1.0	28.40 \pm 2.7	29.26 \pm 2.3
Anaerobic Power (watts)	634.45 \pm 28.2	753.43 \pm 31.5 [†]	509.21 \pm 25.3	662.41 \pm 40.5	605.02 \pm 39.1
Bench Press (kg)	68.28 \pm 5.1	93.18 \pm 5.3 [†]	42.06 \pm 2.6	73.44 \pm 7.9	62.84 \pm 6.4
Leg Curl (kg)	41.04 \pm 2.4	51.98 \pm 2.5 [†]	29.51 \pm 1.9	42.56 \pm 3.7	39.43 \pm 3.0
Leg Extension (kg)	55.76 \pm 3.8	72.87 \pm 4.1 [†]	37.75 \pm 2.7	58.11 \pm 5.5	53.29 \pm 5.2
Upright Row (kg)	54.01 \pm 3.3	69.92 \pm 3.2 [†]	37.28 \pm 2.1	56.52 \pm 5.0	51.37 \pm 4.2
Bicep Curl (kg)	27.24 \pm 2.5	38.36 \pm 2.6 [†]	15.53 \pm 1.9	29.40 \pm 3.9	24.97 \pm 3.0

Table 2 – continued

Tricep Pushdown (kg)	62.40 ± 4.4	81.95 ± 4.8 [†]	41.82 ± 3.5	65.60 ± 6.8	59.02 ± 5.6
Vertical Jump (cm)	47.28 ± 1.7	54.36 ± 2.1 [†]	39.84 ± 1.2	48.13 ± 2.3	46.39 ± 2.6
Horizontal Jump (cm)	193.50 ± 5.6	219.33 ± 5.9 [†]	166.30 ± 4.0	195.58 ± 7.6	191.30 ± 8.3
Sit and Reach (cm)	11.20 ± 2.0	6.35 ± 3.0 [†]	16.31 ± 2.2	7.75 ± 3.0	14.84 ± 2.6

Data are presented as means ± SE. * Indicates significant difference between high and low status ($p < 0.05$); [†] Indicates significant difference between males and females ($p < 0.05$).

Table 3. Data by 25OHD Status and Gender

	Females		Males	
	LOW	HIGH	LOW	HIGH
Number of Participants	9	10	11	9
Age	23.56 ± 1.0	22.00 ± 0.8	22.09 ± 0.5	25.70 ± 2.3
Height (cm)	162.00 ± 2.4 [†]	159.77 ± 3.8 [†]	175.26 ± 3.0	173.28 ± 3.0
Weight (kg)	61.34 ± 3.6 [†]	58.29 ± 1.4 [†]	80.54 ± 3.0	73.18 ± 3.76
% BF	29.81 ± 1.2 [†]	30.20 ± 1.5	20.45 ± 2.3	16.46 ± 1.9
BMI	23.27 ± 1.0	23.08 ± 1.0 [†]	26.40 ± 1.2	24.30 ± .89
RMR (kcal/day)	1266.00 ± 96.2 [†]	1271.01 ± 44.0 [†]	1579.32 ± 85.4	1611.46 ± 63.4
25OHD (ng/mL)	26.04 ± 1.9 [†]	46.34 ± 3.8* [†]	25.92 ± 1.6	41.71 ± 1.6*
Dietary Intake (IU/week)	686.00 ± 202.8 [†]	535.7 ± 117.9 [†]	1181.30 ± 287.3	1731.22 ± 369.8
Sun Exposure (score)	29.33 ± 3.6 [†]	26.8 ± 2.3 [†]	27.64 ± 4.0	32.00 ± 4.2
VO2max (mL/kg/min)	45.98 ± 1.7 [†]	45.02 ± 2.4 [†]	49.66 ± 1.96	59.21 ± 2.9*
Anaerobic Power (watts)	517.35 ± 38.1 [†]	501.88 ± 35.4 [†]	781.09 ± 39.6	719.62 ± 50.9
Bench Press (kg)	43.34 ± 5.2 [†]	40.82 ± 1.8 [†]	97.94 ± 7.9	87.19 ± 6.8

Table 3 – continued

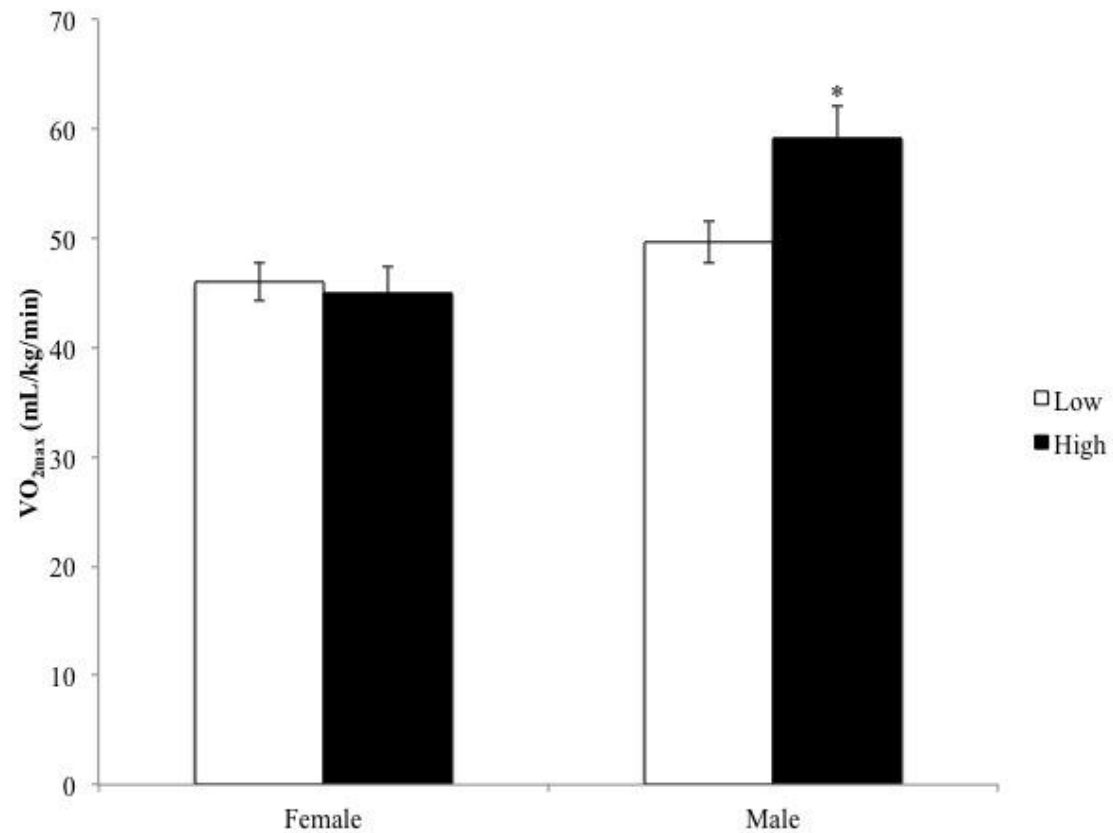
Leg Curl (kg)	28.98 ± 3.4 [†]	29.94 ± 2.1 [†]	53.61 ± 3.7	49.90 ± 3.2
Leg Extension (kg)	39.31 ± 5.5 [†]	36.29 ± 1.9 [†]	73.40 ± 5.8	72.07 ± 6.1
Upright Row (kg)	38.81 ± 4.1 [†]	35.83 ± 1.6 [†]	70.93 ± 5.3	68.54 ± 3.2
Bicep Curl (kg)	16.38 ± 3.9 [†]	14.74 ± 1.4 [†]	40.00 ± 4.1	36.29 ± 3.2
Tricep Pushdown (kg)	44.86 ± 7.4 [†]	39.01 ± 1.21 [†]	82.47 ± 7.6	81.14 ± 5.6
Vertical Jump (cm)	39.79 ± 1.5 [†]	39.88 ± 1.9 [†]	54.96 ± 2.4	53.62 ± 3.8
Horizontal Jump (cm)	169.05 ± 4.8 [†]	163.83 ± 6.4 [†]	217.29 ± 9.0	221.83 ± 7.5
Sit and Reach (cm)	11.85 ± 3.8 [†]	20.32 ± 1.8 [†]	4.49 ± 4.4	8.75 ± 4.0

Data are presented as means ± SE. * Indicates significant difference between comparison groups of the same gender ($p < 0.05$). [†]

Indicates significant difference between females and both HIGH and LOW males ($p < 0.05$).

Figure 1.

Data represent maximal cardiorespiratory fitness ($\text{VO}_{2\text{max}}$ mL/kg/min) expressed as mean (SE) for males and females above (HIGH) or below (LOW) a normal standard level of serum 25OHD (35 ng/mL). * Indicates that HIGH male subjects are significantly higher than their LOW counterparts.



Weekly dietary intake of vitamin D among subjects (n = 38, outlier excluded) are presented as international units per week. Solid line is simple regression line.



APPENDIX 2

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ days per week

☐

No vigorous physical activities



Skip to question 3

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

_____ hours per day

_____ minutes per day

☐

Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ days per week

☐

No moderate physical activities



Skip to question 5

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking ➔ **Skip to question 7**

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
<input type="checkbox"/>	<input type="checkbox"/>	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
<input type="checkbox"/>	<input type="checkbox"/>	2. Do you feel pain in your chest when you do physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	3. In the past month, have you had chest pain when you were not doing physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
<input type="checkbox"/>	<input type="checkbox"/>	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
<input type="checkbox"/>	<input type="checkbox"/>	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
<input type="checkbox"/>	<input type="checkbox"/>	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

DATE _____

SIGNATURE OF PARENT _____
or GUARDIAN (for participants under the age of majority)

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.



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SunExposureLog

ID: _____ Dates: From _____ To _____

	Time	Exposure	Total
Monday			
Sunday			
Saturday			
Friday			
Thursday			
Wednesday			
Tuesday			

Time	Exposure
<5min/day=1point	Face,Hands,Arms=2points
5-30min=2point	Face,Hands,Arms=3points
>30min=3points	Face,Hands,Arms,Legs=4points
	BathingSuit=2points

Hanwell et al, 2010

APPENDIX 3

Louisiana State University Institutional Review Board Approval

ACTION ON PROTOCOL APPROVAL REQUEST



Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu | lsu.edu/irb

TO: Laura Stewart
Kinesiology

FROM: Robert C. Mathews
Chair, Institutional Review Board

DATE: April 8, 2011
RE: IRB# 3176

TITLE: Vitamin D, Body Composition, Strength and Fitness Study

New Protocol/Modification/Continuation: New Protocol

Review type: Full ☐ Expedited ☒ **Review date:** 3/21/2011

Risk Factor: Minimal ☒ Uncertain ☐ Greater Than Minimal ☐

Approved ☒ **Disapproved** ☐

Approval Date: 4/8/2011 **Approval Expiration Date:** 4/7/2012

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 40

Protocol Matches Scope of Work in Grant proposal: (if applicable) ☐

By: Robert C. Mathews, Chairman 

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at <http://www.lsu.edu/irb>*

Application for Approval of Projects Which Use Human Subjects

This application is used for projects/studies that cannot be reviewed through the exemption process.



Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.6792
irb@lsu.edu
lsu.edu/irb

Applicant, Please fill out the application in its entirety and include two copies of the completed application as well as parts A-E, listed below. Once the application is completed, please submit to the IRB Office for review and please allow ample time for the application to be reviewed. Expedited reviews usually takes 2 weeks. Carefully completed applications should be submitted 3 weeks before a meeting to ensure a prompt decision.

A Complete Application Includes All of the Following:

(A) Two copies of this completed form and two copies of part B thru E.

(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)

(C) Copies of all instruments to be used.

*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.

(D) The consent form that you will use in the study (see part 3 for more information.)

(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (<http://phrp.nihtaining.com/users/login.php>.)

(F) IRB Security of Data Agreement: (<http://www.lsu.edu/irb/IRB%20Security%20of%20Data.pdf>)

1) Principal Investigator*: Laura K. Stewart

Rank Assistant Professor

*PI must be an LSU Faculty Member

Dept: Kinesiology

Ph:

578-3549

E-mail:

stewart6@lsu.edu

2) Co Investigator(s): please include department, rank, phone and e-mail for each

Laura Forney, Department of Kinesiology, PhD Student, 859.285.9192, lforne2@tigers.lsu.edu

3) Project Title:

Vitamin D, Body Composition, Strength and Fitness Study

4) Proposal Start Date: March 2011

5) Proposed Duration Months: 12 months

6) Number of Subjects Requested: 40

7) LSU Proposal #: N/A

8) Funding Sought From: College of Education Dean's Fund

ASSURANCE OF PRINCIPAL INVESTIGATOR named above

I accept personal responsibility for the conduct of this study (including ensuring compliance of co-investigators/co-workers) in accordance with the documents submitted herewith and the following guidelines for human subject protection: The Belmont Report, LSU's Assurance (FWA00003892) with OHRP and 45 CFR 46 (available from <http://www.lsu.edu/irb>). I also understand that copies of all consent forms must be maintained at LSU for three years after the completion of the project. If I leave LSU before that time, the consent forms should be preserved in the Departmental Office.

Signature of PI

Date 2/25/2011

ASSURANCE OF STUDENT/PROJECT COORDINATOR named above. If multiple Co-Investigators, please create a "signature page" for all Co-Investigators to sign. Attach the "signature page" to the application.

I agree to adhere to the terms of this document and am familiar with the documents referenced above.

Signature of Co-PI (s)

Date 02.25.2011

IRB# 3176 LSU Proposal #

☐ Full

☒ Expedited

☒ Human Subjects Training

☒ Complete Application

Study Approved By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Approval Expires: 1-1-2013

1. Study Title: Vitamin D, Body Composition, Strength and Fitness Study
2. Performance Site: Louisiana State University
Baton Rouge, Louisiana 70803
3. Investigators: The following investigators will be available for questions about this study
Monday – Friday 8am – 8pm.
Principal Investigator: Laura K. Stewart, Ph.D., 225.578.3549
Co-investigator: Laura Forney, 859.285.9192
4. Purpose of the Study:
The purpose of this study is to investigate and compare the vitamin D status of healthy individuals to measures of body composition, aerobic and anaerobic fitness, strength and power.

Subject inclusion: Participants must be healthy and between 18-40 years of age. Subjects will have been engaging in regular (at least 3 days per week for at least 40-60 min per bout) physical activity for at least three months prior to the start of the study. Subjects will have had a consistent body weight (within 5%) for the three months prior to testing and not be supplementing their diets with more than 400 IU of Vitamin D3 daily. Females must not be pregnant and will need to have regular menstrual cycles. You will also need to fill out a physical activity readiness questionnaire to ensure that you are ready to participate in sessions that involve exercise.
5. Study Procedures: You will report to the lab for testing 6 times. In the first visit, you will be given the informed consent and health and physical activity assessment, and height, weight, heart rate, blood pressure, and resting metabolic rate measurements will be taken. In the second visit, your blood sample (20 ml or 4 teaspoons) will be collected and daily sun exposure will be estimated. The third visit, conducted at Pennington Biomedical Research Center, will involve body circumference and body composition measurements. In the fourth visit, you will complete the aerobic fitness assessment and a mood evaluation survey. In the fifth session, you will complete anaerobic power and flexibility tests. Finally, in the sixth session, you will complete a brief warm up followed by vertical jump, long jump, and strength assessments.
6. Benefits: While no guarantee of benefits can be made, you will be given measures of anaerobic and aerobic power, as well as strength test results and a body composition analysis at no cost to you. These measures are a valid assessment of physical fitness and health status. Vitamin D is becoming more widely accepted as a valuable nutrient, so knowing your vitamin D status can help improve your health.
7. Risks/Discomforts:
Exercise Testing: Because of the nature of the testing procedures, there is a remote risk of a heart attack or stroke and in very rare cases, death. Precautions to minimize this risk have been taken by requiring completion of a health history questionnaire. Your honest answers in completing the health history form will

decrease this risk. As with any exercise program, there is a chance that you will experience muscle soreness, fatigue, or even injuries such as sprains or strains.

Blood Sampling: There is a risk of bruising and a remote risk of infection with the blood sampling techniques. You may also become light-headed and faint during these procedures. These risks will be minimized by having trained technicians using sterile, single-use supplies for blood sampling. You will be seated during blood sampling, but you should tell us if you feel dizzy or faint.

DXA: The Dual Energy X-Ray Absorptiometry test uses an x-ray technique to assess the density of your body and can then provide an accurate estimate of body fat percentage and lean body mass. The whole body DXA scan exposes subjects to low levels of ionizing radiation. No discomfort will be felt during the DXA scan. There is a risk of radiation exposure from this test, but it is well below the level that would provide any adverse effects. The total body DXA Scan will produce less than 0.37 μ SV (0.037 mrem) of ionizing radiation skin entrance dosage. The skin entrance dose of 0.37 μ SV is well below the yearly public limit dose for incidental exposure of 1,000 μ SV (100 mrems).

Skinfold Measurements: Since a slight pinching of the skin is required to measure subcutaneous fat through calipers, you may experience mild bruising in the measurement sites (chest, midaxillary, triceps, subscapular, abdomen, suprailiac, and thigh).

In addition to the risks listed above, you may experience a previously unknown risk or side effect.

Injury/Illness: In the unlikely event of injury or medical illness resulting from the above procedures, contact **Laura Stewart, Ph.D., 225-578-3549**. You will be referred for treatment, but the expense of medical treatment will be your responsibility. No compensation is available in case of study-related illness or injury.

8. **Right to Refuse:** You may choose not to participate or to withdraw from the study at any time without penalty or loss of any benefit to which you might otherwise be entitled.
9. **Privacy:** Your identity will remain confidential unless disclosure is required by law. In other words, data will be kept confidential unless release is legally compelled. All data collection will be handled only by the investigators and kept in a secure location. Results of the study may be published using group means only and names or identifying information will not be included in the publication.
10. **Financial Information:** These tests are provided at no cost to you, nor is there any compensation for participating in the study outside of the results of your personal tests.
11. **Signatures:** The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators.

If I have any questions about subjects' rights or other concerns, I can contact Robert C. Matthews, Institutional Review Board at 225.578.8692. I agree to participate in the study described above and acknowledge the investigators' obligation to provide me with a signed copy of this consent form.

Participant's Signature

Date

The study subject has indicated that s/he is unable to read. I certify that I have read this consent form to the subject and explained that by completing the signature line above, the subject has agreed to participate.

Reader's Signature

Date

Study Approved By:

Dr. Robert C. Mathews, Chairman

Institutional Review Board

Louisiana State University

203 B-1 David Boyd Hall

225-578-8692 | www.lsu.edu/irb

Approval Expires: 4-7-2012



CONSENT TO PARTICIPATE IN A RESEARCH STUDY FOR AN ADULT

Informed Consent - Part I

Title of Study: Vitamin D, Body Composition, and Fitness Study

What you should know about a research study

- We give you this consent form so that you may read about the purpose, risks and benefits of this research study.
- The main goal of research studies is to gain knowledge that may help future patients.
- You have the right to refuse to take part, or agree to take part now and change your mind later on.
- Please review this consent form carefully and ask any questions before you make a decision.
- Your participation is voluntary.
- By signing this consent form, you agree to participate in the study as it is described.

1- Who is doing the study?

Investigator Information:

Principal Investigator: Laura Stewart, PhD
225-

Medical Investigator: Timothy S. Church, M.D., MPH, PhD
225-763-2632:
24-hr. Emergency Phone Nos.:
225-763-2632 (Weekdays 7:00 a.m.-4:30 p.m.)
(225) 765-4644 (After 4:30 p.m. and Weekends)

Co-Investigators: Conrad Earnest, PhD
Laura Forney, BS

Dr. Stewart directs this study, which is under the medical supervision of Dr. Time Church. We expect about 40 people from 1 sites will be in this study. The study will take place over a period of 1 year. Your expected time in this study will be 2 weeks.

2- Where is the study being conducted?

This study is being conducted through the department of Kinesiology at Louisiana State University (LSU) and Pennington Biomedical Research Center. Of your six visits, only one visit will take place at Pennington.

3- What is the purpose of this study?

The purpose of the study is to examine the relationship between Vitamin D, Body composition, strength and fitness. Your visit to Pennington today will entail the body composition portion of the study. The test you are going to do today is the most accurate means of measuring body composition. Body composition is defined as how much muscle, bone and fat you have on your body.

4- Who is eligible to participate in the study? Who is ineligible?

You are eligible for this study because you have volunteered for the main portion of the study being performed at LSU. You are between the ages of 18 and 40, generally healthy and exercise 40-60 minutes per week.

5- What will happen to you if you take part in the study?

In this portion of the study you will be scanned on a GE iDXA Whole Body Scanner.

- The test will take about 10 minutes
- This scan measures the amount of bone, muscle, and fat in your body.
- The scan will be performed using a whole-body scanner.
- You will be required to wear a hospital gown, to remove all metal-containing objects from your body, and to lie down on the table.
- You will be carefully positioned on the table, and your legs will be placed together using two Velcro straps.
- A scanner emitting low energy X-rays and a detector will pass along your body.
- You will be asked to remain completely still while the scan is in progress.

6- What are the possible risks and discomforts?

- The amount of radiation used for this procedure is very small.
- The radiation dose for this scan is equivalent to the radiation you are naturally exposed to in the environment in less than one day.
- **Scans will not be performed on any subject who is pregnant, and all females should inform the DXA technologist if there is any possibility that they are pregnant.**

7- What are the possible benefits?

The relationship between Vitamin D and health is important to a variety of age groups. By participating in this study you will help us determine how vitamin D relates to aerobic fitness, muscle strength, and body composition.

8- If you do not want to take part in the study, are there other choices?

If you do not want to participate in this portion of the study a similar measurement of body composition using skinfold measurements will be performed during one of your visits at LSU. While DXA is considered a "gold standard," the skinfold technique will provide the investigators with another means of determining your body composition.

9- If you have any questions or problems, whom can you call?

If you have any questions about your rights as a research volunteer, you should call the Institutional Review Board Office at 225/763-2693 or Dr. Steven Heymsfield, Executive Director of PBRC at 225/763-2513. If you have any questions about the research study as whole, contact Laura Stewart, PhD (PI) at 225-578-3549.

If you have any questions related to the DXA test performed at Pennington Biomedical Research Center today, contact, Conrad Earnest, PhD at 225-763-2923.

If you think you have a research-related injury or medical illness, you should call Tim Church, MD, MPH, PhD at 225-763-2632 (phone number) during regular working hours. After working hours and on weekends you should call the answering service at 225/765-4644. The on-call physician will respond to your call.

10- What information will be kept private?


Every effort will be made to maintain the confidentiality of your study records. However, someone from the Food and Drug Administration, the National Institutes of Health (*if applicable*), the Pennington Biomedical Research Center, and Louisiana State may inspect and/or copy the medical records related to the study. Results of the study may be published; however, we will keep your name and other identifying information private. Other than as set forth above, your identity will remain confidential unless disclosure is required by law.

11- Can your taking part in the study end early?

Dr. Stewart or the study sponsor can withdraw you from the study for any reason or for no reason. You may withdraw from the study at any time without penalty. Possible

#PBRC 11010

Full approval by IRB received 5-24-11

reasons for withdrawal include a general disinterested in continuing or for any other reason you decide on The sponsor of the study may end the study early 

12- What if information becomes available that might affect your decision to stay in the study?

During the course of this study there may be new findings from this or other research which may affect your willingness to continue participation. Information concerning any such new findings will be provided to you.

13- What charges will you have to pay?

None.

14- What payment will you receive?

None.

15- Will you be compensated for a study-related injury or medical illness?

No form of compensation for medical treatment or for other damages (i.e., lost wages, time lost from work, etc.) is available from the Pennington Biomedical Research Center. In the event of injury or medical illness resulting from the research procedures in which you participate, you will be referred to a treatment facility. Medical treatment may be provided at your expense or at the expense of your health care insurer (e.g., Medicare, Medicaid, Blue Cross-Blue Shield, Dental Insurer, etc.) which may or may not provide coverage. The Pennington Biomedical Research Center is a research facility and provides medical treatment only as part of research protocols. Should you require ongoing medical treatments, they must be provided by community physicians and hospitals.

16- HIPAA

Records that you give us permission to keep, and that identify you, will be kept confidential as required by law. Federal Privacy Regulations provide safeguards for privacy, security, and authorized access. Except when required by law, you will not be identified by name, social security number, address, telephone number, or any other direct personal identifier in records disclosed outside of Pennington Biomedical Research Center (PBRC). For records disclosed outside of PBRC, you will be assigned a unique code number.

#PBRC 11010

Full approval by IRB received 5-24-11

17- Signatures

The study has been discussed with me and all my questions have been answered. I understand that additional questions regarding the study should be directed to the study investigators. I agree with the terms above and acknowledge that I have been given a copy of the signed consent form.

With my signature, I also acknowledge that I have been given either today or in the past a copy of the Notice of Privacy Practices for Protected Health Information.

Signature of Volunteer

Date

Date of Birth of Volunteer

Signature of Person Administering Informed Consent

Date

Name of Principal Investigator

Principal Investigator

For LSU, Laura Stewart, PhD

For Pennington Biomedical Research Center, Conrad Earnest, PhD

Name of Medical Investigator Tim Church, MD, MPH, PhD

Medical Investigator

**PENNINGTON BIOMEDICAL RESEARCH CENTER (PBRC)
INSTITUTIONAL REVIEW BOARD**

**AUTHORIZATION FOR USE AND DISCLOSURE OF PROTECTED HEALTH INFORMATION
FOR RESEARCH PURPOSES
INFORMED CONSENT – PART II**

(Instructions for Investigators: This form must be reviewed and signed by subjects participating in research/clinical trials that require a signed Informed Consent. These documents should be kept together. A copy of this Authorization and the Informed Consent must be given to the subject and/or his/her representative.)

Title of Research Project: **Vitamin D, Body Composition, Strength and Fitness Study.**

Principal Investigator: **Laura Stewart, Ph. D. (LSU)**
Conrad Earnest, Ph. D., (PBRC)

IRB Number: **11010**

I hereby request and authorize the PBRC to use and disclose protected health information from the record(s) of:

Subject's Name/Address: _____

Birth Date: ____/____/____ **Social Security Number:** _____

Specifically, I request and authorize any part of my health information relevant to the research project, identified above and in the Informed Consent document, to be used and/or disclosed to the Principal Investigator identified above or his/her designee, in connection with the research project. I understand that this may include information relating to: Human Immunodeficiency Virus ("HIV") infection or Acquired Immunodeficiency Syndrome ("AIDS"); treatment for or history of drug or alcohol abuse; and/or mental or behavioral health or psychiatric care.

I understand that copies of the records indicated above will be:

- Used by employees of PBRC including researchers and treatment providers, and/or other members of its workforce.
- Disclosed to government officials or government agencies, study sponsors, study monitors, or others responsible for oversight of the research project.
- Sent to collaborating researchers outside PBRC if and to the extent indicated in the attached Informed Consent document(s).

I understand that by signing this form, I will allow PBRC and its researchers to use or disclose my health information in connection with the attached Informed Consent and for the purpose of the research that is described in the Informed Consent. For example, the researchers may need the information to verify that I am eligible to participate in the study, or to monitor the results, including expected or unexpected side effects or outcomes. Other University and government officials, safety monitors, and study sponsors may need the information to ensure that the study is conducted properly. I understand that any privacy rights not specifically

mentioned in this Authorization are contained in the Notice of Privacy Practices that I received or will receive from the Principal Investigator or at the facility that I attend.

I understand that I may revoke this authorization at any time, except to the extent that PBRC has already relied on the authorization, by sending or transmitting of a facsimile, a written notice to the contact person listed in the attached Informed Consent document(s).

I understand that if my information already has been included in a research database or registry as described in the attached Informed Consent document(s), PBRC considers itself to have relied on it, and therefore my information will not be removed from those repositories, unless I request for it to be removed. Unless otherwise revoked, I understand that this authorization will not expire during the length of the research study. I understand that if I do not sign this form, I will not be able to participate in the above research study or receive the study-related interventions, but that PBRC cannot otherwise condition treatment on my signing this form.

While the research study is in progress, my right to access any research records or results that are maintained by the facility may be suspended until the research study is over. If my access is denied, I understand that it will be reinstated at the end of the research study.

I understand the information disclosed by this authorization may be subject to re-disclosure by the recipient and no longer be protected by the Health Insurance Portability and Accountability Act. The PBRC facility, its employees, officers, and physicians are hereby released from any legal responsibility or liability for disclosure of the above information to the extent indicated and authorized herein.

I UNDERSTAND THAT THIS AUTHORIZATION SUPERSEDES ANY CONTRARY INFORMATION IN ANY OTHER DOCUMENTS I HAVE SIGNED RELATED TO THE ATTACHED STUDY.

Signature of Subject or Subject's Legal Representative

Date

Printed Name of Legal Representative (if any): _____

Representative's Authority to Act for Subject (e.g., relationship to subject): _____

Verification of Representative's Authority: () viewed driver's license () viewed Power of Attorney

() viewed other _____ (specify)

PBRC Institutional Review Board
FWA 00006218

Approved On 5-24-11

Signature 

VITA

Laura was born in September of 1987 in Bloomington, Indiana. She was raised by her parents Chuck and Marla, and has a younger brother. Starting at an early age, she had a passion for physical activity – whether it was enjoying the outdoors with brothers and friends, or playing a variety of organized sports for city leagues or school teams. She graduated with honors from high school in 2006 and attended Purdue University, majoring in biological sciences and chemistry. During this time, she invested many of her extracurricular hours to working in clinical settings as well as developing her interest in long distance running. Through her research mentor at Purdue, she was introduced to the field of exercise physiology, culminating her interests in biological pathways, physical activity, and patient care.

In anticipation of earning her undergraduate degree in the spring of 2010, Laura applied to the Kinesiology Department at Louisiana State University, under the mentorship of Dr. Laura Stewart. During her first year of graduate school, she completed many hours of bench work and cell culture studies at Pennington Biomedical Research Center with the assistance of Dr. Tara Henagan, giving her an opportunity to discover the excitement of examining the physiological phenomena at a cellular level. With the help of Dr. Stewart, Laura began her thesis project – which also serves as the milestone project for her doctoral degree – in the summer of 2011. As the results of this project were promising, Laura plans to build upon the premise and continue research in the area of vitamin D supplementation in physically active individuals. She will defend her thesis early in the summer of 2012 in order to be awarded a Master of Science in Kinesiology.

Laura's immediate future plans are to finish her doctoral degree at Louisiana State University in the Kinesiology Department, with a focus on exercise physiology and a minor in nutrition. She hopes to eventually focus her research on vitamin D on cellular mechanisms and

pathways and its role in anti-inflammatory properties. Upon completion of the PhD program, Laura is considering a career in academia, although would also consider pursuing a career in laboratory research.