Vitamin D Testing Practices in Collegiate Cross Country and Track and Field Athletes

by

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Bachelor of Science in Athletic Training, University of Pittsburgh, 2019

Submitted to the Graduate Faculty of the

School of Health and Rehabilitation Sciences in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2021

UNIVERSITY OF PITTSBURGH

SCHOOL OF HEALTH AND REHABILITATION SCIENCES

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Vitamin D insufficiency and deficiency has become problematic within the global population. Low levels of Vitamin D may have significant impacts on bone health and the musculoskeletal system, key factors in athletic performance. Recently, Vitamin D testing has gained popularity amongst athletic populations, but there is little research in cross country and track and field (XC and TF) collegiate athletes. The purpose of this study was to investigate the Vitamin D testing practices of NCAA sponsored XC and TF programs. Fifty-five Certified Athletic Trainers (ATs) participated in the study (43 XC and TF ATs, 12 non-XC and TF ATs). The responses of XC and TF ATs were analyzed separately and compared by region of the U.S. and NCAA Division classification. Few participants (6/30) identified their institution as having a Vitamin D testing policy in place. The six participants indicated that red flags and health history are the primary indications for Vitamin D testing while preventative screening occurs at half of the Division I institutions. There was little consensus regarding adequate Vitamin D levels and number of Vitamin D tests per year. Although, 70.6% of Division I XC and TF ATs support Vitamin D testing in their athletes while 66.7% of Divisions II and III ATs did not. In addition to testing practices, this study gathered data regarding indoor training duration and bone stress injuries for XC and TF collegiate athletes. There was no significant association between indoor training duration and region of the U.S. for XC athletes, however, there was a statistically significant association for TF athletes (p = 0.016, 0.050). Using the injury data provided, an injury incidence and frequency was calculated of which women's XC had the highest rates (11.9, 14.1),

followed by women’s TF (6.3, 9.2), men’s XC (5.4, 7.6), and men’s TF (4.1, 4.9). A major limitation of the present study was the small sample size, however, future research utilizing an increased sample size may produce different or more statistically significant results. Overall, continued education and research regarding the importance of Vitamin D and athletic performance is necessary to create universal testing policies in collegiate athletics.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

Vitamin D is a fat-soluble micronutrient found in a small portion of the diet and from exposure to sunlight, specifically ultraviolet beta (UVB) light.[52] Vitamin D is essential in the regulation of calcium homeostasis and bone metabolism and serves an additional role in neuromuscular function, musculoskeletal, autoimmune, oncologic, cardiovascular, and mental health.[9,19,52] From a sports medicine perspective, Vitamin D is crucial for bone health, muscle strength, and overall physical performance.

Despite the known importance of this micronutrient, Vitamin D insufficiency is a global problem affecting up to billions of people across all age groups.[4,19] In athletes, the presence of Vitamin D insufficiency or deficiency places them at a greater risk for injury, decreased performance, and prolonged recovery. A recent systematic review and meta-analysis that included over 2,000 athletes found that 56 percent displayed Vitamin D insufficiency.[17] In an analysis of 223 National Collegiate Athletic Association (NCAA) Division I athletes, 33.6 percent were reported to have abnormal Vitamin D levels; however recent studies have estimated that up to 80 percent of athletes may possess inadequate levels.[20,22,57]

Athletes competing in certain sports and seasons, such as indoor sport activities and winter and early spring seasons, have been deemed as “high risk” individuals for Vitamin D insufficiency or deficiency.[17] In addition, the region of training plays a factor in Vitamin D status, leading to an increased prevalence of insufficiency in athletes competing at higher latitudes.[17] Many observational studies have indicated declines in muscle function and recovery and higher incidence of stress fracture, soft tissue injury, inflammation, and illness in athletes suffering from inadequate Vitamin D levels.[4,17,19,20,22,46,49] Given this information, cross country and track and field (XC and

TF) athletes are arguably the athletic population at highest risk due to the length and timing of their seasons combined with their predisposition to bone stress injuries.[49,59]

Vitamin D status is effectively determined by measuring the serum 25-hydroxyvitamin D [25(OH)D] concentration.[4,57] Although Vitamin D has become a popular topic amongst athletic populations, there are few studies examining the use of 25(OH)D testing, especially in cross country and track and field athletes. This study will investigate the Vitamin D testing practices in XC and TF athletes by NCAA sponsored programs by means of a survey. Results of this study may inform clinical practice guidelines and establish routine testing procedures for student athletes.

1.1 Epidemiology

1.1.1 Vitamin D Disorders

The definitions of Vitamin D deficiency and insufficiency are ambiguous. Vitamin D deficiency is commonly accepted as the level at which an individual is at risk for numerous health complications such as osteomalacia, dental problems, cardiovascular and infectious diseases, musculoskeletal disorders, and malignancy.[43] Vitamin D insufficiency is a borderline state between sufficiency and deficiency and is of concern because an individual is subjected to the aforementioned health complications associated with deficiency.[25] Vitamin D deficiency and insufficiency are also collectively classified as hypovitaminosis D, a disorder characterized by a Vitamin D deficit.[43] In 2011, the Endocrine Society developed clinical practice guidelines to assist in the evaluation, treatment, and prevention of Vitamin D deficiency. These guidelines define

Vitamin D deficiency as 25(OH)D levels below 20 ng/ml and insufficiency as levels between 21 to 29 ng/ml.[26] However, consensus regarding these definitions is widely debated and many studies have adopted their own definitions for these terms leading to inconsistencies in the literature. Figure 1 illustrates the differing thresholds recommended by various international organizations.[41] Nevertheless, it remains that an estimated one billion people worldwide fall into these categories due to low Vitamin D levels.[23,25]

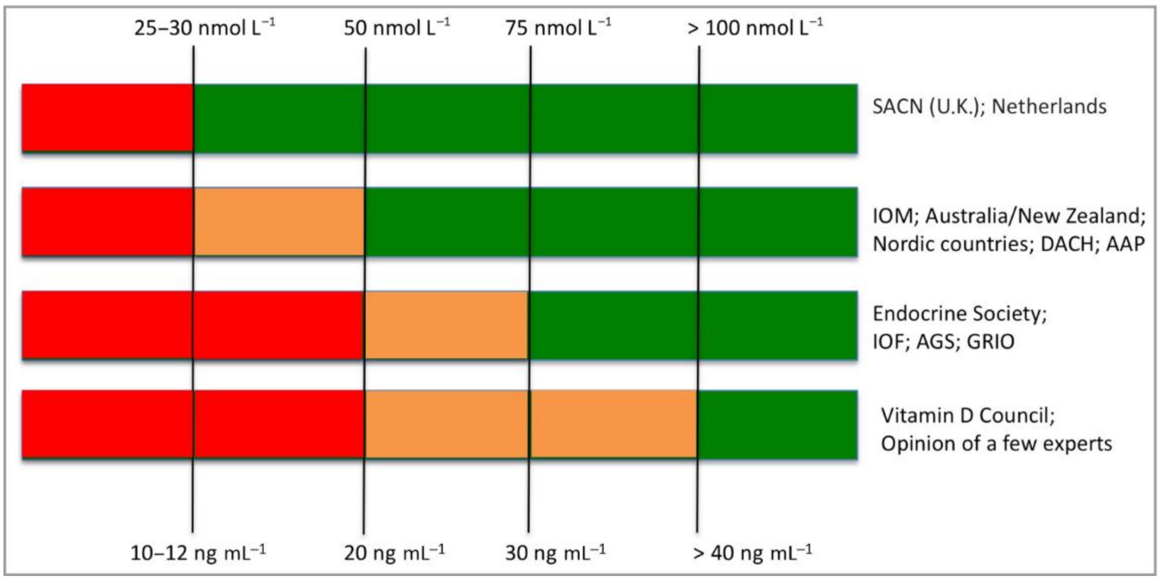

Figure 1 Serum 25(OH)D Blood Concentrations Recommended by International Organizations[41]

Within the last three decades, the prevalence of Vitamin D insufficiency and deficiency has reached an all-time high. In the United States alone, low Vitamin D levels are present in 36 to 57 percent of the population.[18,23,25] Beyond this, Vitamin D insufficiency is an overwhelmingly prevalent issue in European countries, affecting 28 to 100 percent of healthy individuals and 70 to 100 percent of hospitalized adults.[23,25] This is likely caused by an inadequate diet that lacks fortified nutrition, limited exposure to UVB sunlight, Vitamin D malabsorption disorders, and it commonly affects individuals with dark skin pigmentation.[18,23,25]

Even though athletes are often deemed healthy individuals, this high prevalence of Vitamin D deficiency is also substantial in the athletic population. Vitamin D levels were recorded in 279 professional basketball players participating in the National Basketball Association (NBA) combine from 2009 to 2013; roughly three-quarters or 73.5 percent of the players were found to have hypovitaminosis D.[19] In a similar study conducted by Maroon et al., 68.8 percent of National Football League (NFL) players from a single team were found to have insufficient Vitamin D levels.[34] This study also found that Vitamin D levels were lower in the athletes who experienced a bone fracture ($p < 0.001$), when the number of NFL seasons played were accounted for.[34] A measure of Vitamin D levels in 214 NFL combine participants determined that over half of the athletes were insufficient [25(OH)D < 32 ng/ml], 10 percent of which were classified as severely deficient [25(OH)D < 20 ng/ml].[44] In the same study, those athletes with an injury history were found to have significantly lower Vitamin D levels compared to uninjured athletes ($p = 0.03$).[44]

In XC and TF athletes specifically, 80 percent of elite Polish track and field athletes were found to have insufficient Vitamin D levels during the wintertime.[31] Another study in well-trained XC and TF athletes conducted in the southern United States, showed that 42 percent of participants had insufficient Vitamin D levels [25(OH)D < 32 ng/ml], whereas 11 percent were found to be deficient [25(OH)D < 20 ng/ml].[60] An additional finding in the same study includes a relation to one particular biomarker of inflammation that may lead to muscle wasting in distance runners.[60]

1.1.2 Bone Stress Injuries

Bone stress injuries (BSIs) are difficult and debilitating injuries that cause significant impairment in athletic performance and may lead to decreased function in everyday activities. Stress injuries are categorized as overuse injuries due to repetitive submaximal loading on a bone that occurs over extended periods of time.[29,30] It is cited that upwards of 20 percent of all sports medicine injuries are stress related in nature; 80 to 90 percent of which are stress fractures occurring in the lower extremity.[29,30]

Stress injuries are more common in weight-bearing bones, and most frequently reported in the tibia, fibula, and metatarsals.[30] Running, jumping, and other high-impact activities are the most common causes of stress injuries.[29,30] Due to this, the populations with the greatest risk include military recruits and XC and TF athletes. Stress injuries are the number one cause of missed training days in military recruits.[30,32] Stress fracture rates range from 0.2 to 5.2 percent in male recruits and 1.6 to 21 percent in female recruits.[32] Nevertheless, the highest reported incidence of stress injuries are seen in XC and TF athletes, ranging from 16 to 31 percent.[29,30,32]

A recent study using data from the NCAA Injury Surveillance Program from 2004-2005 through 2013-2014 by Rizzone et al. found that stress fractures resulted in an overall injury rate of 5.70 per 100,000 athlete exposures.[45] Two of the sports with the highest incidence included women's cross country and women's outdoor track with rates of 28.59 and 22.26 per 100,000 athlete exposures, respectively.[45] For male sports, cross country also had the highest incidence with a rate of 16.14 per 100,000 athlete exposures.[45] Comparably, Tenforde et al. discovered that female cross country runners had the highest incidence of BSIs, accounting for 64 percent reported in their study.[53] A large proportion of the BSIs were sustained by predetermined moderate and high-risk cross country runners, leading to a 4-fold and 5.7-fold increased risk rate for said athletes, respectively.[53]

1.2 Pathophysiology

Vitamin D is paramount in the maintenance of calcium and phosphate stores within the body.[4,27,52] Although limited, sources of dietary Vitamin D can be found in fatty fish, dairy products, eggs, and other fortified foods.[4,27,52] The major source of Vitamin D, however, comes from sun exposure, which results in a key interaction between the skin and UVB radiation.[4,27,52] Following UVB contact, 7-dehydrocholesterol, a chemical residing within the skin, is converted to previtamin D_3.[4,27,52] Previtamin D_3 is transferred to the liver and hydrolyzed into 25-hydroxyvitamin D [25(OH)D]—the main circulating metabolite utilized for serum testing.[4,27,52] The kidneys further metabolize 25(OH)D into its biologically active form of 1,25-dihydroxyvitamin D [1,25(OH)2D].[4,27,52] A depiction of the metabolism of Vitamin D can be found below in Figure 2.[2]

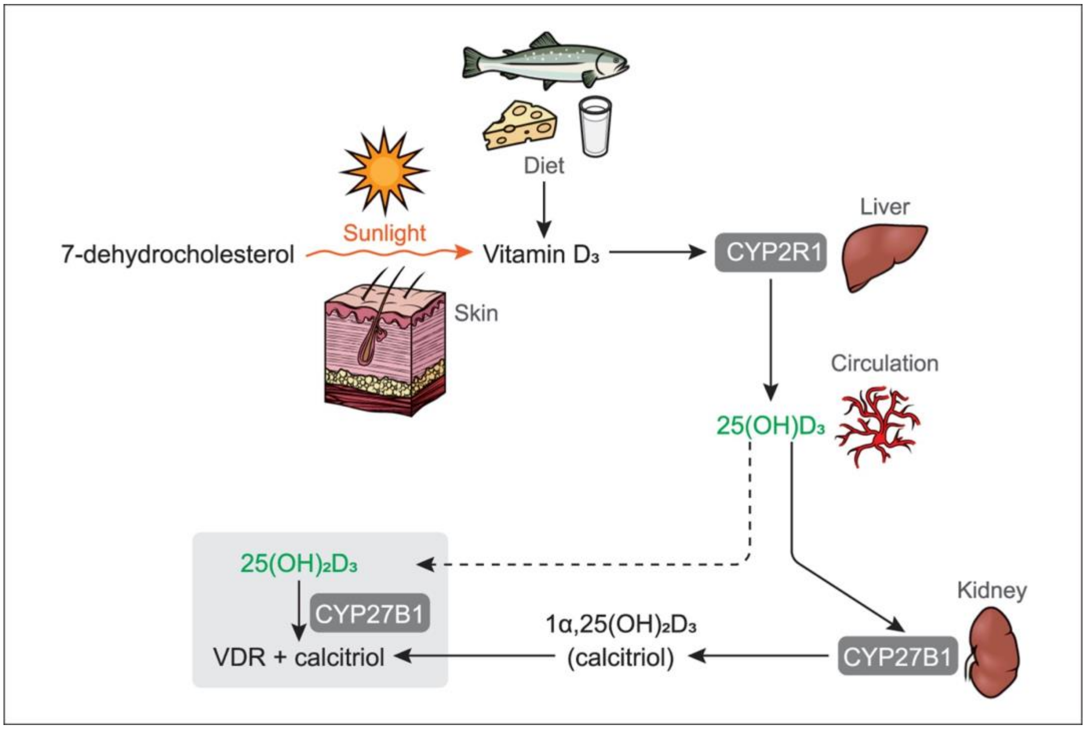

Figure 2 Vitamin D Metabolism[2]

The transformation of Vitamin D is controlled via a feedback loop based upon bone calcium stores, intestinal phosphate, and the parathyroid glands.[4,27,52] Vitamin D receptors can be found at major target tissues like the gastrointestinal tract and bones, along with other locations including skeletal muscle, immune system, parathyroid glands, cardiovascular system, and cancerous cells.[4,27,52] When activated, Vitamin D receptors enhance intestinal calcium absorption, mobilize osteoclastic activity, and contribute to skeletal muscle function.[4,27,52] Additionally, it has been proposed that Vitamin D is responsible for the regulation of up to 1,000 genes, including those that assist with cell growth, differentiation, apoptosis, and angiogenesis.[4,27,52]

In individuals that have insufficient or deficient Vitamin D levels, gastrointestinal calcium absorption decreases, leading to a reduction in circulating serum calcium.[2,52] Subsequently, parathyroid hormone secretion increases to restore normal calcium levels.[2,52] The restoration of calcium levels is accomplished by decreased renal excretion and increased osteoclastic activity that results in bone resorption.[2,52] Chronic Vitamin D insufficiency and deficiency is often combined with hyperparathyroidism; this creates a vicious cycle requiring excessive calcium resorption from bones to maintain adequate circulating calcium levels.[2,52] Ultimately, continuous bone breakdown may result in a substantial loss of bone mineral density placing an individual at risk for additional health problems.[2]

1.3 Vitamin D and Stress Fracture Occurrence

The available literature examining a link between Vitamin D and stress fracture occurrence suggests a noteworthy relationship exists between these two variables. Ruohola et al. prospectively followed 756 healthy Finnish military recruits with a mean age of 19 years; 22 of the recruits developed a stress fracture.[49] A multivariate analysis found that serum 25(OH)D levels below 30.4 ng/mL proved to be a significant risk factor for a stress fracture (OR = 3.6, $p = 0.002$).[49] Comparatively, Davey et al. conducted a large case-control cohort study that included over 1,000 Royal Marine recruits from the United Kingdom.[14] A total of 92 stress fractures were diagnosed and it was determined that recruits with serum 25(OH)D levels below 20 ng/mL had a higher likelihood of suffering a stress fracture compared to matched controls (odds ratio = 2.3).[14] Findings from the aforementioned studies are supported by a systematic review and meta-analysis in which the authors investigated serum 25(OH)D concentrations and stress fractures.[13] Eight studies, that comprised over 2,600 military personnel, established an association between low Vitamin D levels and lower extremity stress fractures.[13]

A nested case-control study in female Navy recruits found that individuals with serum 25(OH)D levels less than 20 ng/mL had double the risk of tibial and fibular stress fractures compared to those with a concentration of 40 ng/mL or more (OR = 0.51, $p \leq 0.01$).[8] Halliday et al. examined Vitamin D status relative to factors like injury and illness throughout the academic year in NCAA Division I athletes.[20] Seven of 33 athletes developed overuse injuries including Achilles tendonitis, five stress reactions, and one stress fracture of the foot.[20] Five of these injuries happened in cross country or track and field athletes and was not directly tied to Vitamin D status, however, it was significantly negatively correlated with bone mineral density ($p = 0.02$).[20] Likewise, Williams et al. retrospectively reviewed stress fracture occurrence in 453 athletes from high-risk teams, including women's cross country and men's and women's track and field, between 2010 and 2015.[59] In that timeframe, Vitamin D was not screened for and supplementation was not provided by the sports medicine staff, yet, there were 34 diagnosed stress fractures—

which is equal to an incidence of 7.51 percent.[59] The following academic year, a Vitamin D supplemented cohort of 118 athletes from the high-risk teams saw a significant reduction in stress fracture occurrence with an incidence of 1.69 percent.[59] There are many contributing factors to a stress fracture, one primary concern may be Vitamin D as evidenced.

1.4 Vitamin D and the Role in Athletics

1.4.1 Effects of Vitamin D on Athletic Performance

A relationship between Vitamin D status and parameters of athletic performance has been identified and examined in numerous studies over the years. Historically, Vitamin D has been known for its role in calcium maintenance and bone remodeling, however, further research has demonstrated the effects are much more extensive. Those of importance to the athlete include, but are not limited to, improved muscular function, decreased risk of infection, and preservation of vascular tissue.[9,15,40] The multiple functions of Vitamin D are relevant to sport and athletic performance, placing it in the spotlight on a worldwide stage.

1.4.1.1 Muscle Function

Skeletal muscle function is significantly impacted by the Vitamin D levels in the body. 25(OH)D is responsible for the regulation of intracellular phosphate in muscle cells, which is a critical component in muscle function and metabolism.[4] Furthermore, the active metabolite, 1,25(OH)2D, exerts multiple mechanisms of action via a genetic pathway and by binding to the

Vitamin D receptor.[4,9] The effects of this pathway have been found to influence calcium transport and the regulation of intracellular calcium along with the promotion of muscle cell protein synthesis and growth.[4,9] Vitamin D receptor null mutant mice, known as the VDR knockout mouse model, showed alterations to this vital pathway resulting in abnormal muscle fiber development and maturation.[4,9] Additional testing demonstrated that VDR deficient mice lack adequate balance and postural control indicating there may be a loss in vestibular function.[4,9]

Further research has also indicated that 1,25(OH)2D activates various signaling cascades, including the mitogen-activated protein kinase (MAPK) signaling pathway.[4,9] Fast activation of this pathway leads to myogenesis, cell proliferation, differentiation, or apoptosis within muscles.[9] MAPKs are also responsible for the regulation of cell processes through phosphorylation of other kinases, proteins, and transcription factors. Triggering of other kinase pathways leads to the stimulation of muscle cell proliferation and growth.[9,11] Consequently, absence of Vitamin D may lead to insufficient muscle mass and function.

Skeletal muscle biopsies in adults with hypovitaminosis D has shown atrophy of Type II muscle fibers related to enlarged interfibrillar space and encroachment of fat, fibrosis, and glycogen granules.[6,9] Type II muscle fibers, also referred to as fast-twitch fibers, are often the first muscle fibers recruited during activity. Atrophy or degeneration of these fibers as a result of inadequate Vitamin D levels may place athletes at risk for muscular injury, especially XC and TF athletes, such as sprinters, that rely on the recruitment of Type II fibers for explosive power. This has been demonstrated by Trappe et al. in their examination of skeletal muscle fiber characteristics in a world champion sprint runner.[55] The results of the study revealed that the sprinter had a high abundance of Type IIx muscle fibers obtained from the vastus lateralis muscle—71 percent of which were identified as fast-twitch fibers.[55]

With regards to muscular injury in athletes, in a study conducted by Rebolledo et al., NFL combine participants with insufficient Vitamin D levels were found to have 1.86 higher odds of having a lower extremity strain or core muscle injury.[44] Those same individuals also had a 3.61 higher odds of suffering a hamstring strain compared to players with normal levels.[44] Ultimately, it was determined that NFL combine athletes in the study possessed an increased risk of lower extremity or core injury when hypovitaminosis D was present.[44] Another study involving NCAA Division I and II athletes found that individuals with Vitamin D inadequacy displayed reduced muscular strength and power.[22] These findings were exhibited by slower Shuttle Run Test times and decreased mean force productions that were approximately twofold less in those athletes with Vitamin D deficiency compared to athletes with sufficient levels.[22] Conversely, studies have shown positive improvements in muscle strength and vertical jump heights in athletes taking an oral Vitamin D_3 supplement.[61,62]

1.4.1.2 Immune Function

Vitamin D has been shown to influence both innate and adaptive immunity due to various actions at Vitamin D receptors. Immune cells are significantly impacted by the circulating concentrations of 25(OH)D, which appears to trigger activation of toll-like receptors in the presence of pathogenic microbes.[21,40] In fact, Vitamin D upregulates gene expression of antimicrobial peptides and proteins (AMPs), like cathelicidin and β-defensin, which are critical regulators in innate immunity.[21,40] These AMPS may assist in the direct inactivation of invading viruses and help defend against acute illnesses such as the common cold, gastroenteritis, tuberculosis, and influenza.[15,21,40] As previously mentioned, Vitamin D regulates up to 1,000 genes, one of which includes activation of cathelicidin synthesis in the presence of 1,25(OH)2D.[21,40] Cathelicidin synthesis enhances the oxidative burst potential in monocytes and macrophages, making these phagocytic cells more effective in eliminating infectious material.[15,21,40] Furthermore, Vitamin D affects inflammatory and immunosuppressive T-lymphocytes by strengthening recognition of antigens at receptor sites; an important factor for adaptive immunity.[15,21,40]

A study in endurance athletes, revealed that 67 percent of subjects considered Vitamin D deficient experienced more upper respiratory tract infections.[21] A subsequent finding was that the reported number and severity of symptoms was significantly higher in the deficient group as well as the duration of the respiratory infection.[21] Comparably, Halliday et al. examined the relationship between serum 25(OH)D levels and the frequency of acute illnesses in collegiate athletes and found a negative association.[20] In individuals with profound Vitamin D deficiency, multiple randomized controlled trials have shown that Vitamin D supplementation reduced the risk of experiencing an acute respiratory infection.[35] More research is needed to examine the effects of supplementation and immune health in athletes, however, it appears to be beneficial in reducing infection and inflammation.

1.4.1.3 Cardiac Function

The effects of Vitamin D on cardiac function are controversial; regardless, research has proven that Vitamin D receptors can be located throughout the heart and vascular tissue. These receptor sites allow the active form, 1,25(OH)2D, to stimulate structural remodeling of cardiac muscle and vascular tissue while amplifying myocyte contractility.[15,40] The Framingham Offspring Study determined that individuals with moderate Vitamin D deficiency (< 15 ng/mL) were at an increased risk of experiencing an adverse cardiovascular event.[58] Vitamin D deficiency may also result in damaging effects to cardiac contractility, vascular tone, cardiac collagen content, and cardiac tissue maturation.[15,40] This is thought to be a potential consequence of increased parathyroid hormone secretion that may lead to left ventricular hypertrophy.[15,58,60] Hypertrophy, although advantageous in other muscles, can lead to altered filling capacity and blood ejection of the left ventricle; this can bring about hypoxia of muscular tissue and diminish athletic performance.[15,58,60]

Highly trained athletes have different cardiac adaptations compared to the general population due to their frequent engagement in "heart healthy" physical activity. These adaptations include enhanced diastolic filling, sustained increases in cardiac output, and slight structural and electrical changes—commonly referred to as the "athlete's heart."[15,58,60] Numerous factors influence the athlete's heart such as age, sex, genetic background, and sporting discipline, but, it remains undetermined the exact role Vitamin D may have.[15,58,60] Current available evidence has shown that severely Vitamin D deficient (< 10 ng/mL) athletes possess smaller aortic root and left atria diameters, intraventricular septum diameter, left ventricular diameter and volume during diastole, left ventricular mass, and right atrial area compared to insufficient and sufficient athletes.[3] In addition to this, some research has detected a connection between severe Vitamin D deficiency and sudden cardiac death in athletes.[15,58,60] Research regarding Vitamin D and cardiac function is limited, nonetheless, athletes are one of the highest reported Vitamin D deficient populations and warrant further testing.

1.4.2 Sources of Vitamin D

The demands of athletics require increases in all aspects of an athlete's diet, including micronutrients such as Vitamin D. This can be challenging for individuals as ample dietary sources containing Vitamin D that meet the recommended daily allowance are in short supply. The best natural food sources of Vitamin D are fatty fish like salmon, tuna, and mackerel and fish liver oils followed by beef liver, cheese, and egg yolks.[28,52,56] In the American diet, fortified foods such as milk, plant milk alternatives (soy, almond, or oats), breakfast cereals, some brands of orange juice, and yogurt offer the most Vitamin D.[28,56] Due to this limited selection of fueling options, the predominant sources of Vitamin D are sun exposure and oral supplementation.

1.4.2.1 Sun Exposure

It is well documented that there is seasonal and location-based variability regarding Vitamin D stores. Seasonal differences in Vitamin D status are most related to UVB exposure from the sun, which is predominantly influenced by latitude. A study conducted in elite Polish athletes found that adequate serum concentrations of 25(OH)D (> 30 ng/mL) were obtained, in outdoor athletes only, from June to August.[31] Poland is located in central Europe and has a moderate climate (latitude 49°-54° N) with inadequate sun exposure from October to April.[31] Under those circumstances, Vitamin D absorption via UVB radiation and skin synthesis is virtually nonexistent for half of the year. Interestingly, the track and field athletes included in the study had an inadequate Vitamin D status for 9 months, despite participation in outdoor training sessions from March to November.[31]

Other factors that influence skin synthesis exist, for example the use of sunscreen or the time of day that training sessions occurred.[24,31] A literature review from the British Journal of Dermatology found that the use of sunscreen does not interfere with Vitamin D synthesis in healthy individuals.[41] Remarkably, studies in light-skinned individuals have shown that sunscreens with a higher UVA protection factor improve Vitamin D_3 synthesis.[41] In reality, habits such as wearing sun protective clothing, seeking shade, and limiting sun exposure impact Vitamin D absorption more than a daily sunscreen.[41] In a study conducted in Boston, which has an equivalent latitude to Poland, no Vitamin D synthesis took place before 8 a.m. and after 6 p.m., and synthesis that took place between 8 and 10 a.m. as well as 4 and 6 p.m. was only 20 percent of the values observed during midday.[24] Predictably, 12 p.m. Eastern Standard Time was recorded as the most efficacious time point for maximum Vitamin D synthesis; although the length of time spent exposed to the sun varies by location.[54]

Winter sun exposure is extremely limited and often isolated to the face. Polish track and field athletes that opted to train at lower latitudes in South Africa and Tenerife, experienced an average increase of 21 ng/mL in 25(OH)D serum concentration.[31] Training in an area like South Africa promoted Vitamin D synthesis greater than that achieved from the summer sun in Poland due to its proximity to the equator.[31] Lower latitudes offer accessibility to UVB radiation which creates favorable conditions for peak Vitamin D synthesis; still, this is not a solution readily available to all athletes.

1.4.2.2 Supplementation

Oral Vitamin D_3 supplementation is an efficient alternative to improve Vitamin D status and has been proven effective in many studies in athletes. Backx et al. evaluated elite Dutch athletes with varying degrees of Vitamin D deficiency over one year and provided corresponding supplementation of 400, 1100, or 2200 international units (IU) daily, based upon baseline values.[5] Serum 25(OH)D levels significantly increased in the group assigned to 2200 IU/day (20 ng/mL ± 10.8) compared to the other groups.[5] Eighty percent of the athletes in the 2200 IU/day group achieved adequate 25(OH)D concentrations, classifying them as sufficient; previously, 70 percent of those athletes were categorized as insufficient or deficient at baseline.[5] Comparably, a recent systematic review and meta-analysis that included 433 athletes—244 supplemented, 189 placebo—determined that supplementation with 3000 IU or greater for 12 weeks exceeded the necessary qualifications to reach sufficiency of 30 ng/mL during the fall and winter time.[16]

However, the studies that examined physical performance outcomes reported no significant increases in vertical jump heights and one repetition maximum at the 12 week follow-up.[16]

As has been mentioned, Vitamin D is crucial in bone health and supplementation may offer improvements for individuals susceptible to bone injuries. Lappe et al. found that female Navy recruits supplemented with Vitamin D and calcium had a 20 percent lower incidence of fracture occurrence compared to a control group.[32] Similarly, Williams et al. conducted serum 25(OH)D testing on NCAA Division I athletes at a single institution in August and February.[59] Forty-eight athletes were found to be hypovitaminosis D (23.0 ng/mL ± 4.84) at baseline testing in August and subsequently provided a Vitamin D_3 supplement.[59] Those supplemented individuals saw an average increase in serum 25(OH)D concentration of 11.2 ng/mL resulting in 68.8 percent of the original deficient cohort to achieve sufficient status.[59] In contrast, there were 50 athletes sufficient at baseline that experienced an average decrease in serum 25(OH)D concentration of 9.49 ng/mL.[59] By February testing, 56 percent of the sufficient athletes had become hypovitaminosis D.[59] Not only did supplementation improve Vitamin D status in athletes, it was also related to a significant reduction in stress fracture occurrence in the overall study cohort ($p = 0.01$) and more specifically in women's cross country athletes ($p = 0.046$) compared to past seasons.[59]

1.5 Problem Statement

Vitamin D has become a significant focus of athletes and healthcare providers alike. Although Vitamin D is considered a micronutrient, inadequate concentrations can cause drastic alterations in numerous body systems. Research to date has examined testing procedures, associated consequences of hypovitaminosis D, and parameters of athletic performance in many forms of elite athletes. However, collegiate XC and TF athletes appear to be underrepresented in the literature even with their predisposing risk factors. Knowledge of testing practices and methods is necessary to provide XC and TF athletes with the proper treatment.

1.6 Study Purpose

Identification of Vitamin D insufficient and deficient XC and TF athletes is essential to optimize performance and prevent future injury. The purpose of this study is to investigate the Vitamin D testing practices of NCAA sponsored cross country and track and field programs. Additionally, this study will help to classify specific factors (i.e., previous bone stress injury, history of disordered eating, vegan/vegetarian) that sports medicine personnel track to prioritize individuals for recurrent testing.

1.7 Specific Aims

Specific Aim 1: To determine the number of NCAA sponsored XC and TF programs that examine Vitamin D blood levels in their student athletes.

Specific Aim 2: To identify specific factors that sports medicine personnel use to examine Vitamin D blood levels.

Specific Aim 3: To classify and describe institutions that practice Vitamin D testing by regions of the United States.

Specific Aim 4: To identify the average number of months per a year that XC and TF athletes must train indoors due to weather conditions and describe by regions of the United States.

Specific Aim 5: To quantify the average number of times Vitamin D blood testing is conducted for XC and TF athletes in an academic year.

Specific Aim 6: To identify adequate Vitamin D levels for athletic participation recognized by sports medicine personnel and describe by region of the United States and NCAA division.

Specific Aim 7: To assess the opinions of Certified Athletic Trainers regarding the use of Vitamin D testing in collegiate athletes and describe by region of the United States and NCAA division.

Specific Aim 8: To quantify the occurrence of bone stress injuries in collegiate XC and TF athletes and compare occurrence between men and women.

1.8 Study Significance

Vitamin D may play a significant role in the performance of XC and TF athletes. With the increased use of testing and supplementation in collegiate athletics, comes the need for universal policies. Understanding of current testing practices throughout various divisions and regions of the United States is imperative to implement appropriate policies and improve the health and well-being of student athletes.

2.0 Methods

2.1 Experimental Design

This is a descriptive cross-sectional survey designed to gather information regarding Vitamin D testing practices in collegiate XC and TF athletes. An online survey was sent to individuals at NCAA sponsored schools across the United States to address these specific aims. Survey questions focused on examination of Vitamin D blood levels in XC and TF athletes, purpose for testing, ideal Vitamin D blood levels, current policies or protocols, and the occurrence of bone stress injuries diagnosed in XC and TF athletes from the 2018-2019 academic year at the respective institution.

2.2 Subject Recruitment

Participants were enrolled in the study using the National Athletic Trainers' Association (NATA) Research Survey Service. The Research Survey Service provided access to 1,000 survey participants. Participants were Certified Athletic Trainers that have paid to be members of the NATA. Requested participants include Certified Athletic Trainers that provide medical care for XC and TF athletes at NCAA Division I, II, and III schools. Participants were contacted via email and asked to complete a short survey. The email invitation requested that the recipient forward the survey to the designated cross country and/or track and field Athletic Trainer if it was not them. Participation in the survey was completely optional and participants were free to withdraw from the study at any time. This study was reviewed by the Institutional Review Board (IRB) at the University of Pittsburgh and considered exempt.

2.3 Subject Characteristics

2.3.1 Inclusion Criteria

Individuals were included in the study if they are a Certified Athletic Trainer responsible for the medical care of men’s and women’s cross country and/or track and field.

2.3.2 Exclusion Criteria

Participants were excluded if their sport assignment and associated medical responsibilities did not include cross country and/or track and field.

2.4 Instrumentation

2.4.1 Qualtrics Online Survey System

The survey was uploaded to the Qualtrics Online Survey System, a platform utilized by the University of Pittsburgh and the NATA to create and disperse survey questions. In this study, Certified Athletic Trainers were asked to answer up to 22 questions pertaining to Vitamin D testing in collegiate athletes. Three questions concerned the Athletic Trainer and their respective institution such as sport assignment, NCAA division classification, and the region where the institution is located. The remaining questions evaluated the Vitamin D testing procedures of the sports medicine department at the Athletic Trainer's institution. Additionally, XC and TF Athletic Trainers were asked to answer questions regarding indoor training and bone stress injuries. Anonymity of the Athletic Trainer and their associated institution was maintained through the use of the Qualtrics software. The usability of the survey was assessed via a pilot test completed by four Athletic Trainers working at the University of Pittsburgh. Modifications to the survey questions were made based upon the feedback of the pilot test group. Survey data collection occurred during the 2020-2021 academic year. A summary data sheet is retained on a secure NATA server and by the primary investigator for seven years.

2.5 Procedures

2.5.1 Data Collection

Study participants were sent an email invitation with a brief description of the study purpose and a link to the online survey. The data collection period lasted for six weeks. Survey reminders were sent bi-weekly following the initial email invitation. The initial contact email and reminder emails were sent by the NATA. Subject participation was voluntary, individuals were able to withdraw at any timepoint. All survey responses remained anonymous; information contained in a response that disclosed the identity of the Athletic Trainer or their institution was filtered and omitted from the results. The survey consisted of up to 22 questions and took approximately five to ten minutes to complete. Data was collected and recorded in Qualtrics.

Following completion of the data collection period, the NATA sent a full, unidentifiable data set and summary profile to the primary investigator. The primary investigator was available to answer any questions regarding the study or survey via email.

2.6 Data Reduction

Survey responses were reviewed in Qualtrics. Any response where a subject responded *no* to providing medical care for cross country and/or track and field student athletes was extracted and analyzed separately based upon sport assignment. Incomplete responses were not excluded and were included for analysis of each question answered. Information contained in a response that revealed the identity of the participant and/or their respective institution was omitted before analysis.

2.7 Data Analysis

Survey data was obtained using Qualtrics Core XM Online Survey System (Qualtrics XM, Provo UT, USA). Data was exported and analyzed using SPSS Statistics Version 27 (IBM Corporation, Armonk NY, USA). Injury incidence was determined by multiplying the number of student athletes with a diagnosed BSI by 100, then dividing by the total number of rostered student athletes. Injury frequency was determined by multiplying the total number of diagnosed BSIs by 100, then dividing by the total number of rostered student athletes. For categorical outcome variables, Fisher's exact tests were utilized for group comparison. Responses categorized as "not specified" or "not applicable" and "unknown" were excluded from statistical analysis. Significance level was set a priori at alpha = 0.05, two-sided.

3.0 Results

3.1 Qualtrics Survey Data

3.1.1 Survey Participants

Fifty-five Certified Athletic Trainers participated in the study. 43 participants identified themselves as providing medical care for cross country and/or track and field student athletes. The remaining 12 respondents provide medical care for other sports outlined in Figure 3. The most reported sport assignment from non-cross country/track and field Athletic Trainers was men's basketball with four responses followed by women's lacrosse, men's soccer, men's and women's swimming and diving, and women's indoor volleyball with three responses for each. Survey participants were further categorized by NCAA Division classification and region of the United States that their institution is located, as shown in Tables 1 and 2, respectively. The highest percentage of XC and TF Athletic Trainers responses are associated with NCAA Division I (41.9%) athletic teams located in the Southeast (21%), Mid-West (23.2%), and unspecified regions (28%). The highest percentage of non-XC and TF Athletic Trainers responses are associated with NCAA Division I (66.7%) athletic teams located in the Southeast (41.7%) and Mid-West (25%).

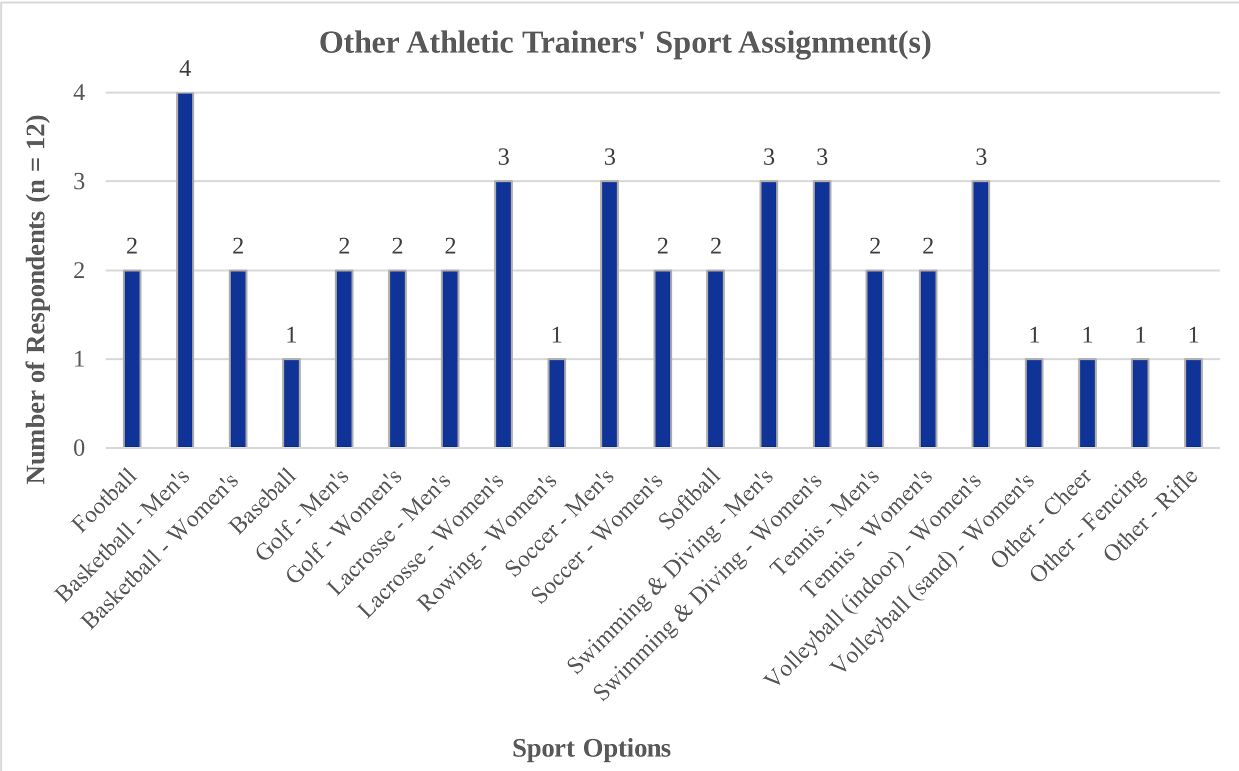

Figure 3 Sport Assignment(s) and Associated Medical Care of Non-Cross Country/Track and Field Athletic Trainers

Table 1 Survey Participants' NCAA Division Classification

	NCAA Division				
	I	**II**	**III**	**Not specified**	**Total**
XC/TF AT	18/43 (41.9%)	6/43 (14%)	6/43 (14%)	13/43 (30.2%)	43
Other AT	8/12 (66.7%)	1/12 (8.3%)	2/12 (16.7%)	1/12 (8.3%)	12

AT = Athletic Trainer

Table 2 Survey Participants' Region of the United States

	Region of the U.S.								
	New England	Mid-Atlantic	Southeast	Mid-West	Rocky Mountains	Southwest	Pacific West	Not specified	Total
XC/TF AT	2/43 (4.7%)	3/43 (7%)	9/43 (21%)	10/43 (23.2%)	1/43 (2.3%)	1/43 (2.3%)	5/43 (11.6%)	12/43 (28%)	43
Other AT	0	2/12 (16.7%)	5/12 (41.7%)	3/12 (25%)	2/12 (16.7%)	0	0	0	12

AT = Athletic Trainer

3.1.2 Indoor Training

Study participants classified as XC and TF Athletic Trainers were asked to state the number of months out of the year that the XC and TF student athletes at their institution are required to train indoors due to weather conditions.

3.1.2.1 Cross Country

The highest percentage of responses were obtained from the Southeast, Mid-West, and unspecified regions. The most reported response from the Southeast was less than 1 month (77.8%) of indoor training for XC athletes. The most reported response from the Mid-West and unspecified regions was 1-3 months of indoor training, selected by 40% and 50% of participants, respectively. Results are displayed in Table 3. Fisher's exact test was used to assess for an association between region of the United States and duration of indoor training for XC athletes. No statistically significant association was found between region of the United States and duration of indoor training for XC athletes (p = 0.280). To further explore the association between regions of the United States and duration of indoor training, regions were re-categorized into East (New England, Mid-Atlantic, Southeast), Mid-West, and West (Rocky Mountains, Southwest, Pacific West). Indoor training duration was re-categorized to < 1 month and other (1-3 months, 3-6 months, > 6 months). No statistically significant association was found between region of the United States and duration of indoor training for XC athletes using the re-categorized categories (p = 0.132).

Table 3 Number of Months of Indoor Training for Cross Country Athletes by Region of the United States

	Indoor Training - XC					
Regions of the U.S.	**< 1 month**	**1-3 months**	**3-6 months**	**> 6 months**	**Not Applicable**	**Total**
New England	0	1/2 (50%)	0	0	1/2 (50%)	2
Mid-Atlantic	1/3 (33.3%)	2/3 (66.7%)	0	0	0	3
Southeast	7/9 (77.8%)	1/9 (11.1 %)	1/9 (11.1 %)	0	0	9
Mid-West	2/10 (20%)	4/10 (40%)	3/10 (30%)	1/10 (10%)	0	10
Rocky Mountains	0	1 (100%)	0	0	0	1
Southwest	1 (100%)	0	0	0	0	1
Pacific West	3/5 (60%)	1/5 (20%)	0	1/5 (20%)	0	5
Not specified	4/12 (33.3%)	6/12 (50%)	2/12 (16.7%)	0	0	12

3.1.2.2 Track and Field

The highest percentage of responses were received by the Southeast, Mid-West, and unspecified regions. Indoor training for TF athletes differed slightly from the duration for XC athletes. The most reported response from the Southeast region was split between < 1 month (44.4%) and 1-3 months (44.4%) whereas the Midwest increased to 3-6 months (50%). The most reported response from regions not specified remained 1-3 months (75%). Results are displayed in Table 4. Fisher's exact test was used to assess for an association between region of the United

States and duration of indoor training for TF athletes. There was a statistically significant association between region of the United States and duration of indoor training ($p = 0.016$). To further explore the association between regions of the United States and duration of indoor training, regions were re-categorized into East (New England, Mid-Atlantic, Southeast), Mid-West, and West (Rocky Mountains, Southwest, Pacific West). Indoor training duration was re-categorized to < 1 month and other (1-3 months, 3-6 months, > 6 months). A statistically significant association was found between region of the United States and duration of indoor training for TF athletes using the re-categorized categories ($p = 0.050$).

Table 4 Number of Months of Indoor Training for Track and Field Athletes by Region of the United States

	Indoor Training - TF					
Regions of the U.S.	**< 1 month**	**1-3 months**	**3-6 months**	**> 6 months**	**Not Applicable**	**Total**
New England	0	2 (100%)	0	0	0	2
Mid-Atlantic	0	2/3 (66.7%)	1/3 (33.3%)	0	0	3
Southeast	4/9 (44.4%)	4/9 (44.4%)	0	1/9 (11.2%)	0	9
Mid-West	1/10 (10%)	1/10 (10%)	5/10 (50%)	2/10 (20%)	1/10 (10%)	10
Rocky Mountains	0	1 (100%)	0	0	0	1
Southwest	1 (100%)	0	0	0	0	1
Pacific West	4/5 (80%)	0	1/5 (20%)	0	0	5
Not specified	1/12 (8.3%)	9/12 (75%)	1/12 (8.3%)	1/12 (8.3%)	0	12

3.1.3 Vitamin D Policy or Protocol

All participants were asked if the sports medicine department at their institution had a Vitamin D testing policy or protocol in place. A total of six out of 31 XC and TF Athletic Trainers stated their institution had a Vitamin D testing policy or protocol. The majority of institutions with testing policies are located in the Mid-West (30%), followed by the Southeast (22.2%) and Pacific West (20%). These institutions are categorized primarily as Division I (27.8%) and Division III (16.7%). These results are displayed in Tables 5 and 6. Fisher's exact test was used to assess for an association between region of the United States and a Vitamin D policy as well as NCAA Division and a Vitamin D policy. No significant association was identified between region of the United States and a Vitamin D policy ($p = 0.968$) and NCAA Division and a Vitamin D policy ($p = 0.559$). To further explore the association between regions of the United States and Vitamin D testing policy, regions were re-categorized into East (New England, Mid-Atlantic, Southeast), Mid-West, and West (Rocky Mountains, Southwest, Pacific West). Using the reclassified categories, there was no significant association between region of the United States and Vitamin D policy ($p = 0.724$). To further explore the association between NCAA Division and Vitamin D testing policy, NCAA Division was re-categorized to Division I and other (Divisions II and III). No statistically significant association was found between NCAA Division and Vitamin D testing policy using the reclassified categories ($p = 0.352$).

Table 5 Vitamin D Testing Policies by Region of the United States

	Regions of the U.S.						
Vitamin D Policy	**New England**	**Mid-Atlantic**	**Southeast**	**Mid-West**	**Rocky Mountains**	**Southwest**	**Pacific West**
Yes	0	0	2/9 (22.2%)	3/10 (30%)	0	0	1/5 (20%)
No	2 (100%)	3 (100%)	6/9 (66.7%)	6/10 (60%)	1 (100%)	1 (100%)	3/5 (60%)
Unknown	0	0	1/9 (11.1%)	1/10 (10%)	0	0	0
Not specified	0	0	0	0	0	0	1/5 (20%)
Total	2	3	9	10	1	1	5

Table 6 Vitamin D Testing Policies by NCAA Division

	NCAA Division			
Vitamin D Policy	**I**	**II**	**III**	**Not specified**
Yes	5/18 (27.8%)	0	1/6 (16.7%)	0
No	11/18 (61.1%)	5 (100%)	4/6 (66.7%)	1 (100%)
Unknown	2/18 (11.1%)	0	1/6 (16.7%)	0
Total	18	5	6	1

3.1.4 Factors for Vitamin D Testing

Survey participants who stated their institution had a Vitamin D testing policy were asked if the blood levels of their student athletes were evaluated based upon specific factors. The specific factors included were preventative screening during a preparticipation physical examination, red flags such as injury status, history of a stress fracture or reaction, history of eating disorder, and/or vegan/vegetarian, and health history based off previous record of low Vitamin D. These factors for Vitamin D testing were compared by NCAA Division. Most participants from Division I responded that red flags (80%) and health history (80%) were indicators for Vitamin D blood testing. Preventative screening of Vitamin D blood levels was reported by 60% of participants from Division I. Red flags and health history were the selected factors reported by the institution from Division III. These results are shown in Table 7.

Table 7 Factors for Vitamin D Testing Identified by XC and TF Athletic Trainers with a Testing Policy Compared by NCAA Division

	Factors for Vitamin D Testing			
NCAA Division	**Preventative screening**	**Red flags**	**Health history**	**Total**
I	3/5 (60%)	4/5 (80%)	4/5 (80%)	5
III	0	1 (100%)	1 (100%)	1

3.1.5 Adequate Vitamin D Levels

Participants with a testing policy were also asked to classify the adequate level of Vitamin D, based off blood serum values, for athletic participation at their respective institution. Table 8 displays the selected Vitamin D level by region of the United States; the New England, Mid-Atlantic, Rocky Mountains, and Southwest regions were omitted from this table as there were no survey responses from these regions. The most reported range from the Mid-West region was 30-40 ng/mL (66.7%) followed by 40-50 ng/mL (33.3%). A participant from the Southeast region indicated that 40-50 ng/mL (50%) is the accepted range at their institution; the other participant selected *unsure*. In comparison, the institution from the Pacific West opts for a level above 60 ng/mL (100%). Adequate Vitamin D levels for athletic participation were also compared by NCAA Division, as outlined in Table 9; NCAA Division II was omitted from this table due to an absence of survey responses with testing policies from this division. In total, five of the responses were from NCAA Division I of which 40-50 ng/mL (40%) was the most selected range while 30-40 ng/mL (20%), > 60 ng/mL (20%), and *unsure* (20%) were equally selected. The response from NCAA Division III indicated that 30-40 ng/mL (100%) is the optimum range at that institution.

Table 8 Adequate Vitamin D Levels for Athletic Participation by Region of the United States

	Regions of the U.S.		
Vitamin D Level (ng/mL)	**Southeast**	**Mid-West**	**Pacific West**
< 30	0	0	0
30-40	0	2/3 (66.7%)	0
40-50	1/2 (50%)	1/3 (33.3%)	0
50-60	0	0	0
> 60	0	0	1 (100%)
Other	0	0	0
Unsure	1/2 (50%)	0	0
Total	2	3	1

Table 9 Adequate Vitamin D Levels for Athletic Participation by NCAA Division

	NCAA Division	
Vitamin D Level (ng/mL)	**I**	**III**
< 30	0	0
30-40	1/5 (20%)	1 (100%)
40-50	2/5 (40%)	0
50-60	0	0
> 60	1/5 (20%)	0
Other	0	0
Unsure	1/5 (20%)	0
Total	5	1

3.1.6 Number of Vitamin D Tests per Year

The six XC and TF Athletic Trainers that work at an institution with a testing policy were asked to indicate the number of times per year that Vitamin D testing is conducted. When comparing by region of the United States, participants from the Southeast selected 2 times per year (50%) and *other* (50%), which was further described as "as needed." The highest percentage of responses from the Mid-West specify testing is conducted once a year (66.7%) followed by 2 times per year (33.3%). The single response from the Pacific West chose 1 test per year (100%). These results are shown in Table 10. Between NCAA Division I and III, 1 test per year was the most common protocol after which 2 times per year and "as needed" were designated. These results are shown in Table 11.

Table 10 Number of Vitamin D Tests Conducted per Year by Region of the United States

	Regions of the U.S.		
Number of Tests per Year	**Southeast**	**Mid-West**	**Pacific West**
1	0	2/3 (66.7%)	1 (100%)
2	1/2 (50%)	1/3 (33.3%)	0
3	0	0	0
4	0	0	0
Other - as needed	1/2 (50%)	0	0
Total	2	3	1

Table 11 Number of Vitamin D Tests Conducted per Year by NCAA Division

	NCAA Division	
Number of Tests per Year	**I**	**III**
1	2/5 (40%)	1 (100%)
2	2/5 (40%)	0
3	0	0
4	0	0
Other - as needed	1/5 (20%)	0
Total	5	1

3.1.7 Opinions Regarding Vitamin D Testing in Athletes

All survey participants were asked their opinion regarding Vitamin D testing in their XC and TF student athletes. Responses were compared by both region of the United States and NCAA Division as seen in Tables 12 and 13. Overall, the leading response for each region of the United States, excluding the New England and Mid-West regions, was that Vitamin D should be tested in

XC and TF athletes. The highest percentage of responses in favor of testing was from the Rocky Mountains (100%) and Southwest (100%) regions followed closely by the Pacific West (75%), Southeast (66.7%), and Mid-Atlantic (66.7%) regions. More than half (70.6%) of the respondents from NCAA Division I indicated that they believe Vitamin D testing should be conducted in their respective athletes. In contrast, the most reported response from NCAA Divisions II and III was *no*, accounting for two-thirds (66.7%) of the responses from each respective division. Fisher's exact test was used to analyze for an association between region of the United States as well as NCAA Division and Athletic Trainer's opinions regarding Vitamin D testing. No statistically significant association was found between region of the United States and an Athletic Trainer's opinion on testing ($p = 0.490$) and NCAA Division and an Athletic Trainer's opinion on testing ($p = 0.149$). To further explore the association between regions of the United States and an Athletic Trainer's opinion on testing, regions were re-categorized into East (New England, Mid-Atlantic, Southeast), Mid-West, and West (Rocky Mountains, Southwest, Pacific West). Using the reclassified categories, there was no significant association between region of the United States and an Athletic Trainer's opinion on testing ($p = 0.283$). To further explore the association between NCAA Division and an Athletic Trainer's opinion on testing, NCAA Division was re-categorized to Division I and other (Divisions II and III). No statistically significant association was found between NCAA Division and an Athletic Trainer's opinion on testing using the reclassified categories ($p = 0.067$).

Table 12 XC and TF Athletic Trainers' Opinions Regarding Vitamin D Testing in their Athletes by Region of the United States

	Regions of the U.S.						
Opinion on Vitamin D Testing	**New England**	**Mid-Atlantic**	**Southeast**	**Mid-West**	**Rocky Mountains**	**Southwest**	**Pacific West**
Yes	0	2/3 (66.7%)	6/9 (66.7%)	4/10 (40%)	1 (100%)	1 (100%)	3/4 (75%)
No	2 (100%)	1/3 (33.3%)	3/9 (33.3%)	6/10 (60%)	0	0	1/4 (25%)
Total	2	3	9	10	1	1	4

Table 13 XC and TF Athletic Trainers' Opinions Regarding Vitamin D Testing in their Athletes by NCAA Division

	NCAA Division			
Opinion on Vitamin D Testing	**I**	**II**	**III**	**Not Specified**
Yes	12/17 (70.6%)	2/6 (33.3%)	2/6 (33.3%)	1 (100%)
No	5/17 (29.4%)	4/6 (66.7%)	4/6 (66.7%)	0
Total	17	6	6	1

3.1.8 Injury Data

Study participants that provide medical care for XC and TF athletes were asked to provide information regarding the number of student athletes on the roster, number of student athletes with a diagnosed BSI (stress fracture or reaction), and the total number of diagnosed BSIs from the 2018-2019 academic year for each team including: women’s cross country, women’s track and field, men’s cross country, and men’s track and field. The total number of diagnosed BSIs was included as a question to account for multiple stress injuries to the same individual. This data was used to calculate an injury incidence and injury frequency per 100 athletes per one season. Results are displayed in Table 14. Fisher’s exact text was used to analyze an association between men’s and women's cross country and men's and women's track and field and BSI occurrence. The occurrence of BSIs was significantly different between men's and women's cross country student athletes (p = 0.001). The occurrence of BSIs was significantly different between men's and women's track and field student athletes (p = 0.038).

Table 14 Bone Stress Injury Incidence and Frequency Rates

Team	Student Athletes with BSI Injury Incidence*	BSI Injury Frequency**
Women's Cross Country	11.9	14.1
Women's Track & Field	6.3	9.2
Men's Cross Country	5.4	7.6
Men's Track & Field	4.1	4.9

*Injury incidence = (number of injured student athletes*100 athletes/season)/total number of rostered student athletes

**Injury frequency = (total number of BSI*100 athletes/season)/total number of rostered student athletes

4.0 Discussion

Knowledge of Vitamin D testing practices in athletics, especially cross country and track and field athletes, remains scarce. The purpose of this study was to identify how many NCAA sponsored XC and TF programs evaluate Vitamin D levels through routine testing. In addition, this study aimed to classify specific factors used to justify testing, quantify the average number of times testing is conducted per a year along with identifying an adequate Vitamin D level for athletic participation. Furthermore, this study intended to gather informative data regarding indoor training requirements and bone stress injuries in collegiate XC and TF athletes. To the author's understanding, this is the first study evaluating Vitamin D testing practices combined with injury data in collegiate XC and TF athletes. The results of the study indicate that bone stress injuries remain prevalent in this athletic population, yet Vitamin D testing appears underutilized across all three NCAA Divisions and regions of the United States. However, most of the NCAA Division I XC and TF Athletic Trainers surveyed in this study believe that Vitamin D testing is an appropriate screening tool for their athletes.

4.1 Indoor Training

Indoor training duration was assessed separately for XC and TF athletes due to the timing of competition seasons. The duration of indoor training was compared by region of the United States in an attempt to observe for variations due to weather conditions. There was no statistical association between indoor training duration and region of the United States for XC athletes. The lack of statistical association may be related to the small sample size per a region as well as reduced study participation. Regardless, the results suggest that XC athletes commonly train indoors less than one month and up to 3 months. In comparison, there was a statistically significant association between indoor training duration and region of the United States for TF athletes (p = 0.016 and 0.050). Therefore, the region of the United States that an institution is located impacts the duration of indoor training for TF athletes. The results show that TF athletes spend less than a month and up to 6 months training indoors due to weather conditions.

As a consequence of indoor training and competition, an individual's Vitamin D serum levels may suffer due to limited UVB exposure. This has been shown in a study conducted in elite Polish athletes in which indoor athletes had significantly lower 25(OH)D concentrations than those athletes training outdoors for a majority of the year.[31] In addition to indoor training duration, the region of the U.S. should be of interest as it is well documented that athletes who live and train at northern latitudes (> 35th parallel) are at a heightened risk for hypovitaminosis D.[1,31] To the author's knowledge, this is the first study that has attempted to determine indoor training duration for XC and TF athletes and compared by region of the U.S. The results from the present study should be further investigated to evaluate for a relationship between indoor training, region of the U.S., and Vitamin D levels in XC and TF athletes.

4.2 Vitamin D Policy or Protocol

Few participants (20%) indicated that the sports medicine department at their respective institution had a Vitamin D testing policy or protocol in effect. Notably, 83% of the respondents that stated their institution had a policy or protocol in place were classified as NCAA Division I while the remaining response was provided by an NCAA Division III institution. Strikingly, there were no responses provided by NCAA Division II. These results are comparable to a similar study by Rockwell et al., in which 20% out of 249 NCAA Division I Athletic Trainers indicated that their institution had a policy or protocol in place regarding Vitamin D evaluation, prevention, and/or treatment.[46] Additionally, survey response data provided by non-XC and TF Athletic Trainers indicated that 50% of participants from NCAA Division I had a testing policy or protocol at their institution. These results are displayed in Appendix C.

Despite the lack of significance between NCAA Division and presence of a testing policy, an argument can be made that Division I athletics programs have the financial means to support such testing policies in comparison to institutions classified as Division II and III. NCAA Division II institutions are financed through the institution's budget, similar to other campus departments while, NCAA Division III institutions are both staffed and funded in the same manner as other university departments.[37] When comparing the reported medical finances of each NCAA Division from 2019, Division I attributed 195 million dollars (1.2%) to medical expenses.[38] In comparison, Division II averaged 36 million (1.6%) and Division III spent 13 million (1.5%) on medical related expenses.[38] This disparity in medical expenses could explain why the large proportion of responses from the present study were obtained predominantly from Athletic Trainers working at Division I institutions.

Another potential factor for lack of testing policies includes discrepancies surrounding the evaluation and treatment of Vitamin D disorders. As previously mentioned, there are differing recommendations regarding optimal Vitamin D concentrations by various international bodies throughout the world.[7,26,47] For instance, the Scientific Advisory Committee on Nutrition based out of the United Kingdom recommends a Vitamin D level greater than 12 ng/mL as sufficient while the Endocrine Society and International Osteoporosis Foundation define sufficiency as 30 ng/mL or greater.[41,47] Furthermore, following the evaluation and identification of low Vitamin D, there are disagreements regarding the recommended dosing of Vitamin D supplementation as a form of treatment. Organizations such as the National Academy of Medicine recommend 600 IU/day whereas the U.K. and Nordic countries recommend 400 IU/day.[41] These recommendations are not specific to the athletic population, whose demands may be higher due to activity status. Conflicting literature reviews may create confusion for sports medicine personnel attempting to develop a Vitamin D specific policy or protocol.

To the author's knowledge, there are no current studies that evaluated Vitamin D policies and compared by region of the United States. Of the participants that stated their institution had a testing policy, half were from the Mid-West and one-third were from the Southeast. Even so, there was no significant association between region of the U.S. and presence of a testing policy. One explanation to explain the lack of significance could be the relatively small sample size of the study and the overall shortage of participants that identified their institution as having a Vitamin D testing policy.

4.3 Factors for Vitamin D Testing

For those institutions that conduct Vitamin D testing, it is important to understand the indications for why testing is conducted. The primary reasons indicated for Vitamin D blood testing by 80% of participants from NCAA Division I and the participant from Division III were red flags (i.e., previous bone stress injury, history of disordered eating, vegan/vegetarian) and previous health history. Preventative screening (i.e., a part of a preparticipation physical exam) was reported by 60% of participants from Division I. The results suggest that preventative screening of Vitamin D blood levels is feasible for NCAA Division I institutions in addition to evaluation due to red flags and previous health history, whereas Division III institutions may only be able to justify testing based upon red flags or health history. In past studies, physicians, the most common individuals ordering Vitamin D testing, have varying opinions, some of which support screening for all patients while others are in favor of testing based upon risk factors.[47] Research by Rockwell et al. reported similar results in regards to an athletic population, in which health history (78%) and injury status or history (74%), Vitamin D blood screening (20%), and previous 25(OH)D test results (9%) were the factors identified for Vitamin D testing.[46] Current recommendations by the American College of Sports Medicine and the Academy of Nutrition and Dietetics in a joint position statement suggest that "athletes with a history of stress fracture, bone or joint injury, signs of over training, muscle pain or weakness, and a lifestyle involving low exposure to UVB" may benefit from Vitamin D testing.[1]

It is worth mentioning that individuals with darker skin pigmentation synthesize Vitamin D at lower rates than those with lighter skin tones.[15,33] Sekel et al. found that NCAA Division I basketball players classified as darker-skinned, 90.9% of the subjects in their study, were at an increased risk of Vitamin D insufficiency at baseline testing.[51] This is of significant consideration as 22% of men's and 20% of women's indoor track athletes and 23% of men's and 21% of women's outdoor track athletes are Black, as reported by the NCAA Demographic Database from the year 2019.[39] Skin pigmentation was not a factor considered in this study; however, it is worth examining in the future in regards to Vitamin D levels in XC and TF athletes.

4.4 Adequate Vitamin Levels

As previously mentioned, there are conflicting recommendations regarding target 25(OH)D serum concentrations. Although survey response data was limited for this question, the results express a large variability in adequate Vitamin D levels accepted by institutions. When examining by region of the United States, the Mid-West accounted for half of the responses, at which 30-40 ng/mL (66.7%) was the most selected adequate range. In contrast, a response from the Southeast indicated that 40-50 ng/mL is an appropriate range while > 60 ng/mL is preferred by an institution in the Pacific West. These variations are consistent when examining by NCAA Division as well. Of the 5 responses provided by NCAA Division I participants, 40% selected 40-50 ng/mL as the adequate range while the Division III participant selected 30-40 ng/mL. These findings are consistent with the previously mentioned study by Rockwell et al., where the target Vitamin D concentration reported by athletic programs in their study varied substantially.[46]

Historically, Vitamin D levels as low as 20 ng/mL have been recognized as sufficient.[8,47] Recently, in regard to military and athletic populations subject to microtrauma and overuse injuries, Burgi et al. suggests a minimum level of 40 ng/mL as a preventative measure for stress fractures and to maintain bone health.[8] Further research is needed worldwide to identify adequate target 25(OH)D concentrations for athletic participation and to achieve a consensus among international organizations in an effort to clarify the available literature.

4.5 Number of Vitamin D Tests per Year

Not only is it necessary to identify specific factors for Vitamin D testing and target Vitamin D levels, but also the number of times testing is conducted per year at institutions that do so. When examining by region of the United States, 66.7% of responses from the Mid-West and 100% of the responses from the Pacific West test one time per year. Comparably, the Southeast participants indicated testing occurs 2 times per year (50%) or "as needed" (50%). When comparing by NCAA Division, if Division I and III are combined, 50% of the responses indicated that testing is conducted once a year. Although the survey question did not ask what time of year testing is conducted, one test per year is potentially problematic as seasonal Vitamin D fluctuations are well documented in the literature.

A study referenced earlier by Krzywanski et al. reported that from September to May 25(OH)D concentrations did not exceed 30 ng/mL in elite Polish athletes.[31] Adequate Vitamin D status was only achieved in track and field athletes training outdoors during the summer months and there was a significant decrease in levels from autumn to winter ($p < 0.001$).[31] Low Vitamin D levels are prevalent during the winter months due to reduced exposure to UVB light.[13,31] In collegiate athletics, it is essential to monitor these seasonal fluctuations in an attempt to optimize performance. Baseline testing at the beginning of an academic year followed by repeat testing during the winter months appears to be an ideal screening method. This was evidenced in a previously mentioned study by Williams et al. who conducted baseline testing in collegiate athletes in August and repeat testing in February.[59] Repeat testing successfully identified 56% of subjects, previously labeled as sufficient in August, that developed hypovitaminosis D by February.[59] Meanwhile, certain clinical practice guidelines recommend the reevaluation of 25(OH)D levels 3-4 months after initial evaluation, especially following therapeutic intervention, to monitor the effectiveness.[26,42] More research is needed to determine the appropriate number of Vitamin D tests per a year and special consideration should be given to those athletes with limited sun exposure during the winter months.

4.6 Opinions Regarding Vitamin D Testing in Athletes

This study aimed to assess the opinions of Athletic Trainers regarding Vitamin D testing in collegiate XC and TF athletes. When analyzing opinions by region of the United States and NCAA Division, there was no statistical association. However, it is important to note that most participants from each region, excluding the New England and Mid-West regions, responded *yes* indicating that Vitamin D should be routinely tested in XC and TF athletes. In addition to this, nearly three-quarters (70.6%) of participants from NCAA Division I answered *yes* while two-thirds (66.7%) of participants from Divisions II and III answered *no*. Likewise, 75% of NCAA Division I Athletic Trainers that do not provide medical care for XC and TF indicated that Vitamin D should be routinely tested in their respective athletes. To reiterate, these differences in Athletic Trainers' opinions compared by NCAA Division may be related to budgetary funding. As previously stated, NCAA Division I institutions typically budget more money for sports medicine expenses; not to mention, some athletics programs may budget sports medicine expenses into individual teams' budgets as well. NCAA Divisions II and III institutions are not funded in the same way and many Athletic Trainers at these schools may recognize that budgetary expenses need to be focused elsewhere.

Overall, the clinical implications of hypovitaminosis D as it relates to athletic performance remains unknown. Due to this, many professional athletics organizations have begun examining

25(OH)D levels in their athletes and even in combine participants as evidenced by studies conducted in the NBA, NFL, and Liverpool's professional soccer academy.[12,19,34,44] As indicated by participants in this study, 25(OH)D screening in collegiate athletics is trending upwards. However, Rockwell et al. found that 58% of their participants felt that Vitamin D blood testing and supplementation was not a good use of athletics programs funds, while 31% said it was a good use, 9% said sometimes a good use, and 2% were unsure.[46] The recruited participants in their study were classified as NCAA Division I head Athletic Trainers and asked to evaluate all athletic teams, rather than the athletic team(s) for which they provide medical care.[46] This may explain the difference in their results compared to the present study, as XC and TF Athletic Trainers may possess differing opinions based upon background knowledge related to the sport and athletes they work with.

4.7 Injury Data

Due to the prevalence of BSIs in the athletic population of interest in this study, injury data was collected in order to calculate an injury incidence and frequency. An injury was defined as a diagnosed stress fracture or stress reaction. Women's cross country had the highest incidence of athletes with a BSI per 100 athletes per one season with 11.9 followed by women's track and field with an incidence of 6.3. Men's cross country and men's track and field had an incidence of 5.4 and 4.1, respectively. Statistical analysis found a significant association between both men's and women's cross country and men's and women's track and field and BSI occurrence. Women's cross country also had the highest injury frequency per 100 athletes per one season with 14.1 followed by women's track and field (9.2), men's cross country (7.6), and men's track and field

(4.9). These results agree with a descriptive epidemiological study by Rizzone et al., which identified women's cross country as having the highest stress fracture rate at 28.59 per 100,000 athlete exposures followed closely by women's outdoor track at 22.26.[45] In the same study, men's cross country was found to have the highest stress fracture rate of 16.14.[45] The prevalence of BSIs in this population is thought to be related to the nature of the sport, which results in high impact and repetitive loading of the lower extremity.[50]

The results are consistent with previous literature that stated BSIs occur more frequently in female athletes than males.[45,48,50,53] In addition to the training demands, female athletes possess physiological differences related to running biomechanics, muscle strength, aerobic fitness, body fat mass, and hormone levels that may alter how the body adapts to microtrauma.[10,48] Female athletes are also subject to low energy availability, a component of a syndrome referred to as relative energy deficiency in sport (RED-S)—formerly known as the female athlete triad.[36,45] Organizations such as the International Olympic Committee have placed greater emphasis on RED-S in recent years and have developed a consensus statement that states low energy availability is associated with impaired bone health, especially in females.[36] Low energy availability is also linked to decreased bone mineral density, bone strength, altered bone microarchitecture and bone turnover markers all of which are associated with an increased risk of BSI.[36] More research is needed regarding the clinical and sport implications related to RED-S to understand sex differences and the incidence of BSIs.

4.8 Limitations

There are several limitations of the present study that need to be recognized. The first is the small sample size of participants. Out of the 1,000 email invitations sent by the NATA, 62 surveys were started and only 55 were completed. This equates to an 89% completion rate and 5.5% response rate. In addition, of the 55 surveys completed, 13 participants did not answer all the questions which lead to decreased representation from each region and/or NCAA division and potentially impacted statistical analysis. Along with that, this study aimed to gather data regarding diagnosed bone stress injuries to determine injury rate and frequency which required information supplied by participants in open ended questions. In total, there were 12 open ended questions that asked participants for information regarding roster size and diagnosed BSIs from the 2018-2019 academic year. It is assumed that most participants would not have this information readily available and would need to reference documentation which in turn may have acted as a deterrent for completing the survey.

Another limitation that may explain the reduced response rate was the inability to target XC and TF Athletic Trainers specifically using the NATA Research Survey Service. Use of the Research Survey Service was convenient and provided access to 1,000 potential survey participants, however, it does not have any sport specific filters. The survey email invitation was sent to 1,000 NATA members that had previously identified themselves as working at the collegiate or university level. As a result, the email invitation requested that the survey be forwarded to the designated XC and/or TF Athletic Trainer at the institution if it was not the immediate recipient. Due to this, there is no way to ascertain if the survey reached the maximum intended study participants. Lastly, as with any survey, participants may be subject to recall bias.

The survey questions were designed carefully, but the request for medical information from past seasons may have been impacted by participants' memories.

4.9 Future Research

Future research should be aimed at developing a consensus regarding adequate Vitamin D levels for both the general and athletic population. It is suspected that target Vitamin D blood levels may need to be higher for athletic individuals due to the physical demands of sport. Previous research and the results from the present study have shown that athletic programs accept Vitamin D blood levels as low as 30 ng/mL and upwards of 60 ng/mL or greater. This wide range and the lack of consensus may contribute to skepticism regarding the role of Vitamin D and athletic performance. A similar study conducted with a larger sample size along with previous literature may help to establish an adequate range for athletic participation.

For institutions that have a Vitamin D policy or protocol and conduct serum 25(OH)D testing, future research is needed to examine the outcomes and/or treatment following testing. Not only is it necessary to identify individuals with hypovitaminosis D, it also imperative to have an established treatment plan. Supplementation is an effective way to increase 25(OH)D levels and is relatively affordable; so much so that some studies have found that institutions have employed what is referred to as "blanket supplementation" (i.e., providing the same dose of Vitamin D supplements to entire teams or groups of athletes without knowledge of their 25(OH)D concentrations).[46] In an XC and TF population, this may be an appropriate solution to combat seasonal fluctuations in Vitamin D levels when athletes switch to training indoors. More research is needed to evaluate the efficacy of blanket supplementation in addition to the outcomes of Vitamin D testing in general.

The results of past research and the present study have shown that BSIs are prevalent in XC and TF athletes. Future research should continue to examine the relationship between BSI occurrence and Vitamin D testing and/or supplementation. A suitable study design may include following a cohort of collegiate XC and TF athletes for the duration of their collegiate athletic careers. Study components may include baseline Vitamin D testing at the beginning of the academic year followed by repeat testing in February to obtain reference serum concentrations. All study participants will be provided with daily supplementation and prospectively followed to evaluate for BSI occurrence. BSI occurrence could be compared to past medical records to determine injury rates. At the conclusion of the study, the effectiveness of Vitamin D supplementation and the association between BSI occurrence may be examined. In addition, future studies could incorporate technology such as dual energy X-ray absorptiometry (DEXA) or high-resolution peripheral quantitative computed tomography (HR-pQCT) to assess for changes in bone microstructure and examine the impact of Vitamin D on a biological level.

Finally, comparing Vitamin D testing by region of the U.S. and NCAA division did not produce statistically significant data in this study, however, an increase in sample size may provide meaningful data. As mentioned, the region in which athletes live and train and the associated climate may impact Vitamin D status. Furthermore, NCAA division classification may influence an institution’s ability to conduct Vitamin D testing. Future studies should continue to evaluate testing policies by geographical location and NCAA division in order to develop guidelines for sports medicine professionals working in collegiate athletics. In addition to NCAA division, it may be beneficial to examine Vitamin D testing by athletic conference to assess for differences. This could help with the continued development of uniform policies and create better practices.

4.10 Conclusion

Vitamin D testing has gained popularity amongst elite and professional athletes. In turn, this has led to collegiate athletics programs evaluating Vitamin D as it is relatively inexpensive and accessible. This study is the first step in evaluating Vitamin D testing practices as well as gathering bone stress injury data in collegiate XC and TF athletes. Based on the data, there are few institutions that conduct Vitamin D testing in XC and TF athletes and have an associated policy or protocol. Nevertheless, a large percentage of NCAA Division I Athletic Trainers are in favor of Vitamin D testing in XC and TF athletes. XC and TF Athletic Trainers possess an understanding of the demands of the sport and the frequent injuries, one of the most common being bone stress injuries. Past research has found that XC and TF athletes, especially females, are at a heightened risk for such injuries. This was supported by the results which found that women's XC and TF athletes have an increased BSI incidence and frequency compared to males. Due to this, BSIs are considered a red flag and a key indicator for Vitamin D testing. Overall, this study has highlighted the need for continued education and research regarding the implications of inadequate Vitamin D levels to inform clinical practice and improve the health and well-being of collegiate athletes. Ultimately, this may optimize performance and assist in preventing future injury, especially in XC and TF athletes.

Appendix A Qualtrics Survey Questions

1. Does your job description entail providing medical care for <u>cross country and/or track and field student-athletes</u> at your respective institution?
    a. Yes
        i. How many months out of the year are the **<u>cross country student-athletes</u>** at your institution required to train indoors due to weather conditions?
            - < 1 month
            - 1-3 months
            - 3-6 months
            - > 6 months
        ii. How many months out of the year are the **<u>track and field student-athletes</u>** at your institution required to train indoors due to weather conditions?
            - < 1 month
            - 1-3 months
            - 3-6 months
            - > 6 months
        iii. *Please answer the next 3 questions regarding your **women's cross country team** from the **2018-2019 academic year**. If you are uncertain, please leave the box blank.*
            - How many student-athletes did you have on the roster?
            - How many student-athletes had a diagnosed bone stress injury (stress fracture or reaction)?
            - What was the total number of diagnosed bone stress injuries? (including multiple stress injuries to the same individual)
        iv. *Please answer the next 3 questions regarding your **women's track and field team** from the **2018-2019 academic year**. If you are uncertain, please leave the box blank.*
            - How many student-athletes did you have on the roster?
            - How many student-athletes had a diagnosed bone stress injury (stress fracture or reaction)?
            - What was the total number of diagnosed bone stress injuries? (including multiple stress injuries to the same individual)
        v. *Please answer the next 3 questions regarding your **men's cross country team** from the **2018-2019 academic year**. If you are uncertain, please leave the box blank.*
            - How many student-athletes did you have on the roster?
            - How many student-athletes had a diagnosed bone stress injury (stress fracture or reaction)?
            - What was the total number of diagnosed bone stress injuries? (including multiple stress injuries to the same individual)

vi. *Please answer the next 3 questions regarding your **men's track and field team** from the **2018-2019 academic year**. If you are uncertain, please leave the box blank.*
   - How many student-athletes did you have on the roster?
   - How many student-athletes had a diagnosed bone stress injury (stress fracture or reaction)?
   - What was the total number of diagnosed bone stress injuries? (including multiple stress injuries to the same individual)

b. No
   i. If "no" is selected – Select the sport(s) **you** provide medical care for:
      - Football
      - Basketball – Men's
      - Basketball – Women's
      - Baseball
      - Golf – Men's
      - Golf – Women's
      - Gymnastics – Men's
      - Gymnastics – Women's
      - Field Hockey
      - Ice Hockey – Men's
      - Ice Hockey – Women's
      - Lacrosse – Men's
      - Lacrosse – Women's
      - Rowing – Men's
      - Rowing – Women's
      - Soccer – Men's
      - Soccer – Women's
      - Softball
      - Swimming & Diving – Men's
      - Swimming & Diving – Women's
      - Tennis – Men's
      - Tennis – Women's
      - Volleyball (indoor) – Men's
      - Volleyball (indoor) – Women's
      - Volleyball (sand) – Men's
      - Volleyball (sand) – Women's
      - Wrestling
      - Other (please specify)

2. Is your institution classified as NCAA Division I, II or III?
   a. I
   b. II
   c. III
3. What region of the United States is your institution located?
   a. New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont)

   b. Mid-Atlantic (Delaware, Maryland, New Jersey, New York, Pennsylvania, Washington D.C.)
   c. Southeast (Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, West Virginia)
   d. Mid-West (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin)
   e. Rocky Mountains (Colorado, Idaho, Montana, Nevada, Utah, Wyoming)
   f. Southwest (Arizona, New Mexico, Oklahoma, Texas)
   g. Pacific West (Alaska, California, Hawaii, Oregon, Washington)
4. Does the sports medicine department at your institution have a policy or protocol in place regarding Vitamin D testing in student-athletes?
   a. Yes
   b. No
   c. Unknown

If "no" or "unknown" is selected, the survey advances to question #8.

5. Are Vitamin D blood levels of your student-athletes evaluated based upon specific factors? Select all that apply.
   a. Preventative screening (apart of your institution's preparticipation physical examination process)
   b. Red flags (i.e. current injury status, history of stress fracture or reaction, history of eating disorder, vegan/vegetarian)
   c. Based on health history (previous history of low Vitamin D)
   d. Other (please explain)
6. What does the sports medicine department at your institution consider to be an adequate Vitamin D level, based off of blood serum levels, for athletic participation?
   a. < 30 ng/mL
   b. 30-40 ng/mL
   c. 40-50 ng/mL
   d. 50-60 ng/mL
   e. > 60 ng/mL
   f. Other (please explain)
   g. I am unsure
7. On average, how many times a year is Vitamin D testing conducted for a student-athlete?
   a. 1
   b. 2
   c. 3
   d. 4
   e. Other (please explain)
8. In your opinion, should Vitamin D blood levels be routinely tested in the student-athletes for which you provide health care?
   a. Yes
   b. No

Appendix B Injury Data

Table 15 Women's Cross Country Bone Stress Injury Data

Number of Rostered Student Athletes	Number of Student Athletes with Diagnosed BSI	Total Number of Diagnosed BSI
34	2	2
9	0	0
14	3	3
12	0	0
9	1	1
13	0	0
15	4	4
68	2	2
12	3	4
8	2	3
8	1	1
10	2	2
10	1	1
16	7	7
17	1	1
22	8	11
28	2	3
20	3	3
19	1	1
10	1	1
22	2	5
10	0	0
19	2	2
Total		
405	**48**	**57**

Table 16 Women's Track and Field Bone Stress Injury Data

Number of Rostered Student Athletes	Number of Student Athletes with Diagnosed BSI	Total Number of Diagnosed BSI
30	0	0
30	0	0
62	2	2
25	1	1
18	1	1
29	5	5
68	2	2
32	5	6
36	3	4
25	1	2
55	0	0
40	2	2
47	2	2
35	7	8
51	2	3
47	12	27
37	2	2
15	0	0
60	2	5
41	0	0
Total		
783	**49**	**72**

Table 17 Men's Cross Country Bone Stress Injury Data

Number of Rostered Student Athletes	Number of Student Athletes with Diagnosed BSI	Total Number of Diagnosed BSI
14	0	0
9	0	0
14	0	0
8	0	0
15	2	2
8	1	1
22	3	3
67	2	2
13	2	2
8	0	0
7	0	0
10	0	0
15	1	1
14	2	2
35	2	2
27	0	0
25	4	12
17	1	1
9	0	0
7	0	0
25	0	0
Total		
369	**20**	**28**

Table 18 Men's Track and Field Bone Stress Injury Data

Number of Rostered Student Athletes	Number of Student Athletes with Diagnosed BSI	Total Number of Diagnosed BSI
35	0	0
30	0	0
60	4	5
26	0	0
15	1	1
14	1	1
39	3	3
67	2	2
32	4	4
37	1	1
21	0	0
55	0	0
40	0	0
34	0	0
35	3	4
51	0	0
48	10	14
29	1	1
8	0	0
55	0	0
Total		
731	30	36

Appendix C Non-XC and TF Athletic Trainers’ Survey Response Data

Appendix C.1 Vitamin D Policy or Protocol

Table 19 Vitamin D Testing Policies by Region of the United States

	Regions of the U.S.			
Vitamin D Policy	**Mid-Atlantic**	**Southeast**	**Mid-West**	**Rocky Mountains**
Yes	0	1/5 (20%)	2/3 (66.7%)	1/2 (50%)
No	1/2 (50%)	4/5 (80%)	1/3 (33.3%)	1/2 (50%)
Unknown	1/2 (50%)	0	0	0
Total	2	5	3	2

Table 20 Vitamin D Testing Policies by NCAA Division

	NCAA Division			
Vitamin D Policy	**I**	**II**	**III**	**Not specified**
Yes	4/8 (50%)	0	0	0
No	3/8 (37.5%)	1 (100%)	2 (100%)	1 (100%)
Unknown	1/8 (12.5%)	0	0	0
Total	8	1	2	1

Appendix C.2 Opinions Regarding Vitamin D Testing in Athletes

Table 21 Non-XC and TF Athletic Trainers' Opinions Regarding Vitamin D Testing in their Athletes by Region of the United States

	Regions of the U.S.			
Opinion on Vitamin D Testing	**Mid-Atlantic**	**Southeast**	**Mid-West**	**Rocky Mountains**
Yes	0	3/5 (60%)	2/3 (66.7%)	1/2 (50%)
No	2 (100%)	2/5 (40%)	1/3 (33.3%)	1/2 (50%)
Total	2	5	3	2

Table 22 Non-XC and TF Athletic Trainers' Opinions Regarding Vitamin D Testing in their Athletes by NCAA Division

	NCAA Division			
Opinion on Vitamin D Testing	**I**	**II**	**III**	**Not Specified**
Yes	6/8 (75%)	0	0	0
No	2/8 (25%)	1 (100%)	2 (100%)	1 (100%)
Total	8	1	2	1

Bibliography

1. Nutrition and Athletic Performance. *Medicine & Science in Sports & Exercise.* 2016;48(3):543-568.

2. Abrams GD, Feldman D, Safran MR. Effects of Vitamin D on Skeletal Muscle and Athletic Performance. *J Am Acad Orthop Surg.* 2018;26(8):278-285.

3. Allison RJ, Close GL, Farooq A, et al. Severely vitamin D-deficient athletes present smaller hearts than sufficient athletes. *Eur J Prev Cardiol.* 2015;22(4):535-542.

4. Angeline ME, Gee AO, Shindle M, Warren RF, Rodeo SA. The effects of vitamin D deficiency in athletes. *Am J Sports Med.* 2013;41(2):461-464.

5. Backx EM, Tieland M, Maase K, et al. The impact of 1-year vitamin D supplementation on vitamin D status in athletes: a dose-response study. *Eur J Clin Nutr.* 2016;70(9):1009-1014.

6. Bartoszewska M, Kamboj M, Patel DR. Vitamin D, muscle function, and exercise performance. *Pediatr Clin North Am.* 2010;57(3):849-861.

7. Bouillon R. Comparative analysis of nutritional guidelines for vitamin D. *Nat Rev Endocrinol.* 2017;13(8):466-479.

8. Burgi AA, Gorham ED, Garland CF, et al. High serum 25-hydroxyvitamin D is associated with a low incidence of stress fractures. *J Bone Miner Res.* 2011;26(10):2371-2377.

9. Ceglia L. Vitamin D and its role in skeletal muscle. *Curr Opin Clin Nutr Metab Care.* 2009;12(6):628-633.

10. Cheuvront SN, Carter R, Deruisseau KC, Moffatt RJ. Running performance differences between men and women:an update. *Sports Med.* 2005;35(12):1017-1024.

11. Chiang CM, Ismaeel A, Griffis RB, Weems S. Effects of Vitamin D Supplementation on Muscle Strength in Athletes: A Systematic Review. *J Strength Cond Res.* 2017;31(2):566-574.

12. Close GL, Russell J, Cobley JN, et al. Assessment of vitamin D concentration in non-supplemented professional athletes and healthy adults during the winter months in the UK: implications for skeletal muscle function. *J Sports Sci.* 2013;31(4):344-353.

13. Dao D, Sodhi S, Tabasinejad R, et al. Serum 25-Hydroxyvitamin D Levels and Stress Fractures in Military Personnel: A Systematic Review and Meta-analysis. *Am J Sports Med.* 2015;43(8):2064-2072.

14. Davey T, Lanham-New SA, Shaw AM, et al. Low serum 25-hydroxyvitamin D is associated with increased risk of stress fracture during Royal Marine recruit training. *Osteoporos Int.* 2016;27(1):171-179.

15. de la Puente Yagüe M, Collado Yurrita L, Ciudad Cabañas MJ, Cuadrado Cenzual MA. Role of Vitamin D in Athletes and Their Performance: Current Concepts and New Trends. *Nutrients.* 2020;12(2).

16. Farrokhyar F, Sivakumar G, Savage K, et al. Effects of Vitamin D Supplementation on Serum 25-Hydroxyvitamin D Concentrations and Physical Performance in Athletes: A Systematic Review and Meta-analysis of Randomized Controlled Trials. *Sports Med.* 2017;47(11):2323-2339.

17. Farrokhyar F, Tabasinejad R, Dao D, et al. Prevalence of vitamin D inadequacy in athletes: a systematic-review and meta-analysis. *Sports Med.* 2015;45(3):365-378.

18. Ginde AA, Liu MC, Camargo CA, Jr. Demographic differences and trends of vitamin D insufficiency in the US population, 1988-2004. *Arch Intern Med.* 2009;169(6):626-632.

19. Grieshober JA, Mehran N, Photopolous C, et al. Vitamin D Insufficiency Among Professional Basketball Players: A Relationship to Fracture Risk and Athletic Performance. *Orthop J Sports Med.* 2018;6(5):2325967118774329.

20. Halliday TM, Peterson NJ, Thomas JJ, et al. Vitamin D status relative to diet, lifestyle, injury, and illness in college athletes. *Med Sci Sports Exerc.* 2011;43(2):335-343.

21. He CS, Handzlik M, Fraser WD, et al. Influence of vitamin D status on respiratory infection incidence and immune function during 4 months of winter training in endurance sport athletes. *Exerc Immunol Rev.* 2013;19:86-101.

22. Hildebrand RA, Miller B, Warren A, Hildebrand D, Smith BJ. Compromised Vitamin D Status Negatively Affects Muscular Strength and Power of Collegiate Athletes. *Int J Sport Nutr Exerc Metab.* 2016;26(6):558-564.

23. Holick MF. High prevalence of vitamin D inadequacy and implications for health. *Mayo Clin Proc.* 2006;81(3):353-373.

24. Holick MF. Vitamin D deficiency. *N Engl J Med.* 2007;357(3):266-281.

25. Holick MF. The vitamin D deficiency pandemic: Approaches for diagnosis, treatment and prevention. *Rev Endocr Metab Disord.* 2017;18(2):153-165.

26. Holick MF, Binkley NC, Bischoff-Ferrari HA, et al. Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. *J Clin Endocrinol Metab.* 2011;96(7):1911-1930.

27. Holick MF, Chen TC. Vitamin D deficiency: a worldwide problem with health consequences. *Am J Clin Nutr.* 2008;87(4):1080s-1086s.

28. Institute of Medicine Committee to Review Dietary Reference Intakes for Vitamin D, Calcium. The National Academies Collection: Reports funded by National Institutes of Health. In: Ross AC, Taylor CL, Yaktine AL, Del Valle HB, eds. *Dietary Reference Intakes for Calcium and Vitamin D.* Washington (DC): National Academies Press (US)
Copyright © 2011, National Academy of Sciences.; 2011.

29. Kahanov L, Eberman LE, Games KE, Wasik M. Diagnosis, treatment, and rehabilitation of stress fractures in the lower extremity in runners. *Open Access J Sports Med.* 2015;6:87-95.

30. Kiel J, Kaiser K. Stress Reaction and Fractures. In: *StatPearls.* Treasure Island (FL): StatPearls Publishing

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31. Krzywanski J, Mikulski T, Krysztofiak H, et al. Seasonal Vitamin D Status in Polish Elite Athletes in Relation to Sun Exposure and Oral Supplementation. *PLoS One.* 2016;11(10):e0164395.

32. Lappe J, Cullen D, Haynatzki G, et al. Calcium and vitamin d supplementation decreases incidence of stress fractures in female navy recruits. *J Bone Miner Res.* 2008;23(5):741-749.

33. Larson-Meyer DE, Willis KS. Vitamin D and athletes. *Curr Sports Med Rep.* 2010;9(4):220-226.

34. Maroon JC, Mathyssek CM, Bost JW, et al. Vitamin D profile in National Football League players. *Am J Sports Med.* 2015;43(5):1241-1245.

35. Martineau AR, Jolliffe DA, Greenberg L, et al. Vitamin D supplementation to prevent acute respiratory infections: individual participant data meta-analysis. *Health Technol Assess.* 2019;23(2):1-44.

36. Mountjoy M, Sundgot-Borgen JK, Burke LM, et al. IOC consensus statement on relative energy deficiency in sport (RED-S): 2018 update. *Br J Sports Med.* 2018;52(11):687-697.

37. NCAA. Divisional Differences and the History of Multidivision Classification. https://www.ncaa.org/about/who-we-are/membership/divisional-differences-and-history-multidivision-classification.

38. NCAA. Finances of Intercollegiate Athletics Database. https://www.ncaa.org/about/resources/research/finances-intercollegiate-athletics-database.

39. NCAA. NCAA Demographics Database. https://www.ncaa.org/about/resources/research/ncaa-demographics-database.

40. Owens DJ, Allison R, Close GL. Vitamin D and the Athlete: Current Perspectives and New Challenges. *Sports Med.* 2018;48(Suppl 1):3-16.

41. Passeron T, Bouillon R, Callender V, et al. Sunscreen photoprotection and vitamin D status. *Br J Dermatol.* 2019;181(5):916-931.

42. Płudowski P, Karczmarewicz E, Bayer M, et al. Practical guidelines for the supplementation of vitamin D and the treatment of deficits in Central Europe - recommended vitamin D intakes in the general population and groups at risk of vitamin D deficiency. *Endokrynol Pol.* 2013;64(4):319-327.

43. Podd D. Hypovitaminosis D: A common deficiency with pervasive consequences. *Journal of the American Academy of PAs.* 2015;28(2):20-26.

44. Rebolledo BJ, Bernard JA, Werner BC, et al. The Association of Vitamin D Status in Lower Extremity Muscle Strains and Core Muscle Injuries at the National Football League Combine. *Arthroscopy.* 2018;34(4):1280-1285.

45. Rizzone KH, Ackerman KE, Roos KG, Dompier TP, Kerr ZY. The Epidemiology of Stress Fractures in Collegiate Student-Athletes, 2004-2005 Through 2013-2014 Academic Years. *J Athl Train.* 2017;52(10):966-975.

46. Rockwell M, Hulver M, Eugene E. Vitamin D Practice Patterns in National Collegiate Athletic Association Division I Collegiate Athletics Programs. *J Athl Train.* 2020;55(1):65-70.

47. Rockwell M, Kraak V, Hulver M, Epling J. Clinical Management of Low Vitamin D: A Scoping Review of Physicians' Practices. *Nutrients.* 2018;10(4).

48. Roos KG, Marshall SW, Kerr ZY, et al. Epidemiology of Overuse Injuries in Collegiate and High School Athletics in the United States. *Am J Sports Med.* 2015;43(7):1790-1797.

49. Ruohola JP, Laaksi I, Ylikomi T, et al. Association between serum 25(OH)D concentrations and bone stress fractures in Finnish young men. *J Bone Miner Res.* 2006;21(9):1483-1488.

50. Saragiotto BT, Yamato TP, Hespanhol Junior LC, et al. What are the main risk factors for running-related injuries? *Sports Med.* 2014;44(8):1153-1163.

51. Sekel NM, Gallo S, Fields J, et al. The Effects of Cholecalciferol Supplementation on Vitamin D Status Among a Diverse Population of Collegiate Basketball Athletes: A Quasi-Experimental Trial. *Nutrients.* 2020;12(2).

52. Sikora-Klak J, Narvy SJ, Yang J, et al. The Effect of Abnormal Vitamin D Levels in Athletes. *Perm J.* 2018;22:17-216.

53. Tenforde AS, Carlson JL, Chang A, et al. Association of the Female Athlete Triad Risk Assessment Stratification to the Development of Bone Stress Injuries in Collegiate Athletes. *Am J Sports Med.* 2017;45(2):302-310.

54. Terushkin V, Bender A, Psaty EL, et al. Estimated equivalency of vitamin D production from natural sun exposure versus oral vitamin D supplementation across seasons at two US latitudes. *J Am Acad Dermatol.* 2010;62(6):929.e921-929.

55. Trappe S, Luden N, Minchev K, et al. Skeletal muscle signature of a champion sprint runner. *J Appl Physiol (1985).* 2015;118(12):1460-1466.

56. U.S. Department of Agriculture ARS. FoodData Central.

57. Villacis D, Yi A, Jahn R, et al. Prevalence of Abnormal Vitamin D Levels Among Division I NCAA Athletes. *Sports Health.* 2014;6(4):340-347.

58. Wang TJ, Pencina MJ, Booth SL, et al. Vitamin D deficiency and risk of cardiovascular disease. *Circulation.* 2008;117(4):503-511.

59. Williams K, Askew C, Mazoue C, et al. Vitamin D3 Supplementation and Stress Fractures in High-Risk Collegiate Athletes - A Pilot Study. *Orthop Res Rev.* 2020;12:9-17.

60. Willis KS, Smith DT, Broughton KS, Larson-Meyer DE. Vitamin D status and biomarkers of inflammation in runners. *Open Access J Sports Med.* 2012;3:35-42.

61. Wyon MA, Koutedakis Y, Wolman R, Nevill AM, Allen N. The influence of winter vitamin D supplementation on muscle function and injury occurrence in elite ballet dancers: a controlled study. *J Sci Med Sport.* 2014;17(1):8-12.

62. Wyon MA, Wolman R, Nevill AM, et al. Acute Effects of Vitamin D3 Supplementation on Muscle Strength in Judoka Athletes: A Randomized Placebo-Controlled, Double-Blind Trial. *Clin J Sport Med.* 2016;26(4):279-284.