Screening, Assessment, and Treatment for Inadequate Vitamin D Status in Athletes: Development of a Policy for Virginia Tech Athletics

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Abstract

In the general population, up to 77% of individuals have inadequate vitamin D concentrations. Athletes are not immune to this pandemic, as many have been identified as having insufficient or deficient 25(OH)D concentrations as well. Insufficient and deficient concentrations of 25(OH)D in athletes have been linked to development of stress fracture, soft tissue injury and upper respiratory tract infection (URTI). With the appropriate tools, sports medicine and sports nutrition practitioners can provide care for at-risk athletes and attenuate the financial, health and sport participation costs of vitamin D related illness and injury. Inconsistencies in the literature and a lack of universal recommendations make it challenging to develop department policies and protocols for athletic education tools. The purpose of this project was twofold: firstly, to create a vitamin D policy based on the literature that may be used by the Virginia Tech Athletic Department. Secondly, to evaluate current Virginia Tech Sports Medicine and Sports Nutrition vitamin D practices and tools to understand the costs and systems that may influence the adoption of the policy while also ensuring current practices and tools are up to date.

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Introduction and Purpose

In the general population, 77% of individuals are believed to have insufficient or deficient vitamin D concentrations (Ginde, Liu & Camargo, 2009). Additionally, studies have identified a high prevalence of insufficient or deficient vitamin D concentrations in athletes within various sports and geographic locations (Todd et al., 2014). A systematic review by Villacis et al. (2014) showed that 33% of Division I collegiate athletes were vitamin D insufficient or deficient. Several factors, including a sun-shy lifestyle and insufficient oral intake of vitamin D may lead to disadvantageous vitamin D concentrations in athletes. It is possible that such factors can be attenuated which may ultimately help prevent or treat illness and injury (Academy of Nutrition and Dietetics, 2016 & Close, 2016).

Insufficient and deficient vitamin D concentrations have been linked to increased injury and illness in athletic populations (He et al., 2016 & Farrokhyar et al., 2014). Emerging evidence regarding the role of vitamin D on illness and injury shows promise in the prevention and treatment of stress fractures, soft tissue injury and upper respiratory tract infection (URTI) (Richards & Wright, 2018, Rebolledo et al., 2017 & Jung et al., 2018). With the appropriate tools, sports medicine and sports nutrition practitioners can provide care for at risk athletes and attenuate the financial, health and sport participation costs of vitamin D associated illness and injury. Establishing a policy is one tool that can be implemented to improve outcomes and consistency. A recent study showed that only 20% of NCAA Division I athletics programs have a vitamin D policy or protocol in place (Rockwell, Hulver, & Eugene, 2020). Major challenges regarding vitamin D, however, include inconsistencies in the literature and lack of universal recommendations. These challenges may explain why only 20% of Division I universities reported having a vitamin D policy or protocol.

The purpose of this project was twofold: it aimed to create a vitamin D policy that may be used by the VT Athletics Department to screen, identify, and treat athletes with inadequate vitamin D concentrations. Secondly, it assessed current Virginia Tech Sports Medicine (VTSM) and Sports Nutrition (VTSN) vitamin D practices and tools to understand the costs and systems that may influence the adoption of the policy while also ensuring current practices and tools are up to date.

I. Literature Review

The purpose of the following review of literature is to summarize the body of scientific evidence as it relates to vitamin D associated athletic injury and illness. Review of serum 25(OH)D concentration testing, concentration reference ranges, and vitamin D supplementation was conducted. Collegiate, professional, and independent sport athletes were the subjects of this literature review. In addition, based on their strict training regimen, physical demands, and injury pathology, military personnel were included to expand the body of literature reviewed.

Vitamin D- What Is It?

Vitamin D is an essential fat-soluble vitamin that is also recognized as a hormone (He, Yong, Walsh & Gleeson, 2016 & Close, 2015). It exists in two forms; cholecalciferol or vitamin D_3 and ergocalciferol or vitamin D_2. Of the two forms, vitamin D_2 maintains a shorter half-life, binds less with vitamin D binding protein, and is less efficacious at raising serum 25(OH)D concentrations compared to vitamin D_3 (He et al., 2016). Vitamin D is most commonly known for its role in bone formation and maintenance. More recently, vitamin D has been found to regulate expression of more than 900 gene variants in several different tissues (Dahlquist et al., 2015). Additionally, vitamin D receptors that were once thought to have limited presence in bone and the gastrointestinal tract are now identified all over the body (Close, 2019). Identified functions of vitamin D include innate and adaptive immune responses, skeletal muscle function, and cognitive function (Anjum, Jaffrey, Fayyaz, Samoo, & Anjum, 2018).

Vitamin D- Where Does It Come From?

Few dietary sources contain vitamin D. The most common include fortified dairy, such as milk and yogurt, fortified cereals and juices, fish, eggs and mushrooms (He et al., 2016). Vitamin D_3 can also be synthesized in the epidermis after exposure to sunlight, specifically ultraviolet B radiation (UVB) (He et al., 2016). Photosynthetic creation of vitamin D from exposure to sunlight is able to maintain an adequate 25(OH)D concentration, however, sunscreen use, time of day, latitude, season, color of skin, sun blocking clothing and lack of time spent outdoors can lead to less than adequate synthesis and status (Halliday et al., 2010). Lastly, supplements, such as multivitamins containing vitamin D along with vitamin D_2 and vitamin D_3 supplements are an additional source.

Recommended Vitamin D Intake

Universal recommendations are not established for vitamin D intake in athletes. The Institute of Medicine (IOM) established a Recommended Dietary Allowance (RDA) for vitamin D intake in the general population at 600 IU/day (Ross et al., 2011). Despite this recommendation, some researchers feel this is not adequate to maintain optimal 25(OH)D concentrations. The Endocrine Society recommends 1500-2000 IU of vitamin D per day to obtain optimal 25(OH)D concentrations. Upper Level (UL) intake recommendations also vary among references (Vieth & Holick, 2018). The IOM established a UL of 4000 IU/day, whereas the Endocrine Society reports 10,000 IU is the limit for intake (Vieth & Holick, 2018).

Recommended Vitamin D Blood Concentrations

Measurement of serum 25-hydroxyvitamin D (25(OH)D) is widely used in practice to assess vitamin D status (He et al., 2016). Similar to recommended intakes, universal recommendations for 25(OH)D concentration ranges are not available for athletes. For general population adults, the Endocrine Society recommends 30 ng/mL as sufficient (Holick et al., 2011). The IOM recommends 12-20 ng/mL is sufficient to meet 97.5% of US adult needs (Rockwell et al., 2020 & Ross et al., 2011). Concern that athletes require more vitamin D exists. Blood concentration levels for athletes have been recommended to be as high as 40 to 100 ng/mL (Rockwell et al., 2020 & Larson-Meyer et al., 2018).

Illness

Vitamin D has been reported to influence chronic diseases such as cardiovascular, gastrointestinal, and cancer to name a few (Wang et al., 2017). Additional influences of vitamin D have been studied on mental health disorders and upper respiratory tract infections (URTI). Of these conditions, athletic populations may be more likely to incur URTI, mental health and gastrointestinal disorders due to their relatively young and healthy status. The focus of this paper will be on URTI and the immune response due to its prevalence and impact. Research on vitamin D and mental health is growing and would be a good addition to consider. Limited information is available regarding vitamin D's relationship with gastrointestinal disorders, however, as evidence becomes available further investigation of its impact on athlete health may be warranted.

On average, adults may suffer three to six URTI episodes per year with each episode lasting about three to fourteen days (Nieman, 1990 & Nieman, 1994). Increased ventilation rates, resulting from high intensity training, increases athletes' exposure to bacterial and viral pathogens which may elevate their risk of illness (Spence et al., 2007). Thirty to 40% of visits to sports medicine clinics by elite athletes were for URTI suggestive symptoms (Gleeson & Pyne, 2001). During high-intensity training or competition, URTIs account for 35-65% of non-injury related illness among athletes (Engebretson et al., 2013, Neville, Molloy, Brooks, Speedy & Atkinson, 2006, & Soligard et al., 2015). Athletes risk contraindication from training or competition due to URTI, which is not optimal for the athlete, their team or medical support staff.

Insufficient or deficient vitamin D concentrations have been linked to risk and severity of symptoms related to URTI. In a randomized, double-blind, placebo control study, 25 male taekwondo athletes aged 19 to 22 years old were separated into two study groups. One group received 5000 IU of vitamin D supplementation for four weeks while the other served as the placebo group and did not receive any vitamin D supplementation. Each athlete was identified as vitamin D insufficient at baseline. At the end of the study, the vitamin D supplementation group reported fewer URTI symptoms and a reduced URTI incidence compared to the placebo group (Jung et al., 2018). While URTI symptoms and incidence were lower, quality of life, including tiredness and daily activity, were not statistically different between the supplemented and placebo groups. These results may suggest vitamin D's impact on infection, however, it is unclear if such an impact has significance on training capacity.

In another study, vitamin D concentration was significantly correlated to frequency of URTI in a group of Division I NCAA athletes at the University of Wyoming (Halliday et al., 2010). Male and female participants from various indoor and outdoor sports were assessed throughout the academic year. During the longitudinal study, each participant had his or her vitamin D concentration measured which was then compared to the rate of illness during the fall, winter and spring semesters. Vitamin D concentration was significantly related to frequency of URTI in the spring semester (Halliday et al., 2010). The impact URTI had on athletes was not discussed, but overall the seasonal correlation provides evidence of the potential relationship between vitamin D concentration and illness.

The impact of insufficient vitamin D concentrations in relation to URTI on sport participation was not measured in the previous two studies. However, it is described in a 2002 study on Finnish military members. A total of 756 young male participants were examined to assess a relationship between vitamin D concentration and acute URTI. Soldiers whose 25(OH)D concentration was below 16 ng/mL had an increased report of absenteeism from duty in comparison to counterparts with higher vitamin D concentrations (Laaksi et al., 2007). This study illustrates the impact vitamin D may have on an athlete's ability to participate in sport. This information could be useful for practitioners looking to develop a vitamin D policy. Such a policy may help reduce the frequency of URTI, ensure better health for athletes and reduce costs associated with medical treatment and sport participation.

A breakpoint at which athletes were identified to have an increased risk of URTI was discovered by Larson-Meyer and Willis (2010). This cutoff was equal to a 25(OH)D concentration less than 38-40 ng/mL. Athletes with 25(OH)D concentrations lower than this breakpoint during winter and spring seasons were at an increased risk of getting sick (Larson-Meyer & Willis, 2010). As mentioned previously, such data could be useful to support the creation of a vitamin D policy to help reduce illness in athletic populations.

In contrast to the above studies which support a connection between vitamin D and URTI, some research does not lend support to this correlation. It is important to identify the inconsistencies in the literature that exist. In a group of Division I collegiate wrestlers, no significant correlation was observed between vitamin D concentrations and illness despite 94% of these athletes having inadequate vitamin D concentrations (Barcal et al., 2016). Similarly, in a double-blind, randomized, placebo-controlled trial involving Division I male and female collegiate swimmers, 25(OH)D concentration was not statistically related to illness (Lewis, Redzic & Thomas, 2013). Such inconsistencies are evidence why there is no conclusive stance on vitamin D in relation to athletes and illness.

Injury

Soft tissue

New research suggests a potential correlation between vitamin D and soft tissue injury, including muscles, tendons and ligaments. The specific mechanism by which vitamin D is believed to influence soft tissue health is through muscle fiber synthesis and maintenance, muscle contraction and musculoskeletal pain associated with inadequate 25(OH)D concentrations (Robelledo et al., 2017, Rodman & Baker, 1978, Plotnikoff and Quigley, 2003 & Houston et al., 2007). National Football League combine athletes were examined for a relationship between 25(OH)D concentration and soft tissue injury. Results concluded that athletes with lower extremity muscle injury and core injury were associated with significantly lower 25(OH)D concentrations (Rebolledo et al., 2017). Additionally, athletes with an injury history had significantly lower 25(OH)D concentrations compared to non-injured athletes (Rebolledo et al., 2017).

One study, examining the relationship between 25(OH)D concentrations and injury in collegiate male and female swimmers, found 25(OH)D concentrations were not statistically related to injury or illness, however, a decrease in 25(OH)D concentration was associated with 77% of the injuries reported during the study (Lewis et al., 2013). In a second study, seasonal correlations were examined between 25(OH)D concentrations and injury in a subject group of thirteen ballerinas (Wolman et al., 2014). Serum 25(OH)D concentrations were tested in the winter and summer seasons. Significant decreases in 25(OH)D concentrations were observed in the winter when comparing summer and winter 25(OH)D concentration status. Significantly higher rates of soft-tissue injuries were reported in the winter season compared to summer, 24 and 13 respectively (Wolman et al., 2014). However, injury risk was not significantly correlated to vitamin D concentration.

Bone and Fracture

Most commonly known for its influence on bone health, vitamin D is responsible for bone remodeling and maintenance in the body. Its function is maintained in part by its influence on calcium homeostasis (Fischer, Haffner-Luntzer, Amling & Ignatius, 2018, Amling et al., 1999 and Li et al., 1997). When 25(OH)D concentrations are low, bone loss through increased bone resorption ensues in order to maintain blood calcium concentrations (Lips & van Schoor, 2011 & Peacock, 2010). In athletic settings, various bone injuries occur including, stress fractures and various partial, complete, open and closed fractures. There is little evidence on vitamin D in relation to non-stress fracture bone injury in athletic populations. The effects of calcium and vitamin D deficiency regarding fracture healing is inconclusive and warrants further investigation (Fischer, Haffner-Luntzer, Amling & Ignatius, 2018).

Contradictory to non-stress fracture bone injuries, evidence for stress fracture injuries in athletic populations is more abundant. In a double-blind, placebo-controlled, randomized clinical trial consisting of over 3000 female basic trainee Navy recruits, vitamin D and calcium intervention were assessed for their potential effects on injury prevention (Lappe et al., 2018). Participants were randomized into two groups, which included the control group and the supplement group. The supplement group was provided 2000 mg of calcium and 800 IU of vitamin D per day. At the end of the eight-week study, the vitamin D and calcium supplementation group experienced a 20% fewer stress fracture incidence rate compared to the control group (Lappe et al., 2018). While the sample size and general study design speak to the strength of this experiment, it is arguable that the combination of calcium and vitamin D challenge the concept that vitamin D was solely responsible for the reduced injury incidence.

Additional evidence suggesting a potential relationship between 25(OH)D concentration and stress fracture incidence was studied in a group of Finnish military recruits (Ruohola et al., 2006). Results from this study identified a significantly lower 25(OH)D concentration in recruits who sustained a stress fracture compared to recruits who did not experience a stress fracture. In a group of 23 collegiate male and female basketball players, injury rates were compared to 25(OH)D concentrations. Participants were categorized into study groups according to their baseline serum 25(OH)D concentration. Based on their 25(OH)D concentration, athletes were sorted into one of the following groups: sufficient, insufficient and deficient. Individuals with insufficient or deficient vitamin D concentrations at the beginning of the study experienced more injuries compared to athletes who had sufficient 25(OH)D levels at baseline (Rockwell, in review).

Stress fracture recovery time may also be affected by 25(OH)D concentration. In 37 male and female military recruits, recovery time for a stress fracture was significantly higher for recruits with inadequate 25(OH)D concentrations compared to those with normal (>20 ng/mL) concentrations (Richards & Wright, 2018). It took about three weeks longer for inadequate vitamin D recruits to recover. For some athletes this may mean missing a significant portion of their competitive season as a result of the increased recovery time.

Not all studies support a correlation between vitamin D and bone injury. In Halliday et al. (2011), injury rates were not related to vitamin D status in collegiate athletes. In a group of 279 National Basketball Association athletes, 25(OH)D concentration was assessed in relation to fracture risk (Grieshober et al., 2018). Data did not support a relationship between 25(OH)D concentration and fracture (Grieshober et al., 2018). Contrary to expectation, athletes with a history of stress fracture had a higher 25(OH)D concentration compared to athletes with no stress fracture history (Grieshober et al., 2018). Researchers hypothesized that athletes with a stress fracture history had higher concentrations because they received supplementation for their injury. It could also have been the injured athletes were more aware of the risk for fracture and modified their lifestyle to reduce risk of future fractures.

In conclusion, research has uncovered potential impacts related to vitamin D associated illness and injury within athletic populations. Multiple studies support an association between URTI, soft tissue injury and bone injury. Contrary to these results, several studies refute this connection and as a result, the body of evidence is equivocal. Despite some limitations in the literature, there appears to be sufficient evidence to initiate the creation of guidelines for practitioners to use when screening, identifying and treating vitamin D deficiency and insufficiency. Further examination regarding the relationship between vitamin D concentration and health outcomes is needed to fully understand vitamin D and its relationship with injury and illness in athletes.

II. Methods

The purpose of this project was to create an evidence-based policy for Virginia Tech (VT) Athletics related to vitamin D. A VT specific policy was created in hopes to standardize and implement best practices based on the literature. The researcher was in a unique role to collect information, assess current practices and apply current research to those findings to make the policy based on her role as Coordinator of Sports Nutrition.

The first step in the creation of this policy included a literature review by the researcher. The purpose of completing an in-depth literature review was to evaluate current evidence examining vitamin D status in association with illness and injury in athletes. A search using electronic databases including, Pubmed and Ebscohost, as well as Google Scholar was completed. Key words included vitamin D, athlete, performance, stress fracture, fracture, injury, illness, upper respiratory tract infection (UTRI), and other relevant terms. Research involving collegiate, professional and military subjects was examined to expand the breadth of data collected from the literature. Information regarding vitamin D testing, blood concentration ranges, and intervention using vitamin D supplementation was assessed. Review of literature and summary related to other roles for vitamin D and athletes (ex: performance) was also explored. Information collected from the research review was stored in notes and tables. After determining the strength and scope of the current literature, recommendations for practice established by professional organizations (i.e. Academy of Nutrition and Dietetics and the International Olympic Committee) were also evaluated.

Compiled evidence was used to inform the development of a vitamin D policy for use in clinical care of Virginia Tech athletes. Additionally, to create the policy, the researcher considered various factors such as resources and systems that may influence the adoption of the policy. Access to resources (i.e. budget, personnel, administrative support, equipment, etc.) was based on current available resources in VT Athletics to make pragmatic suggestions that may improve current practices. This policy is intended to be progressive and change over time based on resources and buy-in of the institution. The intent is for VTSM and VTSN practitioners to be able to realistically implement this policy within the VT Athletics setting. Additionally, a secondary goal is for other collegiate programs to be able adopt the policy and adapt it to best fit their needs. Modifications to this policy based on available resources, individual circumstances, and other needs may be appropriate to customize the policy for a specific athletic program.

Several interdisciplinary professionals within VTSM and VTSN reviewed the newly created policy. The purpose of including reviewers was to extensively evaluate the policy and all its parts by all entities that are involved in carrying out the policy. Three sports dietitians, one athletic trainer and one physician were among the reviewers. Their notes and feedback were compiled and reported in Table 1.

The second portion of this project evaluated the vitamin D protocol and procedures currently utilized by VTSM and VTSN in comparison to the newly established policy. This evaluation was completed in order to assess whether current practices are in line with the current evidence and professional guidelines related to vitamin D, injury, and illness in athletes. The following qualitative data was collected for the evaluation:

1. Existing Virginia Tech Sports Medicine (VTSM) and Virginia Tech Sports Nutrition (VTSN) Stress Fracture Protocol.
2. Interviews concerning existing VT procedures related to vitamin D. Interviewees include the VTSM Insurance Coordinator, Chief Medical Officer, and other Sports Medicine and Sports Nutrition practitioners. Current screening and identification practices, treatment steps, and average medical costs were all among the data collected.
3. Personal observations.

The existing VTSM and VTSN Stress Fracture Protocol was reviewed in detail. Similarities and differences in this existing protocol and the newly created policy established in part one of this project were noted. Data obtained from the literature review, interviews and observations were all used to review the protocol and propose modifications based on current evidence and suggestions for best practice. The modified protocol was included in the appendix of the newly created policy.

To better understand the feasibility of modifying current VT practices, information regarding costs and steps involved in the treatment of an athlete with vitamin D associated illness or injury was collected. Data collection regarding the average medical costs and steps of treatment were completed through interview. A table with the information collected from interviews was generated with the data. After the interviews, an evaluation of the costs was completed and assessed by the researcher for potential cost savings of modifying the current VT policy. Lastly, a flow chart of athletes' care process was created based on most recent information from the Fall 2019 semester for those diagnosed with a stress fracture. This information was also used in the cost analysis to provide a realistic example of costs.

Personal observations of the researcher regarding practices are identified in notes. Records kept of supplementation distribution, diagnosis of stress fracture, and 25(OH)D testing and results were assessed. Observations within VTSN and VTSM practices and discrepancies are also noted. These observations were used to assess practices and the VT Athletics Stress Fracture Protocol in addition to the interviews.

III. Results

A. Project Part One- Policy

A four-page Virginia Tech Athletics Vitamin D policy was drafted based on evidenced-based recommendations from the literature review. It is a progressive policy employing pragmatic suggestions based on current VT Athletics practices and protocols. A total of five reviewers examined the policy. All reviewers were from various disciplines within Virginia Tech. Their names, position and notes are provided in Table 1. Professionals were selected to represent each interdisciplinary entity that may be involved in the process. After obtaining all reviewers' evaluations, feedback was incorporated into the final policy (Figure 1).

Table 1: Reviewers and Respective Feedback

Reviewer	Reviewers Notes

Jennie Zabinsky, MAEd, RD
VT Performance Nutrition Consultant
	• Recommended Virginia Tech (VT) Athletics policy exclusively- remove vitamin D general policy
	• On VT Athletics policy:
	    o Include vegan/vegetarian athletes as increased risk for vitamin D deficiency
	    o Clarify which athletes are being tested
	    o Clarify the process of using specified medical examination criteria
	    o Explain how serum 25(OH)D recommendations were selected
	    o Specifically state where athletes will pick up vitamin D supplements- VTSN
	    o Use titles to organize the procedure section: education, data collection, and follow up

Aly Onyon, MS, RD, CSSD VT Director of Sports Nutrition	• Inquired about changing the policy to include vitamin D supplementation to athletes with broken bones o ideally test them first? • For the stress fracture protocol- should VT change the dose for concentrations >40 ng/ml to 1-2000 IU instead of MVI?
Dr. Mary Mitchell, MD VT Sports Medicine Fellow	• Explain where recommendations for supplementation come from • Consider expressing that the majority of vitamin D absorption is through sunlight exposure and not dietary consumption
Anne Bryan, MS, ATC Senior Director, Sports Medicine	• Recommended switching sports medicine to team physician within nutrition procedure
Dr. Michelle Rockwell, PhD, RD, CSSD VT Instructor HNFE	• Include soft tissue health within background section of policy • Suggested removing some sections within policy and making information more concise • Assess inclusion regarding calcium • Create a flow chart of policy to facilitate understanding of steps • Clarify parts under medical and physical history to explain criteria are separate than full physical exam

Figure 1: Virginia Tech Athletics Vitamin D Policy

POLICY STATEMENT

BACKGROUND

Vitamin D is an essential fat-soluble vitamin, also regarded as a hormone. It exists in two forms; cholecalciferol or vitamin D_3 and ergocalciferol or vitamin D_2. Of the two forms, vitamin D_2 maintains a shorter half-life, binds less with vitamin D binding protein, and is less efficacious at raising serum 25(OH)D concentrations compared to vitamin D_3. Most commonly known for its role in bone formation and maintenance, inadequate vitamin D concentrations may put athletes at risk of bone-related injury. Additional identified functions of vitamin D include innate and adaptive immune responses, skeletal muscle function, and cognitive function. Links between inadequate vitamin D concentrations and increased risk of upper respiratory tract infection (URTI), depression, gastroenteritis, soft tissue injury and decreased athletic performance have been identified as well.

Athlete specific research has identified inadequate vitamin D concentrations in 56-79% of athlete populations. Factors such as skin color, sunscreen use, uniform, weather, participation in indoor sport, latitude, and diet intake can lead to less than adequate vitamin D concentrations. Universal recommendations have not been established for vitamin D concentrations in athletes. Current practice most commonly measures serum 25-hydroxyvitamin D [25(OH)D] concentrations to assess vitamin D status.

PURPOSE:

The purpose of this policy is to identify, treat and prevent inadequate vitamin D concentrations in athletes. Reference ranges for 25(OH)D are defined in Table 2. Based on 25(OH)D results, athletes will be identified as having deficient, insufficient or adequate vitamin D concentrations. During current pre-participation screening (as described here), potential and current athletes are provided with a determination of medical eligibility for competitive sport(s) that is based on various physical and biological evaluations intended to identify (or raise suspicion of) clinically relevant, preexisting medical abnormalities. It is our goal as a medical and performance staff to ensure adequate screening, including biomarker screening, for all athletes, especially, “high-risk” athletes including, but not limited to female athletes, endurance athletes, dark complexion athletes, and indoor sport athletes as it relates to 25(OH)D inadequacy. Appropriate treatment will be prescribed based on 25(OH)D concentration.

Table 2: Reference Ranges for 25(OH)D Concentrations

	Deficient	**Insufficient**	**Adequate**
VT	<20 ng/mL	20-40 ng/mL	>40 ng/mL

ENTITIES TO WHOM THIS POLICY APPLIES:

All medical and nutrition staff

PROCEDURE:

All athletes will obtain a pre-participation physical examination (PPE) prior to participation in athletics. Athletes from high-risk sports* will automatically complete a 25(OH)D test as part of their pre-participation screening. Of special consideration, optimal 25(OH)D testing is during winter months based on seasonal trends of 25(OH)D in athletes. However, given the schedule for current group testing, beginning of fall is when testing will be completed. All athletes from non-high-risk sports will be examined for risk factors for inadequate 25(OH)D by sports medicine staff at the time of their examination. The currently recognized guidelines for this evaluation include the following:

**High-risk sports which require automatic 25(OH)D testing: Men's and Women's Cross Country, Men's and Women's Track and Field, Men's and Women's Basketball, and Women's Soccer*

*Vitamin D relevant medical history criteria examined at pre-participation screening for all athletes**

Personal history

1. History of stress fracture(s) †
2. RED-S, eating disorder, disordered eating ††
3. Serum 25 (OH)D <20 ng/mL
4. DXA result ≤ -1 SD Z-score †
5. Gastrointestinal malabsorption ††
6. Lactose intolerance or milk allergy ††
7. Female identified with amenorrhea ≥3 months ††

Physical examination

1. Body fat percentage; ≤ 14% for females, ≤ 5% for males ††
2. Muscle pain/weakness
3. Bone pain
4. Fatigue
5. Elevated parathyroid hormone
6. Low serum calcium and/or serum phosphorus levels ††

Risk factors identified during pre-participation physical by examiner or during academic year by any and all responsible entities of this policy:

† automatic 25(OH)D test

†† further medical examination and referral to dietitian required (see Stress Fracture Protocol below)

NUTRITION PROCEDURE:

Athletes who are diagnosed with insufficient or deficient serum 25(OH)D will be given a prescription to pick up a vitamin D supplement from the nutrition department in the dosages outlined in Table 3. Additionally, under the discretion of entities of which this policy applies, calcium supplementation may be prescribed in addition to vitamin D supplementation.

Table 3: Vitamin D Supplement Recommendations Based On Serum 25(OH)D Test Results

25(OH) Result	Recommended Vitamin D_3 Supplementation (3 months)
<20 ng/mL	5000 IU/day
20-40 ng/mL	5000 IU/day
>40 ng/mL	1000-2000 IU/day

Athletes will receive education on supplementation and incorporating vitamin D rich foods into their diet along with information regarding calcium supplementation. Sensible sunlight exposure without sunscreen on arms, legs, neck and head for 5-15 minutes, two to three times per week may be an appropriate alternative to increase vitamin D concentration, unless counterindications exist.

Sports Nutrition will input all athletes who are on vitamin D supplementation into a spreadsheet with the following information: athlete name, sport(s), supplement received, date supplements received, initial or refill supplement acquisition, 25(OH)D concentration and notes.

Sports Nutrition will follow up with athletes who need refills and will also coordinate monthly with Sports Medicine to ensure all athletes with inadequate 25(OH)D concentrations are receiving supplementation. Follow up 25(OH)D testing will occur three months from initial 25(OH)D tests. Based on updated results, supplementation intervention will be modified.

PREVENTION

At the discretion of the medical and nutrition staff, additional education may be provided to athletes, groups or teams for preventative measures. The importance of vitamin D on health and performance, along with food sources will be reviewed. Vitamin D rich foods within the Nutrition Oasis and Performance Center will be available. Education addressing preventative supplementation may be discussed as appropriate.

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APPENDIX:

Figure 1: VT Athletics Vitamin D Policy Flow Diagram

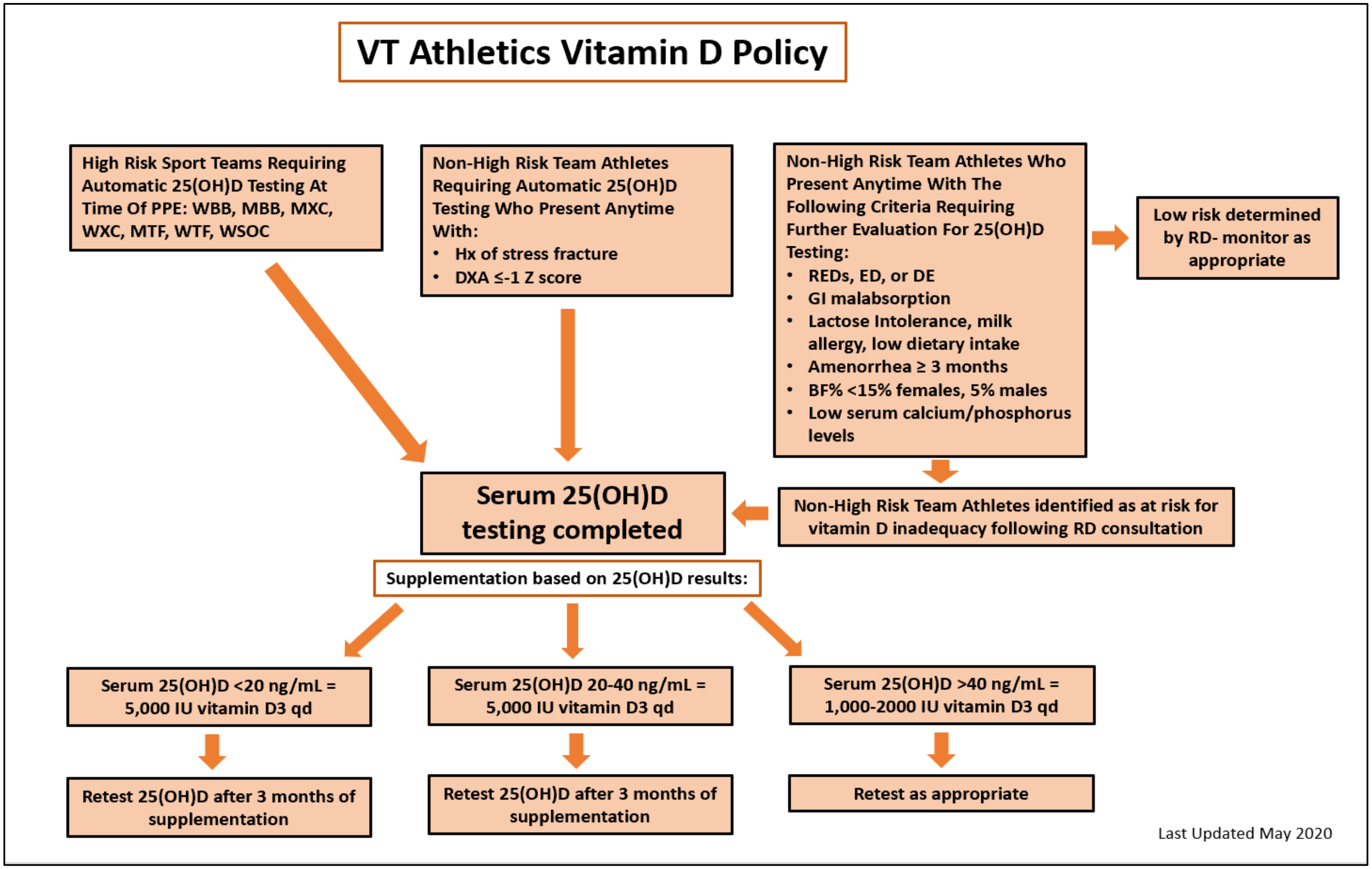


Figure 2: VT Athletics Stress Fracture Protocol

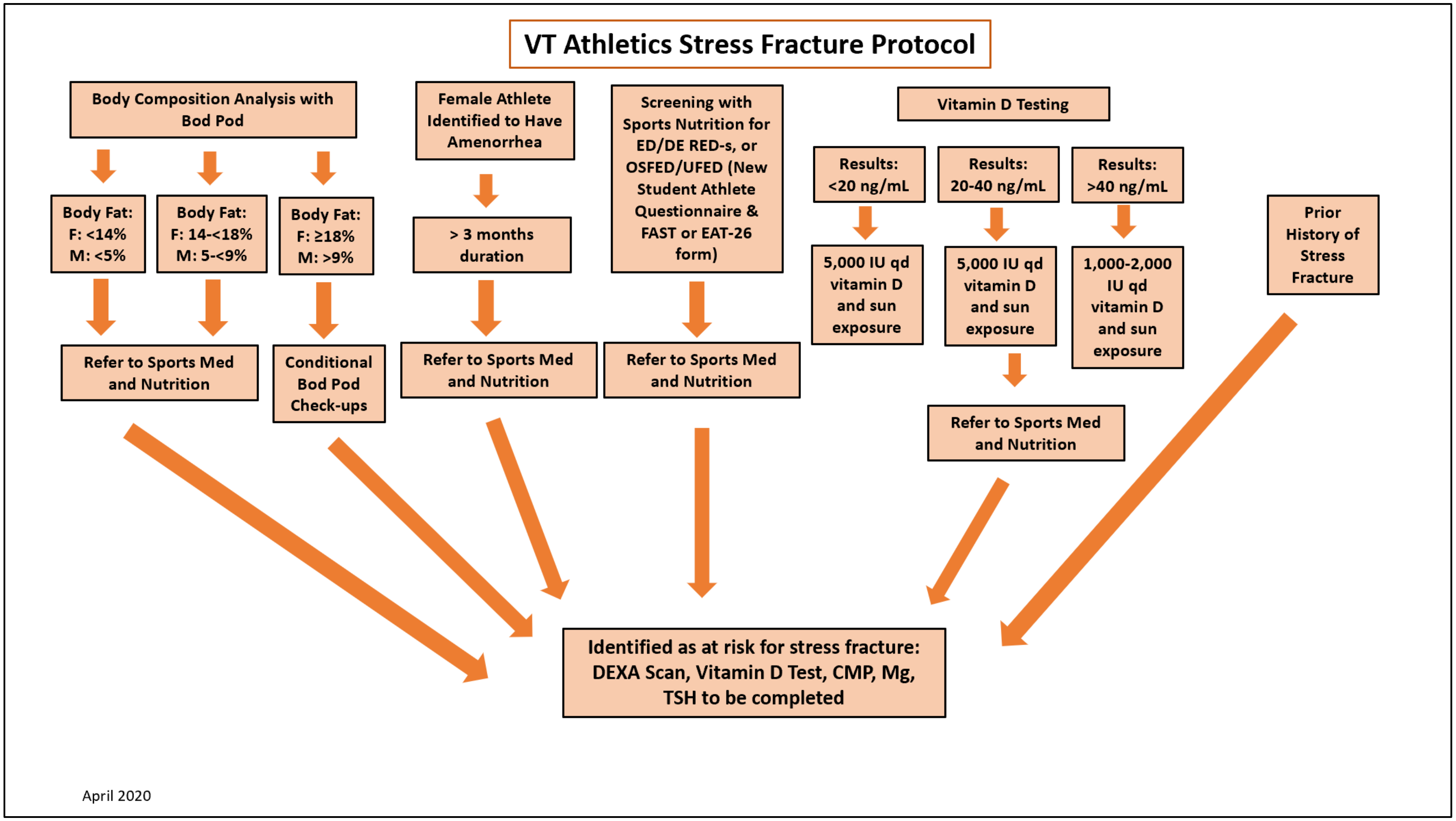


Figure 3: Example of Inadequate 25(OH)D Documentation Template

Low 25(OH)D Athletes Fall 2020									
Athlete First Name, Last Name	Email	Sport	25(OH)D (ng/mL) Fall 2020 PPE	Reading Day Lab Draw Dec 2020	Reading Day Lab Draw May 2021	Supplements Given and Date Provided	Date Emailed with Results and RD Initials	Stress Fracture & Date of Dx	Notes
Jane Doe	jdoe@vt.edu	XC	18.9	24.7	29.2	VD- 8/12, 11/15, 2/21	AB- 8/14, 11/16, 2/22	No	

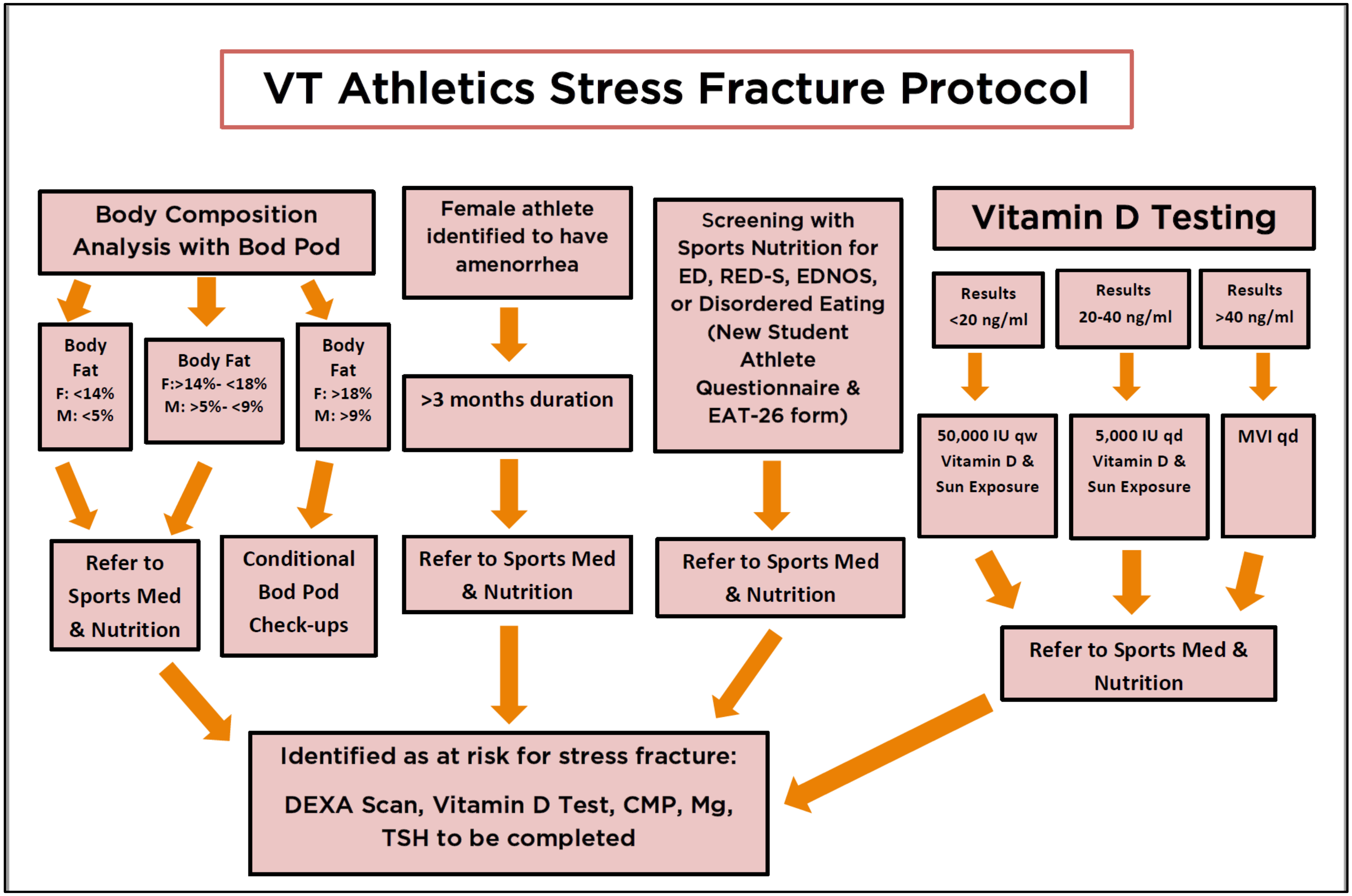
B. Project Part Two- Policy and Practice Comparison

The second portion of this project evaluated current vitamin D protocols and practices currently utilized by VTSM and VTSN particularly as related to stress fracture. Stress fracture was used as a sample diagnosis to examine more closely due to its prevalence, costliness and impact on staff and athletes. This evaluation intended to identify differences between the newly created policy and current practices and tools. This information will be utilized to make recommendations for the advancement of future practices. The following three outcomes were collected for the evaluation.

VT Athletics Stress Fracture Protocol

The current stress fracture protocol is shown in Figure 2. The information within this protocol is one of the main guidelines for VT Athletics regarding vitamin D and stress fracture. It aims to identify risk factors for stress fracture that may warrant a referral for further workup by VTSM and VTSN. Upon further evaluation, an athlete may be recommended for vitamin D testing.

Figure 2: VT Athletics Stress Fracture Protocol



Interviews

To better understand the average healthcare process and associated costs when diagnosing and treating a stress fracture, interviews with the VT Insurance Coordinator and Chief Medical Officer were completed. Information regarding diagnostic testing, care team appointments, equipment, therapy treatment and nutrition testing and supplementation was collected.

During the average medical process for stress fracture, an athlete will at the minimum see their athletic trainer and sport physician for consultation. From there, diagnostic examination, blood testing, medicine or supplement prescription, and acquisition of medical equipment are often required. The average course of treatment includes an initial off-campus x-ray along with a radiologist's reading of the results. Often, a MRI is necessary to confirm the diagnosis of a stress fracture after an initial x-ray. After diagnosis, treatment for a stress fracture includes custom orthotics and may include bone stimulation treatment. Additional tests may be ordered such as a diagnostic bone scan or secondary x-ray to confirm healing. A chronological list of these medical services and the associated costs have been listed in the Table 2. An analysis of the total costs associated with the average healthcare process for a stress fracture was also calculated. A range for the total was calculated to provide an example of lowest to highest costs associated with treatment. The total potential costs to treat a stress fracture for one athlete was $1,680 to $8,956. To treat all eight athletes diagnosed with a stress fracture in the Fall 2019 semester was $13,440 to $71,648.

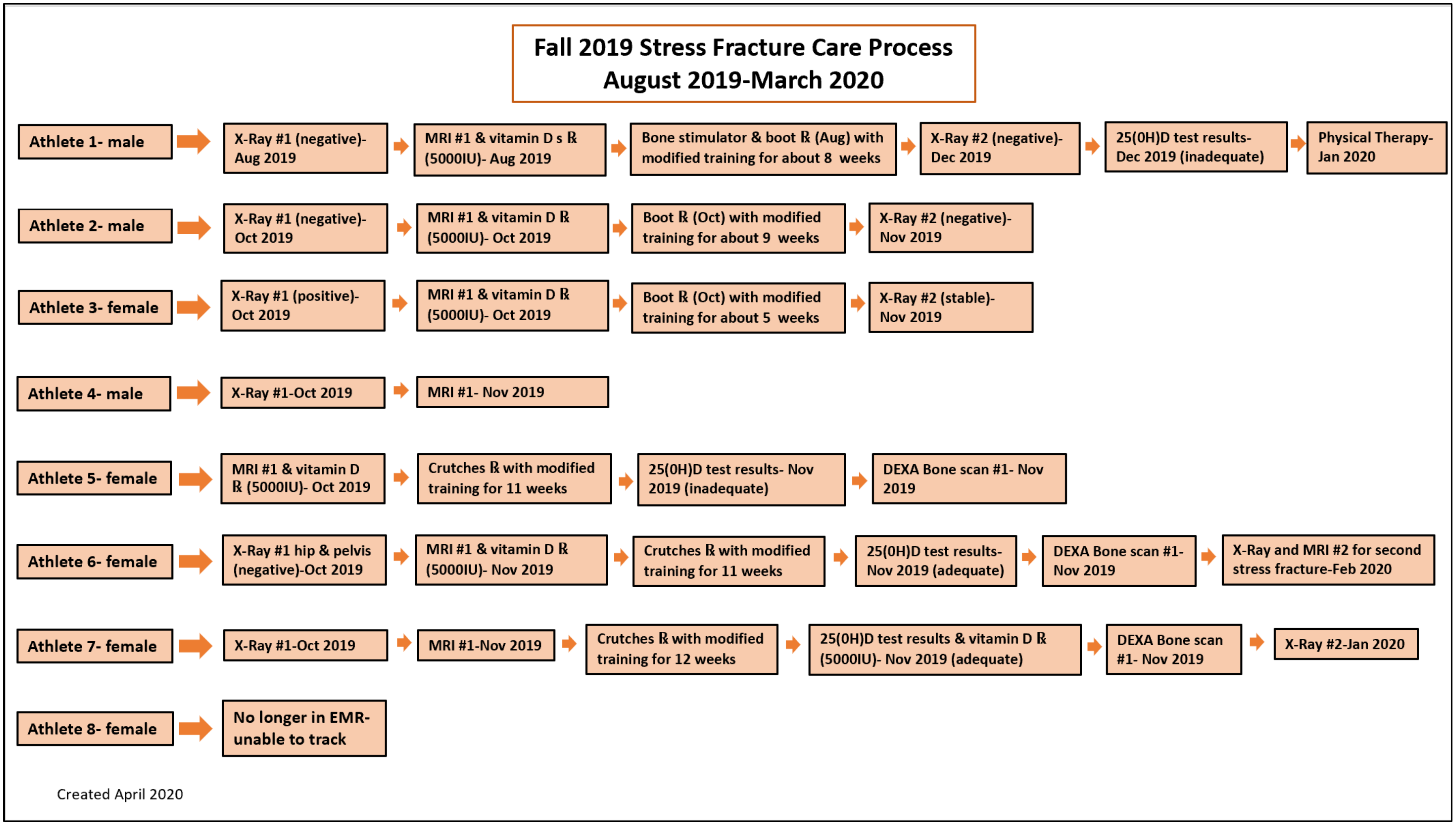
In addition to healthcare care costs, time lost from training and competition was also considered. A total of eight Virginia Tech athletes were diagnosed with a stress fracture in the Fall 2019 semester. Each athlete's care process was examined using the VT Athletics electronic medical record (EMR). One athlete was no longer in the EMR so a total of seven were assessed. The average length of time from diagnosis to return to full activity was 9.3 weeks. A flow chart of each athlete's care process was created (Figure 3).

Table 2: VT Stress Fracture and Vitamin D Cost Evaluation

Medical Service or Equipment	Average Estimated Cost	Average Time Associated to Completion
X-ray *requires radiologist reading	$900 + $380	Average 1 day
Bone scan for stress fracture *requires anesthesiologist	$1500 + $380	Average 1 week to schedule
MRI *requires radiologist reading	$2500 + $380	
Bone stimulator treatment	$2500	
Custom orthotics	$400	
Serum 25(OH)D test	$30-60	
Vitamin D and Calcium *1 bottle of each	$8 vitamin D 5000 IU $8 calcium 500 mg	
Total- bottom range includes 1 x-ray and 1 custom orthotic; top range includes 1 x-ray, 1 bone scan, 1 MRI, bone stimulator treatment, 1 set of custom orthotics and 1 round of supplementation with vitamin D and calcium	$1,680-$8,956 person/stress fracture Cost for 8 athletes = $13,440-$71,648	

*Data received from VT Sports Medicine Insurance Coordinator. Costs reflect those of VT Sports Medicine

Figure 3: Fall 2020 Stress Fracture Health Care Process



Personal Observations

The researcher recorded personal observations of current practices and protocols used within VT Athletics. Observations included practices relating to the VT Athletics Stress Fracture Protocol, record keeping of supplement distribution, serum (25OH)D testing, education, and general practices. In addition to the information collected from the interviews, these observations were used further to assess current VT protocols and procedures.

Table 3: Researcher Observations

	Observation Notes
VT Athletics Stress Fracture Protocol	• Have not observed a 25(OH)D test ordered for listed risk factors: low body fat percent, amenorrhea, ED/DE or RED-S
Supplement Distribution and Record Keeping	• 5000 IU is the only dose provided from VTSN for inadequate vitamin D concentrations • Athletes provided 3 refills of vitamin D, however, inconsistencies regarding period of supplementation were observed • Supplements distributed by VTSN are recorded in supplement log including the following information: name, sport, refill or initial bottle, education provided, script obtaining, RD distributing • Multivitamin (MVI) provided in Nutrition Oasis, which contains 400 IU of cholecalciferol, but is not monitored • Football, Men's and Women's Basketball obtain a daily vitamin D supplement along with daily MVI year long
Serum 25(OH)D Testing	• Vitamin D tests usually ordered during diagnostic testing or after diagnosis for stress fracture only • Do not currently screen athletes for inadequate vitamin D, except for Men's and Women's Basketball • Must be ordered by physician • Have not observed consistent follow up testing for athletes with inadequate vitamin D concentrations
Education	• Athletes provided education when given initial vitamin D supplement-inconsistent follow up education noted
General Practices	• Serum 25(OH)D testing not completed by every athlete diagnosed with a stress fracture

IV. Discussion

The purpose of this project was to create a progressive vitamin D policy specifically for the VT Athletics Department. Policies are commonplace tools in athletic departments that outline a system of guidelines and procedures that athletics personnel are expected to implement. Some current VTSN policies include guidance regarding supplementation, biomarker testing, and body composition. This project's policy aims to standardize care, reduced the risk of potentially preventable conditions, outline financial implications, and advance the quality of care related to the screening, identification, and treatment of inadequate vitamin D. Currently, a VT Athletics Stress Fracture Protocol exists, however, it is incomplete in regards to addressing all screening, identification, treatment and prevention components as it is regarding insufficient and deficient vitamin D.

Vitamin D Policy

In a study on Division I collegiate athletic programs, 20% of schools reported a "formal protocol or policy related to the evaluation, prevention, or treatment (or a combination of these)" of insufficient or deficient vitamin D (Rockwell, Hulver & Eugene, 2020). These findings in combination with the high prevalence of inadequate 25(OH)D concentrations in athletes represents an area of need within programs. Without a policy, inconsistencies may arise, athletes may be accidentally overlooked, and recovery from injury delayed or compromised. Recommendations within the policy are based on the evidence, but were also adapted based on feasibility for VT Athletics. Based on the assessments of the VT Athletics Stress Fracture protocol, current spending related to vitamin D testing and supplementation, and observations, construction of the policy and its parts was conducted. The selection of teams who warrant automatic testing was based on the literature regarding highest risk for stress fracture or inadequate vitamin D concentrations (Lappe et al., 2018; Rockwell et al., 2020). Stress fracture was used for deeper analysis in this study. Risk of stress fracture has been related to vitamin D status and is common, tangible, and costly in treatment for many sport programs (Rockwell, Zabinsky, Frisard, Davy, Hulver, in review). If there was full support and infinite financial resources, the policy would recommend all athletes from all sports obtain a 25(OH)D test and conducted in the winter. The purpose of this would be to protect the health and welfare of all athletes to avoid stress fracture, reduce URTI, boost immune systems and potentially aid performance as supported by the literature. The fall testing time was selected because that is the only time large group testing is performed which coincides with pre-performance physical exams (PPEs). Winter would be ideal based on trends in the literature when 25(OH)D concentrations are lowest.

Protocol Analysis

Prior to this project, the VT Athletics Stress Fracture Protocol was the main guideline for vitamin D testing within the VT Athletics Department. An evaluation of this protocol enabled the researcher to asses two things; currency of evidence and understanding of current guidelines and its components. The protocol is evaluated annually by VTSN staff for currency and accuracy with respect to new literature. As a result, few changes were suggested to the protocol. The most significant modifications included the addition of past stress fracture history to risk factors, changing treatment dosage to 5000 IU for serum 25(OH)D concentrations less than 20 ng/mL, increasing the maintenance dose to at least 1000 IU per day and updating current department eating disorder screening tools. The dosage changes were supported by evidence suggesting high dose vitamin D supplementation may be detrimental to bone mineral density and skeletal muscle function (Owens et al., 2016). The Endocrine Society suggests 1500-2000 IU per day to obtain adequate 25(OH)D concentrations and the current multivitamin provided at VT contains 400 IU of vitamin D. This amount is below the RDA of 600 IU which is debated as adequate to maintain optimal concentrations.

Interviews and Cost Analysis

Interviews with VTSM staff were conducted to gain a better understanding of how stress fracture is treated by the department. The associated time, steps and costs with diagnosing and treating a stress fracture were collected. The purpose of collecting this information from the interviews was to assess all the costs in order to propose feasible suggestions within the policy. Additionally, the cost analysis illustrates current costs in comparison to potential costs of suggested changes. This information may allow VT Athletics to weigh options and ultimately encourage change.

In combination with information collected from the interviews, the EMR was utilized to gather information regarding typical health care processes to treat a stress fracture. From this, a range of estimated financial costs was calculated. Not every case included the same tests, frequency of testing and intervention. This would result in a difference in medical costs. A total of eight athletes were diagnosed with a stress fracture in the Fall 2019 semester. With this number, it was estimated that treatment for all eight athletes ranges from $13,440 to $71,648. The mean cost for one athlete’s treatment is estimated around $4,478. One outcome of the policy is to reduce the frequency of stress fracture. If the policy was adopted this would provide vitamin D screening for selected very high-risk teams and very high-risk individuals (not from very high-risk teams).

The costs of providing such testing as proposed by this policy would be about $9,400. This includes a total of 188 athletes at a cost of $50 per 25(OH)D test (168 very high-risk sport athletes plus 20 very high-risk individual athletes). Hypothetically, if one-third of these athletes (62 athletes) had insufficient or deficient vitamin D, the cost to re-test 25(OH)D once would be $3,100. Supplementation costs for these identified individuals would be $2,967 for three bottles of vitamin D and three bottles of calcium per person.

Understanding the extra expense this policy presents, costs may be mitigated through proactive screening of very high-risk teams and athletes by potentially reducing frequency of stress fracture and its associated costs. Perhaps of more concern, another benefit of adopting the policy is the reduction of sport participation cost to the athletes and teams. Reduced stress fractures would allow more athletes to remain healthy and eligible to train and compete.

Health Care Process

Stress fracture information was collected from the EMR to utilize applicable and current information when calculating the cost analysis. During the process, the researcher was provided a list of athletes diagnosed with a stress fracture from VTSM staff. This list was then used to evaluate the health care process by which the athletes were diagnosed and treated. This information validated the report from the interview with the VTSM Insurance Coordinator. There was a total of eight athletes diagnosed with a stress fracture in the Fall 2019 semester, however, one athlete was no longer in the EMR. A total of seven were reviewed, of which three were male athletes and four were female. The average length of time an athlete had modified training was 9.3 weeks. This information was collected from doctor and athletic training notes in the EMR. All seven athletes had at least two imaging tests completed, in conjunction, some athletes received additional services that varied. Of the seven, four athletes completed a serum 25(OH)D test during time of treatment. Among the four tested, two athletes had adequate 25(OH)D concentrations (>40 ng/mL) and two inadequate (<40 ng/mL). Vitamin D supplementation was provided to six of the seven athletes despite conducting a serum 25(OH)D test or not.

In a group of 249 Division I universities, 78% of collegiate athletic programs reported general health status or health history were indicators for 25(OH)D testing. Of the same 249 programs, 74% reported injury status or injury history as indicators for 25(OH)D testing. Vitamin D screening was conducted by 20% of respondents (Rockwell, Hulver, & Eugene, 2020). The adoption of the newly proposed policy would increase screening and the use of 25(OH)D testing. This aims to standardize care, improve treatment outcomes, prevent stress fractures and reduce financial and sport participation costs associated with stress fractures.

Observations

The third form of data collection was obtained through observations of the researcher. The researcher was in a unique role to observe the VTSM and VTSN practices and tools related to vitamin D. The purpose of recording observations was to reinforce information collected from interviews, protocols and practices. Additionally, the observations intended to identify areas of opportunity that would benefit the department if considered.

Through these observations, the researcher noted, athletes were provided calcium and vitamin D supplementation by VTSN, however, inconsistencies in length of supplementation were observed. Some athletes would take vitamin D for a few weeks, whiles others several months. This may be related to inconsistent serum 25(OH)D testing and follow up testing. Standardizing such testing may help ensure an athlete is taking an appropriate dose of vitamin D for the appropriate length of time. For example, an athlete may be diagnosed with a stress fracture which takes eight weeks to heal and has an adequate serum 25(OH)D. During the eight weeks, they take 5000 IU of vitamin D and continue taking the same dose after recovery. The athlete may be better served taking 2000 IU as a maintenance dose which would be indicated by obtaining an initial serum 25(OH)D test.

Secondly, it was observed that follow up 25(OH)D testing was completed inconsistently. This re-testing is important in assessing the efficacy of supplementation and guides the length and dose of supplementation. This is especially important for athletes with inadequate vitamin D concentrations.

Thirdly, vitamin D tests were inconsistently ordered and typically only occurred when an athlete was suspected to have a stress fracture or was diagnosed with a stress fracture. Enacting vitamin D screening has the potential to reduce the prevalence of stress fracture. Adopting the newly created policy can identify athletes at most risk and aid in the prevention of worsening conditions.

Practical Applications

This progressive policy is intended to be an initial change agent that is expected to evolve and mold to the program's needs. Ultimately, it may improve health outcomes for athletes, reduce the prevalence of vitamin D deficiency and insufficiency, and prevent illness and injury associated with inadequate vitamin D along with its financial implications. This project can serve as a template for other institutions to adopt a policy that best suits their athletes based on program resources too. Some barriers to implementing this policy include the associated costs for the proposed testing and supplementation. Additionally, staffing resources, staff buy-in and athlete compliance may also be barriers. Future opportunities may include research on the impacts implementing a vitamin D policy has on health outcomes, performance and efficacy of implementing a policy.

Strength and Limitations

Intimate and real-life data collection within a Power Five, Division I university enabled the researcher to make relevant recommendations regarding practices relating to vitamin D. Various components including screening, testing, supplementation, and education on vitamin D were assessed. Stress fracture is a pertinent injury that affects many sports programs. Practices and costs associated with stress fracture provide valuable information to guide future practices at the studied institution. Given the lack of universal recommendations regarding vitamin D for athletes, this project provides a pragmatic approach to medical care related to vitamin D. Additionally, through the implementation of the newly created policy, improvements in the efficiency and consistency of care may result and could potentially alleviate costs. The tools in the project may also be used by other institutions which could lead to standardized care across a larger body.

Review of several universities and their practices related to vitamin D would have strengthened this project. Assessment of additional semesters would have added strength to the stress fracture health care process evaluation. Other limitations include costs associated with implementing such a policy. While there is potential that implementation of the new policy may alleviate costs associated with stress fracture treatment, there is no direct evidence to support this. Lastly, fall screening is not the ideal time to obtain a baseline serum 25(OH)D tests, but given the systematic structure within the department this is the best time to obtain the quantity of tests in tandem with other routine lab test.

Conclusion

Navigating care related to vitamin D proposes challenges for health care providers due to inconsistencies in research related to health and human performance. Additionally, practices related to screening, identifying, and treating insufficient and deficient 25(OH)D are variable and costly. The tools from this project including the newly created policy, cost analysis on stress fracture, and health care process flow diagram, aim to provide resources for VT Athletics to ameliorate current practices in a progressive and pragmatic fashion. Continuing research on vitamin D and athletes is essential to clarify inconsistencies. More research on the efficacy of implementing a vitamin D policy is also needed to evaluate the benefits and challenges to athletic departments and their respective athletes.

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