[Primary Care]

Prevalence of Abnormal Vitamin D Levels Among Division I NCAA Athletes

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Background: Up to 1 billion people have insufficient or deficient vitamin D levels. Despite the well-documented, widespread prevalence of low vitamin D levels and the importance of vitamin D for athletes, there is a paucity of research investigating the prevalence of vitamin D deficiency in athletes.

Hypothesis: We investigated the prevalence of abnormal vitamin D levels in National Collegiate Athletic Association (NCAA) Division I college athletes at a single institution. We hypothesized that vitamin D insufficiency is prevalent among our cohort.

Study Design: Cohort study.

Level of Evidence: Level 1.

Methods: We measured serum 25-hydroxyvitamin D (25(OH)D) levels of 223 NCAA Division I athletes between June 2012 and August 2012. The prevalence of normal ($\geq$32 ng/mL), insufficient (20 to <32 ng/mL), and deficient (<20 ng/mL) vitamin D levels was determined. Logistic regression was utilized to analyze risk factors for abnormal vitamin D levels.

Results: The mean serum 25(OH)D level for the 223 members of this study was 40.1 ± 14.9 ng/mL. Overall, 148 (66.4%) participants had sufficient 25(OH)D levels, and 75 (33.6%) had abnormal levels. Univariate analysis revealed the following significant predictors of abnormal vitamin D levels: male sex (odds ratio [OR] = 2.83; P = 0.0006), Hispanic race (OR = 6.07; P = 0.0063), black race (OR = 19.1; P < 0.0001), and dark skin tone (OR = 15.2; P < 0.0001). Only dark skin tone remained a significant predictor of abnormal vitamin D levels after multivariate analysis (adjusted OR = 15.2; P < 0.0001).

Conclusion: In a large cohort of NCAA athletes, more than one third had abnormal vitamin D levels. Races with dark skin tones are at much higher risk than white athletes. Male athletes are more likely than female athletes to be vitamin D deficient. Our study demonstrates a high prevalence of vitamin D deficiency among healthy NCAA athletes.

Clinical Relevance: Many studies indicate a significant prevalence of vitamin-D insufficiency across various populations. Recent studies have demonstrated a direct relationship between serum 25(OH)D levels and muscle power, force, velocity, and optimal bone mass. In fact, studies examining muscle biopsies from patients with low vitamin D levels have demonstrated atrophic changes in type II muscle fibers, which are crucial to most athletes. Furthermore, insufficient 25(OH)D levels can result in secondary hyperparathyroidism, increased bone turnover, bone loss, and increased risk of low trauma fractures and muscle injuries. Despite this well-documented relationship between vitamin D and athletic performance, the prevalence of vitamin D deficiency in NCAA athletes has not been well studied.

Keywords: vitamin D; deficiency; athletes; prevalence

Abnormal vitamin D levels have been implicated broadly in infectious disease, autoimmune disorders, certain forms of cancer, cognitive decline, and cardiovascular disease.[16] Measurement of serum 25-hydroxyvitamin D (25(OH)D) provides the best determination of vitamin D status.[24] Despite an accepted method of measuring vitamin D levels, there exists no consensus for specific optimal vitamin D levels.[23] Vitamin D levels cited commonly in orthopaedic literature are as follows: ≥32 ng/mL (sufficient), 20 to 32 ng/mL (insufficient), and <20 ng/mL (deficient).[4] These values are based on cut-offs believed to optimize intestinal calcium absorption, avoid hyperparathyroidism, and prevent osteoporotic fractures.[3,19]

Many studies document vitamin D insufficiency across various populations. Up to 1 billion people (including children, adults, and the elderly) have insufficient or deficient vitamin D levels.[14] A recent study evaluating 634 healthy adults found that 64% had insufficient vitamin D levels.[22] Of 723 patients undergoing orthopaedic surgery, the prevalence of abnormal vitamin D levels was 43%.[21] High rates of vitamin D insufficiency have also been reported among black and white children in the Northeast United States, with prevalence upward of 30% for both races.[10] In China, the prevalence of vitamin D deficiency during the winter months was 89.2%.[12]

Eighty percent of players on a National Football League team had deficient or insufficient vitamin D levels (Shindle MK, Voos JE, Gulotta L, et al. "Vitamin D Status in a Professional American Football Team." Presented at the AOSSM Annual Meeting, 2011). This is concerning because there is a relationship between vitamin D and muscle power, force, velocity, and optimal bone mass.[12,26] Muscle biopsies from patients with low vitamin D levels demonstrate atrophic changes in fast twitch type II muscle fibers, which are crucial to most athletes.[2,7] Insufficient 25(OH)D levels can stimulate the production of parathyroid hormone, resulting in secondary hyperparathyroidism, increased bone turnover, bone loss, and increased risk of low-trauma fractures.[15] A prospective study of elite ballet dancers found that vitamin D supplementation during winter months resulted in significantly fewer musculoskeletal injuries.[27]

The purpose of this study was to investigate the scope of abnormal vitamin D levels in National Collegiate Athletic Association (NCAA) Division I college athletes at a single institution. We hypothesized that vitamin D insufficiency is prevalent among NCAA Division I college athletes.

METHODS

After incidentally noting a high rate of abnormal vitamin D levels in athletes with stress fractures, our goal was to determine which athletes were at risk and whether supplementation was necessary. Vitamin D levels were obtained for 223 (40%) of 559 athletes at the University of Southern California participating in athletic competition during the year of 2012. We then retrospectively reviewed the data following approval by our institutional review board.

Laboratory Studies

One resting venous blood sample was taken from each study participant between June 2012 and August 2012. Measurement of serum 25(OH)D was done using liquid chromatography–tandem mass spectrometry that had an analytical sensitivity of 4 ng/mL for 25(OH)D$_2$ and 25(OH)D$_3$. Laboratory results were collected by a means of retrospective chart review.

Demographics

Patient demographic variables including age, sex, race, body mass index (BMI), sport type, sport location, and sport season were obtained by retrospective chart review.

Outcome Measures

Vitamin D sufficiency was defined as a serum 25(OH)D level greater than 32 ng/mL. A level between 20 and 32 ng/mL was insufficient, and a level less than 20 ng/mL was deficient.

Statistical Analysis

Descriptive statistics, univariate, and multivariate analyses were performed utilizing the MedCalc statistical software (MedCalc Software, Ostend, Belgium). Descriptive statistics included mean, median, standard deviation, and percentages of patients with sufficient (≥32 ng/mL), insufficient (20 to <32 ng/mL), and deficient (<20 ng/mL) serum 25(OH)D levels.

Univariate logistic regression models were used to determine independent odds ratios for abnormally low vitamin D levels and sex, race, skin tone, or BMI. These models were utilized for each individual sport initially. Subsequently, univariate logistic regression models were used to determine the independent odds ratios for vitamin D insufficiency for sex, race, skin tone, BMI, sport type, sport location, and sport season with data from all sports teams combined. Age was not investigated as a risk factor, as the age range for college athletes was too narrow to offer any clinical significance. The P value was set at <0.05. In addition to unadjusted odds ratios, 95% confidence intervals were calculated for each risk factor.

Multivariate logistic regression analysis was also performed to determine the association between vitamin D insufficiency and the independent variables for each individual sport while controlling for possible confounding effects. Then, multivariate logistic regression analysis was performed again, for all sports combined, to determine the association between abnormal vitamin D levels and sex, race, skin tone, sport type, sport location, and sport season. BMI was not included in our multivariate analysis given that BMI values were not available for nearly half of our study cohort. A stepwise logistic regression model was used to determine the adjusted odds ratio, 95% confidence interval, and significance (set at $P < 0.05$). In our multivariate analysis, sex, race, skin darkness, sport type, sport location, and sport season were all analyzed as categorical variables.

RESULTS

Subject Characteristics

There were 223 NCAA Division I college athletes participating in the 2012-2013 athletic season; 121 men and 102 women (Table 1). Table 1 and Figure 1 show the distribution of athletes by race. Table 1 also shows the breakdown of athletes by BMI, skin tone, sport type, sport location (indoor vs outdoor), and sport season.

For statistical analysis, we stratified study participants by BMI (Table 1). Of note, however, BMI provides a poor measurement of fitness and general health for athletes with high muscle composition.

Vitamin D Insufficiency Prevalence

Analysis of serum 25(OH)D levels for all 223 members of this study cohort revealed a normal distribution, with a mean of 40.1 ± 14.9 ng/mL, a median of 37 ng/mL, a minimum value of 13 ng/mL, and a maximum value of 92 ng/mL. Overall, 148 (66.4%) members had sufficient 25(OH)D levels, and 75 (33.6%) had abnormal levels. Among the group with abnormal levels, 68 (30.5%) had insufficient levels and 7 (3.1%) had deficient levels (Table 2).

Vitamin D Insufficiency Prevalence by Sport

Table 2 and Figure 2 show the number of athletes found to have normal, insufficient, or deficient vitamin D levels for each individual sport.

Risk Factors for Abnormal Vitamin D Levels for All Sports Combined

Possible independent associations between abnormal serum 25(OH)D levels and sex, race, skin darkness, BMI, sport type, sport location, and sport season were investigated through univariate analysis (Table 3).

Male athletes had a statistically significant 2.8-fold higher odds of having had abnormal vitamin D levels relative to female athletes in our cohort (95% confidence interval [CI] = 1.57-5.13; $P = 0.0006$).

Athletes with dark skin tone had a statistically significant 15.2 times greater likelihood of having abnormal vitamin D levels relative to light-skinned athletes (95% CI = 7.6-30.5; $P < 0.0001$). Sixty-five percent of dark-skinned individuals and 11% of light-skinned individuals had abnormal vitamin D levels (Figure 3).

Athletes with BMIs of 25.0 to 29.9 kg/m^2 were less likely to have abnormal 25(OH)D levels relative to those with BMIs of 18.5 to 24.9 kg/m^2, with a 95% CI of 0.21 to 1.86. This association, however, was not statistically significant, with $P = 0.40$. Furthermore, athletes with BMI ≥ 30 kg/m^2 were also less likely to have had abnormal 25(OH)D compared with athletes with BMIs of 18.5 to 24.9 kg/m^2 (95% CI = 0.23-2.18). This association was also not statistically significant, with $P = 0.55$.

Spring sports participants had a statistically significant 96% decreased odds of having abnormal vitamin D levels relative to participants in fall sports (95% CI = 0.0026-0.73; $P = 0.03$).

Table 1. Athlete characteristics

	Overall Population
Number of patients	223
Men	121
Women	102
Body mass index	
Known body mass index	120
Average body mass index, kg/m^2	29.2 ± 4.3
Underweight (<18.5 kg/m^2)	0
Normal (18.5-24.9 kg/m^2)	17
Overweight (25.0-29.9 kg/m^2)	58
Obese ($\geq$30 kg/m^2)	45
Race	
Black	78
Hispanic	12
White	114
Asian	7
Other	12
Skin tone	
Dark	94
Light	129
Sport season	
Fall	176
Winter	26
Spring	21
Sport location	
Indoor	38
Outdoor	185

Winter sports participants had a 2.20-fold greater risk of having abnormal vitamin D levels relative to fall sports participants, but this association was not statistically significant (95% CI = 0.96-5.05; $P = 0.06$).

For all sports combined, only dark skin tone remained a significant predictor of outcome after controlling for all other
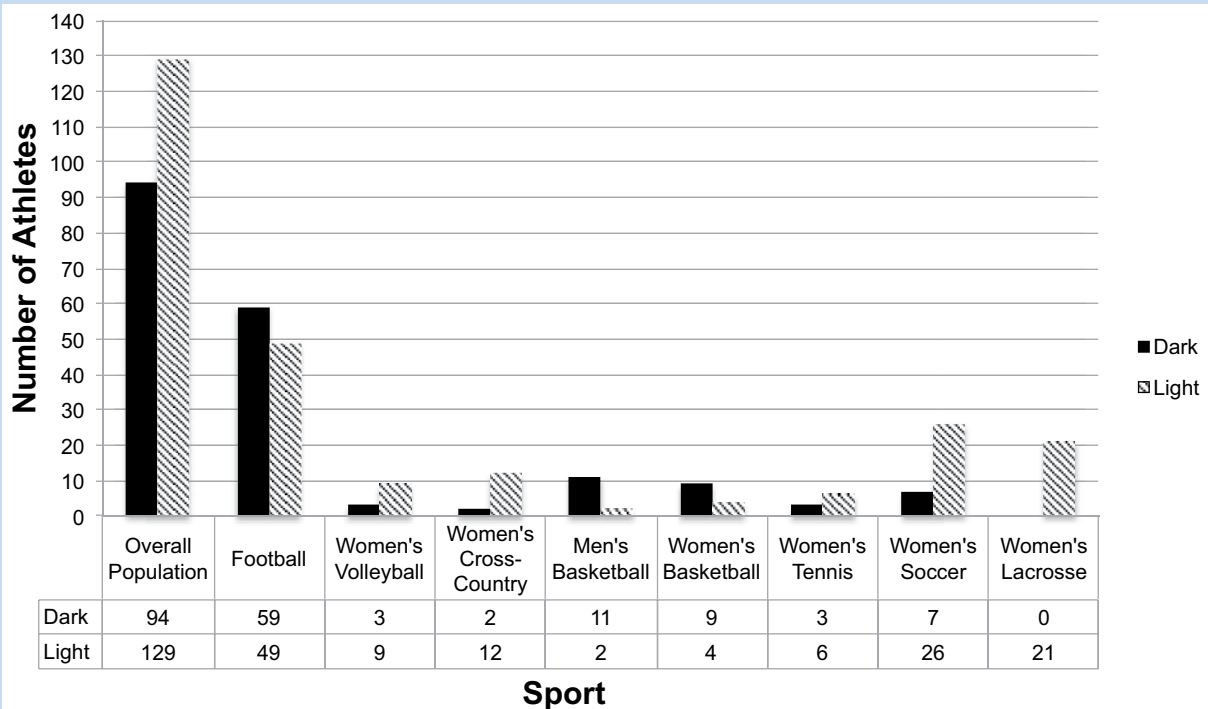
Figure 1. Skin tone by sport.

variables in our multivariate analysis. Dark-skinned athletes had an adjusted odds ratio of 15.2 (95% CI = 7.5-30.5), with a P value of <0.0001. All other variables were eventually dropped from our stepwise logistic regression model as they did not maintain statistical significance as predictors of abnormal vitamin D levels (Table 4).

DISCUSSION

Prevalence studies for vitamin D insufficiency are complicated by the diverse nature of different studies' subject cohorts, especially given that many factors, including geographic location, sport type, sex, and race, can influence vitamin D levels.

Our finding of a statistically significant association between skin tone and vitamin D levels is similar to that of Bogunovic et al,[4] who also found that dark-skinned athletes had statistically significant increased odds of having abnormal vitamin D levels relative to light-skinned athletes. Dark-skinned individuals likely have higher odds of vitamin D insufficiency as they maintain higher melanin levels.[1,14,15]

Although we investigated BMI as a potential risk factor for abnormal vitamin D levels, we posit that the investigation of BMI as a possible risk factor for vitamin D insufficiency among athletes poses a dilemma as athletes, especially football players, have high BMIs in general secondary to high muscle rather than

fat composition. BMI provides a poor measurement of fitness and general health for athletes with high muscle composition, and therefore, any correlation would be weak and the significance would be confusing. In fact, it has been suggested that subcutaneous fat patterns provide a better screening tool to characterize fatness in physically active, young athletes.[25]

Our finding that the women's volleyball and women's lacrosse teams had a statistically significant decreased risk of having abnormal vitamin D levels relative to the football team did not remain statistically significant after multivariate analysis. This suggests that although certain teams appear protected from abnormal vitamin D levels, this is more likely related to the race, skin tone, and sex composition of the team.

Similarly, our finding that indoor sports athletes had an increased odds of having abnormal vitamin D levels relative to outdoor sports athletes did not maintain statistical significance after undergoing multivariate analysis, suggesting that the univariate association was more likely secondary to the race, skin tone, and sex composition of the indoor sport athletes.

Athletes with muscle injuries have significantly lower vitamin D levels relative to uninjured players.[20] Muscle biopsies from athletes with low vitamin D levels have demonstrated atrophic changes in fast twitch type II muscle fibers, which are crucial to most athletes[2,7] Those with higher serum 25(OH)D levels have statistically significant higher jump velocities, jump heights, and Esslinger Fitness Indexes.[26]

Table 2. Vitamin D levels (in ng/mL)

	Overall Population	Football	Women's Volleyball	Women's Cross-Country	Men's Basketball	Women's Basketball	Women's Tennis	Women's Soccer	Women's Lacrosse
						Sport			
Mean	40.1	35.6	46.7	47.7	30.4	33.0	47.3	43.0	56.9
Median	37	34	53.5	45	32	27	45	42	56
Standard deviation	14.9	11.7	21.0	14.1	6.0	14.2	13.7	16.0	11.1
Minimum	13	13	15	31	18	14	25	16	38
Maximum	92	72	75	78	41	66	68	92	80
No. normal	148	61	8	13	7	5	8	25	21
No. abnormal	75	47	4	1	6	8	1	8	0
No. sufficient (≥32)	148	61	8	13	7	5	8	25	21
No. insufficient (20 to <32)	68	45	2	1	5	7	1	7	0
No. deficient (<20)	7	2	2	0	1	1	0	1	0
% abnormal	33.6	43.5	33.3	7.1	46.1	61.5	11.1	24.2	0

Table 3. Univariate analysis of potential risk factors for abnormal vitamin D levels (all sports combined)[a]

	Abnormal	Normal	Odds Ratio	95% Confidence Interval	P Value[b]
Sex (223)					
Female (102)	22	80	Reference	Reference	
Male (121)	53	68	2.83	1.57-5.13	**0.0006**
Race (223)					
White (114)	12	102	Reference	Reference	
Hispanic (12)	5	7	6.07	1.66-22.15	**0.0063**
Black (78)	54	24	19.12	8.88-41.20	**<0.0001**
Asian (7)	1	6	1.42	0.16-12.78	0.76
Other (12)	3	9	2.83	0.67-11.92	0.16
Skin darkness (223)					
Light—White, Asian, others (94)	14	115	Reference	Reference	
Dark—Black, Hispanic (129)	61	33	15.18	7.56-30.52	**<0.0001**
Body mass index, kg/m^2 (223)					
Underweight—<18.5 (0)	–	–			
Normal—18.5 to 24.9 (17)	9	8	Reference	Reference	
Overweight—25.0 to 29.9 (58)	24	34	0.63	0.21-1.86	0.40
Obese—≥30 (45)	20	25	0.71	0.23-2.18	0.55
Sport type (223)					
Men's football (108)	47	61	Reference	Reference	
Women's volleyball (12)	4	8	0.65	0.18-2.29	0.50
Women's cross-country (14)	1	13	0.10	0.013-0.79	**0.029**
Men's basketball (13)	6	7	1.11	0.35-3.53	0.86
Women's basketball (13)	8	5	2.08	0.64-6.76	0.23
Women's tennis (9)	1	8	0.16	0.020-1.34	0.092
Women's soccer (33)	8	25	0.42	0.17-1.00	0.051
Women's lacrosse (21)	0	21	0.03	0.0018-0.51	**0.015**
Sport location (223)					
Outdoor (185)	57	128	Reference	Reference	
Indoor (38)	18	20	2.02	0.99-4.11	0.052
Sport season					
Fall (176)	61	115	Reference	Reference	
Winter (26)	14	12	2.20	0.96-5.05	0.063
Spring (21)	0	21	0.04	0.0026-0.73	**0.030**

[a]Numbers in parentheses indicate the total number of athletes included.
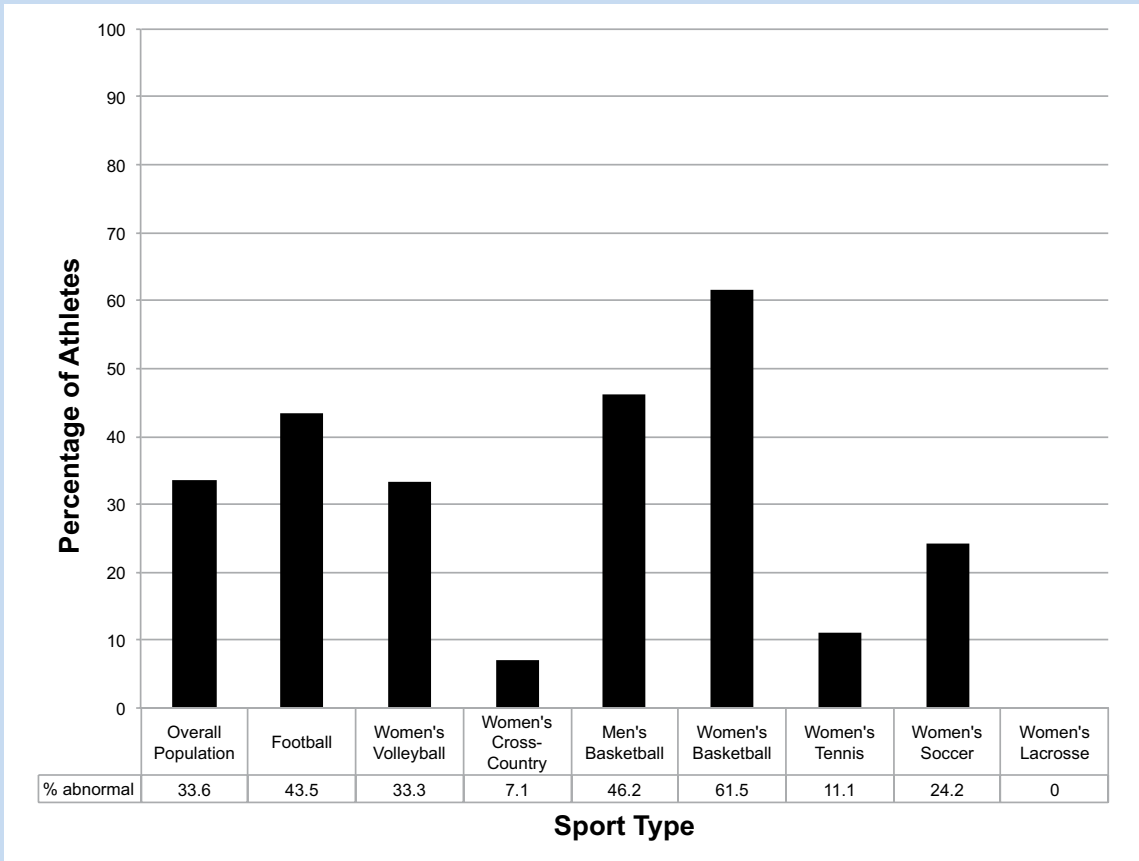[b]Boldfaced P values indicate statistical significance (P < 0.05).

Figure 2. Abnormal vitamin D levels by sport.

% abnormal	Overall Population	Football	Women's Volleyball	Women's Cross-Country	Men's Basketball	Women's Basketball	Women's Tennis	Women's Soccer	Women's Lacrosse
	33.6	43.5	33.3	7.1	46.2	61.5	11.1	24.2	0

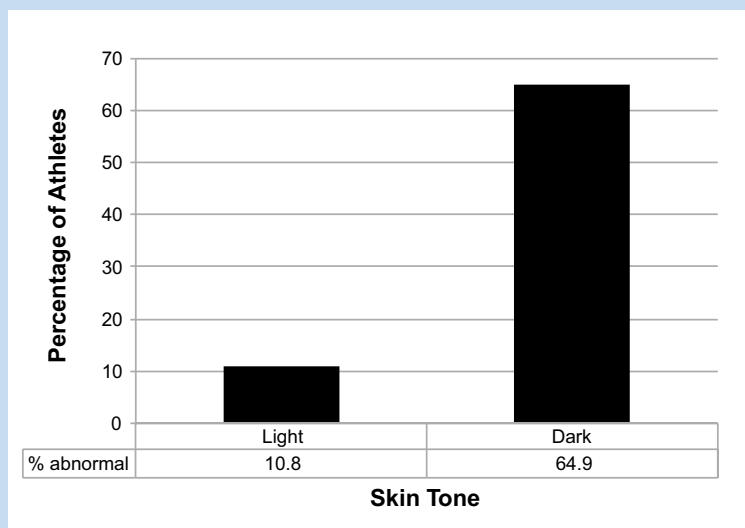| % abnormal	Light	Dark
	10.8	64.9

Figure 3. Abnormal vitamin D levels by skin tone.

Table 4. Multivariate analysis of potential risk factors for abnormal vitamin D levels (all sports combined)

Variable	Odds Ratio	95% Confidence Interval	P Value
Dark skin tone[a]	15.2	7.5-30.5	<0.0001

[a]All other variables dropped from stepwise logistic regression as they did not maintain statistical significance.

Subsets of this cohort should not have had vitamin D insufficiency given the outdoor nature of the sport, optimal equatorial position for ultraviolet B–induced vitamin D production, and testing toward the end of the summer season for optimal sunlight exposure. The effect of seasons on physical fitness and vitamin D levels is also well known.[5,6,11,13,17,18]

Many questions remain in regard to vitamin D supplementation. An 8-week course of vitamin D$_3$ supplementation was shown to significantly increase 25(OH)D levels and result in significant increases in vertical jump height, 10-m sprint times, and 1-repetition maximums in various weight lifting activities.[9] In contrast, in a randomized, dose-dependent study of athletes with vitamin D insufficiency, athletic performance did not improve after vitamin D supplementation.[8] Young et al[28] found significant increases in both the percentage and area of fast twitch type II muscle fibers, even without any physical training, in nonathlete elderly osteoporotic athletes receiving a vitamin D analog and calcium supplementation for 3 to 6 months.[28]

Study Limitations

Our univariate analysis for each individual sport lacked power (with the exception of our univariate analysis of the football team). Also, age may be a risk factor for vitamin D insufficiency.

CONCLUSION

Vitamin D insufficiency is prevalent among elite-level athletes. Dark skin tone was the only statistically significant risk factor for abnormal vitamin D levels.

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