

Vitamin D Profile in National Football League Players

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Background: By maintaining phosphate and calcium homeostasis, vitamin D is critical for bone health and possibly physical performance. Hence, vitamin D is important to athletes. Few studies have investigated vitamin D levels in relation to fractures and performance in athletes, and no published study has included a multiracial sample of professional American football players.

Purpose: To assess vitamin D levels, including the prevalence of vitamin D deficiency/insufficiency, in professional American football players and to evaluate the association of vitamin D levels with race, fracture history, and the ability to obtain a contract position, which may be a marker for athletic performance.

Study Design: Cohort study; Level of evidence, 3.

Methods: Serum vitamin D levels of 80 professional football players from a single team in the National Football League were obtained during the 2011 off-season (mean age, 26.5 ± 3.7 years; black, $n = 67$ [84%]). These levels were used to compare injury reports from the 2011-2012 and 2012-2013 seasons. Statistical analyses were performed to test if vitamin D levels were related to race, fracture history, and the ability to obtain a contract position.

Results: Mean vitamin D level was 27.4 ± 11.7 ng/mL, with significantly lower levels for black players (25.6 ± 11.3 ng/mL) versus white players (37.4 ± 8.6 ng/mL; $F_{1,78} = 13.00$, $P = .001$). All athletes who were vitamin D deficient were black. When controlling for number of professional years played, vitamin D levels were significantly lower in players with at least 1 bone fracture when compared with no fractures. Players who were released during the preseason because of either injury or poor performance had significantly lower vitamin D levels than did players who played in the regular season.

Conclusion: Black professional football players have a higher rate of vitamin D deficiency than do white players. Furthermore, professional football players with higher vitamin D levels were more likely to obtain a contract position in the National Football League. Professional football players deficient in vitamin D levels may be at greater risk of bone fractures.

Keywords: football; injury prevention; vitamin D; 25-hydroxyvitamin D; athletic training

Vitamin D deficiency is epidemic, with an estimated 1 billion people worldwide affected.¹⁷ The general health consequences of low vitamin D levels are well established in the general population and have wide-ranging adverse health

effects that involve every organ system. Both deficient and insufficient vitamin D levels have been associated with a greater rate of cardiac morbidity and mortality.^{7,27,30} Vitamin D levels <20 ng/mL are associated with a risk increase of 30% to 50% for developing colon, prostate, and breast cancer, as well as with an increased mortality from these cancers.^{11,13} Increased rates of depression,² suicide rates,²⁹ and many autoimmune diseases—including type I diabetes,²⁰ multiple sclerosis,^{9,12,25} and rheumatoid arthritis²⁴—are also associated with low vitamin D levels. In addition, the consequences of vitamin D deficiency as it pertains to bone health and muscle function are widely recognized.

Despite this knowledge, vitamin D levels have not been widely assessed in team sport athletics such as football. Elite athletes of high-impact sports, such as professional football players, who put extreme demands on their musculoskeletal system, require optimal musculoskeletal functioning. Yet, the role of team athletic trainers and physicians for determining vitamin D levels and the need for supplementation

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One or more of the authors has declared the following potential conflict of interest or source of funding: Support was provided by Heindl Neuroscience Foundation, Nelson Peltz Foundation, Lewis Topper Foundation, Cameron Foundation, and Mylan Laboratory Foundation.

to obviate potential detrimental effects of low vitamin D levels on performance and increased risk of injury are not clearly established. The primary aim of this study was to identify the vitamin D levels in professional football players and to identify the prevalence of deficient, insufficient, and adequate levels. In addition, we associated vitamin D levels with race, age, number of National Football League (NFL) seasons played, history of bone fractures, and performance.

Vitamin D has a key role in maintaining a healthy musculoskeletal system. After the conversion of vitamin D to 25-hydroxyvitamin D—or 25(OH)D—in the liver, it will further convert to its active form 1,25(OH)₂D in either the kidneys or other tissues, such as breasts, colon, prostate gland, and immune cells. While the production of 1,25(OH)₂D in local tissue regulates cell growth, controls immune function, and affects gene expression, the renal production of 1,25(OH)₂D is used for calcium and phosphorus metabolism. Both calcium and phosphorus are important to bone and muscle health.¹⁷

The mechanism underlying the effect of vitamin D on bone health is relatively well understood. Adequate calcium and phosphorus levels promote bone mineralization. The interaction of 1,25(OH)₂D with vitamin D receptors markedly increases intestinal absorption of calcium and phosphorus. Furthermore, lower vitamin D levels are associated with increased levels of parathyroid hormone. Parathyroid hormone employs several mechanisms to regulate and achieve optimal blood calcium levels, among which is the activation of osteoblasts, which stimulates transformation of preosteoclasts to osteoclasts. Osteoclasts dissolve the mineralized collagen matrix in the bone, which weakens the bone structure and increases risk for fractures.

The mechanism of how vitamin D affects skeletal muscle performance is not well understood,⁵ but several pathways seem to play a role. Multiple studies showed that low vitamin D negatively affects handling, binding, and storage of calcium in the muscle sarcoplasmic reticulum. Hence, one proposed role of vitamin D is to increase calcium accumulation in the sarcoplasmic reticulum. Furthermore, phosphate imbalance, as induced by low vitamin D, was shown to cause muscle weakness, which can be reversed with vitamin D supplementation. Last, there is a direct effect of vitamin D on the muscle cells via the vitamin D receptor that induces new protein synthesis.⁵

There is currently no consensus on the ideal level of vitamin D in humans as measured by serum level of 25(OH)D,³ neither for general health nor for sport-specific benefits. A commonly used categorization defines vitamin D deficiency as 25(OH)D levels <20 ng/mL; insufficiency, between 20 and 32 ng/mL; and adequacy, >32 ng/mL.^{3,8} This categorization is supported by studies showing that 25(OH)D is inversely associated with levels of parathyroid hormone, which promotes bone loss until 25(OH)D reaches levels between 30 and 40 ng/mL. Furthermore, intestinal calcium transport increases steeply between 20 and 32 ng/mL.^{10,16,17,19} Unless otherwise specified, comparison studies in this article use the above categorization.

Risk factors for vitamin D deficiency and insufficiency include limited dietary intake of vitamin D and diminished sun exposure and absorption of ultraviolet B (UVB) radiation

(wavelengths, 290-315 nm). UVB skin absorption can be limited by training or working indoors, living in northern latitudes (>35°), having darker skin pigmentation, consistently covering the body, or using UVB ray-blocking sunscreen.^{4,14,18}

Vitamin D deficiencies have been well documented in certain risk groups, such as children, elderly, women wearing burqas in Muslim countries, the obese, and those with dark skin. More recently, studies have indicated that athletes, including elite athletes, have an increased incidence of vitamin D deficiency.^{1,22,23}

In a recently published abstract, Shindle et al²⁸ assessed vitamin D levels and skeletal muscle injuries in 89 professional American football players playing for a single NFL team. They found that only 19.1% of the players had adequate vitamin D levels; 50.6% had insufficient levels; and 30.3% had deficient levels. The mean vitamin D level was 30.3 in nonblack players and 20.4 ng/mL in black players ($P < .001$). In addition, they found that players who had at least 1 muscle injury throughout the prior season had significantly lower vitamin D levels than did players with no muscle injury during the same time frame.

The purpose of the current study was to confirm the observations of Shindle et al by studying vitamin D levels in an additional group of professional football players using similar vitamin D deficiency criteria. We also compared bone fracture history and ability to obtain contracted employment by vitamin D level.

MATERIALS AND METHODS

Study Design

Previously collected data on 83 active NFL players from a single team were reviewed following University of Pittsburgh Institutional Review Board approval. The data included the most recent 25(OH)D serum levels obtained as part of the team's routine health screening during the 2011 off-season to and including the 2012 preseason training camp, along with injury reports of the athletes for the 2011-2012 and 2012-2013 seasons. Three athletes were excluded owing to unavailability of blood work results, leaving a sample size of 80 athletes for further analyses. De-identified medical records were reviewed that included age, race, number of years in the NFL, and history of bone fractures.

Measures

Categorical Vitamin D Levels. Athletes were categorized according to their vitamin D levels as deficient (<20 ng/mL), insufficient (20-32 ng/mL), or adequate (>32 ng/mL).

Race. Race was categorized as African American/black, white, and Polynesian. Because of the low number of Polynesians ($n = 2$), they were combined with the white athletes.

Bone Fractures. We collected information on self-reported injuries both pre- and mid-NFL career that included bone fractures obtained during athletic and non-athletic activities.

TABLE 1
Descriptive Statistics and Group Differences Among Athletes
With Deficient, Insufficient, and Adequate Levels of Serum Vitamin D^a

	Total	Vitamin D Category			Group Differences	
		Deficient	Insufficient	Adequate	<i>F</i> (2, 77)	<i>P</i> Value
Sample	80	21 (26.3)	34 (42.5)	25 (31.3)		
Vitamin D level, ng/mL	27.4 ± 11.7	13.6 ± 3.6	25.9 ± 4.3	41.0 ± 7.3		
Age, y	26.5 ± 3.7	25.5 ± 3.5	26.0 ± 3.2	27.9 ± 4.1	3.08	.052
No. of NFL seasons	4.6 ± 3.9	3.0 ± 3.8	4.3 ± 3.5	6.5 ± 3.9	5.38	.007
					$\chi^2(2)$	<i>P</i> Value
Race					15.814	<.001
Black	67	21 (31.3)	31 (46.3)	15 (22.4)		
White/Polynesian ^b	13	0 (0)	3 (23.1)	10 (76.9)		
Bone fracture					.352	ns
No	50	12	22	16		
Yes	30	9	12	9		
Released in preseason 2012					19.327	<.001
No	45	5	22	18		
Yes	21	13	6	2		

^aDeficient, serum vitamin D <20 ng/mL; insufficient, 20 to 32 ng/mL; adequate, >32 ng/mL. Values are presented as n (%) or mean ± SD.

^bBecause of the low number of Polynesians (n = 2), white and Polynesian players were combined.

Statistical Analysis

Statistical analyses were performed with SPSS version 20.0. Results are presented as mean ± standard deviation, unless indicated otherwise. Groups were compared with analysis of variance or chi-square statistics. Post hoc analyses of significant *F* value were performed with the Tukey honestly significant difference (HSD) test. To determine if vitamin D levels were associated with bone fractures, we used analysis of covariance. In a separate analysis of the 66 players that remained with the team for the 2012-2013 season and started preseason training camp, we identified those who were selected to play in the regular season and those who were released during preseason by August 31, 2012.

RESULTS

Sample characteristics (N = 80) are shown in Table 1. The serum vitamin D levels ranged from 8 to 59 ng/mL, with 68.8% of the team (n = 55) having vitamin D levels that were less than adequate. The ages of athletes ranged from 22 to 37 years.

The majority of the athletes (84%; n = 67) were black. The black athletes had significantly lower vitamin D levels than did whites (25.6 ± 11.3 vs 37.4 ± 8.6 ng/mL; $F_{1,78} = 13.00$, $P = .001$) and had a much higher rate of deficient or insufficient vitamin D levels (77.6% vs 23.1%). Notably, all athletes with vitamin D levels categorized as deficient were black, as were 91% of the athletes with insufficient vitamin D levels (Table 1).

The number of NFL seasons played ranged from 0 (no regular season played) to 15 seasons completed. The numbers of seasons in the NFL and vitamin D levels were significantly correlated ($r = 0.388$, $P \leq .01$), with more seasons played

being associated with higher vitamin D levels. This significant association is also reflected through categorical vitamin D levels (Table 1). Post hoc group comparisons with the Tukey HSD test revealed that athletes with adequate vitamin D levels had played significantly more NFL seasons than athletes with deficient levels ($P = .005$). Athletes with deficient and insufficient vitamin D levels did not differ significantly in the number of NFL seasons played.

Twenty-one athletes (37.5%) had experienced a bone fracture, of which 9 experienced more than 1. The vitamin D levels did not differ between athletes who had a bone fracture and those who did not (26.7 ± 13.2 vs 27.8 ± 10.8 ng/mL; $F_{1,78} = .19$, ns). However, for obvious reasons, bone fractures are strongly related to the number of NFL seasons played. When correcting for number of NFL seasons played, vitamin D levels were significantly lower in the athletes who experienced a bone fracture ($F_{2,77} = 7.75$, $P = .001$).

At the end of the 2011-2012 season, 14 players left the team—hence, no information for the subsequent season was available for them—and 66 started preseason training camp at the same facility for the 2012-2013 season. Of those 66 players, 45 were placed on the regular season roster and played in the regular season of 2012-2013, while 21 were released before the regular season started. The 21 players who were released during 2012-2013 preseason had significantly lower vitamin D levels when compared with the players who made the team ($F_{1,64} = 27.60$, $P < .001$) and were more likely to be vitamin D deficient (Table 1).

DISCUSSION

In this study, we identified vitamin D levels of professional football players and focused on the prevalence patterns of

vitamin D deficiency and its correlates. We found vitamin D deficiency and insufficiency to be significantly greater among black football players as compared with white players in a single professional football team. Furthermore, low vitamin D was associated with an increased number of bone fractures and being released during preseason play.

Our study results corroborate the finding by Shindle et al that low vitamin D levels are common among professional football players. The overall prevalence of vitamin D deficiency in our study (<20 ng/mL; 26.3%) was comparable with the 30.3% prevalence found by Shindle et al. We also found a comparable percentage of players with abnormally low (deficient or insufficient) vitamin D levels (≤ 32 ng/mL): 68.8% in our study and 80.9% in that of Shindle et al.

Prevalence of vitamin D deficiency in this cohort of NFL football players (26.3%) is far less than the estimated prevalence of 41.6% reported in the general population by Forrest and Stuhldreher,¹⁰ and the players' vitamin D level (27.4 ± 11.7 ng/mL) was higher than that of the general population of men (20.1 ± 7.9 ng/mL). Importantly, though, Forrest and Stuhldreher's study population consisted of only 11.1% blacks, while our sample consisted of 84% blacks. Since dark skin is a risk factor for low vitamin D levels, comparisons between samples with unequal race distribution are likely biased. Yet, a "within race" comparison between our sample of football players and the general population (ie, whites with whites and blacks with blacks) also shows that vitamin D deficiency in our sample of professional football players is less prevalent for both blacks (31.3% in our sample vs 82.1% in US population) and whites (0% in our sample vs 30.9% in US population). The comparatively lower prevalence of vitamin D deficiency of professional football players' is encouraging and may represent increased sun exposure during practice and game play.²¹ Additionally, professional football players generally have a higher socioeconomic status, owing to advanced financial means that allow access to healthy food, which others have reported is associated with higher vitamin D levels.²⁶ Despite the healthier vitamin D profile in our sample when compared with that of the general population, a substantial number of professional football players were still vitamin D deficient, and the majority was vitamin D insufficient.

Consistent with previous literature,^{10,15} black football players had a much higher prevalence of inadequate vitamin D levels when compared with white players (77.6% vs 23.1%). Dark skin is a known risk factor for low vitamin D levels owing to inhibited UVB absorption and the increased amount of melanin skin pigmentation.^{4,14,18} Diet also plays a role influencing race-related vitamin D levels. Studies in the general population suggest that from puberty and onward, median vitamin D intakes of blacks in America are below recommended intakes in every age group of the general population.¹⁵ Our results, showing a generally higher-than-normal vitamin D profile across both races, may be due to access to better nutrition. Future research into vitamin D levels in athletes will need to assess both vitamin D intake and the amount and quality of sun exposure to provide a more conclusive insight regarding vitamin D deficiency in athletes. Furthermore, some research suggests that between-race vitamin

D-level comparisons can be influenced by the fact that blacks and whites differ in their physiology regarding their ability to bind and metabolize vitamin D.¹⁵

Our finding that lower vitamin D levels are associated with more fractures is consistent with previous research conducted in athletes. A limited number of studies have investigated vitamin D levels in athletes in relation to bone fractures. In an Australian cross-sectional survey among 18 female elite gymnasts (age, 10-17 years), Lovell found that 83% who primarily trained indoors had vitamin D levels below adequate and had a higher incidence of bony stress injuries in the year before the testing than did those gymnasts with adequate vitamin D levels.²³

In this study, we found that players who were released before the official season started and hence did not make the roster had significantly lower vitamin D levels than did players who made the team. This finding suggests an association between vitamin D levels and suboptimal performance. Previous studies have investigated performance in athletes of other sports. For example, using jumping mechanography, Ward et al³¹ studied vitamin D levels in 99 girls who were 12 to 14 years old to investigate the relationship between serum vitamin D levels and muscle power and force. They found a positive relationship between vitamin D levels and muscle power and force. In a recent randomized placebo controlled study with 61 professional male athletes and 30 age-matched nonathletes, Close et al⁶ found 62% of the athletes deficient in vitamin D at baseline. With vitamin D supplementation, there was an increase of serum total 25(OH)D from baseline (11.6 ± 10 to 41.2 ± 10 ng/mL; $P < .01$), and performance levels, including sprints and vertical jump, in the treatment group significantly improved when compared with baseline measures and the placebo control group. Note, however, that we did not control for potential confounding variables or moderators of this association, such as age and a player's general health and nutrition status. It is crucial for future studies to assess and account for these potentially confounding variables.

Despite the established evidence that adequate vitamin D levels are critical to the musculoskeletal system, few studies have examined vitamin D levels in (professional) athletes, and no study has been published on athletes in high-impact sports, such as American football. Our study is one of the first to describe vitamin D levels in professional football players and to assess vitamin D levels in relation to the ability to obtain a contract position, which may be a marker for athletic performance.

This study has several limitations. First, the sample size is relatively small for the effect size that we expect. A larger sample size would increase power and reduce the likelihood of type II errors; hence, our study may underestimate associations. Second, the observational cross-sectional nature of our study does not allow us to draw causal inferences. Longitudinal cohort studies and experimental studies are necessary for a better understanding of the role of vitamin D in fracture risk and performance. Also, we measured vitamin D levels at a single time point. While vitamin D levels are considered to stay relatively stable across years, repeated measurement

may provide a more reliable estimate of the vitamin D profile of an athlete. Third, we did not have information on what athletes may have supplemented with vitamin D. Last, several other variables for which we were not able to control may influence vitamin D levels, fractures risk, and/or ability to obtain a contract position. Variables of interest include general health status, body mass index, the type of fracture (acute vs stress), player's position, and actual playing time. Future research should aim to include these relevant variables as well as a more direct and measurable assessment of muscle strength and performance to confirm or reverse our finding.

CONCLUSION

The vitamin D profile of professional NFL football players in our sample was more favorable than that of the general population; yet, vitamin D deficiency and insufficiency levels were found to be significant in the subset of black players evaluated. We found that vitamin D levels were inversely related to bone fracture prevalence. Furthermore, low vitamin D levels were associated with a higher risk of getting released during preseason, possibly indicating poorer performance. Based on these findings, routine monitoring and optimization of vitamin D levels should be considered as part of the routine care of NFL players, with special attention to black athletes.

ACKNOWLEDGMENT

The authors thank James Bradley, MD, and Ryan Grove, ATC, for their valuable assistance.

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